The Alan Turing Institute Programme on Data Centric Engineering's Response to the National Infrastructure Commission's Second Call for Evidence

1. Introduction

Background

The Alan Turing Institute is the national institute for data science, with a mission to make great leaps in data science research to change the world for the better. The programme on data-centric engineering (DCE) will develop critical data analytic capabilities to address the challenges in improving the performance and resilience in engineering systems and national interdependent infrastructure nexus. The evidence presented in this document will be based on the Turing Program for DCE will focus on 3 grand challenge areas of:

1. **Resilience:** Resilient and Robust Infrastructures,
2. **Monitoring:** Monitoring Safety of Complex Engineering Systems,
3. **Design:** Data Driven Engineering Design under Uncertainty.

2. Better Asset Management

Summary and Response to Questions: The application of new data analytic methods in critical infrastructure (CI) asset management can significantly improve the efficiency, consumer experience, and reduce operating costs. The immediate technology priorities for efficient algorithm scalability and integration into asset management methods and tools include: sparse data combining methods, high-dimensional statistical inference models, and to automated data wrangling. Potential barriers to rollout include the: a) differential attitude and readiness to adopt new technology due to geographic or political segregation in certain CI operators (e.g. water management), b) complexity and uncertainty in integrating new methods into large-scale existing practices, and c) data privacy restrictions. The latter two cases are especially a concern for large CI operators. To overcome these barriers, we hope the government can encourage the uptake of new data-driven solutions through raising awareness of projects and the targeted investment in joint academic-industry research grants, with a focus in breaking down CI silos and unlocking data access restrictions. Certainly, the development of a national digital twin can help to: (1) overcome the barriers by bridging geographic and sectorial divides through linking interdependencies via a common model, (2) provide a framework for determining sensor locations, and (3) serve as a technology demonstrator for new tools. As such, the digital twin must connect disparate CI sectors and be open to the demonstration of new data analytic tools.

National Importance: UK infrastructure is ageing, and requires an ever-increasing amount of investment in maintenance and upgrade to maintain existing performance levels. In addition, infrastructure assets are characterized by long life and complex deterioration modes; knowledge about the way these assets deteriorate over time and how the deterioration affects the risks and asset performance is patchy. In summary, today's infrastructure is faced with familiar and seemingly insurmountable problems – too little money, too many assets and increasing complexity.

We now give **examples of projects** underway in using data analytics to improve engineering assets in **critical infrastructure sectors**:

- **Flood Risk in London Underground:** Transport infrastructure assets are at risk from changing environmental conditions, in part contributed to by climate changes observed in recent decades. In the U.K., increased precipitation amounts are leading to rising groundwater levels, presenting transport operators with performance issues associated with flooding of rail tracks and ballast. A NERC funded feasibility study (NE/M007987/1) derived a groundwater rise vulnerability model for the cut-and-cover tube tunnels bearing on terrace gravel deposits in London Underground (LU). This sets out the mechanics of the seepage problem and through a deterministic approach has identified upper and lower risk boundaries considering a groundwater level fluctuation range [1]. The autonomous systems developed will enable cost-efficient continuous monitoring strategies to be put in place, and are especially valuable at network scale where interconnected assets require simultaneous inspection to fully understand the risks. Once analyzed, these will provide a probabilistic understanding of the risks posed to asset performance through robust hazard-structure interaction modeling. This data-driven approach to asset management will provide LU with high-resolution performance statistics that reflect the risk model in place. This allows optimisation of drainage, ballast and track maintenance through predictive strategies not currently achievable with traditional inspection regimes. This in turn empowers LU into shaping and optimizing the resilience of these assets for the future.
- **Self-Organisation in 4G Networks:** The ICT industry is a leading producer of digital data and has for decades used its own data to automate asset management. In recent years, there is a growing recognition to combine ICT data with new forms of social media and mobile data to create stronger user-centric understanding of consumer demand and consumer experience [2]. To do so, joint academic and industrial initiatives are underway (EU H2020 project 778305, InnovateUK project 010734) to transfer state-of-the-art heterogeneous big data analytics and machine learning tools into applied ICT automation algorithms in critical industries such as 4G/5G mobile networks. The analytical techniques involve high-dimensional statistical models using Gaussian Processes and Deep Learning to forecast heterogeneous data demand, as well as stochastic multi-armed bandit algorithms with performance guarantees to drive a range of automated asset management across time scales (millisecond resource assignment to daily asset adjustments). These form the important building blocks to virtualise asset management and reduce OPEX in current and future networks (5G).
- **Railway Infrastructures:** Asset management in the rail industry is critical. For example, in the financial year 2009/10, whole-industry costs totaled £12.7bn. Of this, over half was spent on maintenance, renewals and enhancements. National Rail own 30,000 railway bridges and considerations are underway to instrument the bridges, yielding a data storage and analysis bottleneck. What is required are on-the-fly procedures that can be employed without storing all data. Currently, a collaboration is formed between the DCE at the Alan Turing Institute and the Cambridge Centre for Smart Infrastructure and Construction at Cambridge University, and Imperial College to develop *intelligent digital twins* for two railway bridges (in collaboration with Laing O'Rourke Plc. as part of the Staffordshire Alliance Improvements

Programme - SAIP). The instrumentation of bridges has changed the hands-on assessment of a bridges behavior to include a statistical data analysis. A statistical model will give an understanding of the stochastic nature of bridges and lead to an efficient monitoring system for predictive maintenance. The combined use of statistical analyses, big data, physical modelling and numerical modelling constitutes the main features of the digital twin. The real world SAIP self-sensing bridges are serving as the training ground for validating the intelligent digital twins. The approach, if employed over a system of assets, enables asset managers to (1) to develop a novel whole-system asset monitoring and maintenance capability and (2) get appropriate and accessible asset information that enables timely and cost-effective decision-making at different times of the assets' lifetimes.

3. Smart Traffic Management

Summary and Response to Questions: Smart traffic management (STM) has already started. There are 3 decisive challenges STM systems may have to tackle.

1. STMs will need to collect and process real time, high quality data.
2. increased demand for individual transportation will need to be offset by improvements in traffic flow density.
3. It will be necessary to improve the efficiency of movement via increased ride sharing and interchangeability between modes (i.e., improved coordination).

Access to relevant data is a key contemporary challenge for urban policymakers as they deal with ever growing demand on public infrastructures and considerable financial constraints. As part of its work on data centric engineering, the Oxford Internet Institute (OII) in conjunction at the Alan Turing Inst. have been conducting research into the deployment of open and social media data for facilitating smart urban management. The key aim of this strand of work is to find ways of enabling an internet of things style awareness of the surrounding urban environment without the up-front costs and difficulty of installing large sensor grids (which are out of reach of all but large urban megacities): instead, we are exploring ways of repurposing existing data created by third parties and government itself. This creates what we have described as a "lightweight" smart city [3].

We now give **examples of projects** underway in using data analytics to improve traffic management in different sectors:

- **Data Bias from Public and Social Data:** The research frontier in this area concerns plugging missing traffic data with repurposed data and accounting for the biases. Open data has the potential to change the way we collect and process transport data. One of the most promising projects is the open data platform created in the city of Manila. Easy Taxi, Grab and Le.Taxi – three ridesharing companies – partnering with the World Bank are sharing their driver's GPS streams to the public using an open data license. This Open Transport Partnership makes it possible for transport agencies to make real time evidence-based decisions at relatively low cost. Examples of recent work by the OII including the use of OpenStreetMap data for understanding the spatial availability of alcohol [4], and Twitter data for understanding local high resolution commuting patterns [5]. In so doing, we highlight two key findings. First, there are biases in the demographic makeup of the

groups which contribute to open and social media platforms. Second, we have found that these biases are not so severe that they impede the extraction of reliable proxies, which were found in the case of both alcohol availability and local commuting patterns.

- **Demand Mitigation using Autonomous Vehicles:** Autonomous cars may lead to higher congestion due to demand effects from the forecasted substantial drop in the monetary costs of travelling by car. To mitigate demand externalities, traffic efficiency gains will have to be maximized. Depending on the level of automation, substantial gains could come from smart lights. Recent works shows that a simple light system with human drivers could increase traffic flow efficiency up to 200%. Autonomous cars make it possible to move from the traffic flow based system to a vehicle level system. This could substantially increase capacity and significantly reduce delays at intersections. Another way to respond to increased demand will be through improved coordination, and specifically, via ride-sharing and better interchangeability between modes. The technological innovation of smart phones and the decreasing cost of computing made it possible to efficiently share rides. Researchers at MIT have created a model that predicts the potential for ride sharing in any city. This potential, measured by the compatibility of individual mobility patterns in space and time, is shown to be substantial with important implications for demand management.

4. Big Data

Summary and Response to Questions: The effective use of big data requires greater standards to make the data accessible and usable. Currently data from numerous sources will be in various states of readiness, and combining datasets and getting value from them in an arduous task. This would be made easier by having defined and widely accepted standards for data structures, data labelling, data cleanliness and data-sharing methods. The Alan Turing Institute is working with industry and public bodies on the development of standards for data science and on defining Data Readiness Levels to better methodology is how big datasets are managed. Also vital is the widespread acceptance of appropriate data security procedures. Many company are failing to protect vital infrastructure data, through reliance on lax procedures or outdated hardware and software. Solutions to these problems exist, but are not being adopted enough.

Open Data: The benefits to having open data in the modern age are unprecedented, especially where they impact public services. Open data and accessible APIs can lead to greater public awareness and engagement with infrastructure, new services, greater safety and gains in efficiency. It also opens the sector to greater innovation from data science firms, especially the UK's wealth of start-ups and SMEs in this space. However, the sector as a whole is unwilling to share data openly, and even private data-sharing agreements (B2B, collaborations with academia, etc.) can be difficult to arrange. The unwillingness to openly share data is largely a cultural issue stemming from conservatism in many parts of the infrastructure business sector. There is a fear of the implications of sharing data openly, particularly around legal ramifications, security considerations and loss of IP. Many of these

fears stem from a lack of knowledge and experience in operating with open data. Possible solutions to address these issues include:

- Government guidance on data-sharing methods, including standards for ensuring security of data structures and advice on adhering to legal restrictions around data protection and other data-related legislation.
- Flagship schemes or pilot projects to show the value and potential of data-sharing initiatives. This could build on existing schemes, such as the use of APIs by TFL for tube and bus services which has led to a range of improvements for customers travelling by public transport.
- Financial incentives for firms which engage in open data sharing
- Regulatory incentives which can nudge companies towards sharing data

Digital Twin: A national digital twin is important to provide modeling and forecasting to an ageing UK infrastructures. It should provide a platform for using data and data science to validate and reinforce existing mathematical models of complex engineering systems and assist in the development of new models. Certainly, the development of it can help to: (1) overcome the barriers by bridging geographic and sectorial divides through linking interdependencies via a common model, (2) provide a framework for determining sensor locations, (3) identify abnormal behaviour using machine learning techniques that do not expose it to adversarial attacks [6], and (4) serve as a technology demonstrator for new tools. As such, the digital twin must connect disparate CI sectors and be open to the demonstration of new data analytic tools. Only by bridging data (collection, analysis) and engineering knowledge, working with engineers and knowledge stakeholders, can a national digital twin help to manage both the data and the infrastructure in an efficient and reliable way.

References

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The Alan Turing Institute Programme for Data Centric Engineering would be pleased to provide further detail of any of the issues raised above, either in writing or by way of oral evidence. This response was initiated by [name.redacted]
and coordinated by [names.redacted]

Anglian Water is delighted to have the opportunity to respond to NIC's second call for evidence on New Technology, as a supplement to the material we have already shared on our innovation work. We would welcome the opportunity to discuss any of the issues raised.

BIG DATA

How can we support the effective deployment of innovative data-based technologies in infrastructure? What issues are there around the collection, management, and use of infrastructure data, and what are the barriers to sharing data? What can government do to address these issues? What data challenges would be presented by a national digital twin? This case study will consider the legislative, regulatory and cultural landscape, the quality and interoperability of data, and methods for promoting the secure sharing of data, focussing in particular on the energy sector.

10. What governance arrangements are needed to manage the huge amount of data being generated and used in the infrastructure industry and to encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

To support our data and information capabilities, Anglian Water have developed four integrated information strategies to guide our business; Data, Content, Mobile and Business Intelligence. We are now developing an Integrated Technology Strategy to align all of the strategy roadmaps, ensuring we develop a coherent plan that is deliverable, affordable, and meets all business requirements. An organisational capability plan is being developed in parallel to the project, ensuring that we have the right leadership, governance, people, skills and communication in place to make this a sustainable and business-as-usual way of working for years to come. All of these strategies and plans can be shared and discussed with NIC on request.

Big data is often described along three dimensions called the 3V's – Volume, Velocity, Variety. Within Anglian Water our main data set of high volume is through operational site SCADA and regional telemetry. This data set is not currently considered to be of high velocity; though it will need to develop in frequency over time. Managing these high volumes of data for use through analytics is a major challenge. Over the next 18 months, Anglian Water (in line with our Business Intelligence strategy) plans to:

- Upgrade our Enterprise Data Warehouse (this will encompass time series, geospatial and unstructured data)
- Implement data integration technologies to enable real time data analytics
- Implement best of breed reporting technologies to enable self-service reporting and analytics
- Provide a data exploration and discovery platform for predictive analytics, modelling and new data insights through predictive modelling and data science

- Implement a real time data historian for telemetry and IOT (Internet of Things) time series data.

The Anglian Water Smart Infrastructure program is an example of another current strategy developed by the business to build a resilient communications network and operational technology (OT) platform to host OT data. Communicating operational data is a key success factor for big data within infrastructure owners. Over the next 5-10 years as the use of sensors increases, so will the amount of data produced and thus there is a need to build a scalable data capture solution. This gives rise to a clear need for a strong security governance structure as the program relies on complex data integration and sharing. The Internet of Things (IOT) is being considered to allow effective communication between IT systems; however, currently one of the main challenges is that there is not an IOT network and a very limited range of devices for the water industry. Many of the sensor devices we are trailing in our innovation Shop Window are sold as a service with a cloud platform which includes specialist analytics. We are now identifying how we integrate these into own OT platform in the future to allow for those data sets to be used in wider business analytics through our historian and enterprise data warehouse.

Additionally, by the end of the current AMP period (2015-2020) we will have delivered a modern BI platform that delivers high quality inter-connected information that people can access whenever they need it and self-serve without the need to hand-off to the IT department. We will create an enterprise operational data store that people can use to store locally generated transactional data. Over time we will ensure that self-serve information is the easiest and most trusted source for insight and remove the need for future data silos to be created.

Anglian Water also faces a major challenge in dealing with and aligning the large variety of data that must be handled. Often this data must be used for numerous purposes, while coming from a variety of sources. This data will also cover many formats, database records across many functional domains such as enterprise resource planning systems (e.g. SAP), images, geographical information systems, computer aided design (CAD) drawings and paper based records (both digital images and physical hard copy). Historically these different data areas have been managed separately. Due to the complex needs of the organisation, a governance structure that enables multiple domains of specialism (customer service, asset management, regulatory affairs, etc.) to understand their differing needs from other parts of the organisation is imperative.

It is however important to distinguish between data management and software solutions at an early stage. The latter is a methodology and process that relies on the use of technology, which can be in the shape of software, but it is not in itself a software or technology. Anglian Water has defined a set of data management principles that can be found in our Data Strategy. These principles are the foundation of all new projects, serving as a guide and helping to control behaviour across multi-disciplinary teams. They should also form the foundation of any governance arrangements being developed around the issue of data management. Any such governance structure must have a number of basic characteristics; it must be effective in the way it can share data through complex integration methods (often restricted by limited performance). Furthermore,

there must be a standardisation of approaches with a clear focus on avoiding duplication, and there must be the capability to forecast using external and internal data. Our solutions include:

- Enterprise data architecture management; data definition, data relationships, meta data management, etc. - through open database technologies for data integration. This will readily enable integration with other external system via industry standard API's on premises and in the cloud.
- Data ownership - with a clear understanding that Anglian Water architects will ensure standardisation of data across the organisation internally and a responsibility to provide organisation-wide guidance on the location of existing data sets.
- Data quality management – definition, standards and measures of quality
- Data security management for personal and sensitive data protection
- Master data management- through authoritative 'golden' data stores in a single, centralised location for shared business-critical data, to drive down fragmentation of master data.
- Data retention and archiving – driven by policy and particularly in relation to existing data that has not yet been digitised

In addition to this, Anglian Water plans to have a common set of self-serve tools with an open architecture to enable specialist teams to leverage niche analytical and visualisation tools to drive competitive advantage. We want to support our culture of collaboration and leverage new social capabilities to share knowledge and promote feedback on new information sources so everyone can find them and maximise their potential.

Data governance will ensure that data and system overlaps are investigated and identified at the enterprise level at an early stage, and any potential synergies are realised. However, for all these solutions to be executed effectively there is an underlying need to change mindsets within Anglian Water and right across the supply chain, as well as a willingness to embrace new technologies and funding increases for data capture.

To commence implementing our data strategy, Anglian Water has set up an Enterprise Data Architecture team as part of existing Enterprise Architecture capabilities. We are using best practices brought to us through our IS Alliance partners. This will facilitate and coordinate the development of necessary data management capabilities and support governance. To prove the value of enhanced data analytics and eventually 'big data', Anglian Water has also set up a collaborative Data Science function, using internal and external resources from our IS Alliance partners. This team tackles complex analytical challenges primarily to improve our service offering to customers, and improve our operational effectiveness and management of assets. It is real business case benefits that will support and inspire the massive cultural changes required in digital transformation.

To further encourage the effective use of database technologies across our company and partner base, we see being able to support mobile working and digital communications across the whole supply chain with appropriate connectivity coverage, speed and data volumes is a key success factor. If all our

people cannot access the information they need when and where they need it, data and information quality will never be improved and maintained.

11. What barriers are there to sharing data internally within systems and organisations and externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

Many of Anglian Water's current data challenges stem from overly project-centric, system-centric, silo'd business unit strategies or funding practices, and lack of standardisation (definitions, languages and formats). These practices effectively perpetuate the creation and development of data silos both internally and externally.

As the IT world evolves rapidly and with the phased adoption of technologies such as IOT there is often a disconnect between data capture formats and a severe lack of standardisation. This issue is then amplified when looking across the infrastructure industry as a whole, where different organisations and sub industries have developed and are developing at varying speeds. Barriers to sharing internally will be removed through delivering the enterprise data governance capabilities described above across our whole supply chain.

As a specific example, Anglian Water currently has an asset management framework (AMF) which defines the information that needs to be captured for each asset type. This information standard may be a barrier if not aligned with national asset standards; however this strategy could potentially form the nucleus of any proposed standard.

Anglian Water is looking to improve and upgrade the Service-orientated architecture (SOA) infrastructure and related processes. There is a programme underway to deliver our next generation of middleware and update management processes to enable us to react to changes quickly and integrate all internal or external systems. The government can assist by providing guidance and a platform to facilitate interested parties to develop standards for commonly required needs. A central hub/database to enable secure sharing of information (similar to Water Industry Market Reform through the Market Operator solution) is one way in which the government can aid effective data management across the national infrastructure industry. This will however also require cooperation between organisations to define data standards and API's and has security implications that need to be addressed with mitigations agreed upon.

Regarding barriers to sharing data externally, we recognise major challenges regarding:

- Legal issues relating to conforming to General Data Protection Regulations and patient privacy. We think there may be merit in the sector developing guidance collectively so that we all have a common understanding – and don't all reinvent the wheel.
- Cultural barriers – the need for incentives, fears regarding miss-use of shared data, and building trust in what we share and how it is subsequently used. We need to recognise that failing to share data can result in a loss of trust.
- Technical issues – common standards, definitions, technical interfaces and external facing portals. We need standard data protocols to allow us to share data and to facilitate innovation. Again, we think that companies can work together to establish these standards.

Anglian Water would welcome the opportunity to discuss these areas in more detail as we plan how to tackle all of these challenges. To support our transformations in data sharing we have recognised the recent Ofwat report "Unlocking the value of customer data" that worked with the Open Data Institute, and are identifying what we can release and how to support those principals.

To further develop our plans for data sharing, we are actively engaging in a number of collaborative national groups. In the area of asset information one specific group is the BIM4Water task group, as part of the National Building Information Modelling (BIM) group. This has been set up to deliver the objectives of the Government Construction Strategy and the requirement to strengthen the public sector's capability in BIM implementation. The BIM4Water group has 4 priorities for action:

1. Build an evidence base and library of best practice case studies to help build a business case for BIM in water

2. Developing a 'plan of works' and associated data drops for the water sector

3. Work with BIM4Manufacturers and other representative groups to influence the creation of BIM product libraries for the water sector

4. Work with the BIM Task Group to influence the business case for BIM adoption with senior representatives from client organisations

As part of the work we are actively sharing details about our asset data, and how we define, categorise and structure hierarchies, inventories and catalogues.

We are also working with the IP3 knowledge transfer network for Infrastructure Client Organisations. Their aims are to support innovation, idea and information sharing. Anglian Water is also collaborating with the Infrastructure Client Group "Project 13: From Transactions to Enterprises", set up to create a community of infrastructure owners and suppliers committed to change and to unpicking the UK's productivity knot through new models of working. All these initiatives will support our understanding of what we need to share and why, and how to technically and culturally share data across our supply chains, across sectors, and open data environments.

12. How can a national digital twin help to manage infrastructure data as an asset?

We view a "Digital Twin" as a bridge between the physical and digital worlds, an exact virtual representation of a physical 'thing', as if the system or product was looking in a mirror. It is important to recognise that a digital twin is not just a physical mirror, but a "virtual mirror" as well – cross discipline – not just a mechanical / geometric representation, but also including the electronics, sensors, wiring, software, firmware, telemetry etc. Certainly not just computer aided design (CAD).

We believe that digital twins will allow analysis of data and monitoring of systems to head off problems before they even occur, prevent downtime, develop new opportunities, rehearse delivery of work and train staff, and even

plan for the future by using simulations. As products (including assets and equipment) of all types move to include connectivity, sensors and intelligence we can't just think about the data streaming back from the field. Without accurate "Context" – a Digital Twin – time series data generated during production and on-going operation, is difficult or even impossible to understand and analyse. The ability to interpret and act upon this data often requires traceability to historic information from related events.

As artificial intelligence / cognitive computing are introduced over time, the necessity for the Digital Twin becomes even greater. If "Knowledge = Information in Context", then without a Digital Twin, machine learning won't work as intended, will be rendered ineffective or worse potentially leading to risky misinterpreted or misdirected action. Without Context – a Digital Twin – the benefits from the future "Internet of Things" proposition is severely limited and could introduce real liability. Without clear data architecture of what specific data needs to brought together (at local and enterprise levels and subsequently regionally and national levels), and how that data relates to each other we will never achieve that future.

Through Anglian Water's Asset & Operations Strategy (available on request to NIC) we recognise that we are living through a time of unprecedented digital transformation which means our virtual assets are critical to our success. The opportunities offered by the digital revolution to better understand, manage and control assets that provide service and value to customers, and improve ways of working for our teams are immense. The value of the digital asset is now equal to the physical asset and we need to adapt to that reality. We have identified that creating real time digital twins of our entire physical and technology networks and an environment to rehearse engineering and operational scenario's, are one of seven key enablers to our success. We believe Digital Twins will support realising value and benefits in the following areas; mitigation of carbon emissions, asset management and operational and maintenance efficiency, safety and risk management, engineering and assembly management, emergency and incident management, people and skills development, and overall service delivery improvements and benefits and for customers.

A national digital twin, supported by all the required standardisation, protocols and security measures, would enable organisations to focus on developing high quality digital data on infrastructure that is of most benefit at the national level and within their own operating environments. Infrastructure decisions and commitments have long term consequences and major implications for the whole nation's economic and environmental sustainability. Digital capabilities that support effective planning, delivery and risk management are essential. At regional and local levels this might focus on areas where multiple infrastructure organisations commonly interact (such as services in built up areas) and provide enabling infrastructure and governance to facilitate efficient sharing of asset data, and asset operational activity. This would help improve the overall experience for all customers of infrastructure owners and service providers by reducing mistakes but also supporting shared activity such as working on

multiple services, e.g. parallel work within a closed road section. A greater understanding of risks to individual service providers from the activities and operations of others would also support more effective planning processes. At times of major emergency and natural disasters, the effectiveness of incident response through ease of visualisation, decision-making, scenario modelling and sharing information would be significant; e.g. climate change impacts such as regional flooding.

Anglian Water has previously worked with the UK Infrastructure Transitions Research Consortium (ITRC), a collaboration of seven universities and over 50 partners from infrastructure policy and practice.

ITRC's research provides concepts, models and evidence to inform the analysis, planning and design of national infrastructure, very much along the early concepts of Digital Twin. They investigate infrastructure and its interdependencies in energy, digital communications, solid waste, transport, waste water, water supply and infrastructure governance. ITRC helps governments, utility providers, designers, investors and insurers by developing new ways to evaluate the performance and impact of long-term plans and policy for infrastructure service provision in an uncertain future. Anglian Water are keen to support the concepts offered by a National Digital Twin which we believe would positively affect the experience customers within our region receive from all infrastructure owners.

Anglian Water is delighted to have the opportunity to respond to NIC's second call for evidence on New Technology, as a supplement to the material we have already shared on our innovation work. We would welcome the opportunity to discuss any of the issues raised.

WATER EFFICIENCY

How can new technologies support the water sector in delivering and driving efficiencies, in terms of operational cost and reduction of leakage and wastage? How can we use new technologies to increase resilience? This case study will look at use of sensors, meters, thermal imaging and drones in the water sector to increase efficiency. It will also compare and contrast different practices amongst the water companies to see how new technology, benefits and understanding can best be shared and tested across the sector. We want to identify the key barriers to rolling out new technologies regionally and nationally.

Our approaches to harnessing new technologies to drive efficiency and improve service are shown in our Newmarket Shop Window. This is a real-world location where we drive innovation through collaboration across our business, supply chain and the entire man-made water cycle. By concentrating innovation in one place, we unlock synergies between new technologies and different ways of working. This accelerates our learning and allows us to improve customer service, environmental stewardship and the efficiency of our business at a much faster pace. In this respect, our Shop Window is a microcosm of what a future water company looks like, today.

We have shared our Shop Window experiences and plans separately, as part of NIC's case study, so this response concentrates on the two questions you asked, below. We are looking forward to continuing to share the outcomes from our Shop Window as the programmes mature.

8. In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

Anglian Water's leakage performance leads the industry. We've cut leakage by more than a third since privatisation in 1989 and it is now at record low levels – around half the national average based on the amount of water lost per kilometre of main. Our three-year average has continued to fall from 191Ml/d at the start of the AMP.

- 2015/16: 189Ml/d
- 2016/17: 186Ml/d

This is ahead of our target level of 192Ml/d.

We don't believe it is good enough to stop at the targets set by our regulator; not when reducing leakage is so important to customers and so vital for us in

this dry part of the country. We are determined to reach 172Ml/d by 2020 and are on track to achieve it.

Over this AMP we will invest £124 million in people and in state-of-the-art technology to drive it even lower. The main planks of our strategy are:

• Optimised Water Networks, in which bursts are prevented through better management of pressure in the pipes. The approach aims to deliver a 'calm' network that provides a reliable and resilient service through a reduction in leaks, low pressure and interruptions to supply, while improving serviceability and water quality. In the first two years of this AMP, OWN has been responsible for a reduction of just over 6.27Ml/d in leakage across the region, saving 3.08Ml/d in the first year and 3.27Ml/d in the second. Work has been going on in Peterborough since 2013, with large pressure-reducing valves and major cross connections allowing us to manage the pressure of water supplied to 92 per cent of properties. Similar schemes are now under way in Bury St Edmunds and Bedford, with three more planned for Milton Keynes, Lincoln and Ely in 2017/18.

• Intensive Leakage Detection teams that track down hard-to-find leaks and target areas with ageing pipes. Three teams have been formed with the mandate, training and equipment to track down hard-to-find leaks and to proactively target areas where we believe pipes may be coming to the end of their useful life. This year, the teams saved a total of 3.75Ml/d. The East Intensive Investigation team used a new ultrasonic meter and old-fashioned investigatory skills to track down a major leak in North Norfolk. The leak had been running for two years, losing 0.43Ml/d. It was finally found at a point under the River Stiffkey near Little Walsingham and the main was replaced using directional drilling equipment to bore under the river

• an Integrated Leakage and Pressure Management system to bring together network information, making it easier to control leakage and target work. New and enhanced tools further improve our ability to target work at areas of the network with rising leakage and to plan our detection teams' activities.

In the future, smart metering offers a step change in detecting leaks. Currently, around a quarter of reported leakages is estimated to be due to Customer Service Pipe Leakage (CSPL) and Internal Plumbing Losses (PL), but work underway in Anglian Water and other water companies is starting to show that this percentage is higher.

In addition, live data for actual consumption will make the identification of network leakage more accurate by measuring the actual difference between bulk (district) meters and customer use, rather than using allowances.

9. Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

We do not take a view on national roll out of smart metering: the business needs and customer benefits will be different for different regions.

On the question of compulsory metering, we have achieved very high levels of meter penetration (of 'dumb' meters) without the need for compulsory metering,

which customers do not like. We would not endorse a compulsory smart meter roll out. We think an important benefit of smart meters is the greater communication and engagement with customers that they offer. A compulsory programme could put that at risk.

Nevertheless, we do think that a targeted smart meter roll out is a necessary part of delivering water efficiency and resilience. We think this is particularly relevant in our region where the combined challenges of climate change, economic growth and changes to abstraction licences will make securing clean, safe water supplies for our customers harder than ever. Smart meters will form the cornerstone of an ambitious programme of water demand management and efficiency in our region. We see the benefits of smart meters in our region in two broad categories: directly improving customer service; and improving our operations (and hence indirectly improving service).

Improving customer service

A major benefit of smart meters is the potential they unlock for much better customer engagement and a more tailored individual service.

- **Better billing**: moving from estimated bills or annual meter reading to more accurate and timely bills helps customers. It could also identify innovative tariffs in the future.
- **Finding customers' leaks**: closer to real-time data allows us to proactively identify high bills and alert customers about customer side leakage or internal plumbing losses, saving customers' money and saving water.
- **Tailored engagement on demand and efficiency**: showing customers their water use in near real-time via an online app or in-house display unit means they can understand their own consumption better and we can tailor efficiency initiative and demand reduction to suit their needs.

Improving our operations

- **Better understanding use**: more detailed information on household use helps us understand actual household and per capita consumption (PCC), and differentiate between use, internal plumbing losses and customer supply pipe leakage. We will also be able to better identify unbilled and empty properties.
- **Reducing network leakage**: improving our understanding of night usage and identifying customer supply pipe leakage helps us better target leakage detection and reduction efforts.
- **Optimising our network operations**: understanding consumption patterns better means we can improve our models and pumping schedules to save energy and costs.
- **Reducing costs**: reductions in leakage and demand allow us to avoid or defer investment in supply capacity, reduce treatment and pumping costs and leave more water in the environment.

National Infrastructure Commission: New Technology Study (Second Call for Evidence)

ACE consultation response

15 September 2017

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Response to consultation questions

Better asset management

Q1. What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

There are a number of initiatives underway across the infrastructure sector where the collection and analysis of data is improving the operational performance of assets. The water sector is a good example where UK water companies have been collecting historical data on assets in order to use statistical modelling to predict where network failures are likely to occur and where proactive intervention is cost effective. This is being funded from price review (PR) funding and there can be a long lead time between incurring costs and reaping the benefits. These activities are made more difficult by the relatively short asset management programme (AMP) investment cycles and the reluctance of regulators to think long term.

Noting the above challenge in the water sector, the Government could encourage and facilitate funding mechanisms for infrastructure companies to implement longer term planning on the use of data to improve asset management, without any short-term disadvantages.

Q2. What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

An immediate priority could be the introduction of technology that supports public engagement on asset optimisation and maintenance. ACE believes the public can play an important role in collecting data on our infrastructure assets. For example, most water companies in the Netherlands have adopted a software tool called “Human Sensor” to optimise leakage detection, responses and feedback to increase service levels and to save money. The tool combines real-time information from consumers, a contact centre, maintenance and operations units, and distribution units; and then applies algorithms to determine the probable cause and location of leaks. This concept has huge potential for many infrastructure assets, particularly where the public can play a role alongside interconnected services.

Q3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

A failure to realise the commercial benefits from collecting data on infrastructure assets, particularly over the long term, is a significant barrier preventing the rollout of these new technologies. The upfront cost, effort or time required for useful data on infrastructure assets may be turning off some asset owners from adopting this technology. ACE believes this can be addressed through a greater awareness of the long-term value of this technology. The

Government also needs to be a leader in addressing these barriers by promoting best practice through their investments in infrastructure.

There is also a skills deficit for collecting and handling data from infrastructure assets. We believe this is causing a lack of understanding on how to use these technologies to achieve operational improvements. There may be an opportunity for senior leaders to engage with younger members of the workforce to better understand how data can support better asset management and help build traction in industry to consider these technologies as 'business as usual'.

Q4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

ACE is supportive of and excited by the concept of a national digital twin. Common digital standards will be critical for establishing this capability, particularly by allowing data to 'talk' to each other and be user friendly. To this end, the quality of data will need to be a key consideration, in addition to the quantity of data required, to establish a national digital twin.

ACE was not provided any views on the development and specific functions of digital twins.

Q5. How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

The Government, infrastructure providers, researchers and SMEs should work together to explore how new technologies can offer commercial value for infrastructure asset owners. These key stakeholders are also well placed to promote common data standards and to encourage a culture of sharing data.

ACE believes the water utility sector may be a useful current example for how various stakeholders can successfully work together to leverage and scale rapid innovation. The sector's approach to flood defence and innovative approach to optimising product and service combinations (such as software and technology) is an area currently being explored by the newly formed UK Flood Partnership.

Smart traffic management

Q6. What are the latest developments in intelligent traffic systems, and what technologies underpin them?

Recently, there has been a significant focus on understanding how vehicles will connect with one another and the roads network to ensure the introduction of autonomous vehicles is tangible. Developments are also focused on intelligent smart loading of infrastructure to monitor the capacity and provide real-time loadings of the roads network. Traffic data is

critical to underpinning these technologies and ACE believes the Government can play a role here.

Q7. What barriers do local authorities face in deploying these systems, and how could these be overcome?

The need for testing and significant legal barriers are two barriers that local authorities face when deploying intelligent traffic systems. ACE also notes that there is a need for consistency across the roads network when implementing these technologies and city regions may play a useful role here.

Some ACE members noted that the development of national standards for intelligent traffic systems may be appropriate.

Water efficiency

Q8. In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

Tools and concepts used in other countries provide useful information on how the UK can use new and emerging technologies to address and reduce ELL and to make it more financially viable to repair more leaks. The “Human Sensor” in the Netherlands is a prime example. As discussed in the response to question 2, most water companies in the Netherlands have adopted a software tool to optimise leakage detection, responses and feedback to increase service levels and to save money. The “Human Sensor” tool combines real-time information from consumers, a contact centre, maintenance and operations units, and distribution units; and then applies algorithms to determine the probable cause and location of leaks. This concept has huge potential to significantly reduce the EEL.

Q9. Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

ACE believes SMART meters have a role to play in a culture change to recognise the value of water and to change consumption behaviours. This becomes increasingly important as new housing developments are planned and water scarcity becomes a real concern. However, meter programmes need to be part of wider change programmes related to water efficiency and resilience. Economically, it would be a stronger argument to strengthen the governance and outcomes of the efficiency programmes.

Big data

Q10. What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

There is value in establishing governance arrangements on data sharing. A centrally managed approach to data sharing can consider and address some of the current concerns in the area, such as legal responsibilities, ownerships of data and any commercial elements to sharing data.

Governance arrangements can play a role in managing common data standards and performance metrics to promote consistency across the infrastructure industry. The Government should support this by developing or accrediting national standards, to ensure the high volume of data in produced in the infrastructure sector is also of a high quality. ACE believes this will encourage the uptake of these technologies by asset managers by reducing maintenance and operational challenges.

Monetarising data should be supported through governance arrangements. The value of data from infrastructure assets will continue to grow in the future as productivity and environmental pressures increase. ACE therefore believes there should be a focus on creating a clear monetary value of important data from infrastructure assets.

Q11. What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

There are a number of legal considerations to sharing data. In addition to restrictions under the Data Protection Act 1998, infrastructure companies are wary of liability concerns from 'open sourcing' their data.

Companies are reluctant to share data that doesn't represent a success. This may distort the quality of the shared data available and prevent the infrastructure industry from learning from previous failures.

Lastly, the bespoke nature of various internal and external systems can limit the sharing of data between them. Systems are often designed with a particular purpose in mind, and it can be difficult to 'retrofit' their design to interact with other systems effectively.

The Government can address some of these barriers by managing some of the governance arrangements suggested in the response to question 10, such as managing how data is shared and encouraging data consistency across the infrastructure industry.

Q12. How can a national digital twin help to manage infrastructure data as an asset?

The concept of a national digital twin could enable a 'virtual library' of infrastructure data for the public's benefit. This concept, if successfully implemented, could provide a one-stop shop for information on how our infrastructure functions, and would be extremely value for the infrastructure sector, governments, academia and the general public. This concept could also be an avenue for the uptake of common data standards, particularly if there is a mutual benefit for all stakeholders.

About ACE

As the leading business association in the sector, ACE represents the interests of professional consultancy and engineering companies large and small in the UK. Many of our member companies have gained international recognition and acclaim and employ over 250,000 staff worldwide.

ACE members are at the heart of delivering, maintaining and upgrading our buildings, structures and infrastructure. They provide specialist services to a diverse range of sectors including water, transportation, housing and energy.

The ACE membership acts as the bridge between consultants, engineers and the wider construction sector who make an estimated contribution of £15bn to the nation's economy with the wider construction market contributing a further £90bn.

ACE's powerful representation and lobbying to government, major clients, the media and other key stakeholders, enables it to promote the critical contribution that engineers and consultants make to the nation's developing infrastructure.

Through our publications, market intelligence, events and networking, business guidance and personal contact, we provide a cohesive approach and direction for our members and the wider industry. In recognising the dynamics of our industry, we support and encourage our members in all aspects of their business, helping them to optimise performance and embrace opportunity.

Our fundamental purposes are to promote the worth of our industry and to give voice to our members. We do so with passion and vision, support and commitment, integrity and professionalism.

Further information

For further details about this consultation response, please contact:

[name and contact details redacted]

bsi.

...making excellence a habit.™

15th September 2017

Written evidence submitted by the British Standards Institution to the National Infrastructure Commission New Technology Study Second Call for Evidence.

Submission by BSI

1. BSI (the British Standards Institution) is making this submission as the National Standards Body for the United Kingdom.

2. BSI facilitates the development and use of voluntary standards, bringing together stakeholders (including Government, industry and consumers) to share expertise and establish good practice. As the UK's National Standards Body, BSI operates in accordance with an MOU with the UK Government. Our robust standards development process requires open and full consultation with stakeholders to build consensus based outcomes. This gives standards the legitimacy and degree of market acceptance to be used for public policy purposes, including as an alternative to regulation.

3. BSI is pleased to respond to the NIC's call for evidence. In particular, we would like to respond to Questions 5, 7, 10 and 11.

BETTER ASSET MANAGEMENT

Question 5: How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

4. International standards help to deliver global leadership for the UK by accelerating innovation and commercialisation of technologies in areas where the UK has, or is looking to develop, strong R&D capability, such as infrastructure development. This is in line with the Government Office for Science's recommendation to use standards as market framing policy levers, exploiting 'insights from "living labs" to develop UK standards – setting the global agenda by "showing, not telling"'.[1]

5. The development and use of voluntary consensus industry standards has an important role to play in leveraging rapid innovation by bringing stakeholders together, sharing expertise and establishing good practice. This facilitates market development, increased capacity (scaling up), and improved communication along a supply chain.

6. Standards can also:
   - overcome risk by providing the basis for certification and warranty schemes;
   - improve quality and performance through benchmarking of agreed best practice;
   - achieve growth by enabling speed and certainty and therefore a return on investment;
   - improve skills by forming the basis of CPD activity;

[1] Government Office for Science (2017). Technology and Innovation Futures, London.

- drive best practice at an international level through ISO (International Standards Organisation), helping to facilitate market leadership for the UK industry in future export markets.

7. BSI believes that standardization activities can bring demonstrable benefits in the area of infrastructure innovation and productivity. For example:
   a. Community building – ie bringing together industry, owners, operators, end-users and government. This model has worked effectively in the area of Smart Cities where the **Cities Standards Institute**[2] has enabled cities, key industry leaders and innovators to come together to identify the challenges and provide solutions. More recently, the development of **Hypercat**[3] has brought together online communities to accelerate the development of standards solutions for the Internet of Things.
   b. Research into the existing standards landscape. Mapping the existing national and international standards for infrastructure assets against the smart infrastructure pyramid concept (see below) will enable us to better understand the challenges and opportunities in this area and underpin a better asset management "smart infrastructure" benefits case. It will also enable us to identify where standards can accelerate the delivery of benefits, through identifying gaps or potential revisions.
   c. Development of a Standards roadmap with short, medium and long term goals. Working with industry and experts such as Cambridge Smart Infrastructure Centre a Standards roadmap will streamline cross-sectoral working and ensure the benefits are demand/user led. The development of industry capability through knowledge exchange and dissemination of good practice is a clear benefit from the implementation and roll out of the roadmap.
   d. Development of strategy and planning around scale-up and export opportunities for the UK. This approach has been proven through **Building Information Modelling (BIM)**[4], where adoption of the UK suite of Level 2 BIM standards in overseas markets has created clear advantage for UK industry.

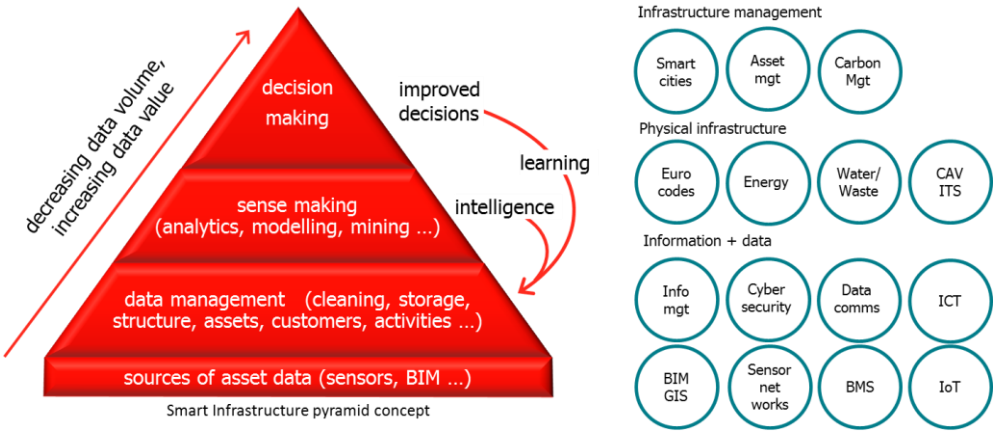

Figure: the smart infrastructure pyramid concept with related British Standard subject areas

[2] https://futurecities.catapult.org.uk/project/cities-standards-institute/
[3] http://www.hypercat.io/
[4] http://bim-level2.org/en/

SMART TRAFFIC MANAGEMENT

Question 7: What barriers do local authorities face in deploying these systems, and how could these be overcome?

8. Research prepared by BSI and the Transport Systems Catapult published in 2017 identified a number of barriers related to the deployment of Connected and Autonomous Vehicles (CAV) and performance of Intelligent Transport Systems (ITS).[5] These include issues regarding the lack of application-level standardisation to support the flow of information from the road-side infrastructure to the vehicle and vice-versa (e.g. traffic orders in vehicle-to-infrastructure (V2I) communications). Standards were also identified as a priority to optimise integration of vehicles with traffic management systems operated by transport networks, including local authorities and network operators.

BIG DATA

9. In 2016 BSI commissioned external market research to better understand the needs for standardization in Big Data in the United Kingdom.[6] The research identified a number of potential areas where there is greatest need for standardization. BSI took these ideas and, over four workshops, honed them into a series of British Standards which are at the beginning of their development process. These four standards are:

   - *Big Data. Guidance on terms and conditions (T&Cs) for obtaining and using data*. In projects that typically comprise vast quantities of data (sometimes provided indirectly as part of using a 'free' service), the consent and trust of the data provider (often members of the public providing their personal data) are vital to underpin Big Data projects and the value derived from them. As such, those providing data need to understand clearly what data they are contributing and what they get in return - including any potential adverse impacts. This standard will define best practice for T&Cs that are simple to understand and to optimise informed consent prior to data being used in such projects.
   - *Big Data. Specification for a data engaged organisation.* Data-centric organisations that exploit the benefits of data do not follow traditional organisation structures. This standard provides a framework to allow an organisation to be data centric and hence maximise the benefits they obtain from data and at the same time ensure compliance with the regulatory framework around the use of data.
   - *Big Data. Guidance on Big Data project communications*. There are examples of where Big Data projects (as opposed to IT projects) have failed to deliver, not because of the quality of the project, but due to a lack of understanding of the benefits from the perspective of those whose data has been used. This standard will help such projects to define and articulate benefits to ensure public trust and societal/economic benefits/disbenefits in comprehensible terms with the 'data subject'. This standard will provide guidance (primarily for projects using personal data – whether or not the data is 'anonymised') on how to communicate to data subjects and other relevant stakeholders before, during and after such projects.
   - *Big Data. Code of practice for Big Data analytics project management.* Big Data projects are new to most organisations and hence many do not know where to begin or how to avoid issues. Some may be research led projects that generate new insights for existing business process, whilst others may lead to a new business process. Projects often need

[5] BSI and TSC (2017). *Connected and autonomous vehicles. A UK standards strategy*, London. Available from: https://www.bsigroup.com/innovation/cav/
[6] https://shop.bsigroup.com/forms/The-Big-Data-and-market-research-report/

to be agile, yet they cannot be a weak link in an organisation's information security policy.

BSI is also working on the potential to developed additional specific standards around ethics and metadata.

Question 10: What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

10. Governance is a clear theme of the standards identified above and was central to the feedback from the market. At present, there is no clear guidance on ensuring governance of data to match some of the good legal (i.e. data protection) guidance. Having such guidance in place would encourage infrastructure providers to manage and share data.

11. In terms of the deployment of data-based technologies, Government could assist by encouraging industry to see the value of data sharing. Having agreed best practice in place (e.g. APIs) is also a way to facilitate data sharing – it is likely that no "infrastructure" industry-wide API exists. BSI has 120+ API specific standards and can aid the development of new infrastructure industry standards, provided that there is demand for such standards.

Question 11: What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

12. The report referred to in paragraph 8 above identified business challenges that organisations are currently facing when undertaking Big Data projects (including sharing of data). One broad area is around technology. At the heart of many organisations are decades-old IT systems. Often cumbersome, disjointed and inflexible, these IT systems present a tangible barrier to growth in Big Data usage. This is a particular challenge when it comes to creating a single holistic data source. For many organisations, investment in Big Data will need to be accompanied by investment in IT systems and will probably require using cloud technology.

13. Cultural challenges also present issues. Whilst possessing IT talent is certainly necessary to execute complicated Big Data initiatives, such talent is wasted if there is not a strategic imperative from senior management within businesses to ask the right questions. Another cultural challenge is around businesses adopting a different attitude towards data. Rather than seeing data sources as pieces of property that are owned by individual functions within the business, it is important to consider data as a single and unifying company resource. This requires cooperation and collaboration between all organisational functions – something that isn't always easy.

14. There are also challenges around perception, in particular the real fear of breaking data protection legislation.

15. Government can help with these challenges by:

    - Working with the Information Commissioner's Office to ensure that organisations understand data protection regulation and what data sharing they can (and cannot) do.
    - Helping infrastructure providers to recognise the benefits of Big Data/data sharing to ensure

the resources and objectives of the organisation are focused to ensure that it becomes a reality. When it is completed, the British Standard "*Big Data. Specification for a data engaged organisation*" will help organisations to do this.

Background on BSI

BSI is the UK's National Standards Body, incorporated by Royal Charter and responsible independently for preparing British Standards and related publications and for coordinating the input of UK experts to European and international standards committees. BSI has over 115 years of experience in serving the interest of a wide range of stakeholders including government, business and society.

BSI represents the UK view on standards in Europe (via the European Standards Organizations CEN and CENELEC) and internationally (via ISO and IEC). BSI has a globally recognized reputation for independence, integrity and innovation ensuring standards are useful, relevant and authoritative.

BSI is responsible for maintaining the integrity of the national standards-making system not only for the benefit of UK industry and society but also to ensure that standards developed by UK experts meet international expectations of open consultation, stakeholder involvement and market relevance.

British Standards and UK implementations of CEN/CENELEC or ISO/IEC standards are all documents defining best practice, established by consensus. Each standard is kept current through a process of maintenance and review whereby it is updated, revised or withdrawn as necessary.

Standards are designed to set out clear and unambiguous provisions and objectives. Although standards are voluntary and separate from legal and regulatory systems, they can be used to support or complement legislation.

Standards are developed when there is a defined market need through consultation with stakeholders and a rigorous development process. National committee members represent their communities in order to develop standards and related documents. They include representatives from a range of bodies, including government, business, consumers, academic institutions, social interests, regulators and trade unions.

Further Information

BSI would be pleased to provide further information or to discuss the content of this submission with the National Infrastructure Commission.

For further information please contact:

[names and contact details redacted]

The Catapult Network comprises 10 technology innovation centres across the UK. We provide expertise, facilities and equipment that help to translate early stage research by universities, research centres and businesses into commercial products and services, and consequently increase productivity and strengthen the UK economy.

BETTER ASSET MANAGEMENT

1. *What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?*

The Satellite Applications Catapult has worked with the National Physical Laboratory (NPL) on a Transport Infrastructure Integrity Monitoring project to determine the viability of using satellite InSAR in concert with in-situ Internet of Things (IoT) based sensors deployed on the Queen Elizabeth II Bridge over the Thames, as well as nearby unstable embankments to determine stability and inform preventative maintenance.

It is now working with the UK Government Business Information Modelling (BIM) Task Group to extend the learning from this project and conduct a remote bridge condition-monitoring trial. This trial will determine (independently) whether satellite and IoT technology can provide a reliable and sustainable solution for improving and lowering asset-management costs of remote assets. As a neutral and trusted entity with extensive knowledge about the space industry's capability, the Satellite Applications Catapult is well placed to undertake an unbiased assessment of InSAR as a technique that can potentially be used by the engineering/construction community. It expects to deliver the findings from this one-year project in March 2018.

Drainage

Those responsible for the maintenance of individual infrastructure types can overlook the importance of the drainage network and the potential impacts if faults occur, such as network disruption, flooding and environmental damage.

TrackWater is a collaborative R&D project part funded by InnovateUK, in which the Transport Systems Catapult is taking part, designed to tackle drainage management challenges within the rail sector. It builds on the SmartClean project developed for the highways sector. This innovative IoT sensor-based predictive maintenance solution has been shown to deliver a potential 80% reduction in cleaning for drainage assets, while also helping to deliver real-time status information for the drainage network, and minimise the risk of flooding by ensuring appropriate gullies are cleaned when they stop performing as intended (https://www.intouch-ltd.com/smartwater). The information that this can provide includes real time alerts, predictive data modelling and clear, user friendly visualisations, all of which can transform understanding of how best the network can be maintained.

2. *What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?*

The biggest technical challenges discovered so far relate to the challenges of retrofitting sensors and extracting the key information from low-integrity and noisy data sources. This requires the

integration of disparate data sets and use of machine learning techniques. These techniques need large scale, long-time-baseline data sets and ongoing operational data, hence collaboration with infrastructure partners is essential.

Technologies such as Light Imaging Detection & Ranging (LIDAR), infra-red and optical could provide benefits to support better asset management if they were used in a more complementary fashion, and together could be expected to provide more information and wider coverage, often with a better level of detail than at present.

New lower-cost IoT-enabled sensors represent a step-change in ability to obtain network-wide data on asset condition, use and utilisation. With machine learning techniques applied to monitor and analyse the data produced, the potential is enormous for developing predictive capabilities to monitor asset performance and degradation and enable pro-active management based on condition and an asset's expected residual life.

3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

Identifying who is responsible for managing the infrastructure and ensuring interoperability is important to improve asset management.

Working with the Transport Systems Catapult, Network Rail identified that responsibilities for managing the Permanent Way, Signalling, and Telecoms and Overhead Electrification assets are split between three distinct parts of the organisation; and technical disciplines run their own asset management systems, without a common referencing system and with little overlap in terms of asset management activities. This siloing of responsibilities can lead, and has led, to issues of lack of clarity of accountability and responsibility, particularly when dealing with planned renewals and enhancements to the network.

Information needs to be integrated into operational procedures in a way that is seamless and does not require specialist separate human analysts to interpret the information. Ancillary environmental data is often key to distinguishing false alerts from real threats, and this data is not always easy to access and integrate.

This was highlighted by a project that the Satellite Applications Catapult worked on in early in 2016 for Innovate UK, to support them with a market challenge for Network Rail concerning prediction of landslide events across their Network. This opportunity challenged businesses to demonstrate that Earth Observation data with relevant analysis techniques could potentially improve risk assessment associated with landslide events, demonstrating the enhancement that could have been made to Network Reliability and preventative maintenance through the application of these technologies.

As part of the project, the Satellite Applications Catapult was on a panel assessing the responses from businesses. It became clear through this project that any national based monitoring system needs to be integrated into integration monitoring systems to ensure that there is a commercial opportunity for operational support systems. In addition, how the predictive and preventative measures are adopted and by whom is less clear, as the benefits do not necessarily accrue to the infrastructure owner.

The cost of acquiring and processing satellite data to the appropriate integrity on a national scale is prohibitive to any single organisation or for a single class of infrastructure.

4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

A national digital twin could enhance the predictive capability using existing datasets and models, providing the relevant organisations are brought together.

The Transport Systems Catapult has undertaken some work in this area, developing a national 'twin' of Highways England's Strategic Route Network (SRN). This was hosted in a cloud based high performance distributed computing environment. Although focusing on traffic and operations initially, it is recognised that this 'twin' has the potential to incorporate all asset and operational data pertaining to the operation and condition of the complete SRN.

One could consider bringing together the knowledge and skills of the Environment Agency; Ordnance Survey mapping and topological capability; British Geological Survey with its sub-surface knowledge; and the meteorological factors from the MetOffice to provide complementary datasets and analytical systems to strong predictive capability. However, since these are independent organisations with different capability and business models, there would be challenges to bringing the capabilities together to provide a powerful digital twin.

5. How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

An important raison d'etre for Catapults is to build commercial relationships between large infrastructure providers and technology SMEs, researchers, innovators and experts to find solutions to challenges and build opportunities for rapid innovation.

Catapults could play a significant role as the neutral trusted entity that combines and builds on the strengths of independent organisations to develop new and innovative solutions. The creation of a National EO-Data Refinery and Digital Information Exchange would, with the appropriate governance and regulatory controls, provide a framework in which data providers, researchers, and innovators could collaborate to create services for the infrastructure sectors.

SMART TRAFFIC MANAGEMENT

6. What are the latest developments in intelligent traffic systems, and what technologies underpin them?

In our view there are several main enablers for intelligent traffic systems:

- Intelligent infrastructure: where infrastructure systems companies complement existing offerings with new intelligent services and additional capability;
- Systems that incorporate digital information gathered from vehicles (especially pertinent for future connected and autonomous vehicles), leveraging IoT technologies and particularly relevant for the automotive sector;
- Systems that gather crowd-sourced information, both in terms of people movement and sentiment to determine stress on transport infrastructure;
- Technologies that facilitate data processing on mobile platforms, and the anticipation of future ubiquitous and resilient mobile data connectivity (5G terrestrial/ satellite integration);
- Technologies that provide secure means of ensuring transactional (eg blockchain) and data integrity (artificial intelligence for information signature analysis);
- Technologies, particularly sensors, which provide data in real-time to enable more pro-active management of transport networks, particularly when combined with Artificial Intelligence/Machine Learning (AI/ML) techniques to provide predictive power for active management of the networks;

- Vehicle to Infrastructure (V2I) technology introduction of simpler 'bottom-up' rules at traffic lights – to enable cars to control the lights rather than the other way around – enables the system to achieve an emergent (dynamic) equilibrium by itself. Existing UK examples of real-world deployment and implementation of Co-operative Intelligent Transport Systems (C-ITS) are COMPASS4D (http://www.compass4d.eu/) and ACCRA (Autonomous and Connected vehicles for CleaneR Air).

The Satellite Applications Catapult is working with organisations involved in the first five of the above and is finding the greatest challenges around how organisations react to the information. For example a recent project looking at Healthy New Towns worked with Earthsense on mapping air pollution to consider how to re-route traffic to reduce air pollution at peak times. To achieve this requires interoperability between systems and the capability for relevant organisations to respond as appropriate to information.

7. What barriers do local authorities face in deploying these systems, and how could these be overcome?

There are number of barriers associated with the exploitation of such systems by local authorities, which include, but are not limited to:

- A lack of understanding of the economic benefits of such systems and the value they accrue to the citizen;
- Challenges with regard to budgetary mechanisms and the need to invest at scale prior to the impact being obtained;
- Difficulties in transforming internal processes and transitioning from existing operational practices;
- A lack of collaborative frameworks that allow National and Regional Government organisations to work with professional services companies to share and exploit new information sources;
- Ensuring common standards and language are necessary to enable interoperability which will allow a more integrated response to the information acquired;
- A shortfall of suitably skilled staff in local authorities who can design/deploy/manage and operate these new types of system. Whether these are budgetary or skill/capability driven will vary across local authorities. Nevertheless, the impacts of not having the resources to meet the demand is a very real and near-term challenge;
- Economic value models (WebTag, Green Book) for economic development proposals need updating to allow for more accurate forecasting. Value return mechanisms should be developed to deliver the efficiencies needed to extract and amplify the potential gains these technologies can provide.

BIG DATA

10. What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

The Government (working with the National Infrastructure Commission?) should play a facilitating role, helping industry parties to develop architectures, policies, practices, procedures and standards to manage Big Data effectively. The Government should drive the adoption of open data standards to improve efficiency and inter-operability whilst ensuring that platforms and technologies are both secure and cyber-resilient. It may be appropriate that a Government departmental team is created to

act as a 'data scientist' to provide the capability to conduct, interpret and consume the outputs of data and ensure that analytics work intelligently.

The Transport Systems Catapult's Intelligent Mobility (IM) Data Hub is a trusted neutral enabling capability and open data platform for innovation, i.e. the IM Data Hub can be part of the transport sector's critical infrastructure for big data. The grand vision is to have an 'API First' approach to build a robust pipeline for data ingestion and efficient storage of either raw data or aggregated data. The IM Data Hub offers advanced data curation and data analytics capabilities to address any real-world transport problems such as predictions, situational awareness and network resilience.

See also: https://hortonworks.com/solutions/data-ingestion/
https://www.gsma.com/iot/iot-big-data/iot-big-data-api-directory/

11. What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

Data is generated from many different sources in many different formats. Collecting the data by itself is complicated by the existence of multiple sources with different formats and types and different usage and access policies. In addition, the unstructured nature of the data makes it hard to categorise or organise in an easily accessible way for applications to use. Therefore, the introduction of standard data protocols should be considered along with open interfaces to facilitate the collection, transfer and sharing of data.

Sharing data and information among different entities is another challenge. Each entity typically has its own warehouse or silo of confidential or public information, and is often reluctant to share what might be considered proprietary data. In addition, some data may be governed by certain privacy conditions that make them hard to share across different entities. This provides a challenge between collecting and using big data without ensuring rights of privacy.

To ensure proper and useful utilisation of data in the infrastructure industry, it is important to have suitable and effective 'Big Data' management tools in place. Big Data management includes the development and execution of architectures, policies, practices and procedures that properly manage the full data lifecycle requirements. As the data comes from different sources with different formats, there is a need for advanced data management features that will recognise the different formats, structures and sources of data.

12. How can a national digital twin help to manage infrastructure data as an asset?

A digital twin allows access to all archive and real-time data associated with a national asset within a single environment, opening up access to that data and insight across the asset owner's business.

Owing to the regionalisation of their control systems, Highways England and Network Rail, for example, do not have a strategic overview of their network assets. Whilst this allows control of the asset/network to be undertaken close to the operational frontline, it does not easily cater for cross-regional issues which may need to be managed or dealt with.

The digital twin is the ideal receptacle for real-time data from new and existing sensor technologies, allowing the asset owner to maintain a real-time operational overview of asset performance and capability.

Another benefit of a 'twin' is the ability to incorporate modelling and predictive technologies to enable future scenarios to be evaluated that are 'forked' from a point in time. In the high-performance computing environment investigated by the Transport Systems Catapult for Highways England, this enabled real-time operational decision making to be supported by running rapid 'what-if' scenarios, e.g. for identifying the best way to deal with an incident on the Strategic Route Network, in terms of number of lanes closed/speed limits imposed/diversion routes used etc.

The digital twin also allows for longer term strategic planning to be undertaken if all asset information is available in archive format. Using this data, predictive algorithms can be developed and implemented to produce forecasts of asset condition and usage, which can be used for planning future asset renewals, enhancements and additional/new infrastructure.

Digital twins will become essential assets for monitoring, managing and planning national infrastructure assets.

Catapult Network, 15 September, 2017

NEW TECHNOLOGY STUDY

SECOND CALL FOR EVIDENCE

ch2m SM

Introduction/ Summary

We welcome the opportunity to respond to the call for evidence and, in our role as one of the leading global infrastructure providers, we are pleased to be able to share our experience from a range of major programmes incorporating the development of new technology and delivering significant benefits. We have provided full responses to each of the questions raised in the call for evidence and can provide further information, on request.

In summary:

- From our experience, both globally and in the UK, we have seen the delivery of significant benefits through the investment in innovation and technology enabling better asset management - reducing risk, improving resilience and increasing efficiency
- ISO55001 provides a significant opportunity to help organisations understand asset health and reliability to deliver productivity gains, a source of currently untapped potential in the UK. Our most successful examples have been through integrated service delivery contracts, which are necessary to generate the necessary behaviours and incentives
- Alignment is required across the project lifecycle (operations and design) as well between organisations and sectors to ensure the full range of benefits can be realised
- One of the major barriers to overcome is recognising that long-term benefits far outweigh the cost of short-term investment. Greater certainty and clarity of benefits is required to help our clients invest in this new technology
- Cross government agreement and support in the development and implementation of a common and consistent technical framework is key to facilitate greater functionality and interoperability between sectors. We believe significant progress can be made through targeted investment to accelerate key initiatives
- The creation of a national digital twin has significant long-term potential, but this requires both a top-down and bottom-up approach
- We need to recognise that different sectors will develop at different rates, but there needs to be a strong overall vision to deliver the greatest benefits aimed at understanding and delivering the ultimate goals, and how mutual success can be delivered by connecting previously unconnected sectors through the power of big data and smart technology

Better Asset Management

1. What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

Data Speculation: The collection of asset data has been underway for some time, and in many different sectors by many different parties, however we are beginning to see a change in the business models behind firms operating in these spaces. We have witnessed the arrival of firms who are speculatively capturing asset condition and performance data, e.g. Gaist, who have utilised new technology to collect asset condition data across the road network, and firms like TomTom and Google, who are collecting journey time data that can inform road network performance. This data is currently available for purchase, but it is an expensive annual cost.

Unequipped to extract value: The BIM Level 2 mandate has catalysed the collection of asset attribute data. In many circumstances our clients are not equipped to receive and utilise this data to its fullest extent. This is primarily due to the fiscal and time constraints many of our clients are experiencing, preventing them from developing the capabilities internally to receive and utilise data being given to them. Only once our clients have full visibility of the data they have can they start extracting value. To assist our clients with this, we have developed a tool with Autodesk on the Highways England Smart Motorway Programme (ACBOS) contract, which allows the incorporation of infrastructure data into existing asset systems facilitating BIM Level 2 compliance at a much reduced cost.

Design operation disconnect: Often there is still a disconnect between data from design into operation, and the feedback from operational performance is still not informing the design process consistently through project delivery. Benefits of data collection are not being fully realised. We have the capabilities and tools to identify system level improvements should we get access to

quality data that can inform system design and operational requirements.

Asset data for health and reliability modelling: Technology developments have enabled the value of data to be realised by reducing the costs associated with the collection, storage and analysis of data. Our most successful examples, the Environment Agency's TEAM2100 and East Sussex County Council's Highways Programme, have collected and utilised the advances in sensor, drone, mobile device, communications infrastructure technology, allowing us to collect and transmit our own data cheaply, quickly and easily. Asset data is combined with modelling approaches to understand asset health and reliability. Individual asset health data is then fed into asset system modelling approaches that allow asset system reliability to be understood. Combining system reliability outputs with asset management best practices, informed by ISO55001, allows whole life costs (or TOTEX) to be accurately estimated. Interventions can then be identified to deliver sustainable efficiencies. On TEAM2100, this has led to significant savings running into the £100 millions over the life of the assets, and on East Sussex we have increased operational productivity by 70%, and reduced costs by 60%. These types of tools are critical to enabling the joining up of asset attribute, performance and condition data to enable improvements in line with the philosophy of big data.

No interoperability standards: Currently these individual asset and infrastructure system databases are independent of each other and not connected. There are no defined standards that force interoperability between systems and databases, and this presents a barrier to the realisation of big data approaches and its benefits. Standardising interoperability, much as the computer industry did with physical standards, will allow greater utilisation and innovation within the sector and will unlock the productivity gains hypothesised.

Integrated service delivery contracts: We expect to see this type of digitally enabled infrastructure system to become the norm. The delivery of these benefits has been enabled by appropriate integrated service delivery contracts, where one organisation has responsibility over the entire lifecycle. Through appropriate contractual incentivisation, innovation in how data can be used has been unleashed. This evolution in contractual arrangements is entirely consistent with the ICE's Project 13 findings, and we have the data to demonstrate that it works.

2. What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

The value of infrastructure data can be evidenced through our projects named above, however the true economic value of data has not been clearly articulated yet. Data has a cost to collect, transmit and store, has an expiry date and its quality directly affects its utility value. To better inform this, we see technology priorities in the following areas:

- **Sensors and data capture technology developments** to increase use and to reduce costs; currently units can be very expensive (e.g. ANPR cameras in roads), or are fixed in infrastructure, requiring it to be taken offline for instalment or maintenance (e.g. SCOOT loops); this can cause operational delays and raise costs.
- **Real time connectivity between assets**, field operatives, databases and decision support platforms. This will require investment in communication infrastructure. Different sensors and assets can operate on different technologies (e.g. 3G, 4G, 5G, LoRa, Bluetooth and WiFi). We need to find the optimum mix to enable the necessary data to be collected and transmitted at lowest energy and cost.
- **Asset health and deterioration modelling** is well underway and delivering results through the application of practices and standards such as ISO55001. Its practice needs to be distributed more widely, and standardization between systems needs to be enabled in order to release intra-system and interdependency benefits to be realised. This requires open Advance Passenger Information systems (APIs) as well as an agreed common metadata language, such as used in the airlines industry, to enable better information management across more than just the design phase (i.e. IM not just BIM).

3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

Barriers include:

- **Technological barriers:** as above. This requires greater investment in technologies, the way they communicate between themselves, and the analysis of the data they collect.
- **Financial barriers**: cost of buying and installing sensors and their associated systems is often prohibitive for many public-sector clients. Investment in different technologies will stimulate competition and reduce costs.

- **Organisational barriers**: Collaborative working between infrastructure projects and sectors could also help reduce total costs
- **Uncertain benefits**: clients not confident enough in the application of systems to take the risk. Targeted funding supporting innovation trials will not only accelerate development but also provide greater certainty for investors.
- **Procurement**: often there is uncertainty on how to specify technologies without unfairly influencing competition. Standards and guidance are needed for procurement teams trying to buy new technologies.
- **System/ supply chain/ asset lifecycle fragmentation**: often the benefits generated through the development and application of technology are not realised by those whom it costs to implement. A value network approach and cross-industry collaboration could reduce this barrier, and greater use of integrated service delivery contracts (e.g. TEAM2100) is highly recommended.
- **Poor asset management practices**: reducing CAPEX spend is often the priority, and embedded monitoring and controls systems are often ommitted. Government could help prioritise TOTEX through the mandate of the achievement of minimum standards through mechanisms such as ISO55001, as they did with BIM Level 2.

4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

The main benefit of a digital twin is to reduce the whole life costs associated with operating and designing infrastructure assets. This can be achieved through real time monitoring of asset conditions and performance. This allows operators to identify and take interventions to ensure operational efficiency and effectiveness through proactive asset management. Combining data sets between infrastructure assets allows learning though big data analytics and for continuous improvement across assets to be realised and future designs informed. Facilitating infrastructure asset systems to communicate and operate interdependently allows system level optimisations and productivity gains to be realised.

The first step is to ensure that these 'parts' of the national digital twin are functioning, and that lessons learnt from their design, installation and operation can be distilled and distributed within and between industries. Lessons and best practices can also be gained from other industries that are significantly further down this technology path, e.g. manufacturing, automobile and aviation industries.

The second concurrent step would be to ensure data interoperability, security and quality. This will require a cross-industry approach to agree standards, protocols and best practice, while allowing the activity to be focused on the aspects most needed to deliver the hypothesised productivity gains. The third step is to support and encourage collaborative working between actors in the infrastructure industry. This is underway through the Infrastructure Industry Innovation Platform (i3P) and the Infrastructure Client Group (ICG). Government supplementation of the industry investment in these platforms, and the ideas that they are generating, could help increase the reach and speed of the distribution of innovation, and lead to dramatic productivity and export gains.

5. How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

Alignment and cohesion between organisations are needed. Identifying and agreeing the purpose and required outcomes of the development of these technologies and capabilities should be achieved through consensus across industry and public and third sectors. Reassigning responsibility between actors is required to deliver rapid progress in the development and application of technologies. The tabled merger between the Research Councils and InnovateUK could provide an opportunity for realignment within Government. The private and public sectors are beginning to align and collaborate through voluntary organisations such as ICG and i3P. While providing mechanisms for collaborative working to identify problems, these platforms are also stimulating the creativity and ingenuity of individuals and organisations, providing a safe space for innovations to be trialled and lessons shared rapidly between organisations.

Supporting innovation and technology development is also necessary. As was the case with the automobile, aviation and defence industries, the infrastructure industry is coming together under one voice. This is a global first in the infrastructure industry. Government must significantly invest and support this industry, as it did in the aforementioned industries, in order to realise significant productivity gains and allow the UK to become a world leader in this field. Engagement now through these vehicles like ICG and i3P is highly recommended to inform Government plans.

Smart Traffic Management

6. What are the latest developments in intelligent traffic systems, and what technologies underpin them?

The three main areas for progress and development can be seen in the following groupings:

Real time traffic models: utilising and fusing sensor, ANPR, mobile and floating car data (sat navs) on local road networks, these systems identify patterns in vehicle movements through the application of algorithms in order to predict issues and provide a 15-30-minute window for teams to intervene and redirect traffic to prevent, reduce or alleviate congestion. The primary technology provider, PTV, has just been bought by Porsche, highlighting the emerging market and the car manufacturers' intention to move into resource and people logistics. This type of technology underpins 'dynamic road user charging' or 'pay as you go'. This is a revenue generating potential for road operators. There are no comprehensive examples of this in the UK. We do have an example from Oregon, US, where we have trialled such a payment system.

Connected Corridors: infrastructure to vehicle communications (primarily on the strategic road network) sharing multiple information streams relating to congestion, road and weather conditions to allow drivers to take action and avoid problems and operators to influence variable speeds. We are beginning to see these technologies requested by our clients, e.g. Highways England Smart Motorways Programme, A2 Connected Corridor, Lower Thames Crossing and the A9. There has been no clear or concerted communication with the car manufacturers as of yet to understand opportunities for connectivity. Real system benefits can only be realised once the strategic road network (connected corridors) and the local road network (real time models) control systems are fused, allowing the orchestration between the two road networks to manage congestion and reduce H&S risks associated with queueing vehicles at motorway junctions.

Connected and Autonomous Vehicles (CAV) – connected vehicles would link to each other and infrastructure whereas autonomous vehicles can stand alone. Development in CAV capabilities is enhancing all the time and can continue without intervention. There is a revenue generating opportunity for infrastructure operators. CAVs currently have no clearly articulated back-up system in case of positioning or other system failure. They also cannot currently optimise traffic flows as they are only interested in getting themselves to their destination. An 'orchestrator' type of system can help optimise flows and provide a backup system for CAVs. Road operators could charge for connection to such a system.

7. What barriers do local authorities face in deploying these systems, and how could these be overcome?

Through our Bristol Transport Services Framework and work with Highways England and Transport Scotland, we have been exploring this topic. The main barrier is currently uncertainty in the benefits that these systems could deliver. European examples (Milan, Paris, Moscow) are often met with scepticism by our clients, and this prevents the detailed consideration or investment in trial projects. Due to there being a limited number of suppliers for this technology, procurement issues also arise that prevent some forms of funding.

This leads to a lack of funding, organisational capability and skills to develop, manage and maintain these high technology systems both within client and supplier organisations. The benefits of such systems are hypothesised not only in reducing congestion and journey times, but also in reducing the revenue costs of local authorities delivering their responsibilities. These systems will have high operational and maintenance costs, and the reduction of costs associated with other revenue activities needs to be guaranteed.

There is a lack of political support, evidencing itself in a lack of support for road pricing/ pay as you go models and through various DfT funding schemes that do not explicitly specify these systems as fundable under current agreements, even though they are in scope. InnovateUK funding currently does help as the suppliers of the systems do not want to reduce their revenue selling the technology through a match funded approach.

To overcome this, a set of measures that balance the negative political consequences and provide both a carrot and a stick to local authorities is required. For example, in Bristol the Clean Air Zone study and congestion charging /work place parking levies could support desirable Metro/LRT provision and provide funding for system improvements and true cross-modal ticketing. This could lead to reduced congestion, reduced operating costs, increased revenue generation and greater accessibility for economically disadvantaged groups. The top down political support and early concept funding are missing to make this a reality.

Water Efficiency

8. In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

Smart meters in combination with real time pressure management can provide a significant improvement in the financial viability of leak reductions The water industry has a good foundation to build on as most water networks are captured in digital models. The challenge is how to link those models to real time operation- progress is being made in these areas. To fully understand the networks and drive greater efficiency, more investment is required in monitoring and control systems. We are seeing some of our clients investing and developing in this technology in the UK, but currently the best examples are global.

Do you feel that a national and compulsory roll-out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

Smart meters have two benefits: understanding and managing the network, and informing and driving customer behaviour. Potentially 50% of leakage is on the customer side; having daily meter reads from customers whether the meter is internal (in the house) or external (at the property boundary) will provide clarity on daily use patterns that can help identify supply pipe leaks, plumbing losses and more accurately define household consumption usage patterns for different property types.

It is important to note that not all customers are metered and many still pay a fixed rateable value irrespective of usage, so smart meters are two steps away (indeed some parts of the UK such as Scotland domestic customers do not actually receive a water bill). In some areas, companies will find it difficult to support a metering programme because the costs far outweigh the benefits, and only in water scarce areas do companies have authority for a compulsory programme.

We need to be very careful as while this investment will drive short term efficiency, it does not address the underlying deterioration of the aging asset base or the management of water resilience across regional scales. A combination needs to be found between approaches to leakage reduction and water resource resilience management. To focus solely on smart water meters for water resource management does not present the greatest benefit. Our work with the Water Resources South East Group showed how managing water at a regional scale, through collaborative working between the six water companies in the South East, can lead to significant improvements in water resource availability and planning for sustainability reductions and climate change. Some of the real gains come from having linked smart water and smart energy meters, which provide greater benefits to customers (combined billing and introduction of home management systems) and greater efficiency across both sectors (energy and water use are directly related). To achieve this, it needs a co-ordinated approach across Government departments and a common communications and data management platform. As we have seen in the energy sector and many cases around the water industry, the use of smart meters becomes a key enabler not only for the management of the system but also in providing flexibility in charging tariffs, reflecting capacity and availability.

Big Data

9. What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

We believe that a metadata common language approach would be best suited to ensure interoperability, coherence and consistency that are required to manage and use the data being generated by the infrastructure industry. This metadata common language approach facilitates information management between infrastructure actors and assets, and informs the requirements for open APIs. The interoperability delivered through this approach will deliver a step change in adoption, as more and more use cases start to deliver benefits that can be demonstrated to others. A cross-industry working group with cross asset lifecycle representation, taking lessons learnt from other industries, would be the most effective way of achieving requirements. This will happen organically but it needs a catalyst. PAS1192-5 is trying to deliver a standardised approach and this will be useful. The full adoption of BIM in our clients has been slow and it is suggested that more assistance is needed to be given to a handful of asset operators in order for the full range of benefits to be realised and demonstrated for others to follow.

10. What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the Government do to support the secure sharing of data in the infrastructure industry?

Organisations, and the industry as a whole, are very siloed. The data that exists is correspondingly siloed too. It has not been shared between clients, designers, contractors and operators: it is split between different actors at different asset lifecycle stages. In many cases, data quality is uncertain- there are several data sets that overlap, many that are out of date and many that are simply inaccurate or wrong. The perception of data as an asset to be managed is in its infancy in many organisations within the infrastructure industry. Data and organisational maturity assessments are probably a wise first step to systematically understand the barriers at play. As is referred to above, interoperability is a key issue, ensuring that data can be exchanged between devices, databases and systems in an integral step. Data quality and assurance become easier once consistency and coherence between data sets are delivered. Once organisational competencies are developed in the data management space, benefits will be more easily realised. Best practice can be identified and lessons shared among actors. The Digital Built Britain working group is a good place for many of the interoperability standards to be discussed and agreed, but resource needs to be given to projects to implement the agreements and demonstrate benefits and value. It is suggested that the Government could enable these demonstrators through cross-industry working groups, such as the i3P, which can directly take innovations and technology developments and trial them. i3P needs financial support from Government; it is currently self-funded by the industry and it needs to be aligned to the wider activities going on throughout society, see Q1.

11. How can a national digital twin help to manage infrastructure data as an asset?

Many of the ways in which the twin can help are through the encouragement and development of the market, and the soft skills associated with its delivery and operation:

Ensuring interoperability: an effective and operational digital twin requires data interoperability between and within sectors. The development of standards and protocols for the national digital twin will facilitate the management of data as an asset, for example in its storage, transmission and use, throughout connected industries. Standards set at a national level will filter down to regional and sectoral twins. As interoperability is achieved the value of data will increase. This will organically lead to its management as an asset.

Changing infrastructure data perspectives and mindsets: As infrastructure data becomes perceived as an input that provides tangible benefits to its users, data will gain a value and the perception of infrastructure data as an asset will increase

Enhancing skills and investment in infrastructure data: As plans for the twin become agreed and publicised, this vision will help with investment, skills development and capability building in data management.

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Chartered Institution of Highways & Transportation (CIHT) response to the National Infrastructure Commission (NIC) – New Technology Study (deadline 15 September 2017)

CIHT is a charity, learned society and membership body with over 14,000 members spread across 12 UK regions and a number of international groups. We represent and qualify professionals who plan, design, build, manage and operate transport and infrastructure networks. Part of our vision is to demonstrate transport infrastructure's contribution to a prosperous economy and a healthy and inclusive society. Our values are to be Professional, Inclusive, Collaborative and Progressive.

CIHT welcomes the opportunity to respond to the National Infrastructure Commission New Technology Study Call. CIHT has a range of resources that might be beneficial in assessing organisations at the cutting edge of this arena and would recommend that the Commission would benefit in looking at previous CIHT Award winners – particularly in categories that look at technology, innovation and asset management [www.ciht.org.uk/awards].

One area on which CIHT has particularly focused with its members is the consideration of the security aspects in the uptake and deployment of new technology e.g. Building Information Modelling (BIM), LIDAR and sensors on infrastructure. This is important when it comes to technology and consideration of this must underpin all work in this field. CIHT produced a podcast on this ['How to be security minded' www.ciht.org.uk/podcasts] and this provides a range of useful issues relevant to this area – from issues around the use of BIM and Lidar to potential risks for sensor data.

Another important area to consider and where CIHT is making an important contribution is the need to ensure that the sector has the right skills to keep pace with the evolution of technology and its widening application. For example more ICT and systems engineering skills will be required in future, as well as more traditional engineering and planning disciplines.

BETTER ASSET MANAGEMENT

There are a wide range of new technology initiatives underway to collect, collate and analyse data on infrastructure assets and the transport sector is already making use of these e.g. through the use of LIDAR, BIM, SCANNER, Video/Artificial Intelligence (AI) capture, sensors (e.g. for gully cleansing or monitoring bridge condition), drones, to augmented reality (for asset management). The concept of 'self-repairing' roads using small robots to detect and repair defects in city infrastructure is being researched, virtual reality technology is advancing quickly and in future could significantly enhance the way transport provision is designed and planned.

The immediate priorities must be to ensure asset resilience. This means both that assets are managed effectively (to ensure they meet safety standards and service levels) but also that they are also resilient to a huge range of disruptions (e.g. severe weather). Additional factors that should be considered include making better use of existing data (repurposing it where necessary) and the use of asset management data to inform better predictive models and strategic decision support tools.

The barriers to rolling out technology could be through a reluctance from organisations to take a risk in trialing new technologies, lack of funding, or technologies not confirming to

current standards – to name a few key ones. An additional issue is that new technologies could just produce further work for authorities and this could be seen as a burden to organisations always experiencing pressures with resource constraints. For example images captured by high resolution cameras from drones inspecting bridges will require resources to analyse the recorded information. The more that machine learning and AI can be used to automate defect detection and deterioration would be most beneficial.

There is therefore a role for the government – from the client side – to help work with industry to achieve an increased use of new technologies. This should involve:

- *Vision* – there is a need across the client side of the infrastructure community to establish both *how* and *why* it will benefit from new technology.
- *Communication* – there is a need for the sector to share the experience of lessons from the application of technology. CIHT has, for example, highlighted how drones can be used to manage resilience challenges and for bridge inspections.
- *Supporting trials and initiatives* - The role of Government can be to support new initiatives to trial new technologies. For instance the Thurrock & York pothole spotter trial is a great initiative that uses a combination of digital scanning with machine learning.
- *Standard setting* – With regards to the Pothole Spotter trial this might be viewed as a disruptive technology and as such does not comply with current standards. The role of government will therefore need to ensure the compatibility of new technology (for measuring road condition) within existing standards (in this case for reporting road condition).

Government can provide a facilitation and co-ordination role between the many different technology and innovation projects and activities, helping reduce duplication of effort, harmonise standards, and share purpose and learning in an open way. They can also intervene where standardisation/resolution of problems (like TRO digitisation, and Street works notifications) are common to all of the 153 English local highways authorities, and it is not in the market interest to solve nationally.

There is a role for Government and infrastructure owners/operators to encourage and facilitate innovation with new technologies through procurement processes.

Good examples exist, for example Transport for West Midlands (TfWM) and Innovation Birmingham are supporting a new style of collaboration between infrastructure providers, researchers and SME's to help solve their significant network resilience challenges. This is being developed and delivered by an SME working closely with TfWM, Birmingham City Council, and Innovation Birmingham. It involves repurposing of the Transport Systems Catapult (TSC)/West Midlands Combined Authority Intelligent Mobility incubator in iCentrum, to bring industry partners, universities SME's, TSC, Birmingham City Council, TfWM, Amey, Open Data Institute and others together to deliver a new style of collaborative working. By providing access to existing datasets and exploration/analysis/visualisation tools, plus staff from all these areas, the space enables prototype innovation of solutions immersed in a deeper understanding of public sector needs. The longer term intention is that collaborative units such as this can bid for work as a collective, enabling SME's to access wider market opportunities, and clients to benefit from collaborative, experienced support.

The Government is also supporting the industry with connected and autonomous vehicles and the UK is establishing itself as one of the leading countries in the world on this. One

issue with this is that as vehicles will collect more and more data on road networks condition (through sensors, image capture and so on), there is a question of how this data could be shared with road administrations for asset management.

SMART TRAFFIC MANAGEMENT

The UK has been one of the leading countries in using data to optimise capacity – for example through Smart Motorways. This allows up to a third more capacity on a road by introducing hard shoulder running in peak hours and having variable speed control throughout the smart motorway. This regulates traffic flow, removing or reducing the stop start effect that you get often on roads operating at or beyond capacity. There is significant monitoring and supervision from Highways England's control centres, so that if there's any sort of disruption or accident they can get people to the site and close off lanes more or less immediately.

Recent developments in intelligent traffic systems include the interface of real time data (e.g. SCOOT systems) against historic data trends to optimise efficiency on the network. Urban Traffic Monitoring Control (UTMC) systems enable sharing of journey time monitoring, public transport information, fault monitoring, VMS, CCTV, car park guidance etc. for local highways authorities to manage their networks. Much of the data is standardised, but not yet fully open. The UTMC community is exploring how to connect, share and open up their data consistently for reading and use by connected and autonomous vehicles. One area of innovation is translating SCOOT data into traffic signal timing information in-cab for drivers (Greenwave project, Birmingham)

WATER EFFICIENCY

CIHT would note the importance of coordinating works by water companies (and other utilities) to ensure a reduction in interventions on the road network.

BIG DATA

Any physical infrastructure that is built has to be planned for and must conform to standards. CIHT think of data in exactly the same way.

CIHT strongly support the use of Application Programming Interfaces (API) are a means of way of making data accessible to networks. The benefits of pushing forward with API is that this would seek to establish a framework and method by which data is structured and this could then be fed into a national system. The whole system could be open and on a shared platform. To get this to work would require a lot of collaboration and coordination by authorities and would also require robust testing. There is some interest in this work following initiatives in the West Midlands.

We must consider data as infrastructure just as we consider our roads and rail networks infrastructure. Just like our road network, the data associated with them is a great national asset – the quality and availability of data – is therefore vitally important. Data can help with capacity planning, maintenance and routing – a wide range of elements needed to run our transport networks effectively. Creating the data and making it open (accessible) is therefore crucial.

There are a number of potential barriers to sharing data for commercial reasons, contractual limitations or resource constraints. TfL has demonstrated that unlocking open data can create opportunities for app developers to deliver new services, but there is much progress to be made across the UK.

DIGITAL TWIN DATA

There are a number of brief observations CIHT would like to note on this:

- In principal looks to be a good idea.
- Must cover resilience interdependencies.
- Should involve scenario planning to forecast different potential events.
- Considering of climatic modelling would be helpful.

OTHER COMMENTS

The Transport Systems Catapult (TSC) report 'Benefits of Shared Data' March 2017 looks at barriers to sharing data and recommends a Policy Advisory Group to set out the agenda, roles and responsibilities of a Mobile Data Hub. The report estimates if nothing is done to improve access to data and break barriers the UK stands to lose £15bn in mobility solution benefits by 2025 than if data were effectively shared.

Security considerations are vital to all of this, but the Centre for the Protection of National Infrastructure (CPNI) provides a range of useful resources for the infrastructure sector. The NIC, CIHT expects, will work closely with the CPNI but would urge the NIC to increase general awareness within the sector on the need for everyone to be security-minded.

NEW TECHNOLOGY STUDY SECOND CALL FOR EVIDENCE

This document represents the Costain Group PLC (Costain) response to the New Technology Study Second Call for Evidence. Costain works to improve people's lives by deploying technology-based engineering solutions to meet urgent national needs across the UK's energy, water and transportation infrastructures.

We therefore welcome the opportunity to contribute to this call for evidence as the future of technology in our sector is pivotal to what we do. Technology will have a profound impact on our infrastructure in order for it to address four critical outcomes in meeting the UK's national needs:

- **Increase Capacity** – changing consumer demands, consumer use, technology, population growth, business change, and environmental conditions are some of the pressures being applied to our existing infrastructure as demand outstrips supply.
- **Enhance Service** – the end users of our infrastructure will have even greater demands, changing needs, expectations, increased speed of service and influence as to how the end service is delivered to them. Providers of infrastructure are committed to and financially incentivised to improve customer service in terms of quality of service, reliability of service, cost of service and impact of service.
- **Ensure Resilience** – critical to the continuing prosperity and growth of the UK economy, and wellbeing of the UK population, is security of supply in having an effective fit-for- purpose transport system, a safe and secure supply of clean water, and a sustainable energy supply.
- **Achieve Efficiency** – the Government, regulators and the public all have a common expectation that costs for transportation, energy and water services will not increase but decrease, despite the need for asset replacement, asset improvements, and service quality upgrades.

Our response addresses all of the four areas in the Call for Evidence. We see Big Data as being the underpinning theme which is a pre-requisite for all the others, and have structured our response as follows:

1. Better Asset Management enabled by Big Data
2. Smart Traffic Management enabled by Big Data
3. Water Efficiency enabled by Big Data
4. Summary and Recommendations

1. Better Asset Management enabled by Big Data

Today Costain are significantly enhancing asset performance with the potential to extend asset lifetimes through the application of novel technologies in an integrated approach, all underpinned by the generation, analysis, insight generation and optimisation of big data. This integrated technology is mature and delivering significant benefits in other sectors, such as aviation[1], and Infrastructure will move to similar operational models through intelligent infrastructure. We are delivering significant enhancements in asset efficiency and reduced cost for our customers through the application of our Intelligent Asset Optimisation (IAO)[2] and Capital Maintenance Optimisation (CMO) services. The Costain approach of Sense; Connect and Integrate; Analyse / Optimise; communicate Insight and Optimise Maintenance provides a useful framework to consider the practice application of IAO and CMO approaches to the masonry bridge example in both the near term and longer term. This is similar to the referenced aviation model. The next steps are to up scale the work done to date across our customer's asset base.

[1] GE and Rolls Royce aircraft engines monitor what each engine is exposed to in type of use, conditions flow in and asset degradation. From this they can understand performance and optimise asset maintenance. This increases customer service, capacity, efficiency and resilience.

[2] Costain have implemented Intelligent Asset Optimisation with Severn Trent Water which will provide savings in operational costs and support extension of the asset life and optimising planned maintenance through the early identification of non-optimal or failing components

Sense: we are seeing significant benefits as a result of the rapid and continuing development in low cost sensors. These are not only in the traditional application of measuring typical engineering parameters, but include increasingly novel developments that are energy neutral, self-powered, biodegradable, miniaturised (in some instances to nano scale) and able to measure an enhanced range of environments e.g. through hyperspectral imaging. The pace of development will continue to accelerate, with dramatic cost reduction, opening up the pervasive application of sensing throughout all new asset builds, and the ability to cheaply apply to legacy assets.

Connect / Integrate: The ability to connect and integrate multiple data sources is enabled by common technology; common/open data models and standards; and communication platforms. There will be increasing amounts of data convergence across not only IOT but also with other off-asset sources such as (for highways) traffic sensing, cameras, weather, sporting fixture schedules or other drivers for demand peaks and direct customer interactions through social media or direct customer-facing systems (e.g. Costain's development of East Sussex Highways' Customer Service Portal[3]), sentiment analysis or other technology capable of generating insight on actual (as opposed to design-predicted) asset condition and use. This is business as usual in aviation, with a near real-time end-to-end view of the engine; linking asset information with flight routes, maintenance plans and inventory allowing performance (running time, fuel use and maintenance scheduling) to be optimised and enabling innovative 'As-a-Service' commercial models to develop.

Increasing the use of automated survey methods such as the use of Unmanned Aerial Vehicles (UAVs), Remotely Operated Vehicles (ROVs) and other robotic technologies deployed with an increasing array of sensor types is presenting significant opportunities for us to drive further efficiencies in asset maintenance and condition monitoring. Survey costs will reduce and quality, quantity and usability of condition data will improve. Service interruptions will be reduced or eliminated through automation, with surveys able to take place safely in a live environment reducing risk to personnel. This already takes place in other sectors such as BAE submarines and aviation; we are working to ensure this expertise is more widely applied to infrastructure assets.

Analyse / Optimise: There is increasing application of technologies such as Deep Learning to generate experiential real-time insights of 'normal' vs 'abnormal' condition or performance and opportunities for optimisation that previously would have been impossible using deterministic analytical methods. Integration of multiple data sources, including interpretation of customer behaviour will drive a better understanding of consumption / usage patterns, improving alignment of consumer demand and service supply. This enables investment to be targeted where its needed to achieve desired outcomes, rather than where its felt to be needed. Giving our customers and end users greater visibility of usage data also has the potential to drive self-regulating behavioural change, therefore changing the demand use and peak capacity needs.

Communicate Insight: With the proliferation of data comes the added challenge of the human ability to assimilate and develop meaningful insights. We will see a significant increase in pace of data production, the capacity to process data and a paradigm change in how insights are lifted from large volumes of data driving the need for increasing use of immersive and even neural technologies. In the future state, automation will completely eliminate the need for a human to try to understand, plan and execute interventions.

Optimise Maintenance. Understanding and being able to predict an issue on an asset will not in itself generate the required outcome. The ability to optimise the maintenance response is also needed to maximise productivity, which will draw on many of the same technologies as for asset optimisation, but applied with a focus on maintenance process and scheduling, supported by the use of mobile-accessible Digital Twins, automated assistants and augmented reality for diagnostic and repair tasks. Looking further forwards, the increasing use of robotics incorporating artificial intelligence will further automate previously manual processes and support enhanced maintenance with assets that can "think" for themselves, adapting configuration based

[3] Our innovative Customer Service Portal developed with East Sussex Highways has significantly enhanced the end customer experience of the highways maintenance service, allowing residents (or other users) to have easy online access to up-to-date schedule of highways maintenance and to submit and track problems

on experience patterns and other insight, auto-requesting repair which is performed by a robot or for high integrity or safety-critical tasks via human with remote sensing.

All of the above requires the continued drive to digital twins. By digitising the asset base from conception through to operational life and decommissioning, it is possible to perform complex modelling, operational training and impact analysis in the virtual realm before performing tasks in the physical world. This will drive reduced cost of ownership through the 'digital twin' approach and introduce similar efficient lifecycle management to that already prevalent in the manufacturing and automotive industries.

At enterprise level, higher fidelity, integrated asset data will support better evidence-based business planning, enabling businesses to make more informed decisions to achieve ever more demanding outcomes regarding their assets.

2. Smart Traffic Management and Big Data

Traffic flow intelligence and associated traffic management has improved and evolved steadily over the years. The traffic technology domain has been at the vanguard of the Internet of Things pioneer due to its use of distributed intelligent "sensors" such as traffic counters, MIDAS Outstations and distributed "actuators" such as traffic signals, message signs and signals. In the urban environment, complex sets of Traffic Signal Control algorithms optimise vehicle movement both locally and over a wider area with many refinements including optimisation of pedestrian crossing times, bus priority and buffering of traffic in London to keep it outside zones susceptible to pollution[4].

A pioneering IoT and Big Data product "BlueTruth" was designed and launched by Costain in 2008. This product disrupted the traffic flow market using a completely new technique for measuring traffic flow as well as origin and destination of traffic. Small low cost solar powered detectors are mounted on existing roadside equipment and each detector can cover up to 8 lanes of traffic at a particular location passively tracking Bluetooth equipment within vehicles. The detectors report data back to the cloud where the data is collected, merged and processed offering journey time, lorry count, congestion level and origin destination insights along with visualisations and predictions[5].

Recognising a specific journey pattern

A great benefit of this type of vehicle tracking system is that vehicles are identified and their origin and destination patterns can be established. The bigger benefit of this is that we also know, if we detect that vehicle on the road at a particular time, where that vehicle is heading – based on his previous journeys at that time. For example, we can predict when a vehicle is joining a motorway which junction they leave the motorway and we can therefore predict where that driver will be affected or contribute to congestion and delays along their journey and where that driver will be in 5, 10, 15 minutes. Taking into account all other similarly derived vehicle data, vehicle counts per section of motorway can be predicted.

Predictions based on past movement patterns

A common complaint with all travel time estimation and traffic control systems is that they are based on out of date information. For example, journey times estimations are based on the last known travel times between two points and the distance between those points dictates how out of date the information will be.

With the knowledge of vehicle destinations, we can obtain much more accurate journey time estimation as we can anticipate congestion. We can introduce much smarter traffic control algorithms based on accurately predicted congestion and then operate traffic control measures before the onset of that congestion instead of reactively when the congestion starts to occur.

Connected Vehicles deliver more traffic control opportunities

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[4] As providers of the TfL Digital CCTV System and key traffic signal products, Costain has been closely involved with the digital technology of this domain for over 30 years providing various types of vehicle detection equipment, monitoring equipment, signalling equipment and wide area scale control and monitoring software. Our technology is in routine use in TfL supporting city-wide situational awareness and allowing operators to control the whole network from one location

[5] BlueTruth was put to exceptionally good use in July 2015 where it was deployed rapidly across Kent forming the basis of the Operation Stack situational awareness system which helped to end the "Summer of Stack".

An area of rapid development at present is that of Connected Vehicles. Although there are existing methods for identifying and tracking vehicles e.g. ANPR and Bluetooth, as Connected Vehicles are introduced, vehicle identification and tracking will become inherent. Connected Vehicle Technology - V2X is emerging strongly because it promises to make vehicles safer and drivers better informed. Vehicles messages are sent and received from other vehicles and Infrastructure. The data will be extremely valuable but the quantity of data transfer will be immense and to fully exploit it, a Big Data/AI based system will be needed. This system will gather the vehicle origin, destination and travel time data, along with roadworks information, meteorological information, school calendar and other parameters influencing traffic flow.

The AI system will use analytics to predictively model traffic flow over the course of the next 30, 60,120 minutes based on historical patterns and existing real time data from all sources e.g. traffic approaching the area, current weather, surface water, accidents, roadworks etc. The AI system will implement urban traffic controls and motorway traffic controls which result in best overall throughput constantly recalculating as the situation changes.

Probability of an accident calculated in real time

The AI system could for each section of highway, include a real time accident and breakdown likelihood calculation, using the historical and real time data sets. For example, fog, heavy congestion, stop start traffic, wet road, surface water, vehicle speeds, lane changing, side winds, dark conditions, high accident rate area, all point to a stronger likelihood of an accident. With knowledge of individual vehicles, it is conceivable that this algorithm could also take into account the profile of the drivers in a particular section of road including capability, experience, past behaviour, familiarity with the specific section of road, type of vehicle etc.

High accident probability would normally be mitigated and reduced by additional traffic controls such as slowing down traffic, switching on street lighting etc. Accident probability for a given section of highway will also be used by the Traffic Authorities to determine where best to position emergency services for a quick response along with restoration to normal traffic conditions following an accident.

CAV Benefits: Ability to control individual vehicles

CAV will bring highway capacity and throughput improvements due to a new traffic control capability where individual vehicles can be addressed independently. At present message signs and matrix indicators on a specific section of highway are seen by all drivers (and not strictly adhered to). Connected Vehicle telematics include an in-car driver message display. Via this display it will be possible for future highway control systems to communicate with each vehicle individually. This offers Traffic Control the capability to influence individual driver decisions and change the way they use the road in the interest of safety and capacity. For example, Traffic Control could request that driver stops changing lane, identify a driver's journey as single junction journey and request that the driver stays in lane 1 etc. In the medium term and distant future many of the vehicles on the highways will become self-driving as well as connected, and as such will be fully controllable by the Traffic Controller. This will offer further opportunities for improving capacity and journey times as the Connected Self Driving Autonomous vehicle will be guided by and will by default adhere to central control system requests.

Connected Infrastructure (to Support Connected Vehicles)

Connected vehicles will bring new traffic control capabilities and substantial opportunities for traffic flow and traffic throughput optimisation resulting in a capacity boost. In the wake of the SMART motorway rollout, this evolutionary step is exactly what our close to capacity roads will need to support further growth of traffic numbers. To fulfil the capacity potential of the connected vehicles it is important that communications infrastructure is in place to provide control and monitoring of these vehicles. There are two alternative approaches to communicating with Connected vehicles; ITS G5 which is based on a dedicated peer to peer short range network and C-V2X which is based on commercial cellular communications network infrastructure. In both cases, there is a need to provide infrastructure to support the connected vehicles so that messages can be reliably sent between vehicles and the Central Control Systems.

C-V2X is seen as a revenue stream by cellular network providers hence is being promoted by the mobile service providers, it uses existing cellular infrastructure upgraded to 5G. Our general feeling is that safety related communications such as "stopped vehicle" etc. should not be constrained by cellular service agreements,

commercial firewalls and tariffs and that the free to air ITS G5 802.11p approach is more appropriate in the long term.

As a particular consideration it is important that these radio based services are highly robust in terms of information security and resilient to penetration, hacking, spoofing and denial of service/jamming. We also note that there are existing issues of GPS jamming to contend with – where couriers, taxi drivers etc use jammers which destroy GPS reception near their vehicle to prevent their own on-board equipment from tracking their movements. This is becoming an issue in cities and is likely to affect future CAV trials in the short term.

3. Water Efficiency and Big Data

The water leakage problem has many of the same overall characteristics as the better asset management problem; in that it will benefit from improved sensing, integration analysis, insight generation and maintenance optimisation. Much of the above analysis regarding Better Asset Management therefore applies to how new technologies can support the water sector in delivering and driving efficiencies, in terms of operational cost and reduction of leakage and wastage.

Water utilities are also installing smart water meters to help them understand where leakage variances occur, therefore targeting interventions; and whether the water supply is optimised, i.e. the water pressure is unnecessarily too high or low. In implementing water meters it's important to measure the water in various network points to ensure an understanding of water use and its efficiency is maintained.

4. Summary and Recommendations

Industry has significant opportunities to improve customer service, increase capacity, ensure resilience and increase efficiency. The revolution in technology enabled by Big Data presents a transformational opportunity to meet and lead on these opportunities. Other industries have embraced technology to enhance asset performance, and we will use this experience to deliver this step change. Costain is already implementing many of these in practice and will continue to lead the industry in the application of new technology to improve the productivity of our infrastructure.

We believe that Government should focus on the underpinning enablers rather than technology per-se. In order to maximise benefits, Costain recommends that Government:

- Customers should procure long term collaborative programmes of work, based on the outcomes they need to achieve, offering incentives for out-performance and demanding technology integration. Out performance being transformed through the integration of technology.
- Continue to encourage the adoption of common or open data standards, supported by an Infrastructure API strategy to guide better data integration and convergence across organisations;
- Require regulators to ensure ring fenced investment is included in regulatory business plans and budgets linked to the digitisation of the asset base. Such revenue being released against an evidenced investment and increasingly digitised asset base.
- Establish an Infrastructure Technology Centre to enable government, customers and the supply chain to collaborate to implement innovation in technology; and to work with other industries to build on already proven technology integration. This would perform on a similar basis to the Oil and Gas Technology Centre in Aberdeen.

Contact:

[name and contact details redacted]

Digital Built Britain

Response to National Infrastructure Commissions new technology second call for evidence

15th September 2017

Introduction

Digital Built Britain is delighted to respond to this second National Infrastructure Commission (NIC) new technology call for evidence. Following the meeting on 6th September 2017 between Lord Adonis of the National Infrastructure Commission and Dr. Mark Bew of Digital Build Britain (DBB), it is clear we are aligned in our thinking about the options, challenges and potential benefits. We have established the strategic case for change as part of our SOBC activity, which complements the use cases you have identified.

We see both programmes as complementary and would wish to work closely with the National Infrastructure Commission on our shared ambitions. This will ensure your ambitions for a national digital twin can be realised with the work we will be conducting at the new Centre of Excellence in Cambridge. Here we will identify the necessary standards, business change and underlying architecture to achieve digital enabled transformation of the full lifecycle of the built environment to increase productivity, improving economic and social outcomes.

BETTER ASSET MANAGEMENT

1. What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

There are a variety of initiatives, proofs-of-concept, pilots, trials and single sector activity that have shown how data about the UK infrastructure can be used. This has been a useful start to demonstrate potential or fulfil the needs of a specific sector for the duration the funding can be secured, but it will not be possible to simply join-up the initiatives without addressing the fundamental aspects of data management on a national level. It is necessary to create an object based information management landscape to define reference data structure, integration, provenance and trust in an architecture that supports any asset, anywhere and at any time. Anything else will result in a propagation of well-meaning data silos. Furthermore, if only the infrastructure is addressed without the natural environment or consideration of the functional purpose of the assets and the socioeconomic impact, the full potential of digital transformation will not be released.

Digital Built Britain (DBB) has completed a Green Book Strategic Outline Business Case (SOBC) with the support of EY. This SOBC builds the strategic case, identifies the economic impact of the built environment on each stage of the asset lifecycle, proposed 5 candidate options for further consideration and the potential benefit that could be yielded. This has shown that by achieving our vision of *digital enabled transformation of the full lifecycle of the built environment to increase productivity, improving economic and social outcomes,* the UK economy could grow by 0.5-6% in the next 15 years.

Government can assist by continuing to support the activities of DBB and channelling other programmes that are attempting to solve this complex problem into a single national initiative – Digital Built Britain.

2. What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

During the SOBC phase of DBB, working with EY we identified 5 high value use cases, these are the sectors where the influence on economy and spend is greatest. These being: transport, energy, education, social infrastructure and housing. These sectors were used a basis to test the different options in achieving the vision and determine the programme benefit.

DBB identified five options to achieve the vision of digital enabled transformation of the full lifecycle of the built environment to increase productivity, improving economic and social outcomes. These being:

1. Continue with Level 2
2. Create a new Level 2 (Convergence) Standard which amalgamates Level 2, IOT measurement and Smart City Services using COBie file base model
3. Create an IFC based “object sharing” solution
4. Create an iRing based “integration” solution
5. Create a new “object for object” (Digital Twin) solution for any-asset, any-where, at any-time.

We are about to begin the Outline Business Case (OBC) stage where one of the five options will be selected to develop the full business case. We believe the NIC should prioritise supporting the activities of DBB as we seek to make an assessment of the appropriate option to carry-forward. This assessment will consider all of the infrastructure sectors and we would invite the NIC along with other industry groups to participate in this process.

3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

We consider the main barriers to be:

- Selection and coalescence around a solution that achieves the objectives in full. This can be addressed by the completion of the next phase of the DBB programme.
- Absence of standards that provide data pathways from the asset definition in the PAS1192 series, through to measurement with the plethora of standards including PAS212 for IoT, through to Cities in the PAS18x series. Which also needs to include the linkages to other sectoral standards. This could be addressed through the planned activity of DBB where we will, with our partners, develop the pathways and support the creation of these new standards.
- Clients who understand the value in the creation of asset data and seek to use it throughout the lifecycle, feeding-back to improve future planning. DBB continue to work with clients and Government on an international level to educate and promote adoption.
- A mandate for adoption by Government, this exists for Level 2 and will be needed for Level 3 to ensure a critical mass for adoption. This mandate is being sought for DBB.
- The mathematics that will enable these complex data models need to be developed. DBB seek to build an R&D bridgehead to solve this challenge.
- The new commercial models that will emerge as a result of the transparency throughout the asset lifecycle will require new forms of contacts to be developed and will require the development of a new RegTech market to provide independent verification of data assets. DBB has identified this as a workstream with the programme, where we will work with the financial sector who have already addressed this problem with SWIFT and are looking to new techniques with Distributed Ledger Technology.
- The cultural change needed to operate in this digitally transformed world will be considerable. The industry has operated in an opaque adversarial nature for many years and this will need to change if the benefits are to be realised.
- The security risks and unintended consequences surrounding a higher degree of data generation are significant if not properly considered. DBB has launched PAS1192/5 and PAS 185 security mindedness for BIM and Cities respectively.

4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

Digital Built Britain consider digital twinning refers to an object-for-object virtual representation of any-thing, any-where, at any-time. Whilst smaller scale twinning is possible, it is arguable whether there is a difference between a classical model and a small scale twin.

We believe an object-for-object representation is a potential solution to achieve our vision of digital transformation and is included as our option 5 for further evaluation. The required breadth or depth of coverage is dependent on the purpose. We would suggest at a national level a broader integrated sectorial asset capability model would yield benefit than a granular narrower model. This integrated asset capability model should include the strategic networked assets: road, rail, utilities, telecoms, housing, educational attainment and health (physical and mental).

We would foresee the full object-for-object digital twin being used to help develop the right assets by developing a better brief in the first instance, measuring the in-use asset performance, relating this to the functional services provided and the socioeconomic benefit achieved. At each stage a feedback to the brief for the subsequent investment cycles could be established.

5. How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

Digital Built Britain has established a centre at the University of Cambridge in combination with BEIS/DCMS and industrial partners to achieve the very same targets. We would propose this centre is used as a hub for the convening of the aforementioned parties along with broader community listed in question 4.

SMART TRAFFIC MANAGEMENT

6. What are the latest developments in intelligent traffic systems, and what technologies underpin them?

Focusing on the traffic management developments and ignoring autonomous vehicles, the latest advances can be broadly grouped into the following:

Detection: determination of the location, number and type of vehicle. Traditional inductive loop technologies are being being challenged with 'fit-and-forget' magnatometers; vision systems are becoming more viable, particularly if the camera and interpretation software is decoupled (or suggested it is) in procurement; likewise, radar and laser technology is becoming cheaper to deploy. Ultrasonic/RFID tags are mature and the price point reducing. These can all be used to determine where, what and how many with different levels of granularity throughout the network work. When augmented with floating vehicle data acquired from the vehicle or from devices within the vehicle, the level of fidelity can improve further.

Use: Once the vehicle is identified, its validity to be in a specific area and the implications of being so can be determined. This is highlighted with road user charging, low emission or selection based on defined criteria successfully used around the world. The greatest challenge is normally the policy and legislative changes to introduce such a scheme. How it is achieved is well understood, there are sufficient schemes in the world now and knowledge of how to build such systems that more cost effective solutions can be achieved.

Management: Whilst there has been advances in larger scale cloud based traffic management systems, there are many areas where improvement could be achieved. The traffic management systems are underutilised and where used, applied in silos and not in consideration of the wider infrastructure system. The lack of connectivity between schemes like NTIS and local authority traffic management systems, will always underserve the potential at a national level. The use of new methods of detection such as floating vehicle data augmented with traditional loop data, means that systems like SCOOT are not optimised on a network level. Furthermore, the advances in simulation are not met with closed-loop verification of the invention success or consequence if deficient.

If the information captured from each loop, camera and floating vehicle node was combined in a standard way, it would be possible to develop real-time network models that would allow for better interventions to be made. If connected with models of the wider built environment, it would be possible to link these rich data sources with other systems to understand how transport impacts the wider economy.

7. What barriers do local authorities face in deploying these systems, and how could these be overcome?

Notwithstanding the fiscal pressures on local authorities that often drives tactical decision making, they may not have visibility or be incentivised to include the manage the impact of transport on the local economy. Therefore, decisions are made based on often very local traffic control issues without

ensuring the capability of the network. The economic impact of traffic management at a local authority level needs to be established and controlled.

The solutions offered by many are becoming more open to exchange information, but they do not always allow for integration. Whilst the intellectual property of vendors is understood, there is a visibility needed to ensure the wider network performance, and this needs to be established.

WATER EFFICIENCY

8. In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

9. Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

Digital Built Britain support the national and compulsory roll-out of smart water meters. We see this as a lever to driving economic and social improvement through greater transparency and integration with wider causal data sources. We would consider a different approach to the electricity and gas smart meter roll-out is taken with respect to data consolidation and timely availability.

We would see many benefits from smart water meters, for example, awareness of consumption has been proven to drive changes in individual behaviour. It also provides insight into patterns of behaviour that allow for intervention with vulnerable members of society if the consumption is lower than would be expected. At a national scale it will provide insight into supply, demand and leakage enabling a 'system operator' view of the network to be taken. This will provide the visibility necessary to make the informed decisions that will improve resilience.

BIG DATA

10. What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

In order to achieve the ambitions of the NIC which are shared with DBB, the amount of data generated, shared and used will be significant. That said, the amount the amount of data currently generated is also large but it is not generated or used in a consistent manner, resulting in the potential benefit unrealised. For the big data to be of any use, it needs to be generated in accordance with specific standards that allow it be used within other environments, its authenticity and provenance needs to be assured, and only those who need access, should have access. Having achieved these basic requirements of standards and structures, how the data is integrated is the next challenge. DBB has identified five options that will achieve some, if not all of the programme objectives. We would propose this selection is completed with the involvement of the NIC.

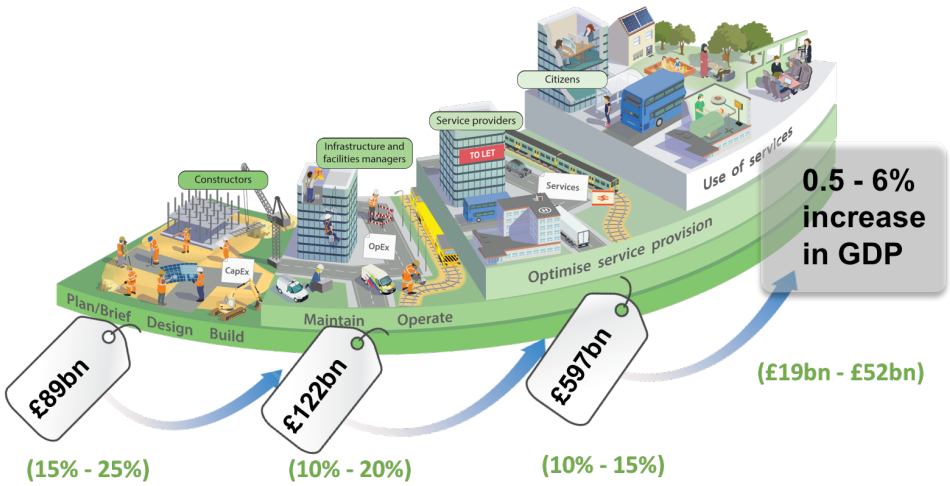
11. What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

Whilst there is value in sharing data, it needs to be shared with the right people for the right purpose. There is risk of unintended consequences associated with the merging of multiple anonymised datasets to uncover patterns of behaviour or information that should be kept private or is classified. One of the workstreams of DBB is headed by CPNI who are working with their partners within the security community and within the DBB programme team to ensure these aspects are properly considered.

It is anticipated that there will be a clear delineation between who needs to have access to what information and at what stage in the process. For example, how a transport network capability is achieved does not need licence plate information shared even if used as part of the unpinning model.

12. How can a national digital twin help to manage infrastructure data as an asset?

Using the DBB definition of a digital twin, a representation of any-asset, any-where, at any-time, we believe this will have the potential of dramatic improvement to the UK economy. This was set-out in the SOBC economic analysis by EY. Here it was demonstrated that digitisation will enable CapEx, OpEx and service outcomes to systematically learn from each other. The feed-forward of information from construction to operations and service provision allows for assets and asset systems to operate for less cost and services to be optimised. The feed-back of information of how infrastructure is used and how it performs allows for improved planning, briefing and design, construction and operation/maintenance approaches. An open transparent platform will enable the Government, the service industries and the public, the ultimate consumer of the services, to understand how public money is spent and how value is ensured. This is shown in the illustration below.



END

Summary

A better digitised asset base will enable Government and private companies across different sectors to develop services that to date have been hampered by the lack of integration across systems in the urban environment. Yet to realise the benefits from a digitised view of infrastructure, is it necessary to think wider than the sectors cited by the NIC. Whilst digitising infrastructure networks in their existing silos will gain efficiencies, it is only by seeing them in the context of the land they sit in, the homes they serve, the communities they support and the services that are delivered there will the wider opportunities be revealed, and the maximum value be gained.

However, there are still big barriers to looking across sectors - data availability, harmonisation and standardisation, legacy systems and processes, underdeveloped urban platforms market , governance and security, poor incentives for collaboration and immature business model, cultural barriers between sectors and poor insight into city needs and drivers.

A critical first step is opening, harmonising and standardising more data, funding its long-term maintenance and making it more accessible to both humans and machines, which in turn can provide the foundation for a ~~national digital twin~~ harmonised and interoperable digital twins to drive the market higher up the data value chain, spur innovation in Government, industry and civic society and create opportunities to both enhance the user experience and lower the costs in central and local government.

Architecturally, the immensely complex space of digitalised assets and digital twins needs a distributed and federated systems approach in order to succeed. Successful digital twins architecture could be built for example by using a microservices architecture combined with an open API ecosystem, where different stakeholders in the ecosystem (managers of local, regional and sectoral twins) build their systems using jointly agreed data models and APIs for secure data exchange.

In the future Smart Contracts, or other automated transactions could be used to ensure the exchange of usage rights and possible payments.

1. **What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?**

Future Cities Catapult, Ordnance Survey and the British Geological Survey recently completed a research project (Project Iceberg) to explore the potential and value of a data exchange framework for sub-surface assets. The ownership of data about the location of subsurface assets and conditions (from telecommunication lines, to water pipes, to underground tunnels, to contamination) are held by a wide variety of public and private organisations. Emerging sensor and ground penetrating radar technologies mean that more and more precise data is being collected about sub-surface assets and conditions. It would not be feasible for all subsurface data to be captured by a single digital twin (due to financial, commercial and security issues) however it is in Government's gift to create the regulatory conditions for more effective and consistent capture of sub-surface data (for example through the planning system) as well as promoting the effective exchange of data about the subsurface.

Future Cities Catapult, working with Greater Manchester Combined Authority and Belfast City Council, has developed a working prototype of a tool that enables city planners and utility providers to have a shared view of the capacity of the water, wastewater and electricity networks today and

up to 15 years into the future. More information about GrowthPlanner can be viewed in this short film. Due to the IP position FCC holds on this tool and that this response could be disclosed via FOI, we do not wish to disclose the precise approach to data collection on this project. However, one our learnings from this project was that security concerns about the location and functionality of national infrastructure can be overcome (our software development approach has been approved by the Centre for the Protection of National Infrastructure).

In 2015 the Cabinet Office reportedi the application of Level 2 BIM standards, tools and skills has already helped save £2.2bn across Government. Future Cities Catapult is collaborating with Digital Built Britain (DBB) to develop the Level 3 strategy which expands this agenda to the planning and city services domain, focusing on how assets are used and operated. During this work key data-related insights fell under the following categories:

- *Data generation*: generating and recording information is costly and time consuming especially when the value of the data is not understood fully.
- *Data interoperability*: data sets are disparate and not easily used in conjunction.
- *The value of data*: the role of the client in dictating the terms of data information management is underutilised.
- *Data ownership*: the average lifespan of a built asset can range from 40 to 120 years. Change in ownership is a significant barrier to effective information management.
- *Communication of data*: communication barriers exist across transition points throughout the asset's lifecycle (e.g. from design to construction, from planning to operation).
- Data-related *education and skills development* is needed to drive change.

2. What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

Assets on their own, or even as part of a broader infrastructure system, are still limited by their understanding of the context they operate in and the different public policy and commercial objectives they are put in service of. Whilst sensor, IOT and data analytic technologies can drive greater efficiency for these assets individually and as part of wider networks, the greater opportunities lie in combining data about these assets with wider contextual data such as buildings, land uses, socio-economic statistics etc.

Of the specific sectors mentioned and use-cases of optimisation and maintenance, 'digital' is the one which is most in need of optimisation as it impacts on all sectors. The opaque structure of the telecommunications market and the ever-increasing importance of digital telecommunications networks to future innovation, productivity and (cyber) security means it will be critical to better understand and optimise this sector.

Digital infrastructure provides the 'backbone' to all the other 'hard' infrastructure sectors as these become more digitally dependant for their operation. New technologies such as 5G, LPWAN and others are creating new options for connecting infrastructure and information about the built environment but an overall standards and governance framework is required to make effective use of their capabilities.

3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

- *Data Supply* - Upfront investment in connectivity requirements for new and existing infrastructure is costly and risk and consequently the private sector won't invest, but this provides the framework for other innovation.
- *Data Governance and Accessibility* - Successful implementation of networks and use cases at scale will depend on access to assets, both infrastructure assets and data assets. Infrastructure assets such as lamp posts or other street furniture will be needed to house sensors and network equipment. Public and private sector data will be required as the raw material for new products and services. In many cities, the ownership and management of city assets is regulated and fragmented. Historic contracting arrangements are often in place regulating maintenance and service provision through outsourcing structures. New tools, data clearing operations and governance arrangements will be needed to open digital and physical assets for large scale trials of use cases linked to 5G network technology deployment and advanced urban services.
- *Security* – as part of our GrowthPlanner project we worked closely with the Centre for Protection of National Infrastructure to ensure that the data gathered from utility companies about their asset locations and performance was appropriately protected. Part of the solution was to provide aggregated and pre-processed data that provided a general spatial overview of capacity on the network, not specific asset location and performance details.
- *Commercial Value/Business Models* – Large scale innovation projects in cities require public and private actors to enter into collaboration agreements where the outcomes are uncertain and risks are high. Large sums of investment mean partners will require the terms of collaboration (for example IP ownership, liabilities) to be explicitly agreed upfront. Although collaborations tend to be agreed on a case by case basis, there is a need for a degree of standardisation and process to capture lessons learned in areas such as arbitration, open innovation and data management in contracting.

4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

National Digital Twin should never be a single system, as that would be a very inefficient, unsecure and astronomically expensive way to realise such an asset. The age of monolithic, vastly expensive and rigid IT systems is over. National Digital Twin, as one monolithic system, would almost certainly collapse under the weight of its own complexity, in the same manner than the NHS Lorenzo system failed in 2013. Even if it succeeded, the security risks and maintenance costs of such a centralised system would be immense.

The present-day approach to develop the National Digital Twin is to solve the challenge of complexity in the Internet way, as a massively distributed and federated ecosystem, linked together by open APIs, following the principle of loose compatibility – different systems and datasets are connected only when the connection is needed in order to deliver the service. In the federated national Digital Twin, different stakeholders of the ecosystem (cities, regions, sectors) each manage their own twins, which are built following harmonised IT architectures, using standardised data models and standardised open APIs. These twins are connected together, when larger holistic views are needed.

In the remaining document, we refer to the National Digital Twin as such an interoperable and harmonised ecosystem of numerous digital twins.

Government should take a use-case driven and agile-development approach to determining the focus, functionality and capability of digital twins. In parallel, Government must set out a clear governance, legal and business model framework defining the role of public and private actors in the creation, ownership and maintenance of a national digital twin, especially regarding ownership, IP and security considerations. Furthermore, special attention should be placed in the interoperability and scalability of digital objects that will contribute towards the digital twin.

One of the early opportunities we have been exploring at Future Cities Catapult is around the land use planning system. Our Future of Planning programme has researched the present way the planning system works and how in the future it may be focused around a digital twin or 'city information model' (See our short film here). Our user research into the planning system identified a significant reliance on spatial data but that data was locked up in Pdfs and hence difficult to access, analyse and communicate by either humans or machines.

Making planning data accessible to develop a local plan or submit a planning application and making it available on a spatial data platform in machine readable formats, this enables consumption and analysis of the information more quickly and cheaply. This in turn, encourages new partnerships between planning experts and technology companies. Overall, these new processes and activities are re-designing the planning process as we know it. Much of the spatial data required for local planning is of use to other actors and service providers in cities. Surfacing the added value of the information is key to encourage the systematic creation, sharing and consumption of the data.

5. **How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?**

Our view is that central and local government should be orchestrating the framework for the design and operation of the digital twin, and marshalling the identification, acquisition and production of "core" data, but have a limited role in creating the products and services that run on it. This task will need to be done in collaboration with industry to ensure buy-in and support from the largest systems providers but ensuring the role of "system operator" exists to lower the barrier of entry for smaller organisations with innovative products and services.

There needs to be a clear strategy and governance for the leadership of the interface of digital and physical infrastructure, in government, academia and industry. It is already a crowded stakeholder environment with multiple departments, quangos and academic institutions all having relevant (but sometimes competing) capabilities and interests.

City-based demonstrators have a significant role to play in market creation, providing focused activities for stakeholders to 'learn by doing' and if structured well can lead to commercial opportunities for SME's, and demand creation. Any city based demonstration where digital and physical infrastructure is combined must aim to develop repeatable governance, financial and legal tools and policy instruments that will:

- Support the transition from place-based R&D into commercial operations.
- Ensure ethical and privacy issues are addressed
- Support scaling of new products and services between cities in the UK and internationally.
- Mobilise digital and physical assets and services at scale in cities currently owned by 3rd parties
- Support integration between different sectors and address security risks.
- Address local government jurisdiction issues.

The Future Cities Catapult has a programme of work underway with industry experts to develop a new set of tools and policy instruments for test beds and demonstrators, reporting in spring 2018. This is in support of our proposal for a large-scale demonstrator in partnership with industry (the Hyper-Connected City) which has been shaped to maximise market creation and innovation outcomes.

6. **What are the latest developments in intelligent traffic systems, and what technologies underpin them?**

This isn't our particular area of expertise. However, there are promising UK start-ups in the sector of Mobility as a Service, such as DOVU, which has developed a blockchain-powered platform for seamless mobility ecosystem across all stakeholders.

7. **What barriers do local authorities face in deploying these systems, and how could these be overcome?**

Main challenges for the disruption of transport systems are existing business barriers and diverse ways with which local transport systems have been developed, with lots of long-term contracts, legacy systems and fixed mindsets in place.

WATER EFFICIENCY

8. **In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?**

As part of a commercial project with Thames Water we developed a concept for a customer survey that related levels of service (including ELL) to customers' bills (see news release here). Whilst new sensor technologies can assist in locating leaks and a greater data exchange between utility providers can make it cheaper to repair leaks, citizen understanding of the water network and the business model of utilities is still a key part of this equation. The use of a data and digital platforms to better engage citizens in the planning, delivery and management of infrastructure is a critical benefit of more digital approaches to infrastructure.

9. **Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?**

No view.

10. **What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?**

a) Effective legislation and development of a framework that enables access to information in a secure and reliable way is fundamental. The skills and capabilities in the infrastructure industry need to respond to the new digital trends. This information framework and related legislation should be developed with the wider public benefit in mind – where infrastructure is no longer a silo industry and sector, but responds to the needs of its users. This will enable a new approach to digital infrastructure that can support the effective creation of a market for data for the infrastructure and built environment.

b) Digital Built Britain, following from the BIM level 2 mandate, is now leading the development of the next generation of digital infrastructure tools. This focuses on the management of information

across the built environment lifecycle[1], and looking at the impact of using information of the built environment in relation to activities outside the Capex and Opex worlds. Government should ensure clarity of leadership in the different aspects of the needs of a digital twin, with Digital Built Britain being most directly linked to policy and data framework[2] development for the construction and infrastructure world.

11. What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

a) Barriers to sharing data internally within systems and organisations should be limited, but cross-government protocols may be required to share data that emanated from third parties.

b) Many of the issues cited above regarding ownership of data are relevant here. Whilst government and its agencies are central to opening data to realise indirect value, there needs to be better mechanisms for capturing public value from data once opened. The current review into 'Digital Land' must ensure that there is some recourse to the value added to the datasets of Ordnance Survey, Land Registry etc. There is also a business model and regulatory challenge as currently many privatised data owners are unwilling to share their data or collaborate more broadly as they think the data they hold has an intrinsic value however in most instances this value can only be realised when combined with other (public/private) data. Lastly, there is the challenge of value recognition and value exchange in data transactions. Current contract and payment systems are a rather inefficient way to manage machine-to-machine transactions, which the National Digital twin requires. Smart Contracting systems, using for example blockchain or other distributed ledger technologies, are required to provide efficient, reliable and fast transactions.

12. How can a national digital twin help to manage infrastructure data as an asset?

In a national Digital Twin data would be created, classified and managed in a consistent way, enabling all actors linked to the built environment sectors to access the 'right' data. The format of the data and how it's shared would be consistent, enabling a more systematic update to the datasets as infrastructure changes and develops. Development of early use cases is essential to understanding the functionality required from a digital twin. A combination of use cases across different industries, sectors and actors in infrastructure, would provide a first draft of the design requirements for a digital twin. Future Cities Catapult has developed some of these requirements through its Future of Planning initiatives, creating also prototypes of future modelling tools and services demonstrating how this data can be monetised.

The data and info in the digital twin would provide feedback of performance of private and public infrastructure assets. This will enable the planning authority to identify strategies to increase the utilisation of its assets, make existing services more efficient or plan the development of new assets to accommodate growing demands.

[i] Cabinet Office cost benchmarks 2015

[1] http://digital-built-britain.com/DigitalBuiltBritainLevel3BuildingInformationModellingStrategicPlan.pdf
[2] http://digital-built-britain.com/DigitalBuiltBritainLevel3BuildingInformationModellingStrategicPlan.pdf

INTELSAT
Envision. Connect. Transform.

National Infrastructure Commission Call for Evidence – Intelsat Response

Smart Traffic Management: What are the latest developments in intelligent traffic systems, and what technologies underpin them?

Smart traffic management (STM) and intelligent transport systems (ITS) are two of the most transformative new technologies and are already delivering real world benefits to citizens. By making make full use of the data produced by transport systems and networks, they improve safety, efficiency and security, as well as reducing the transport sector's environmental footprint.

In this paper, we set out some of the recent innovations in satellite technology used to deliver STM and ITS services, focusing on advances in satellite and antenna technology. We ask that the NIC ensure satellite technology is recognised as a key enabler of STM and ITS services in any future assessment of the UK's infrastructure needs.

Key Developments in ITS

- Improving safety

The Society of Motor Manufacturers and Traders (SMMT) and KPMG estimated in 2015 that connected and autonomous vehicles could save over 2,500 lives a year and prevent more than 25,000 serious accidents in the UK.[1] The single greatest impact of ITS is how it can improve road safety and reduce fatalities. For example, ITS can inform drivers of hazardous conditions on the road before they are visible, giving drivers more time to react appropriately. It can also keep moving vehicles at a safe distance from one another, giving drivers more time to react to sudden changes in traffic and thereby reducing the likelihood of multi-vehicle collisions. ITS can provide constant communication between vehicle, driver and roadside furniture, providing a wealth of information which can be used to massive reduce and ultimately eliminate unnecessary fatalities.

- Improving efficiency

Better planning and separation of traffic also has enormous benefits for vehicle efficiency, reducing the need for frequent, resource-intensive braking and accelerating. Dynamic traffic signal control, advanced incident detection, vehicle separation and variable message sign systems are all already available in Europe and can be used to ensure that vehicle spacing and routing is optimised, reducing congestion. The Institute for Economic Affairs calculates that congestion on Britain's roads cost around £20 billion in 2013.[2] SMMT and KPMG suggest more efficient journeys, combined with consumers' ability to make better use of their time in their vehicles, would accrue £35 billion a year by 2030.

[1] KPMG and SMMT, *Connected and autonomous vehicles – the UK economic opportunity* (London: March 2015), available from: https://www.smmt.co.uk/wp-content/uploads/sites/2/CRT036586F-Connected-and-Autonomous-Vehicles-%E2%80%93-The-UK-Economic-Opportu...1.pdf

[2] Roth, Gabriel, "Moving the Road Sector into the Market Economy" (London: Institute for Economic Affairs, 2013), available from: https://iea.org.uk/publications/research/moving-the-road-sector-the-market-economy.

- Reducing environmental impact

Efficiency savings are not just about finances. Cutting congestion reduces the amount of energy expended per-vehicle on a given journey, thereby reducing the amount of pollutants released into the atmosphere and cutting the overall environmental footprint of the transport sector – essential to meeting the Paris emissions goals. This is no small undertaking, given that the transport sector represented 23% of greenhouse gas emissions in the UK, 93% of which came from road transport.[3] Improving routing for both passenger and freight transport on the roads eases congestion, speeds up journey times and cuts the amount of greenhouse gases produced.

Role of Satellite Technology

As the market for connected and autonomous vehicles matures, there will be a significant increase in the amount of data that must be delivered to and from vehicles. This will include software updates for a vehicle's control system, as well as entertainment and a range of machine to machine (M2M) capabilities. A key challenge is to create a reliable, ubiquitous, and scalable communication system that is both highly secure and economically viable. At Intelsat, we believe that advances in satellite technology mean it has an important role to play in enabling the future of intelligent transport.

For example, the wide area coverage of satellites allows a single satellite to deliver data to many vehicles at once. This will allow vehicle software to be updated without the hassle to drivers, and the cost to car manufacturers, of receiving updates at a dealership. The market is responding accordingly: IHS Automotive forecasts over-the-air (OTA) update revenue alone to grow from $102 to $800 million from 2018 to 2022 driven by shift from basic telematics to OTA updates and content.

Satellite Use Cases

Analysis by ERTICO-ITS, the European ITS stakeholder platform and participant in a number of EU initiatives, has highlighted some of the ITS services that can be delivered by satellite. It splits the services into two categories: those reliant on broadcast (one way) transmission of data, and those reliant on bi-directional data transmission. In addition, Intelsat is able to provide broadband services, and we expect demand for those services to increase as the market matures and customers begin to demand access to more data rich services.

Satellite Data Broadcasting (SDB)	Satellite Narrowband bidirectional data transmission (SND)
Vehicle Navigation Service • Digital maps update • Traffic information • Weather • POI information update	**Safety & Security Services** • eCall • Anti-theft • Remote vehicle diagnostics • PAYD insurance **Road User Charging** **Commercial Vehicles Services** • Fleet management systems

Source: ERTICO-ITS

[3] Department for Transport, *Transport Statistics Great Britain 2016* (London: 2016), available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/576095/tsgb-2016-report-summaries.pdf.

As cars become more connected and ITS evolve, we are seeing the beginning of other use cases where satellite technology will play a major role:

OTA updates with acknowledgement	Enhanced Navigation	Telematics	Cyber and Managed Security Services	Infotainment
Efficient and secure broadcast service to update software in TCU, ECUs, and head units	Differential corrections, GNSS integrity monitoring, and anti-spoofing support services for semi and fully autonomous driving	Increased coverage and reliability for e-Call services, stolen vehicle tracking and vehicle telemetry	Alternate secure channel for global certificate and key management; managed service for OEMs and Tier 1s patching latest vulnerabilities and attacks by updating firewall and Intrusion Detection System (IDS) systems	Real-time information, entertainment and connectivity enhance passenger experience

Revolution in Satellite and Antenna Technology

Intelsat has responded to the demand from consumers, and the first commercial connected car powered by Intelsat will be on the road before the end of 2018. This is possible due to recent innovations in satellite communications. In particular, three technological breakthroughs allow satellite to support present and future ITS requirements on the roads of the UK:

High-throughput satellites

New generations of high-throughput satellites can deliver order-of-magnitude improvements in data rates and capacity. Today, high throughput satellite (HTS) networks are operating on a global basis and can provide broadband service to end-users with speeds of 25 Mbps and higher, while Intelsat's EPIC fleet can deliver 10 times the throughput of the previous generation of satellites. With multiple spot beams and digital payloads able to be flexibly configured, these satellites are designed to support mobility.

Low-Earth orbit constellations

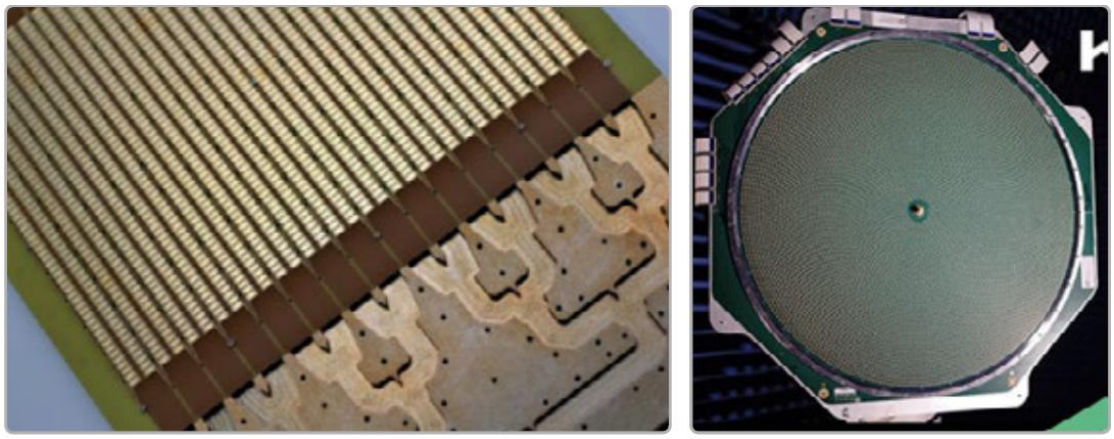
From 2018, Jersey-based OneWeb will begin launching its satellite constellation. Due to the close partnership between OneWeb and Intelsat, the new satellites will add an additional 5 Tbps of connectivity to Intelsat's existing broadband offering. Located in a low-Earth orbit, OneWeb satellites will also be able to support applications where latency is a factor in service delivery.

New antennas

Cars connected by satellites will not require traditional satellite dishes to receive the signal. Intelsat, working with and investing in companies working on next generation terminal technology, has developed with its partners a flat-panel antenna that can fit discreetly into a car roof. The first commercial deployments will begin before the end of 2018.

The dividing lines between satellite and terrestrial networks are softening. Developments in terrestrial wireless networks and services are influencing the prospects for satellite services. In the past, the establishment and configuration of services across satellite and terrestrial segments was mostly performed manually and in a static way. Today, the delivery of services and content over networks calls for new types of partnership arrangements and for unified end-to-end control and management, agnostic of the communications technology used.

To enable the widespread adoption of satellite broadband for in-motion applications, Intelsat is developing next-generation terminals using, among other things, a new reconfigurable antenna technology, known as metamaterials surface antenna technology (MSA-T), shown in the figure below. This antenna offers the electronic beam-steering performance of a typical phased-array antenna with a dramatic cost reduction and the alleviation of many of the size, weight and power challenges associated with the existing techniques. No longer will accessing satellites require traditional equipment with high power requirements; new technology is unlocking the full potential to track satellites while also being portable enough to attach to a vehicle or take into the field.



Antenna array and feed network antenna technology

Unique Characteristics of Satellite Communications

There are several characteristics of satellite technology that make it well suited to supporting ITS:

- *Reach* – With a single geostationary satellite, it is possible to provide communications over the entire UK. This capability allows satellite to act as a back-up for terrestrial communications and deliver services solely by satellite. Intelsat has as number of satellites covering the UK, allowing it to provide capacity as well as coverage.

- *Scalability* – Using broadcast technology, a single satellite can simultaneously deliver a range of services, from software updates to video content, potentially to every car across the UK. This significantly reduces costs for a vehicle manufacturer delivering an update to all vehicles of a particular make, or to content providers delivering content for vehicle passengers.

- *Ready for Launch* – Only 8% of A roads and B roads in the UK have complete 4G coverage.[4] By comparison, Intelsat and other satellite communications companies already have satellites ready to deliver service, once cars are fitted with the new antennas. Connectivity for connected car applications can be made available by satellites in a far shorter time span than waiting for the equivalent terrestrial roll out.

[4] National Infrastructure Commission, *Connected Future* (London, 2016), available from: https://www.nic.org.uk/wp-content/uploads/Connected-Future-Report.pdf.

Recommendations for the NIC

Satellite technology is uniquely well placed to reduce the coverage gaps where ITS networks cannot function, ensuring these benefits can be enjoyed by all UK citizens. In addition, satellite technology is the optimum mode of delivery for services such as traffic information, software upgrades, and remote vehicle diagnostics. The reach and scalability of satellite communications make it an extremely cost-effective solution, compared to either existing solutions or the cost of proposed terrestrial infrastructure deployments.

We ask the NIC to make explicit reference to satellite technologies in its final report as a vital means of enabling UK citizens to benefit from advances in STM and ITS. With the support of the NIC, the capabilities of satellite communications will be more widely recognised by government and industry, directing investment towards satellite solutions. UK citizens will be able to access innovative ITS services within a few years, much sooner than if investment is channelled solely towards terrestrial infrastructure, and at much lower cost.

Satellites will play a vital role as the world's mobility patterns change from driver-operated to autonomous vehicles. At Intelsat, we will continue to collaborate with partners to develop the necessary technologies and applications for future intelligent transport systems.

About Intelsat

Intelsat S.A. operates the world's first globalised network, delivering high-quality, cost-effective video and broadband services anywhere in the world. Intelsat's globalised network combines the world's largest satellite backbone with terrestrial infrastructure, managed services and an open, interoperable architecture to enable customers to drive revenue and reach through a new generation of network services. Thousands of organisations serving billions of people worldwide rely on Intelsat to provide ubiquitous broadband connectivity, multi-format video broadcasting, secure satellite communications and seamless mobility services. The end result is an entirely new world, one that allows us to envision the impossible, connect without boundaries and transform the ways in which we live.

INPUT BY THE LIVERPOOL CITY REGION COMBINED AUTHORITY

NATIONAL INFRASTRUCTURE COMMISSION: CALL FOR EVIDENCE ON TECHNOLOGY AND TRAFFIC SYSTEMS

1. The Liverpool City Region Mayoral Combined Authority (LCRCA) welcomes this opportunity to make a submission to the National Infrastructure Commission's call for evidence on technology and traffic systems. This submission also includes comments from Merseytravel and the Local Enterprise Partnership.

2. As context, the Mayoral Combined Authority was established in May 2017, following the election of Steve Rotheram as the LCR's first directly elected Metro Mayor. The Mayoral Combined Authority draws on new powers and funds that were made available through the Liverpool City Region's 2015 Devolution Deal and follow-on deal in 2016. These powers include: strategic transport planning across the city region, economic development and regeneration, housing and spatial planning, employment and skills. It now exercises powers over a devolved and consolidated multi-year funding package.

3. The city region's response focuses on the questions relating to asset management, smart traffic management and big data, particularly from a transport perspective, being one of the Authority's established areas of responsibility. The issue of water is of critical importance, but falls outside of the Authority's direct remit. The questions posed are also highly operational in nature.

BETTER ASSET MANAGEMENT

4. Wireless sensor networks combined with ultra-low power sensors and drones will make it possible to monitor the condition of a wide range of structures like bridges or tunnels, alerting authorities to weaknesses or disrepair. This will allow pre-emptive repairs to be actioned before any catastrophic infrastructure failure occurs, thereby minimising disruption to users and helping maintain the infrastructure. Additionally technology can also help plan major improvement works to infrastructure.

5. Network Rail used virtual reality technology to save time and money and improve safety as it prepared to redevelop Liverpool Lime Street, As part of Network Rail's Railway Upgrade Plan, virtual reality technology has enabled Network Rail to carry out 4D virtual modelling to prepare for the work, reducing the amount of time needed on track and the potential to impact on train services.

6. New signalling is being installed at Liverpool Lime Street and the positioning of these signals is critical to the safe operation of the railway. Before visualisation software, designers would have to go the railway and plot the location of the new signals and map how the signals could be viewed by train drivers. This was time consuming work that required access to the railway, sometimes in difficult

conditions. Using virtual reality modelling, most of this work can be done from a desktop.

7. Network Rail inspects the railway by air using helicopter and unmanned aircraft vehicles and this improves performance, reliability and safety. They use thermal image surveys, photographic surveys and surveys after bad weather to identify any weaknesses or damage to the infrastructure. This allows pre-emptive repairs to be actioned thereby minimising disruption to users and helping maintain the infrastructure.

SMART TRAFFIC MANAGEMENT

8. Smart communications technology will become one of the key infrastructures of future cities, helping to improve the efficiency and coordination of systems. Linking traffic management systems with in-car systems could help ease congestion by giving drivers advanced warning of congestion or disruption and helping identify alternative routes and enable drivers to make better decisions.

9. Greater use of Intelligent Transport Systems (ITS), will enable better traffic flows, more accurate road pricing, and enhanced capacity and safety. This encompasses a range of technologies used to manage transport – from sensors and surveillance to ticketing and payment systems – that are used to monitor and manage travel conditions. ITS equipment continuously generates new data about the transport network, and enables operators to make real-time interventions to manage traffic and travel.

10. The Internet of Things will enable the rise of technologies such as intelligent vehicles that can measure the latest traffic, road and weather conditions. These vehicles will be able to communicate with each other and the wider environment, transmitting their speed and direction and warning other vehicles about traffic and safety hazards. Wireless sensor networks combined with ultra-low power sensors and drones will make it possible to monitor the condition of a wide range of structures like bridges or tunnels, alerting authorities to weaknesses or disrepair.

11. Road user charging, congestion charging and tolling systems may also become easier to implement through free-flow payment systems like those used on the Dartford Crossing and now being introduced on the Mersey Gateway Bridge and Silver Jubilee Bridge via the Merseyflow system.

12. Technology will increasingly help reduce the need to travel through things such as video conferencing, etc. This could also fundamentally change the world of work across all sectors of the economy. The “people” element may also focus more on the knowledge and creative input and this may result in new jobs and industries being created but upskilling,

BIG DATA

13. The drive towards smarter zero carbon and zero emission transport systems will lead to more efficient and sustainable urban centres. Increases in computer and processing power will enable this shift and will lead to more effective, real-time use of big data. The Liverpool City Region is well placed to lead and pioneer the use of Big Data as part of this technological revolution with the research capabilities of its major universities and technology centres of excellence such as the Hartree Sci-Tech Centre at Daresbury Enterprise Zone.

14. Secure data sharing between organisations will become increasingly important. Big data and the Internet of Things will enable communication between different modes and with the wider environment, leading to truly integrated and inter-modal transport solutions that maximise efficiency gains. Augmented reality technology could transform the onboard journey experience, ticketing and customer information. Cloud-based services will become more widespread driven by the uptake of smarter mobile devices and faster connectivity.

15. Smart communications technology will become one of the key infrastructures of future cities, helping to improve the efficiency and coordination of systems. Linking traffic management systems with in-car systems could help ease congestion by giving drivers advanced warning of any congestion or disruption and helping identify alternative routes and enable drivers to make better decisions. Smart technology will enable real-time information for travellers and more integrated services. Integrated ticketing and payment systems, such as the use of apps, smartcards, phones or bank cards as a single device to pay for journeys, linked to personalised real-time travel information, further simplify inter-modality and improve customer experience.

16. In a similar vein to Network Rail's use of virtual reality technology to plan the Liverpool Lime Street rail improvement works, the University of Liverpool has aspirations to develop a simulated model of the Liverpool City Region (LCR) to enable policymakers to assess the impact of any policy decisions across the city region. This model will place Liverpool City region in the forefront of using 'smart' technology in a way that builds upon the region's strengths. They aim to use this simulation as an environment that enables an understanding of multitude of stakeholders' data, decisions and benefits to be coalesced in one place. The simulation seeks to quantify the utility of stakeholders' data in terms of other stakeholders' decision making and the impact of decisions on all stakeholders.

17. As well as enabling evidence based decision-making, the simulation will also stimulate economic growth: The data generated by the App and insights generated through using the simulation could help local digital/creative industries to prosper. The App could allow personalised services to be delivered to an individual whilst enabling that individual to retain some control over the commercial benefit derived from the valuable data related to their movement through the city.

Rise of On-Demand Mobility:

18. On-demand mobility providers are already revolutionising transport and mobility provision. The governance of public transport modes will play an essential role in either facilitating or impeding the convergence of traditional and innovative mobility services, and of on demand mobility services in particular.

19. Public transport still has a very traditional ticketing system which is paper based, contactless or smartcard based; m-ticketing is also still emerging. Digital technology could allow innovative solutions and open source ways to connect people and goods to transport to help boost economic growth whilst reducing the adverse impacts associated with growth in private transport.

Inter-dependences with other infrastructure:

20. However as transport becomes more reliant on technology the importance of improving telecommunications infrastructure such as fibre-optic superfast broadband, wi-fi and 4G and 5G will increase. At the moment in many areas this infrastructure is inadequate. Improving connectivity and smarter devices will enable cloud-based services to become widespread and more user-friendly. Also technology will increase reliance on the energy and power networks.

21. The growing reliance on smart technologies and systems, however, can give rise to issues of safety and security, especially in the form of cyber-attacks. In addition, use of data gives rise to concerns around privacy and the secure handling of data, including personal and financial details.

Autonomous Vehicles:

22. Autonomous vehicles, enabled through increased connectivity, could fundamentally change urban mobility and have a number of implications for governments, including rethinking transport policies and existing regulatory frameworks, the role of urban infrastructure, car licensing and traffic enforcement, parking and taxi provision.

23. With the rise of the sharing economy, ownership structures are changing with people less likely to own a car but more likely to lease or hire one as and when they need it.. Driverless vehicles will likely cause changes to the infrastructure of cities, as roads could be made narrower and roadside signage could be reduced. Vehicle convoys can reduce congestion and cut fuel consumption. Resilience to weather issues, terrorism and cyber-attacks will also be important to consider in this context. An incremental uptake of autonomous vehicle technologies is more likely. This includes steps to automation within vehicles but also the use of autonomous vehicles within a confined area. Applications could include parking assistance and taxis / buses operating on pre-set routes or within a defined location.

Freight & Logistics:

24. Technology can also be used to better manage traffic to and from ports so that lorries only arrive at the terminal when the cargo is ready. Increasingly automation is enabling more efficient port operations and movement of containers within port estates.

25. Urban logistics systems form the backbone of a functioning city and economy providing the goods and materials needed to successfully operate a city. The way goods and services are delivered has wide ranging implications for urban life, including congestion, safety, noise and air quality considerations.

26. Furthermore, manufacturing might increasingly return to cities; 3D printing, or additive manufacturing, is a revolutionary technology that could lead to reduced transport of certain goods, which could be printed on site or closer to consumers. It is expected to transform the supply chain, reducing the need for mass-produced manufacturing, transport and storage. Increasing automation within warehousing will impact jobs. Urban areas need to ensure that their planning policies seek to ensure that all major new distribution parks are rail (or water) connected and seek to ensure that 'last mile' deliveries are completed by low/zero emission modes where possible.

Conclusion:

27. Technology has the potential to fundamentally change the world of work. Mobility could become entirely automated along with the ticket and payment systems. With technology, the economy increasingly may be cashless with more online or contactless payment. This could mean that the people element becomes purely focussed on technical oversight roles as well as the added value of the customer experience and interaction with passengers as a premium product. Our economic ambition as a nation must be underpinned by infrastructure, R&D and education / skills in order to remain competitive on a global scale and must adapt to global trends such as technological change, demographic change and climate change.

National Infrastructure Commission Technology Study: Second Call for Evidence

Met Office submission, September 2017

Email contact: TechnologyEvidence@nic.gsi.gov.uk

Introduction

The Met Office is the UK's National Meteorological Service (NMS), a Public Sector Research Establishment and an Executive Agency of the Department for Business, Energy and Industrial Strategy (BEIS). We are responsible for monitoring and predicting the weather and providing the National Severe Weather Warning Service (NSWWS) for the public, civil contingencies and emergency responders. We have specific capabilities and responsibilities relevant to infrastructure including being a World Area Forecast Centre for aviation, a Volcanic Ash Advisory Centre, the UK Space Weather Operations Centre and hosting the UK Flood Forecasting Centre in partnership with the Environment Agency. In addition, we host the Met Office Hadley Centre for Climate Science and Services, which delivers policy relevant climate advice to the UK government and we played a leading role in providing underpinning science for the recent National Flood Resilience Review. The Met Office's ability to forecast the weather and predict the climate underpins the construction, operation and use of infrastructure, industry and business in both the public and private sector and it is in this capacity that we respond to this consultation.

Better Asset Management

1. **What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?**

As the UK's NMS, the Met Office owns, operates and develops weather and climate models which can be used to understand both the short term impact of weather events and the longer term climate impacts on the UK. This could be considered to be a 'digital twin' of the global atmosphere, the outputs of which we use to gain a general understanding of possible future evolutions and are provided in data formats which infrastructure providers can use. Armed with information on potential upcoming weather events, infrastructure decision makers can combine it with their data and make informed decisions on efficient running of operations, or introduce contingency measures to protect assets or reduce the impact of an event. On longer timescales, climate predictions and climate change projections based on world leading Met Office Hadley Centre science provide a robust basis to understand future risk, and to inform planning and investment decisions. For example long term flood management or major infrastructure investment decisions – by Government, businesses and individuals.

Initiatives underway

The Met Office has been involved in the Ordnance Survey led analysis of 5G communications which has aimed to investigate the weather dependency of this new network. This demonstrates the importance of collating and analysing data, and testing known vulnerabilities and sensitivities to understand any changes that will occur when moving to a different infrastructure regime.

Another example of where understanding pre-existing sensitivities and vulnerabilities could be of particular importance is in the development of autonomous vehicles and the infrastructure to

support this. The current generation of autonomous road vehicles rely upon lidars, radars and camera type sensors. It is our experience that all can suffer either degraded performance, or even misleading output, in specific severe weather conditions. With this in mind, those involved in the test environment should consider reproducing weather conditions that are representative of the conditions likely to be encountered in future routine operation, including the extremes. This is so that any weather-related degradation in sensor or vehicle performance during tests can be properly understood. It may also be important to be able to relate the weather conditions experienced during tests to the climatology[1] of the test site, different regions of the UK and the rest of the world. This will enable the test results relating to weather sensitivities to be readily translated to more widespread operation.

Joining up initiatives and support by Government

A practical way to approach this issue is to draw on and build upon pre-existing expertise, wherever this lies, as lessons can be learnt from those who have faced similar challenges previously. In addition, many of these challenges will affect a number of different areas, increasing the need for cross-Government working and sharing of information. An example of where drawing upon pre-existing expertise and cross departmental working has been beneficial is the Data Revolution project. This draws upon the expertise of the partner organisations of the Department for Business, Energy and Industrial Strategy to not only identify what data BEIS has and how it uses it, but also to consider how it can capitalise further on the "Data Revolution". This is to unblock the potential of data within BEIS and deliver substantial benefits such as efficiency savings and better quality policy and decision making.

The sharing of information across Government will aid further development of specialist expertise. This in turn will allow the development of more explicit definition of both the challenges being faced and the parameters of the potential solution required. This will enable technology providers to more fully understand the situation and, therefore, develop more tailored solutions.

2. **What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across infrastructure sectors (transport, water, energy, digital, waste and flood defence)?**

[No comment]

3. **What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets and how can these be addressed?**

Data size

The Met Office regularly produces, processes and uses data towards the extreme end of the data size spectrum. This means that we have already faced challenges that will become more widespread as general data size and availability increases. For example, it is challenging to share our data using current infrastructure – the Met Office archives approximately 200 TB of operational and research

[1] A historical record of weather which provides context to the current weather i.e. whether the conditions are normal or abnormal.

data every day to its mass storage system on-site at Exeter. We currently have a 1Gb link to the internet and assuming we used this current internet link, running at theoretical maximum capacity, to transfer this data to the 'cloud', it would take over 18 days to complete. This means that we, and others, will increasingly need a different type of infrastructure to facilitate access to our data. As a result, we suggest encouraging and facilitating different types of working could be beneficial. This could include no longer expecting data to be transferred to another location for analysis but instead users being able to perform some types of analysis at source.

Limitations of some proposed solutions

Some technology companies are increasingly pitching 'black box' technology solutions, whereby the user is not aware of the processes employed to convert input variables to useable output. This can seem an attractive solution as the level of understanding required to operate the solution may not need to be particularly deep. However, it is our experience that to efficiently and effectively utilise the output of technology data analysis it is important to understand these hidden processes. This is because a user with an understanding of the processes involved may be able to identify limitations of the output or suggest areas which may require further consideration before use. Without this deeper level of understanding, decisions may be made based on assumption of how the technology functions, rather than hard evidence. That is not to say that 'Black box' technology solutions cannot play a useful role, however they should be used alongside expertise and wider understanding. We feel that Government could play an important role here in growing its own expertise and being able to knowledgeably challenge.

4. **What are your thoughts on the capability of a digital national twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main use of such digital twins?**

Experience of digital twins

The Met Office has extensive experience in the development and implementation of a digital twin as, in essence, our weather and climate models are a digital twin of the global atmosphere. Our long history and experience in this area has taught us the importance of understanding the level of accuracy of the digital twin and, in turn, the resulting limitations. To help further understand any limitations we have developed and refined verification methodology to regularly compare model outputs with reality. This in turn allows us to evaluate areas which are performing well and potentially identify areas for improvement of the digital twin. We would welcome the opportunity to share best practice in this area if it would be of wider use.

Verification can be useful to highlight areas of potential improvement and long term simulation performance. However, to prioritise these potential improvements the verification data must be combined with an understanding of the relative pace of development. For example, some aspects of development are likely to be dynamic, rapidly improving as understanding develops; whereas other aspects are likely to be more static. It is important to recognise and understand these differing paces of development to ensure that expectations of the end user can be set appropriately.

It is also important to recognise that in reality one large digital twin is often composed of a number of smaller and interoperable models. This means that it may be possible to identify components of the whole digital twin which performs better than other components. This may mean that it is

possible to target investment to areas where significant benefits will be seen, whilst employing pre-existing infrastructure or solutions in others.

Uses of a digital twin:

There are many different ways that a digital twin could be used. For example in our area of specialism, the output of our weather model can be used in conjunction with digital twins of infrastructure assets to understand the impact and full implications of a weather scenario on a particular asset. The output of climate models can also be used in conjunction with digital twins of infrastructure to test for vulnerabilities to different climate scenarios or impacts.

In a broader context, it is our experience that digital twins can be useful to explore potential 'what if' scenarios in both the short and long term. The digital twin enables the safe exploration of potential impacts by bringing together data with the response of the infrastructure asset. This in turn allows effective planning and mitigation for a range of potential, but plausible, future scenarios. A recent example of this was the innovative work the Met Office undertook as part of the National Floods Resilience Review to develop plausible worst case scenarios to stress test flood infrastructure assumptions. In a similar way digital twins could be applied to a variety of policy applications, testing the implications of different scenarios or varying factors to understand impacts on outcome.

5. **How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?**

[No comment]

Water Efficiency

1. **In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?**

The Met Office has considerable experience modelling weather related leakage and burst pipes. Models relating daily leakage and number of burst pipes to weather have been calibrated for a number of water companies demonstrating that changes in leakage, can be confidently predicted based on changes in the weather. The model can be run with weather forecast data providing an operational leakage forecast service out to 10 days ahead. These forecasts have been utilised by a number of water companies which have successfully integrated them into their production planning processes, demonstrating cost saving benefits.

Climate variability and climate change will see the UK exposed to an increasing range of conditions, including an increase in the occurrence of some types of damaging and costly extreme weather events. Many businesses already use climate information to inform their future planning and investment decisions. For example, the use of the UK Climate Projections (UKCP09) by water companies to understand how climate change may affect the supply and demand of water as part of

long-term water resource plans. We therefore support the recognition of the importance of climate change and the drive to reduce the associated risks for both supply and waste water management.

2. **Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?**

[No comment]

<u>Big Data</u>

1. **What governance arrangements are needed to**
    a. **Manage the huge amount of data being generated and used in the infrastructure industry and**

At present different organisations and customers value data in different ways, including different pricing structures and mechanisms for sharing data. This can pose a barrier to collaboration and effective use of data. To address this, governance arrangements could be considered which recognise this challenge, whilst also ensuring that data can be shared without the loss of any commercial advantages. This challenge is particularly acute in the case of multi-source data platforms and products where the governance structures will need to consider how to monetise and reward individual contributions. However, success in this area is likely to enable increased inter-operability of data, unlocking potential new uses and combinations of data.

    b. **Encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?**

Data size is increasing, which is making it harder to transmit and share this data using existing infrastructure. As a result, it may be important to consider policies which not only enable the movement of data, but also the interrogation of data at source. For example, there may be a need for agreed APIs to access data, but also APIs which safely execute code wherever the data is stored.

In the case of meteorological data, transmission of full data sets is constrained by the existing infrastructure. However, not all of this data is of use to those outside of the Met Office and so we are increasingly looking towards a mix of in-house storage capacity (for that of specific internal/scientific interest) and cloud based services (for that of wider interest). In the case of the Met Office we have significant storage and High Performance Computing (HPC) facilities on-site to enable our data production, interaction and usage, but this is not the case for the majority of users. Consideration may need to be given to the importance of the availability of appropriate storage/HPC facilities.

2. **What barriers are there to sharing data**
    a. **Internally within systems and organisations and**
    b. **Externally (e.g. through making data sets open to realise indirect value)? What can the Government do to support the secure sharing of data in the infrastructure industry?**

Data Size

As has been mentioned in the previous question, the increasing size of data presents challenges to sharing data through current infrastructure. And, although data size is increasing, not all of that data can be translated into useful and usable information which has wider applications. To overcome these challenges and turn data into useable information, the tools to interrogate and interpret this data will become increasingly important. However, consideration will need to be given to the sustainability of solutions which are employed as there will be a cost associated with keeping some aspects up to date and relevant to end users.

Protection of competitive advantage

As mentioned in the question on governance arrangements, a significant consideration we have encountered when sharing and collaborating on data is how to ensure that this does not result in loss of competitive advantage for anyone involved. For many, the fear of a loss of this type can make organisations and individuals less inclined to engage. Strong governance arrangements may be a way to mitigate against this barrier.

3. How can a digital twin help to manage infrastructure data as an asset?

It has been our experience that a digital twin can be used as a simulator to produce 'what-if' scenarios and sensitivity experiments. For example, determining an asset's sensitivity threshold to a particular weather event so that appropriate responses and mitigation can be implemented and understood. This can be particularly beneficial as it allows pre-planning and the development and deployment of contingency plans ahead of any event. However, it must be recognised that the reliability of the output and decisions made will depend upon the accuracy of the digital twin and the assumptions included there-in. Both development and understanding of these digital twins and other modelling input requires sustained support.

NIC – NEW TECHNOLOGY STUDY: SECOND CALL FOR EVIDENCE

Ordnance Survey (OS) welcomes the opportunity to respond to the National Infrastructure Commission's Second Call for Evidence to inform the upcoming Technology Study.

Contact: [name.redacted]

Better asset management

1. What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

We are familiar with the following initiatives:

- Digital Built Britain[1] (DBB) is a programme, sponsored by BEIS, focused on implementing digital technologies within infrastructure asset development projects to deliver TOTEX efficiency gains throughout the lifecycle of assets. The programme seeks to align activity in the areas of Building Information Modelling (BIM) and Smart Cities, ensuring a consistent approach in terms of data, standards, architecture and classifications to develop the next digital standard for the construction sector, known as BIM 3, to save owners and managers of built assets billions of pounds a year in unnecessary costs, maintain the UK's global leadership in digital construction and support long-term strategic objectives such as decarbonisation.
- Digital Rail[2] is a programme led by Network Rail Infrastructure Ltd focused on the capacity and reliability of train services in the face of increasing demand and a reduced maintenance budget. The programme shares many of the same aims as DBB, but the two programmes, although aware of each other, currently work independently within domain silos. Requirements and resultant solutions are currently unlikely to align, although both are committed to using standards, reducing future barriers to integration.

We are also aware of these initiatives:

- Smart Motorways[3]
- Smart Grids (water metering for Ofwat and OfGen)
- Smart Meters[4]
- Streetworks Data Hub (DfT)[5]

2. What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

The creation and maintenance of an interoperable data asset is key to unlocking the potential of our existing infrastructure, and this in turn requires the potential of data itself needs to be unlocked. To this end, consideration should be given to:

- Data <u>for</u> infrastructure: the physical requirements needed to gather, store, maintain and disseminate data. A significant future component of that system will be remote connectivity to support IoT sensors and actuators.
- Data <u>about</u> infrastructure: at the most basic level, a consistent description of its location, to which can be appended, for example, condition, owner and alternative name information. The ability to discover data about infrastructure remains a common challenge.
- Data <u>as</u> infrastructure: the factors that will enable data to add value to economy, investing in it as a common good for multiple purposes. This covers issues of ethics, trust, standards, defined actors and business models.

[1] http://digital-built-britain.com/
[2] http://digitalrailway.co.uk
[3] http://www.highways.gov.uk/smart-motorways-programme/
[4] https://www.gov.uk/guidance/smart-meters-how-they-work
[5] http://www.ukauthority.com/data4good/entry/7133/street-works-data-hub-project-to-move-to-alpha

Data – in a generic sense – cannot be addressed in a single step. Geography is widely acknowledged as a core reference framework; location is the lowest common denominator between data sets and therefore presents the lowest adoption barrier to enable exchange of data between organisations. Furthermore, location is a unique characteristic that can distinguish and identify assets and actions in a smart environment, and provide the foundation to dynamic, real time data.

To that end to be fully realised, the DBB vision will require an authoritative geospatial framework to integrate the historically separate realms of mapping and building modelling (which respectively describe the 'outside' and 'inside' worlds) to provide a useful and singular digital representation of the real world.

The requirement for a geospatial framework has been further established within CityVerve[6], the UK's Internet of Things demonstrator project, based in Manchester. The scope of CityVerve spans four key areas; transport, health, energy and culture, and involves assembling and interrogating a wealth of data relating to Manchester's assets. An early learning from the project has been that location has to be embedded as a core element of reference architecture when designing a 'smart' environment to enable true interoperability.

3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

Silos within organisations, established practice and adoption of cost present barriers to all forms of integration including data and new technology. The benefits are often multi-disciplinary in nature and there are limited incentives to discover and describe them. Where a business case can be created, the customer often lacks the mechanism to procure and manage the delivery of the benefits.

OS is keen to participate in an investigation of the benefits and challenges which we have explored in various international contexts, including Chicago, Singapore and Bahrain.

OS is also investigating alternative business models for data utilisation associated with multi-directional flows, in particular through the notion of a data exchange, building on the thinking of the Copenhagen City Data Exchange[7].

4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

When referring to 'digital twin' in relation to infrastructure we mean a digital version of the real world in terms of geospatial data and all physical assets in the environment, covering the primary domains of indoor, outdoor, above and below ground. A digital twin:

1. has the capacity to cover not just currently known but also future infrastructure types;
2. is operated as a federated 'system of systems', managed across a multitude of stakeholder organisations; and
3. upholds the commercial and security interests of the owners and operators of parts of the infrastructure, using technical and legislative tools to ensure a balance between accessibility and security requirements.

Our definition represents a conceptual model. Yet, to date, the terminology 'digital twin' has been used to describe a dynamic software model of a physical thing or system that relies on sensor data to understand its state, respond to changes, improve operations and add value. Digital twins include a combination of metadata (classification, composition and structure), condition or state (location and ambient environment), event data (time series), and analytics (algorithms and rules). Organisations will use digital twins to proactively repair and plan for equipment service, to plan manufacturing processes, to operate factories, to predict equipment failure or increase operational efficiency, and to perform enhanced product development. Examples of digital twins in practice are available from General Electric[8] and McLaren[9].

[6] http://www.cityverve.org.uk/
[7] https://www.citydataexchange.com/#/home
[8] https://www.ge.com/digital/sites/default/files/Digital-Twin-for-the-digital-power-plant-.pdf
[9] http://www.mclaren.com/appliedtechnologies/news/how-digital-twin-will-accelerate-fourth-industrial-revolution

Digital twins will enable scenario modelling, simulation and analytics based on synthetic data to monitor and optimise the performance of any object or system. They will also help improve efficiency by creating a feedback loop into the planning and design stage. Testing scenarios in the digital world has a variety of applications, ranging from supporting policy making, risk reduction, environmental protection, to public safety and security.

An early step to developing a digital twin, whether regional, sectoral or national, should be a national register of existing digital twins. Such a register would have to regulate the flow of incoming data, and ensure interoperability through common standards. Legislation and/or regulation should require infrastructure providers to supply information on asset location for new developments, continuously building and updating a depository of information about the real world.

Geospatial data is increasingly being viewed as the framework within which the inter-relationships across human, natural and physical environments and systems can be recognised, modelled and managed.

5. How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

We recommend the formation of a multi-party steering group, sponsored by government, which:

- is tasked with making infrastructure data accessible
- holds responsibility for data standards, quality and interoperability
- determines protocols and methodologies for data sharing

Smart traffic management

6. What are the latest developments in intelligent traffic systems, and what technologies underpin them?

At the European level, Cooperative Intelligent Transport Systems (C-ITS) will allow road users and traffic managers to share information and use it to coordinate their actions[10]. In 2016, Member States and the European Commission launched the C-Roads Platform to link C-ITS deployment activities, jointly develop and share technical specifications and verify interoperability through cross-site testing. The C-Roads Platform is conceived as a cooperative framework including national authorities, C-ITS stakeholders and the Commission, with the objective of developing a shared vision for the interoperable deployment of C-ITS in the EU. The C-ITS Platform is now in its second phase and will accompany the deployment process with a special focus on the links between connectivity and automation, in particular with respect to infrastructure and road safety issues.

Within the UK, Local Authorities are embracing new approaches to traffic management. A report by The Institute of Engineering and Technology and Intelligent Transport Systems UK draws attention to the variety of local initiatives across the UK. A variety of use cases are described in the report[11]. The report found that the greatest benefits for a number of different use cases were found based on the deployment of Internet of Things, Big Data, sensors, connected and autonomous vehicles, as well as crowd-sourced data and social media.

7. What barriers do local authorities face in deploying these systems, and how could these be overcome?

Data sharing within and between local authorities is fragmented and the quality of data varies greatly. One example is Traffic Regulation Order data (primarily speeds and restrictions) which can take the form of paper-based documents or geo-enabled, attributed data. However, intelligent traffic systems will operate beyond local authority boundaries and, therefore, a common systems of data capture needs to be introduced to ensure the accuracy of the data captured. C-ITS is trying to address this issue nationally as well as internationally to enable local authorities to collaborate. Beyond road traffic, intelligent transport systems are pursuing intelligent mobility, spanning both road and rail, while legacy transport systems will

[10] European Commission, https://ec.europa.eu/transport/themes/its/c-its_en
[11] http://its-uk.org.uk/wp-content/uploads/2017/04/2017-LA-Guide-to-Emerging-Transport-Tech-Brochure.pdf

operate alongside new developments in the industry. However, fragmentation will remain if local authorities trial their own systems without accounting for interoperability beyond local boundaries.

Water efficiency

8. In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

One outcome of the Northumbrian Water Group Innovation Festival in July 2017 was consensus that a common infrastructure map which facilitates the wider sharing of underground asset information could greatly contribute to greater resilience and enhanced industry innovation; these are key goals of Ofwat's 2019 Price Review for the 2020-25 regulatory period[12].

9. Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

No response.

Big data

10. What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

Governance mechanisms need to evolve to recognise data as a valued asset. The Open Data Institute, in collaboration with The Royal Statistical Society, published a letter to the National Infrastructure Commission arguing that 'data is infrastructure' and as such underpins a variety of services essential for the operation of a modern society and its economy[13]. However, we believe that data quality, the security of data supply, the frequency of data updates and data trustworthiness are all governance arrangements needed to manage data generation and its usage, irrespective of whether or not it is open.

11. What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

OS has close working relationships with a range of infrastructure owners. In recent collaborative workshops with infrastructure owners[14] the following barriers to data sharing were identified:

a. The <u>sharing of data internally</u> is primarily limited by technical aspects:
   - Compatibility of data models and information typically being dispersed across disparate, unintegrated systems;
   - Lack of commonality between systems (e.g. different naming conventions, definitions);
   - Lack of common Key Fields between systems;
   - Lack of awareness and knowledge of data in other systems;
   - Availability and utilisation of appropriate applications to read and utilise the data; and

Another common issue is that specialised resources (both human and technical) that have the capability to consume and exploit the data appropriately very often exist within silos.

b. The <u>external provision of data</u> has a number of barriers:
   - Organisations have concerns with respect to the control and security of the data, how it is utilised (i.e. is the application appropriate) and how data quality and integrity is maintained;

[12] Ofwat 2019 Price Review: http://www.ofwat.gov.uk/regulated-companies/price-review/pr19/
[13] https://www.food.gov.uk/sites/default/files/fsa160104-annexa.pdf
[14] We are unable to provide further details due to commercial confidentiality.

- Equally, there are the technical aspects with respect to compatibility of format and data models, the ability to exchange and (securely) hold significant amounts of data, and having common processes established to maintain and update the data;
- Cost of gathering, maintaining, and sharing of data. Similarly, there are concerns around the reliability, quality and accuracy of collected data[15]; and
- Industry is heavily regulated and it is believed that government can support sharing by working with regulators to create an industry specific code of conduct for sharing.

More generally, some of the information may be categorised as critical national infrastructure and, as a result, may be restricted from sharing in either aggregated or raw formats.

Beyond the experience of industry, there are a variety of standards that can remove barriers to sharing data. Work done by the British Standards Institute's (BSI) *Smart and Sustainable Cities and Communities Group* has identified two key barriers to data interoperability[16]:

- Semantic – ensuring that the meaning of the data is fully understood when the data is shared[17]; and
- Security – protecting the data against loss and unauthorised access[18].

12. How can a national digital twin help to manage infrastructure data as an asset?

To optimise the management of data as a whole (including infrastructure), a digital twin needs to be built into a unifying framework based on standards and interoperability.

Network operators identify asset management as the management of value and risk. The provision of a digital twin has the potential to maximise the accessibility, utilisation and subsequent value exploitation of infrastructure data on a national scale. Areas of benefit include:

- safety
- environmental management
- planning and development
- cross-utility coordination
- risk management and mitigation
- civil contingencies planning
- emergency response.

A digital twin offers opportunities for a more complete understanding of assets, enabling richer information analysis and a wide range of other benefits as set out in our response to question 4.

[15] There is a wealth of experience in the relevant ISO standards that could be of use in managing large datasets of asset information: ISO 19157 Geographic information – data quality and 19158 Quality assurance of data supply, and related measures, metadata, and coding standards.
[16] PAS 182 Smart city concept model – Guide to establishing a model for data interoperability
[17] W3C Data on the Web Best Practice "Data Vocabularies": https://www.w3.org/TR/dwbp/#dataVocabularies
[18] BSI standards for more information: PAS 256 provides guidance specifically in the context of buried infrastructure; PAS 1192-5 is specifically about a 'security-minded approach' to data sharing in digital built environments and asset management

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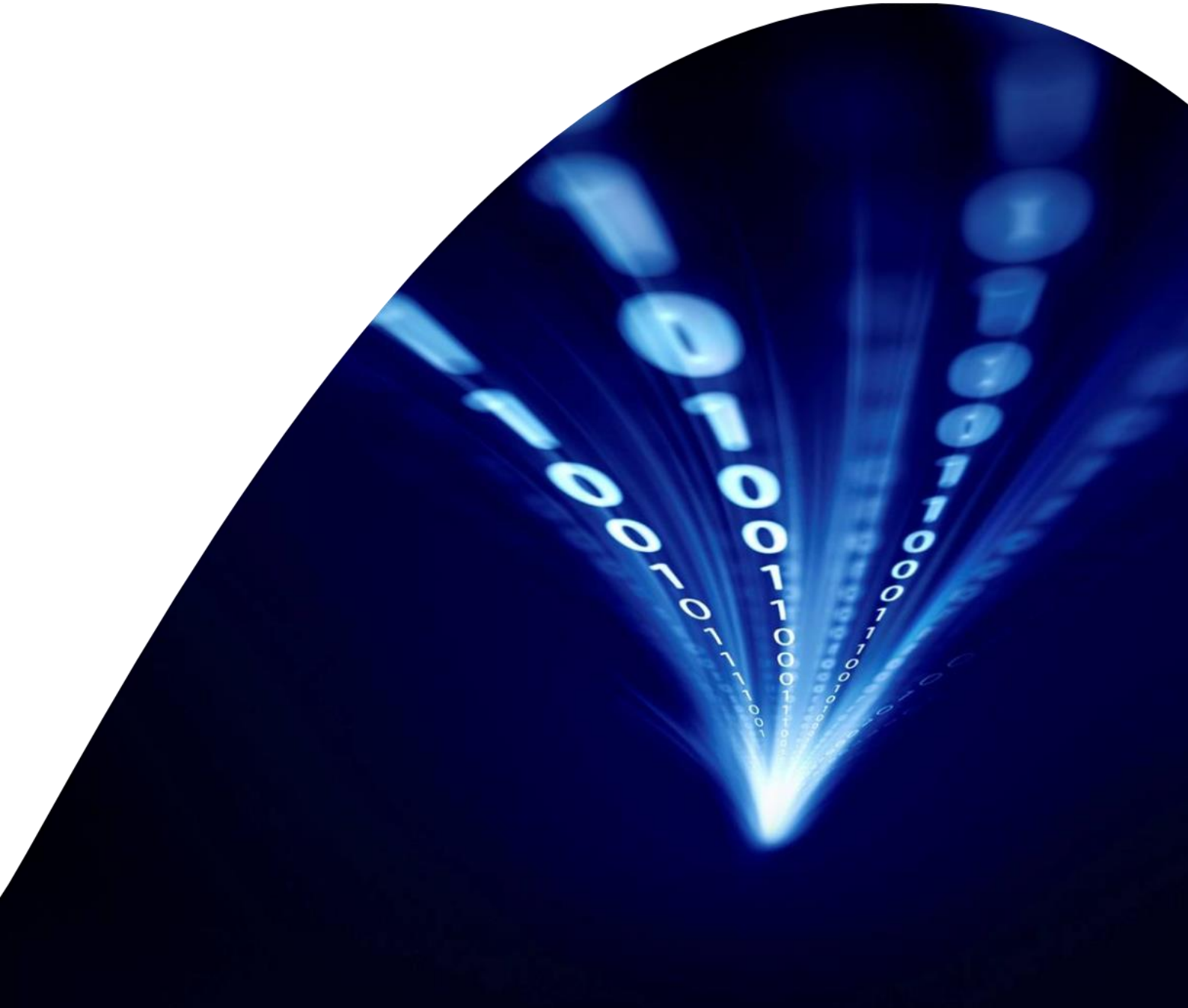
Pinsent Masons

Pinsent Masons Submission

National Infrastructure Commission (NIC) New Technology Study
Second Call for Evidence

15 September 2017



Better Asset Management

1. What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

This submission focuses on a thought leadership campaign by Pinsent Masons* called "**InfraTech**". The objective of the InfraTech campaign is to explore a trend we had observed: digital technologies being deployed or integrated with physical infrastructure to deliver efficient, connected, resilient and agile assets that respond intelligently to their environments, or inform and direct their own maintenance, use and delivery. These assets may also be automated and responsive to real-time or historical data. InfraTech produces benefits for the end user in terms of efficiency, productivity and a better overall user experience. Examples of InfraTech include the deployment of Internet of Things (IoT) solutions in train tunnels to inform maintenance decisions, or the use of sensors and data analytics to optimise and re-direct footfall pathways in transport hubs during busy periods.

In mid-2017, Pinsent Masons commissioned Mergermarket to conduct a survey on InfraTech trends by targeting 300 senior-level executives in the UK, Asia-Pacific and EMEA regions in the infrastructure sector (120 respondents) and the technology sector (120 respondents), along with 60 direct equity investors (**InfraTech Survey**). The InfraTech Survey included comprehensive qualitative and quantitative questions with all interviews conducted over the telephone by appointment.

Detailed follow-up interviews were conducted with select InfraTech Survey respondents. Then, on 7 September 2017, we facilitated a highly successful roundtable event in association with the Institute of Civil Engineers (ICE) and techUK, to discuss some of the trends identified in the InfraTech Survey with 20 executives (**InfraTech Roundtable**). Our thought leadership report on InfraTech will launch in October 2017 (**InfraTech Report**). Post-launch, we intend to continue this forum with subsequent activities globally, positioning Pinsent Masons at the forefront of this convergence of technology and infrastructure.

In addition to the InfraTech campaign, there are a number of relevant initiatives underway in the UK, such as:

- plans by the Department for Digital, Culture, Media and Sport (DDCMS) to test and trial 5G technologies and launch a 5G Innovation Network, and DDCMS's appointment of Ordnance Survey to lead the 5G Mapping Project in the UK;
- the NIC's New Technology Study (including this second call for evidence) and the Data Challenge to be conducted in Bristol;
- the Project 13 initiative run by the Infrastructure Client Group (ICG) and ICE to pilot and peer-review new approaches to infrastructure projects and publish relevant information, including the report published earlier this year called "From Transactions to Enterprises: A New Approach to Delivering High Performing Infrastructure";
- the growth of initiatives relating to big data and artificial intelligence (AI) in the infrastructure sector and the ICE Thinks workshop and report on "Artificial Intelligence – Shaping the Future of the Built Environment";
- the report by the Royal Society and British Academy called "Data Management and Use: Governance in the 21st century"; and
- various projects underway in the UK, such as the procurement and development by Transport for London (TfL) of a surface intelligent traffic system (ITS) for London's entire road network (the **TfL ITS Project**) – Pinsent Masons is involved in this project.

Creating an InfraTech eco-system will help to facilitate joined-up information exchange and dialogue around common issues, some of which are highlighted in this submission. The DDCMS and the NIC are well-placed to establish and lead this eco-system. A key objective will be to establish a world-leading skills base of people in the eco-system with an understanding of InfraTech technologies, the risks and how they are overcome, and the promising opportunities for innovation. For instance, fresh and joined-up thinking in the rail sector might re-focus projects away from outputs (e.g. rail lines to move people and goods) towards cross-sector outcomes (e.g. connected, intelligent and autonomous transport networks).

A worthwhile initiative would be the formation of stewardship bodies. This would include a **data stewardship body**, as proposed by the Royal Society and British Academy in its report mentioned above, to develop data standards, to guide the InfraTech eco-system on data governance issues and risks, and perhaps to provide an enforcement function in respect of data-related offences. Also, an overall **technical architect** would be useful, particularly for digital twin projects, to oversee the large number of relevant, related projects.

* Pinsent Masons is the largest international law firm providing full service legal solutions to the infrastructure sector. We are also ranked by independent directories as a top tier law firm in the technology sector in the UK. We advise all types of stakeholders in these sectors across the life-cycle of infrastructure and technology projects.

2. What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

The results of the InfraTech Survey suggest that the immediate priorities are technologies that facilitate data collection and analytics, and tools to automate assets' response to data, including:

- *sensors* to detect data (58% of the InfraTech Survey respondents consider sensors will have the most significant impact in the next three years, compared with 8% who consider them to have had the most significant impact in the past three years);
- *wireless networks*, such as 5G networks, IoT networks, small cells and mesh networks, to communicate data (80% of the respondents consider wireless networks will have the most significant impact on the delivery of infrastructure in the next three years, compared with 40% who consider them to have had the most significant impact in the past three years); and
- *data analytics* and *machine learning/AI* tools to analyse and action data (37% of the respondents consider machine learning and AI will have the most significant impact on the delivery of infrastructure in the next three years, compared with 11% who consider them to have had the most significant impact in the past three years).

These results are consistent with trends emerging from related initiatives, such as those identified in our responses to question 1.

The crucial role of building information modelling (BIM) remains a key area of focus for the industry, given that most asset optimisation tools require an information management system and process. Currently, much of the infrastructure industry is operating at Level 1 BIM. This typically comprises a mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and production information with electronic sharing carried out from common data environments, often managed by the contractor and limited sharing of models between project team members. Level 2 BIM is distinguished by collaborative working – all parties use their own 3D CAD models, but not necessarily working on a single, shared model, with design information shared collaboratively using a common file format, enabling data to be combined to create (and check) a federated BIM model. While Level 2 BIM has been mandated by the UK Government for all public-sector infrastructure work, compliance remains challenging and this will continue to be the subject of intense activity in the short term.

Cloud will continue to be a priority over the next three years (according to 21% of the InfraTech Survey respondents) though its significance is substantially reduced (69% of the respondents consider it to have had the most significant impact over the past three years). Also, the significance of *wired networks* has reduced from 44% (for the past three years) to 6% (for the next three years). These results should not undermine the critical importance of these technologies to InfraTech – for example, wireless technologies typically require wired networks for backhaul and data analytics tools are often built on cloud infrastructure – and we consider the results point to cloud and wired network technologies being increasingly seen as incumbent.

3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

Unsuitable regulatory frameworks are the top barrier to InfraTech according to 38% of the InfraTech Survey respondents; by analogy, they are also likely to be a primary barrier to the roll-out of new data technologies for infrastructure assets. InfraTech Survey respondents considered *planning laws* to be particularly problematic, leading to complexity in obtaining approvals for InfraTech projects (according to 82% / 73% of the infrastructure / technology respondents). Data protection laws are another barrier (according to 73% / 74% of the infrastructure / technology respondents), though during the InfraTech Roundtable the sentiment was that while privacy risks exist for InfraTech, they were less of a focus than good data stewardship. Environmental laws were considered as the third largest barrier (according to 68% / 56% of the infrastructure / technology respondents), perhaps due to electromagnetic emissions and other environmental risks. The UK Government is taking measures to address some of these concerns and to promote the roll-out of new technologies through legislative reform packages such as the Digital Economy Bill (including a revised Electronic Communications Code to simplify the process for network operators to access land for carrying out works) and the Data Protection Bill (that will implement the GDPR into UK law, among other things). Initiatives like those in our response to question 1 will be good forums to address these regulatory barriers.

A *siloed approach* to infrastructure and technology was rated by InfraTech Survey respondents as the second highest barrier to InfraTech. These silos have developed due to fundamental differences between the infrastructure and technology sectors in terms of maturity, sales cycles, procurement models, business and delivery models, contractual models, financing, regulation and asset lifecycles. Indeed, overcoming cultural differences between the sectors was seen has the main challenge for in-life delivery of InfraTech projects by 44% /

35% of the infrastructure / technology respondents to the InfraTech Survey. Closing these gaps between the infrastructure and technology sectors will require closer, more strategically integrated, longer-term collaboration between the sectors, with a focus on developing new skills and transforming legacy processes. To this end, Infrastructure providers are increasingly interested in securing long-term access to technology by embedding technology capability in-house or forming joint ventures (JVs) with technology providers (53% propose to do so over the next three years) or entering into public-private partnerships (PPPs) with technology providers (43% propose do so). The formation of alliances scored poorly as a means of closer collaboration (only 1% propose to do so over the next three years), though this may change with the formalisation of alliancing in the NEC4 suite of contracts. Indeed, our research suggests that alliances might even replace JVs in the near future, which would further entrench technology in infrastructure strategy.

Concerns about *physical and cyber security* presented another key barrier according to 32% of the InfraTech Survey respondents. New business models and technologies lead to new cyber risks, and a lack of cyber regulation was seen as problematic by 42% / 48% of the infrastructure / technology respondents. Incoming reforms will assist to address these concerns, such as the Data Protection Bill and the Network and Information Systems Directive. Ultimately, however, the InfraTech eco-system needs to better understand security risks and the standards to which they must adhere, and they need to structure their contracts and insurance coverage for InfraTech projects to appropriately allocate and address those risks and to meet those standards. An organisation's defences are never impervious; it is critical that organisations develop security plans, cross-functional response teams and readiness campaigns to prepare for breaches.

4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

We did not seek views on the capabilities and uses of digital twins in the InfraTech Survey. We did, however, ask respondents to identify what is driving the uptake of InfraTech, and from the responses we can identify some of the general capabilities and uses of digital twins. These include using data generated by the digital twin to:

- create flexible and agile infrastructure assets and services by optimising the assets' operation and use (the primary driver for the uptake of InfraTech according to 50% / 45% of technology / infrastructure respondents to the InfraTech Survey);
- improve end user experiences (the primary driver according to 31% of the respondents);
- improve the performance, reliability and resilience of infrastructure assets and services, including proactively through situation testing (the primary driver according to 35% / 23% of the technology / infrastructure respondents); and
- create new markets and opportunities to build new products and services (the primary driver according to 23% / 34% of the technology / infrastructure respondents).

In relation to the initial steps for the development of digital twins, it is important, firstly, to understand the *barriers* and *opportunities*, including an analysis of the privacy and security risks of digital twins - a workstream commenced by the NIC for the New Technology Study. The proposed data stewardship body and technical architect would be useful bodies to lead this effort. Second, involve industry through consultations, such as this second call for evidence, and initiatives such as the Data Challenge. Third, consider practical matters such as which data to collect and for what purpose, how the data is accessed, shared or made available, and who is responsible for the curation of the data and operation of the digital twins (a role, perhaps, for the data stewardship body). Finally, start with small, localised, controlled tests, trials and pilots to develop the technologies, products, processes and governance, before rolling out more widely.

As mentioned in our response to question 2, consider the role of BIM in the digital twin journey. Level 2 BIM is intended to promote sharing, analysis and re-use of electronic BIM data and later levels of BIM should further improve information exchange and are likely to drive forward the data economy around InfraTech.

5. How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

We discovered alarming information gaps in this space. For example, 72% of the InfraTech Survey respondents consider that InfraTech knowledge sharing is inadequate, and we have already mentioned the issues associated with the siloed approach to infrastructure and technology in our response to question 3. Cross-sector programmes involving public, private and academic organisations are important vehicles for collaboration and bridging these information gaps, such as those referred to in the response to question 1. We are already working closely with ICE, techUK, Innovate UK, Project 13 and other programmes to this end.

Working together also involves speaking the same language. According to the InfraTech Survey, agreeing data requirements and standards to support interoperability and data sharing was the second largest challenge for InfraTech initiatives once initiated. Further, 64% / 58% of infrastructure / technology respondents to the InfraTech Survey consider that data standards do not do enough to promote interoperability – the highest proportion of respondents saw this as a problem for Government to fix. This is another reason to consider the establishment of a data stewardship body to accelerate the establishment of data standards.

The InfraTech Survey results suggest regulatory constraints are also holding back innovation. Unsuitable regulatory frameworks and regulatory constraints are top concerns, as mentioned in our response to question 3, and the overwhelming view of respondents was that Governments (globally) are not doing enough to clear the regulatory pathway for InfraTech – this was seen by the InfraTech Survey respondents as the primary role of Government in accelerating the developing and uptake of InfraTech.

Smart Traffic Management

6. What are the latest developments in intelligent traffic systems, and what technologies underpin them?

N/A

7. What barriers do local authorities face in deploying these systems, and how could these be overcome?

We did not seek respondents' views on intelligent traffic systems (ITS) in the InfraTech Survey. However, Pinsent Masons has advised on high profile ITS projects including the TfL ITS Project, the Greenwich GATEway project, and testing and commercialisation of driverless vehicles in the UK. We therefore offer our views below on the barriers for deploying ITS and how those barriers could be overcome.

Local authorities grapple with legislation that has not been drafted with future technologies in mind. For example, road traffic and highway laws dating back to the 1800s still apply to the use of roads and surrounding public realms. This failure to keep pace with technology poses a major barrier. A short term solution is to proceed with the project in any event and engage with relevant stakeholders (e.g. central and local Government, police, local businesses and local residents) to manage the use of the technology. Longer term solutions will require legislative reform.

Legacy traffic management systems often aren't optimised and fully integrated. This results in data from sensors and other deployed technologies (e.g. at junctions or in tunnels) not being fully fused or correlated, and therefore less useful for predicting future conditions. It is important in ITS procurement programmes to address these kinds of issues by sourcing solutions to improve the quality, speed and integration of data, to allow faster detection and response to incidents (including predictive response), and to provide a "single view" of the systems for better decision making by orchestrating and analysing data from multiple data sources.

Standards and interoperability of data and devices is another barrier to infrastructure assets to communicating with vehicles and vehicles to communicating with other vehicles. Several local councils are looking at standards and interoperability, including as part of smart city initiatives, and infrastructure providers are increasing offering connected products that can interact with the ITS ecosystem. Connecting "systems of systems" opens up security vulnerabilities. Cyber security is a critical risk for ITS, as it is more generally for InfraTech based on the results of our InfraTech Survey. Refer to our response to question 3 for a discussion on those risks.

Public perception and acceptance is another barrier. These systems are expensive to purchase, deploy and operate. They present new risks and liabilities which must be assessed and for which somebody must be responsible. Further, they may introduce new elements and artefacts in public spaces to which the public must become accustomed, in addition to what happens behind the scenes. Obtaining public "buy in" will be important to the future success of ITS. This can be achieved through the completion of successful testing and trials and communication of the benefits of the technologies to the public, such as improved safety, time savings, cost savings and increased mobility. In fact, several trials of connected and autonomous vehicles (CAVs) under way in the UK are testing not just the viability of the technology but also the public and consumer response to it. In particular, younger, more technologically savvy generations may feel more comfortable using and accepting ITS and future transport solutions. Local authorities should also consider how they will fund the purchase, deployment and operation of such systems (e.g. grants, partnerships, sponsorship, selling the solution) and how that is communicated to the public.

Water Efficiency

8. In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

N/A

9. Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

N/A

Big Data

10. What governance arrangements are needed to: a) manage the huge amount of data being generated and used in the infrastructure industry; and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

We did not specifically seek respondents' views on this subject matter in the InfraTech Survey. However, feedback we have received for the InfraTech Report highlights the important of each organisation having a robust data governance strategy and, in line with our response to question 1, the establishment of a data stewardship body to provide an industry data governance function and a technical architect. Compliance with data protection laws is of course a critical input to the development of data governance strategies and for the work of any data stewardship body that is established for the infrastructure industry. We would, however, like to send a note of caution to the industry to not allow your organisations and initiatives to be over-awed by privacy at the expense of understanding what data you have, what value it can provide (for your organisation and others), and how it can be appropriately used and commercialised.

Feedback from the InfraTech Roundtable and also public comments from high profile individuals (such as Elon Musk) suggest that there should be an ethical and moral vector to the deployment and advancement of data technologies and particularly AI. We recommend that the UK Government considers a consultation on the regulation of AI and considers the ethical and moral issues through the forums we have highlighted in our response to question 1.

Refer also to our response to questions 1 and 5 (and question 7 in respect of ITS) on the need to promote data standards.

11. What barriers are there to sharing data: a) internally within systems and organisations; and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

Significant barriers exist to "internal" data sharing (including within a project). These include a lack of data standards in the infrastructure sector and also the absence of standard positions relating to data ownership, data use and data commercialisation. Further, there is a tendency for data sharing discussions to become adversarial due to concerns over accuracy or adequacy of data collected for projects, or preferences to maintain control or confidentiality over potentially valuable datasets. According to the InfraTech Survey, an open access model is the most popular model for data ownership in these projects (91% of the InfraTech Survey respondents favour such a model). While this aspiration does not match our observations of reality, it is a heartening statistic and demonstrates an underlying preference in the industry for openness and knowledge sharing.

In relation to "external" data sharing, the internal barriers highlighted above might also apply and, in addition, the general perception is that there is a lack of knowledge sharing across the infrastructure sector (72% of the InfraTech Survey respondents consider that InfraTech-related knowledge is not shared in the sector).

Closer collaboration and a cultural shift in the sector towards knowledge sharing will be necessary. Refer to our response to questions 1 and 5 on the role Government can play to support data sharing in the infrastructure sector.

12. How can a national digital twin help to manage infrastructure data as an asset?

Refer to our response to question 4.

Call for Evidence questions

[name redacted]

Better Asset Management

What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

Nowadays, technology gives ability to collect and analyse data on infrastructure assets. One technology that it is started to be used is Big Data through Predictive Maintenance (PM). PM is sensors installed into various systems and subsystems in trains, which can be collated and analysed 24 hours a day, seven days a week. Another way to collate data is by using Wayside Train Monitoring System, which monitors the condition of rolling stock and infrastructure in real time. Moreover, the Train Conformity Check Systemacquires is another way of collecting data, which processes accurate data for trains to 3D, thermographic and high resolution cameras to detect rolling stock defects or fire on board. However, these initiatives can be joined up and supported by having a Cost Benefit Analysis. The Cost Benefit Analysis should take into account for instance the cost of the maintenance and the cost of using one of the above technologies. The support from the Government could be as well offered by considering that one of them could provide necessary information in order to prevent defects from developing in the first place. As result the meaning of time-cost-quality, which describes every successful project can be accomplished.

What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

The technology priorities depends on the data. A targeted maintenance can be applied if it is well organized. According to Levi D. (2001) railway infrastructure maintenance is complicated to organize and coordinate with the train traffic. Therefore, maintenance possessions and train services can be scheduled on tactical level with the use of optimization model. Having data from other masonry arch bridges will provide us with the essential information to decide the technology priority.

What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

The main barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets are the following:

- Limited resources
- Incomplete or inaccurate dataset
- Quality of data

In order to overcome the above barriers it should be considered staff resources, namely utilization of staff time and effort to prepare the data for use. Thus, the quality of the data can be succeeded by using quality assurance and quality control methods.

What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

The railway sector should plan for digitization now in order to be more efficient in terms of capacity and cost. Digital twin is a vital element for the railway sector because as a software

model analyzes and simulates real world conditions. Elizabeth Line in London has already a digital twin model of the whole network. The first step to developing a digital twins depends on the area that they will be used. The simulation of a regional area is different from the national, therefore the first step is to identify the area of the implementation in order to have the most accurate virtual view of the real world. The main utilization can be in maintenance and to improve the operational performance.

How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

They can work together by having the same goals, which would be for instance offering a better service to the passengers, decreasing the cost in terms of maintenance as well as improvement of the data analysis. All the above can be succeeded by utilizing the new technology.

SMART TRAFFIC MANAGEMENT

What are the latest developments in intelligent traffic systems, and what technologies underpin them?

Control, Command and Communication (CCC) system, which includes:

- Global System for Mobile Communications-Railway
- Pilot projects for Driver Advisory Systems (DAS)
- Planned use of automatic train operation (ATO) on Thameslink and Crossrail

What barriers do local authorities face in deploying these systems, and how could these be overcome?

The high cost of the investments for increasing interoperability and lack of financial resources are the main problems that local authorities face. However, these can be overcome by political knowledge as well as with the involvement of the public. The politicians play a major role in terms of supporting the intelligent traffic systems and implementing them into practice.

WATER EFFICIENCY

In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

In order to use the emerging technologies it should be considered the parameters whic influences the actual level of leakage. These are:

- The average pressure in the system
- The condition of the mains and service pipes
- The facilities available for collecting data

Considering the above a monitoring system together with regular inspections should be considered in order to prevent and repair the leaks.

Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

It would have a positive affect because it is a more accurate way to collect data. Moreover, it will inform about the exact amount of the available water and the quantity that every household spends.

BIG DATA

What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

The arrangements should be by creating:

- digital steering committee
- adress the data skills shortage
- standardisation of data infrastructure

Moreover, an agreed APIs is necessary in order to have a common a operating system or data based system.

What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

The barriers are:

- Data in incompatible format
- Only aggregated data is available
- Approval process for accessing data
- Limited resources

According to Dennis Steinauer, (1997) the secure sharing of data can be supported by a cryptographic policy, which includes the key recovery, key management infrastructure, cryptographic algorithms as well as cryptographic APIs.

How can a national digital twin help to manage infrastructure data as an asset?

A national digital twin creates data and information about an asset for the whole life-cycle. . A model can be created by gathering data from manufacturing, maintenance, operations, as well as operating environments. Therefore, by managing and analysing the data from the digital twin a better approach can be succeeded in terms of cost.

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Annex A1: Rail Industry Readiness Levels

Contact: [redacted]..Network.Rail

Rail Industry Readiness Levels help rail businesses manage risk and opportunity by providing a common language to establish the state of development of systems and equipment that apply new technology.

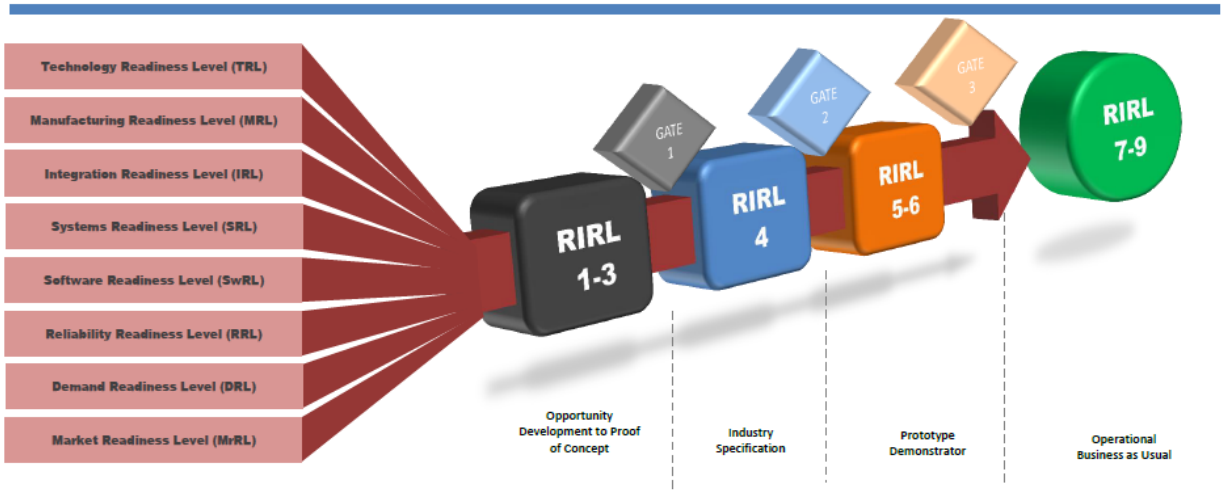
The RIRLs build on the Technology Readiness Levels introduced by NASA and take practice from other sectors that use readiness levels - including defence, aerospace and automotive sector - and configure to optimise their application to the rail sector. RIRLs have been developed through wide consultation in the rail sector and are owned by the rail sector through the Technical Leadership Group.

Network Rail is an early adopter of the RIRLs and has introduced their application as part of its investment governance framework for research, development and technology.

NetworkRail

Product Development Framework

The Network Rail Product Development Framework (PDF) is the key driver to ensuring railway industry concepts, ideas and products enter a disciplined structure allowing for a controlled route to operational transition and deployment.*
At the core of this framework sits the Railway Industry Readiness Levels (RIRLs) where three stage gates allow for the review and assessment of the product. With this control, regulation and discipline the aim is to bring viable solutions to the rail industry challenges in line with the Railway Technical Strategy (RTS) capability Delivery Plan incorporating new and existing technologies.*
This framework will provide one common language linking industry partners (Supply Chain, Universities, and Stakeholder Bodies) to Network Rail tackling current and future demands of Britain's Railways.



**Product Development Framework (PDF) v2.1 / RIRL v2.1*

A2: Insights and case studies for modelling, simulation and visualisation

Contact:[name.redacted], Transport Systems Catapult

Introduction

This note provides a brief insight into the future of transport modelling. It highlights some of the potential issues and barriers that exist within current modelling platforms and then highlights some of the future technologies that TSC is actively investigating and developing. Finally, it provides some case studies of projects where the TSC has used these new technologies.

Current Modelling Platforms

The modelling and simulation of transport infrastructure and services is a mature area of technology. There are many tools commonly used within both the road and rail industries that make use of this technology. These models are typically limited in scope and may focus on one particular aspect of operational or strategic planning, e.g.

The **PLANET** framework model (PFM) provides a strategic overview of the UK rail network which is used to plan strategic rail schemes (e.g. HS2). The PFM includes a national model (which is used for forecasting long-distance rail use) and more detailed regional models (PLANET North, PLANET Midlands and PLANET South) which can be used to model more localised journeys and typically are used to model new rail franchises.

Railsys is a model typically used to model the detailed performance of trains, e.g. can take into account the different performance of different rolling stock and be used to simulate timetables and capacity on the network. Railsys covers the whole UK rail network, but it is typically used to model discrete areas of interest.

Highways England has recently commissioned a series of five **Regional Traffic Models**. These models cover the whole of HE's Strategic Road Network and will be used to assist with the design and appraisal of the road improvement and enhancement schemes set out in the Road Investment Strategy. This marks a significant change for HE, as previously a bespoke model would have been built for each planned enhancement. Having the regional models as a standard platform for all scheme development within an area will reduce the number of bespoke models being built and will enable a high degree of consistency to enable schemes to be compared against each other which is difficult when models are built in different software packages and different forecasting assumptions. These are aggregate models in that they produce results for a specific time period (similar to PLANET) and do not model individual vehicles moving through the network. The models have been built in the **SATURN** highway modelling package. The software for this has been upgraded as part of a separate project involving HE and TSC to speed up model run times through the use of parallel computing technologies using Graphical Processing Units GPUs.

The HEs regional models are not detailed enough to enable the detailed design and assessment of individual components of a scheme, e.g. roundabouts, grade separated junctions or traffic signal controlled junctions. In this case a specific sub-model would typically be built using a specialist package for traffic signal design, or a detailed **micro-simulation** package which can model each individual vehicle.

The above is an example of the models and simulations that area already used within the road and rail transport. They often represent the investment of significant human and financial resources to develop, build and operate. This also highlights that in both HE and NR there are often many different groups and teams that operate models, many with overlapping geographic or technical areas that are operated in isolation and often convoluted methods of sharing data between them.

This current paradigm is reflective of the development path of most of these software packages and tools which have mostly been developed on desktop computing platforms. The major developments in computing software and hardware over the last 25 years has allowed the complexity and capability of these packages to increase with the improvements in processing and memory capacity.

However, there are still hard limits on capability when relying on a PC based computing platform. For example, the run times for the PLANET rail model and HE regional models are measured in hours (even on the highest specification machines using GPU parallel processing) and even with the plentiful availability of on-board memory there is a limit to how many entities that can be modelled simultaneously.

TSC has been looking in detail at the modelling requirements to enable future transport systems to be modelled in greater detail and faster than is currently possible. The next section explores this.

The Future of Modelling & Simulation

A key enabling capability of the TSC is Modelling & Visualisation (M&V). The TSC have a dedicated team who focus on this area. The M&V team hosts the intelligent mobility platform (IMPlatform) which is a unique asset offering a combination of hardware, software, skills and data. TSC use the IMPlatform to:

Create, connect and analyse innovative solutions before deployment using state of the art modelling, simulation and visualisation.

Provide new insights in a collaborative environment – transport modelling making better use of datasets and information from other domains (e.g. the economy, environment, social data, mobile network data).

Enable the development and valuation of new products and services – both within the world of transport modelling and, through the use of improved modelling and visualisation approaches, enabling new transport based products and services to come to market.

Help to optimise solutions, shape thinking and support policy and operational decisions for a wide range of transport related issues.

The IMP programme promotes a 'whole system' approach that underpins Intelligent Mobility through improvements in analytical techniques and enhanced ways of engaging and communicating with users and decision makers through engaging visualisations.

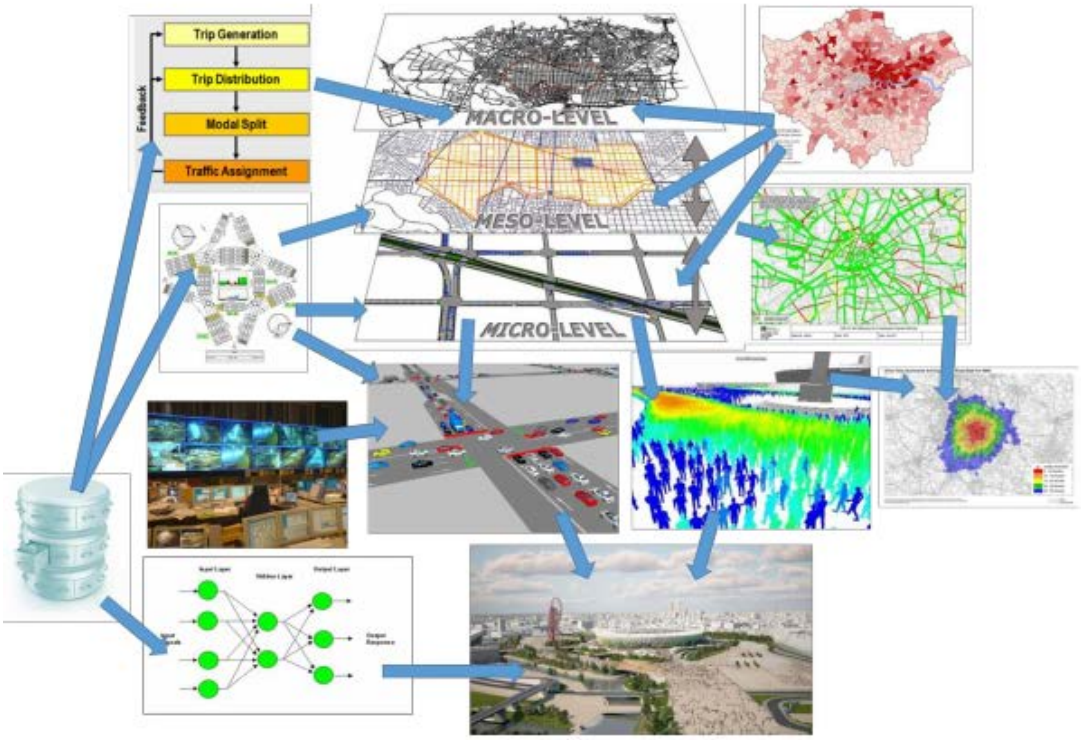
The M&V team contains Transport Professionals, Transport Modellers and Software Developers and we have access to most software packages and platforms that are currently on the market for R&D purposes.

The TSCs views on the future of modelling have been developed through consultation with leaders in academia and industry. Our focus is on development of synthetic environments (simulations) and use of real-time data feeds, together with big data sources and standards to support innovative, integrated models and analytical approaches. Our aim is to share the benefits of this work with the wider community and to pursue and facilitate projects to involve other professional modellers.

TSC recognise that modelling is not an end in itself, but is a support activity to enhance understanding, appraisal or design of initiatives. It appears in many forms and ranges from relatively simple formulae of cause and effect to elaborate representation of complex synthetic environments. Since the interests of the TSC are broad, covering such diverse topics as autonomous vehicles in traffic, behaviour responses of travellers with interactive information, intermodality (person and freight) and the application of real time and 'big' data, all forms of model can find a role.

A2: Insights and case studies for modelling, simulation and visualisation

Figure 1: Simplified overview of interlinks between model types



The full range of current modelling and visualisation tools are shown in Figure 1. Some of these images represent planning methods that have a long history of development and application in transport and will be used in accordance with best practice. Others, involving real time data and behavioural representation of people or vehicles as modelled agents, are less extensively utilised in current general practice.

Simulation modelling is seen as a key capability. There is a growing attention to simulations in many domains and while there are several attractive principal benefits, simulation approaches also face challenges and limitations including those summarised in Table 1.

Table 1: Summary of benefits and challenges of simulation models

Benefits:	Challenges:
Allow representation of a real-life situation in laboratory simulation when it would be more costly, difficult or impossible to create the experiment in the field	Data input can be hard to obtain, interpret or integrate
Explicitly represents process models of sub-systems and their interactions	Links in the model chain can be weak
Create data for analysis or publication	Computing power is often demanding and data output can be voluminous
Facilitate interactive models where human or system decision-making can be represented,	They can be demanding of domain expertise and attract scepticism (is it just a game?)

tested and developed	
Support excellent visualisation that helps explain the simulation to decision makers (or to the public) and to involve a range of people in decisions	Validation is sometimes difficult (particularly when allowing human inputs!)

The limitations highlighted in Table 1 can be treated but must not be ignored. The TSC are demonstrating simulation techniques in ways that illustrate their advantages while managing their potential restrictions. In so doing, we seek to collaborate with existing expertise within and beyond the traditional transport modelling community.

By looking outside of the traditional transport and engineering industry the TSC have identified techniques and technologies that can be applied within transport modelling to overcome some of the barriers that we have identified and support the development of improved transport modelling tools and practices. Some key examples of this are:

SCALE: Gaming (Scalable cloud computing) – through investigations into the computing technologies used in other sectors we have identified that the online gaming industry have developed scalable platforms which allow thousands of individual players, across the world, to operate within a single gaming environment. This technology platforms that this capability is built upon is also capable of supporting non-gaming uses. The TSC and their spin-out company Immense Simulations identified a SME called Improbable who were developing such a platform called Spatial OS. This is the basis of the Highways England Simulation Project.

INTEGRATION: Defence simulation techniques (HLA) – within the defence environment it is common for multiple simulators to be linked together to enable multiple assets to communicate and work together in a common simulation environment, even if those individual simulators were not designed to work together. Higher Level Architecture (HLA) provides a solution to enable disparate simulations to be able to communicate and pass information between them. TSC has developed and demonstrated this capability through linking multiple traffic simulations and allowing traffic to pass between them.

PERFORMANCE: High performance computing – In the desktop/server domain we have worked with industry and academia to investigate ways of speeding up models operated on traditional platforms (e.g. desktop PC's/workstations). Our focus has been on integrating the processing power of Graphical Processing Units (GPUs). These are typically used in PCs and gaming consoles to render high definition graphics to the screen. They do this by being able to undertake thousands of mathematical calculations in parallel. This makes them much more efficient at undertaking mathematical processing than traditional computer Central Processing Units (CPUs). Software will have to be modified to enable it to run on GPU rather than CPU. We have worked with Atkins (developers of SATURN highway modelling software) to investigate using GPUs to operate the HE's regional transport models. The updated software/GPU combination enables the models to run typically eight times faster than on conventional high end PC workstation. This has enabled model run times to be reduced from days to hours.

In all of the areas set out above, TSCs approach has been to develop methods that build on existing validated model assets and use them in the transport arena.

The following section provides specific case studies where we have successfully done this in practice.

A2: Insights and case studies for modelling, simulation and visualisation

Case Studies

1: Large Scale Simulation of the Strategic Road Network

Client: Highways England

Partners: Immense Simulation, Improbable, Telefonica and Kazendi

Highways England (HE) has commissioned the TSC to develop a prototype simulation of the entire Strategic Road Network (SRN). As part of this project we are investigating the user needs of a visionary large scale simulation platform and identifying those that could be developed beyond this prototype project to support Highways England operations. The TSC is collaborating with a number of partners to deliver this innovative project, these are:

Immense Simulations (ImSim)– Is a spin out of the TSC. ImSim was created to commercialise some of the TSC's ideas to support the growing Intelligent Mobility market by developing approaches in modelling and analytics to work in domains with bigger data sets and bigger scopes. ImSim will be developing the SRN simulation model.

Improbable – Developers of the SpatialOS platform which can run large-scale simulated worlds. A simulated world can be anything from a MMO game world or a virtual city to a simulation of the internet or a model of the brain. Improbable will be working closely with ImSim to host and support the SRN simulation on the SpatialOS platform.

Telefonica – Is one of the world's largest private telecommunications companies, in the UK they operate the O2 network. They have recently completed a major project for HE which has entailed using mobile network data (MND) as the basis for developing a series of regional traffic models. In this project, they are setting up a near real-time data feed of MND to feed into the simulation model to allow it to reflect traffic movements on the SRN in near real-time.

Kazendi - Their mission is to help businesses leverage the unique benefits of Microsoft HoloLens and mixed reality to ultimate transform the workplace. Kazendi's role is to develop a cutting-edge user interface for the model using HoloLens technology. This will enable users to interact with a hologram of the simulation and change key operating parameters – e.g. being able to close a lane off on a motorway or change the speed limit on a section of network.

The whole project is being delivered to an accelerated timetable using 'Agile' project management techniques over a series of three two-week sprints. This is only the second 'Agile' project that HE has commissioned. The collaborative working is focussed in the TSC building in Milton Keynes where the project team and client have co-located for the duration of the project. As well as the development of the simulation model, a major output of the project for HE will be gaining 'hands-on' experience of delivering a project in an 'Agile' environment.

2: Modelling Connected and Autonomous Vehicles in a shared environment

Client: Department for Transport

Partners: Improbable, PTV, TSS, SDG and Atkins

The TSC has been working to develop the tools and techniques required to model the impacts of introducing Connected and Autonomous Vehicles (CAVs) to our transport networks. The domain of shared space offers challenges in the complex interaction between motorised CAVs and pedestrians and cyclists, whose own behaviours are more difficult to define. The TSC has developed a High-Level

Architecture (HLA) modelling platform which allows for the integration of pedestrian and cycle simulations with autonomous vehicles, to begin to analyse how different potential reactions impact overall network operation. The HLA platform we have developed has the capability to connect many other combinations of simulations. We are now working with partners to make this available to the modelling community.

3: HRAF for Autonomous Transport Systems (HATS)

Client: Science Technology Facilities Council (STFC)

Partner: SCISYS

The HRAF for Autonomous Transport Systems (HATS) project aims to test and extend the capabilities of the Harwell Robotics and Autonomy Facility (HRAF) to effectively and efficiently simulate terrestrial automated vehicle concepts in a representative synthetic environment.

To accomplish this, an integrated development programme is proposed that brings together cutting-edge expertise from the industrial simulation community (SCISYS Ltd) with the domain expertise and laboratory environments developed to support the UK Driverless Cars programme (Transport Systems Catapult). The developments will be focused on the Central Milton Keynes test site and the vehicles being deployed for the LUTZ Pathfinder and UK Autodrive trials (www.lutzpods.co.uk) but will be explicitly designed to be extensible and reconfigurable to support alternative cases.

4: Short Term Traffic Prediction Study

Client: Highways England

The project is conducting Short Term Traffic Prediction (STTP) for the UK motorway network. It will build upon the TSC's award winning applied research which was presented at the 2015 European Transport conference in Frankfurt in 2015. The key innovation within this project is using machine learning techniques, achieved through the creation of a 'learning' neural network. The neural network will be 'trained' using an extensive set of archive traffic data covering the motorway network. This allows the neural network to 'learn' traffic patterns and hence be able to predict, with a high degree of accuracy, future changes in network conditions to allow for the pro-active management of traffic on the network (rather than the current re-active situation). Metrics used to describe congestion will be predicted 15 minutes and 30 minutes into the future at locations where the Motorway Incident Detection and Automatic Signalling (MIDAS)[1] system is deployed. The project will be a proof-of-concept to prove (or otherwise) if the prediction methods applied by the TSC can be transferred and scaled to parts of the motorway network outside the area originally focussed on by the TSC. The final stage of this project will be to deliver predictions based upon the real-time data feed from HE's on network MIDAS network. If successful, this could lead to this type of predictive technology being rolled out to HE control centres to improve the management of the motorway network.

5: Communicating Complexity / Visualisation Laboratory

In parallel to developing advanced models of transport systems we also recognise that quick effective communication from the early stages in the design process is an area the industry needs to improve on. To help with this the TSC has invested in a visualisation laboratory which is equipped with the latest

[1] MIDAS uses inductive loops in each lane of the motorway carriageway at 500m intervals and can measure traffic speeds and detect slow moving, queuing or stationary traffic.

equipment to support UK companies. We have also undertaken research and undertaken trials to integrate modelling and simulation outputs into computer gaming tools to aid understanding and decision making. The investment that has been made has been built upon extensive research on the art of the possible and we are working to stretch this further through the projects we undertake. We have also developed a joint community through http://www.immerseuk.org/ to improve sharing and collaboration in this area. Further information on the lab can be found at https://ts.catapult.org.uk/innovation-centre/the-visualisation-laboratory/

Conclusions

This note highlights some of the limitations of the current generations of models and simulations used in the transport industry. It also highlights some of the key areas that TSC has been actively investigating and developing capabilities in (e.g. Scale, Integration & Performance) which are likely to have a major impact on the development of future transport modelling and simulation tools. The note also demonstrates through a series of case studies how the TSC has developed and demonstrated the capabilities of innovations in these areas and how this could practically be applied to develop new modelling and simulation tools.

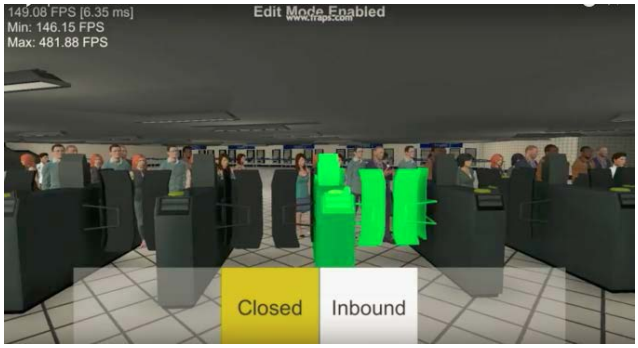
A3: Modelling, simulation and visualisation to design and specify infrastructure

Contact: [name.redacted].Transport for London

Data shaping infrastructure specification

Laboratory trials with University College London at their PAMELA (Pedestrian Accessibility and Movement Environment Laboratory) facility were used to gather data (using video analytics) which supported existing empirical information on the impact of train and platform features (such as door size, stand backs, seat types and platform edge doors) on dwell times. The outputs of these trials were used to inform the Engineering train design specification options and evaluation of different configurations for New Tube for London.

Modelling and simulation shaping infrastructure specification



Major capital investment projects rely on both the specification/procurement of new assets as well as the design and construction of the base railway infrastructure. TfL's Engineering modelling capability enables assessment of the potential permutations that could occur. The outputs typically influence:

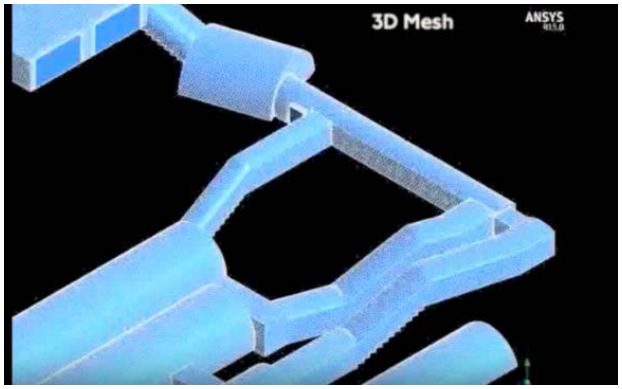
- optioneering and trade-off high-level output business requirements during feasibility phase
- the basis of technical requirements for procurement specifications which relate to business requirements during concept phase
- assurance that all of the elements which are procured will ultimately integrate in order to meet the business requirements during design and delivery phases

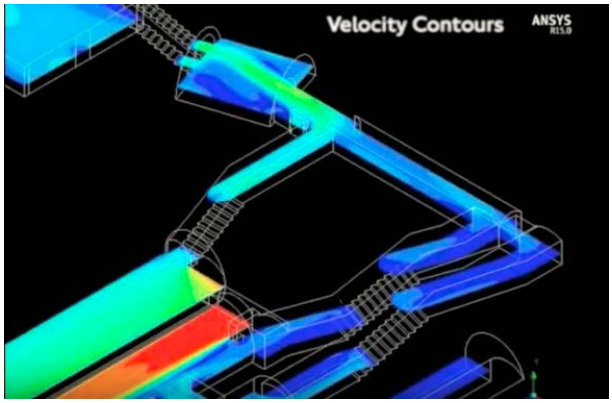
Examples of complex permutations where performance modelling is key are: assessment of any infrastructure works (eg. track lengthening, new junctions, changes to stopping positions) would be required in order to meet hypothetical timetables and train injection rates, given varying

train lengths/performance, signalling systems, operational rules and levels of reliability performance.

The Engineering team are crossing-over gaming technology in order to rationalise simulations, visualisations and processing power.

Modelling and simulation to support operations



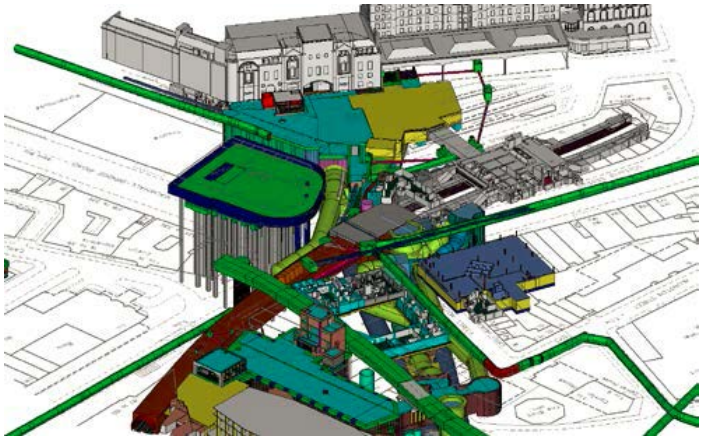


Traditionally, train performance and signalling design have been the limiting factor for capacity, however, future constraints will be around power, cooling capability, windspeeds and the need for step-free access. The relationships between all of these factors are complex and not resolvable via simple linear modelling. Furthermore, mitigating constraints around these attributes (eg. building new vent shaft reliefs) requires extensive capital investment. Other brownfield deep-tube metros across the world have not yet reached the service demands where these parameters come in to play and therefore new and novel analysis techniques are required to predict their interactions. These projects utilise ventilation and power engineering expertise, alongside TfL's specialist toolkits to turn high-level business requirements into delivery requirements during the programme feasibility phase. The work involves optioneering and elegant integration of micro and macro Computational Fluid Dynamic simulations (whilst managing computational demand) and identifying technical as well as optimal whole life cost solutions. These techniques can be used to assess air movements in stations, trains, buses or in the streetscape.

A3: Modelling, simulation and visualisation to design and specify infrastructure

Visualisation supporting efficient design

Combining Building Information Modelling with Virtual and Augmented reality has enabled greater efficiency for projects/sponsors to review options pre-tender. This results in 'left-shift' in the project lifecycle to ensure key requirements are better understood, leading to savings throughout the design, delivery and handover project stages. This example is of a bespoke engineering vehicle that was designed and built to fit London Underground Jubilee Line gauge tunnels, in order to carry out tunnel lining replacement. Augmented reality and survey data was used to ensure full-articulated manoeuvrability and virtual reality was used to train operatives in order to increase shift efficiency. The project won an Institute of Civil Engineering Award for novel methodology. The concept is also being used for future infrastructure upgrades (in some instances saving up to 20% of final cost), including investigating opportunities to accelerate our step-free access Programme. The methodology is part of our Digital Engineering approach which often re-uses existing survey information, integrating different sources of data and supplementing with minimal interventions for new data where required.



A4: Improving the passenger experience through operational and passenger data

Contact: [name.redacted] HS2

Summary

HS2 Ltd plans to deliver a customer experience which delivers new benchmarks for service excellence. To support this, HS2 wishes to develop and deploy a digital platform which joins up the interactions between operator, train, its crew, station staff and travelling passenger to deliver seamless digital control and support, enabling integrated journey planning, personalised information and assured seating (reservation-only). There is also an opportunity to extend this technology to encompass the entire end-to-end journey, irrespective of the mode of transport.

1. Benefits: Deploying this technology could deliver many customer and operator benefits:

- High levels of customer advocacy, driving patronage and revenue – today customer experience is a more powerful driver of loyalty than price-value perceptions (Forbes, 2016).
- Enhanced levels of accessibility and inclusivity through personalised ticketing options, ease of booking, wayfinding and integration with other transport modes, pre and post-journey.
- Guaranteed seat for all customers (based upon a proposition for reservation-only ticketing).
- Flexibility to amend reservations just prior to departure, and the ability for a ticketing system to automatically allocate a seat as a customer approaches the station.
- Reduced customer anxiety of finding a seat – caused by the mixture of allocated and unallocated seating on trains today.
- Better operator yield management – reservation-only allows operators to better manage their capacity and achieve higher occupancy rates (75% on Eurostar versus 43% on Virgin West Coast).
- Operator marketing benefits– e.g. automated refunds and ancillary revenue opportunities.

2. Barriers: The adoption of these technologies to date has been hampered in UK rail but a system to support an integrated customer experience is possible, based on today's technology. The rail industry has been slow to capitalise on this, meaning such technology is largely unproven or immature in railway operations.

- The fragmented structure of the industry has led to a proliferation of different systems, which, coupled with a risk averse mind-set, has slowed the pace of development and made introducing change difficult.
- HS2 offers the opportunity for a 'blank canvass' approach, enabling a radical leap forward above and beyond that which could be delivered by incremental improvement alone.

3. Interventions: The following interventions could accelerate the unlocking of these benefits. Providing streamlined access to funding, directly or indirectly, would enable the supply chain to:

- Accelerate and focus development against HS2 and industry requirements, enable the trialling of new ideas, support customer engagement and help de-risk solutions prior to adoption.
- Support the development of IT platforms that integrate between operational data and customers' existing technology in real time, at high volumes and with applied intelligence.
- Position the UK as a potential market-leader for such technologies, given the pockets of excellence which already exist and in the context of a market which is global, multi-sector and growing.

A4: Improving the passenger experience through operational and passenger data

Overview

HS2 Ltd plans to deliver a level of journey experience that sets new global benchmarks for service excellence – resulting in a situation where passengers, and the wider communities served, take an ongoing pride in the service and spontaneously advocate travelling by HS2.

Consumers of every type of service are demanding more flexibility and control of their experiences, leading to demand for a greater choice of channels and individual interactions (or 'touch-points') which are simple, intuitive, personalised and integrated. These needs and expectations, together with the enabling technologies, are rapidly evolving.

There will be a need for new market capabilities to ensure these expectations are met when the first passengers travel on HS2 in 2026. Many elements of the customer experience will be supported by technology, processes and other innovations that do not currently exist or are at a low level of maturity. These will need to be developed in advance of the first trains running, in conjunction with the West Coast Partner – there is opportunity for ideas to be trialled and benefits to be realised in advance of HS2 on existing Intercity West Coast services. Without intervention to provide the supply chain with focus, there is a risk that these technologies develop too slowly, in a dis-jointed fashion, or become insufficiently aligned to HS2 and industry ambitions.

Integrated digital platform

To focus on an example, the digital experience will be key to delivering a travel experience that is as seamless and hassle-free as possible. This will act as the conduit between HS2 systems, staff and customers, using technology to join up their interactions. In addition, there exists an opportunity for open source data to provide customer information which supports the full end-to-end journey, irrespective of the mode of transport required pre and post-HS2 journey, e.g. car parks, car clubs, light rail, bus, cycle hire and wayfinding etc. HS2 Ltd analysis shows that few user needs can be fully satisfied without the adoption of a fully integrated digital experience. The digital experience of customers in the rail and transport sector today remains fragmented and frustrating, if it exists at all.

Consideration is therefore being given to the use of an integrated digital platform, to give customers the opportunity to access, amend and control aspects of their journey via their smart device. This could integrate journey planning, including journeys with other providers, ticket options, purchase and reservation systems, passenger information and alerts, as well as some on-train systems such as entertainment, retailing offers and ordering of catering.

In addition, information and assistance regarding customers' onward journey could be provided, including proactive ticket purchasing and live wayfinding (to guide a customer to a connecting tram service to reach their final destination, for instance), or activity and promotions relating to the journey or destination itself (such as feedback, personalised or shared loyalty offers, discounts or promotions for local restaurants, attractions, etc.). Innovative approaches to ticketing could be explored where customers buy 'units' of travel or subscription packages across various modes, which could be shared by groups of users, such as families or businesses. During a journey, such a system could dynamically plan and re-plan customers' end-to-end journeys to account for both the evolving needs of the user and for external variables and change, such as any service distribution.

To further explore one aspect – reservation systems – HS2 Ltd aims to ensure all customers who travel on the train have an allocated seat, based upon a proposition for reservation-only (all-seated) services. Currently, UK intercity rail operators typically offer some level of seat allocations, as well as

unreserved areas, with no limitations on standing customers (other than practical safety limits). Under a reservation-only system, there is a need to ensure seat allocations for flexible ticket types, including season tickets, are able to be changed up until just prior to the time of travel (in practice, this is likely to be a few minutes). Seat assurance will need to work with the reservation system for seat allocation, including overbooking arrangements (where operators 'over-book' on the knowledge of a certain percentage of 'no-shows', as is typical in the airline industry).

Projected benefits for HS2 and UK rail

Providing a seamless, stress-free and pleasurable customer experience will offer many benefits. HS2 presents an opportunity to 'fast-track' the implementation of these technologies. At an aggregate level, the benefits will help to drive enhanced levels of advocacy. This will drive greater patronage and in turn revenue for the railway, as well as broader social and economic benefits. Once proven, the technologies used could be cascaded to the wider network, in line with the Rail Technical Strategy (2012) objectives on customer experience, to the benefit of all customers and operators.

Customer benefits from the example outlined include:

- **Confidence** – better and more integrated information will provide customers with a 'one stop shop' service to seamlessly guide them through their end-to-end journey, providing tailored assistance and alerting them to any changes, including automatic re-planning (based on recorded behaviours or pre-determined preferences).
- **Accessibility and inclusivity** – a system which can provide tailored support, according to defined or anticipated individual user needs, would help remove the barriers to travel experienced today. For instance, the ability to automatically book the appropriate level of human assistance, seating preferences and step-free routes, would assist those with specific mobility needs.
- **Guaranteed seat for customers** – Transport Focus identified in their 2014 report *Rail Passengers' Priorities for Improvements* that getting a seat was the second-highest ranked aspect of the train service that passengers most wish to see improved (it was the highest ranked among customers aged 55+).
- **Reduced anxiety** – the confusion and stress caused by today's seating reservations (where seats remain unoccupied due to changes in travel choice which are not then reflected in seating allocations) would be eliminated by a universal seat allocation system. Customers could also avoid being disturbed by staff for revenue protection once they are 'checked into' their seat.
- **Flexibility** – providing the ability to amend seat allocations (for departure at the same time or a suitable alternative departure) and the ability for a ticketing system to automatically allocate a seat as a customer approaches the station, perhaps based on habitual or pre-determined preferences – 63% of passengers that HS2 Ltd interviewed in the *Market Characteristics Survey* (2016) said this flexibility would be important.

Operator benefits from the example outlined include:

- **Enhanced reputation** – high levels of customer satisfaction and advocacy, driving positive feedback, loyalty and broader reputational benefits.
- **Better occupancy and yield management** – Eurostar, which requires pre-reserved seats, has suggested this approach enables them to better 'revenue manage' trains to a load factor (average

occupancy) of around 75%, much higher than other UK operators (Virgin West Coast was reported to have an all-day weekday load of 43% in 2013). Low-cost airlines typically achieve 90% load factors. Security and marketing benefits – seat assurance could be coupled with a passenger name record (PNR) system that would, for instance, better enable automatic refunds in the event of poor performance (in the *Market Characteristics Survey,* 83% of passengers rated this as being important to them when making a high speed rail journey in the future). A comprehensive customer database would enable tailoring of information (e.g. personalised 'push' notifications related to a customer's specific journey) and ancillary revenue opportunities (e.g. on-board catering).

Supply chain development

A system that supports the immersive and integrated digital experience described is already possible, based on today's technology. UK railways have been slow to capitalise on this relative to other sectors (e.g. aviation), and so the technology remains largely unproven or immature in rail operations. Nothing has been achieved on the scale of HS2 either, where up to 300,000 passengers a day will travel on the new network once open. HS2 therefore presents a clear opportunity to leap ahead from the status quo and deliver a step-change that incremental change alone may not achieve.

The landscape of the current UK market is split between large, established multi-nationals and smaller innovative start-ups. In a supply chain mapping exercise conducted in 2016 to identify the potential tier 2 and 3 market for rolling stock, HS2 Ltd identified 37 companies who had capability in 'systems and IT', 31 of whom are UK firms or have a UK operation and many with direct capability in customer experience (such as passenger information systems).

In terms of capability, the UK market is considered to be relatively strong in this area – excellence exists in pockets if not world-leading or currently meeting HS2 requirements. At a macro level, the potential rewards are large, with the customer experience management market estimated to be worth almost £10 billion by 2021 at a compound annual growth rate of 21% (MarketsandMarkets, 2016). In this context, there exists a lucrative opportunity for UK industry to become world-leading in this space.

Investment opportunity

Providing a means for industry to connect to funding streams would accelerate and focus development against HS2 and industry requirements, enable the trialling of new ideas, support consumer engagement and help de-risk solutions prior to adoption. It would support the development of IT platforms that integrate between operational data and customers' existing technology in real time, handling thousands of interactions per second with a personalised level of intelligence, whilst maintaining the security of railway operating systems.

The defined market opportunity the project presents, together with future opportunities across the wider rail and transport sectors, acts as a further incentive for industry to evolve and apply suitable technology to help deliver, if not exceed, the customer experience vision.

A4: Improving the passenger experience through operational and passenger data

Customer personas

HS2 Ltd has created a series of customer 'personas' to help understand the needs of future travellers. The below extract provides a 'day in the life' through the lens of one potential customer, based upon today's travel experience:

Andrea, 17 – the anxious student

I live close to nature to escape city life, so I need to commute twice a week to go to college. I find travel stressful and like to have everything planned in advance so I know what to do. I usually leave my house around 7.30 in the morning; there's a bus stop outside but I never know what time the bus will arrive – they never run to time in the morning rush – so I have to get up and go earlier than I'd like to make sure I get my train.

Because I only get the train a couple of times a week, there's no benefit in me buying a weekly ticket, so I end up queueing to buy a peak-time ticket each morning. I wish I could buy a batch of tickets online beforehand that covered my whole journey and reserved a seat for me (preferably at the front of the train), when I needed to travel. When I'm at the station I find the navigation confusing and never know where to stand on the platform.

On the train I like to shut myself off and stay relaxed – I don't like the constant bombardment of screechy announcements and being disturbed to show my ticket. Sometimes I forget my railcard and have to buy a new ticket – everyone looks at me and I feel so embarrassed! Why do I have to carry a physical card with me? Can't it be uploaded into a system? Only the window seats have power points so it's difficult to charge my smartphone without reaching across someone.

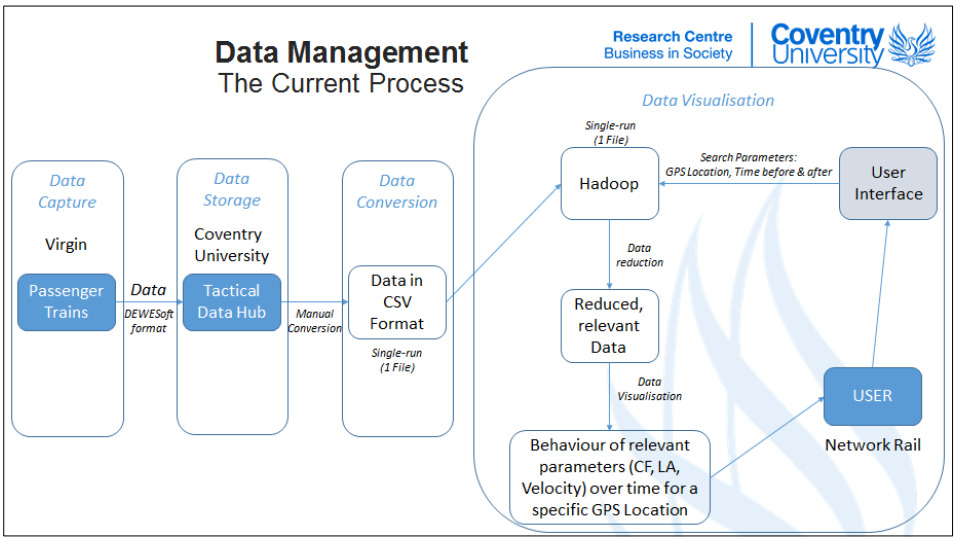
Then, when I'm off the train I have to fiddle around to find my ticket again to put through the barriers – I don't understand why as I've already had to show it on the train. I've now learnt the walking route to college but when I first started I used to get hopelessly lost in the city. I wish I could avoid all this stress and anxiety – why can't getting to college be easier?

A5: Instrumenting train pantographs

Contact: Simon Taylor, Systems Integration Manager – LNW Route, Network Rail

Project Overview

Instrumentation has been fitted to the pan head and the torsion bar within the pantograph.



We are capturing both force and longitudinal acceleration in the Pan OLE interface at line speed under normal service running.

The data captured is stored on the train and transferred from the hard drives onto a Data Hub via a Virgin Server to the University.

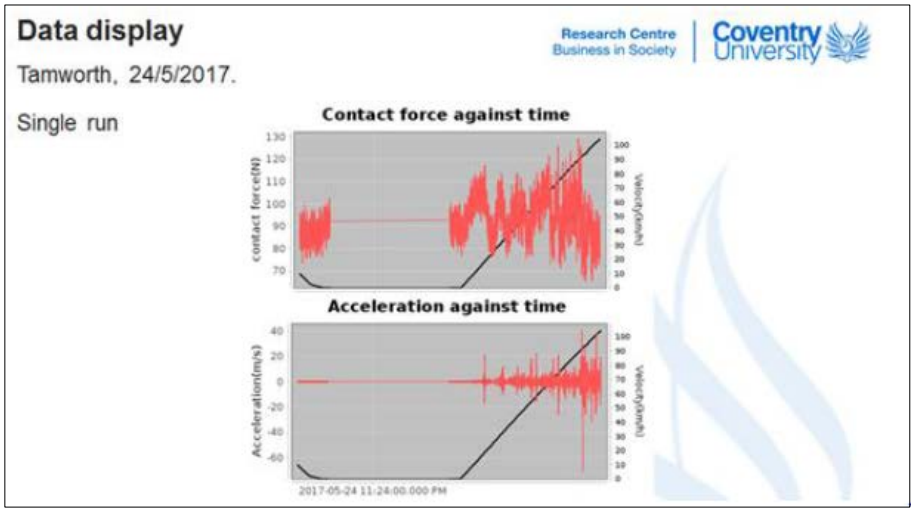
The data management process that is then pictorially shown has two outputs;

1. To provide intelligence to the end user in a searchable database with trending reports.

2. To allow us to perform big data analysis

A user interface has been developed to allow the user to search on one location over a stated time period on one data set.

The next activity is to look at multiple runs of data and produce the same output with trend lines over time on multiple runs.



A6: Avoiding the Reconstruction of Bridges

Contact: [name.redacted] Network Rail

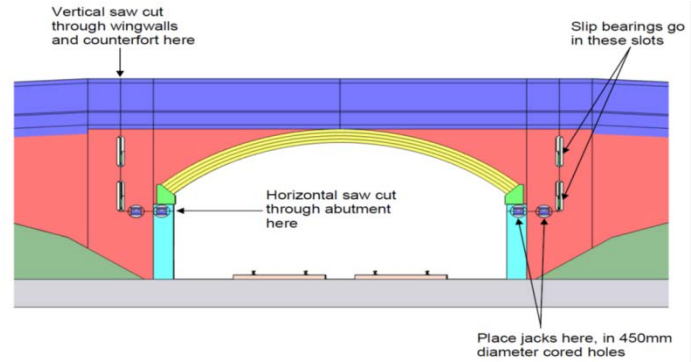
Bridge jacking technique to avoid the reconstruction of bridges.

Competition launched 25th February 2014. Up to £3M budget for phases and 2 (feasibility study and full-scale demonstrator, respectively). Sponsors: Future Railway, Network Rail, Department of Transport. Out of 11 submissions, nine were funded through phase 1 and four won funding for the phase 2 full-scale demonstrator.

The project to avoid the reconstruction of bridges aimed to reduce the elements of capital cost of new overhead line electrification that is driven by constraints in structures, especially bridges. Several techniques were explored to achieve overhead electrification at lower cost - and potentially lower disruption - than bridge demolition and reconstruction:

- Allowing OLE Equipment (Wires) to run underneath the bridge for current collection purposes.
- Improving the sophistication of gauging design/assessment
- Gaining additional clearance by lowering the track without compromising the bridge structure
- Developing insulating cloaking system for structures
- Developing bridge jacking technique

The bridge jacking technique was developed and demonstrated on a brick segmental (masonry) arch bridge, phase 2 of theEast-West Rail project (Bicester to Bletchley). It was an 'accommodation' bridge for a farm, 4.3m wide and with a 10.1m span, designed by Robert Stephenson and built in 1850.



The gauge increase achieved through bridge jacking could also enable the enhancement of routes for greater gauge traffic.

A7: Digital Imaging for Condition Asset Monitoring System (DIFCAM)

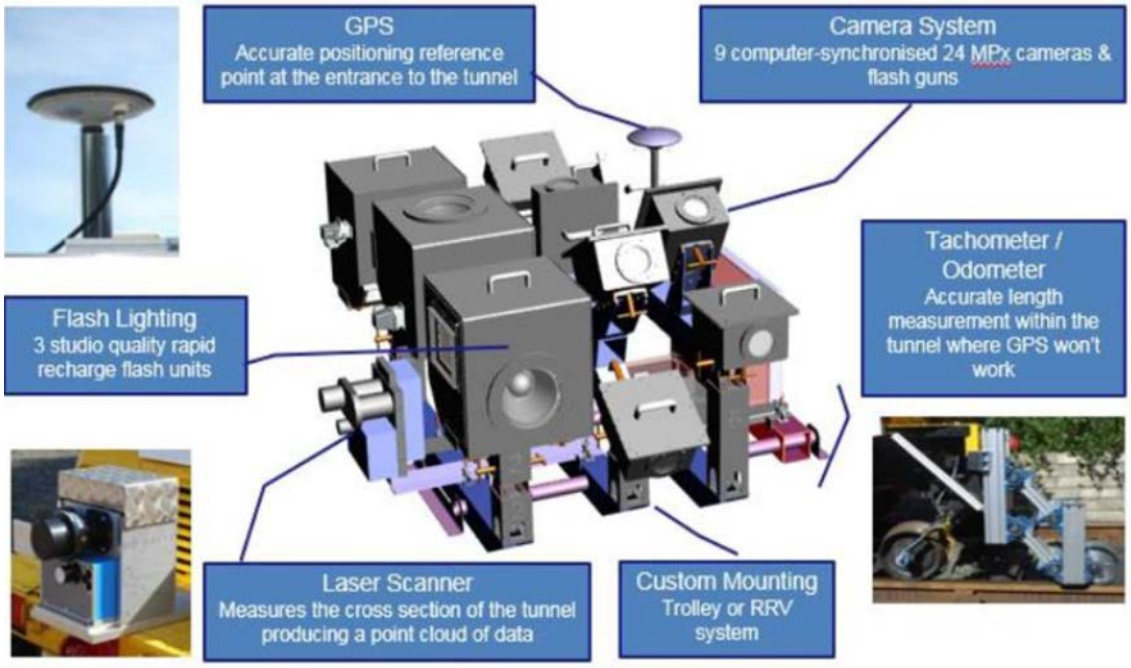
Contact: [name.redacted] Network Rail

DIFCAM is an automated tunnel inspection system using Lidar and digital images to measure tunnel shape, crack detection, water ingress and missing bricks and mortar. Network Rail has worked with the National Physics Laboratory (NPL) and OMNICOM Engineering (now a by Balfour Beatty company) for over 6 years developing a proof-of-concept automated tunnel inspection system called DIFCAM.

The DIFCAM system exists as a concept demonstrator to inspect brick lined tunnels. A project is now underway to improve its capability in two respects:

- Developing machine vision to automate the review of outputs, removing the need for human review of the images, in a form that is configured to integrate with the asset data management system. and development of outputs to align with Ellipse.
- Detecting sub-surface defects through sub-surface inspection.

The DIFCAM system components are summarized below.

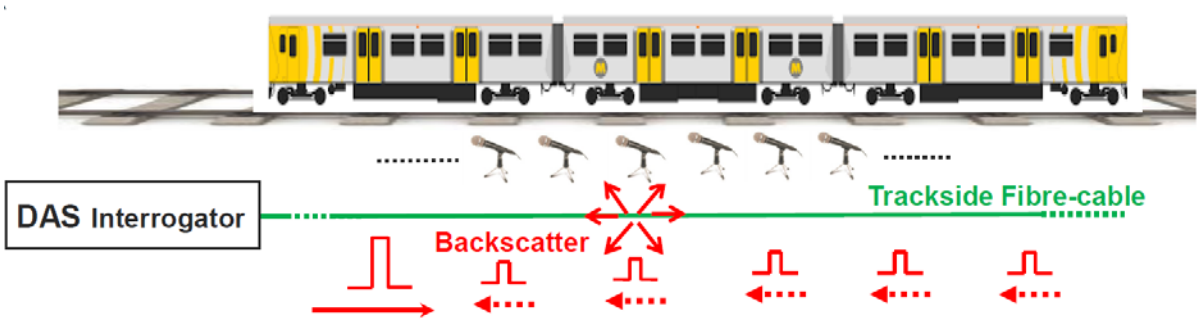


A8: Distributed acoustic sensing for infrastructure monitoring

Contact: [name.redacted] Digital Railway

To provide more railway capacity in safe, reliable and cost-effective manner rail industry's focus is to have "intelligent" infrastructure using network-wide Remote Condition Monitoring (RCM) for rail assets. At present, localised RCM is used at high-risk sites with bespoke solutions to monitor issues such as rail and wheel defects. These solutions have comparatively high operational, maintenance and management overheads, making them uneconomic and un-scalable for infrastructure-wide roll-out and there are issues such as trespass for which fully effective monitoring solutions have yet to be developed. Thus there is a need for the development of novel cost-effective and pervasive RCM solutions.

A potential cost-effective approach is to use Network Rail's extensive telecom network as a "sensor system" for RCM. This could include the use of trackside optical fibre-cable infrastructure (> 16,000 km) and wireless signals (GSM-R and WSN, offering over 3,000 points of presence) to provide infrastructure-wide continuous condition monitoring. Other advantages of this are inherent secure connectivity and ease of integration with advanced predictive data analytics for accurate and reliable condition monitoring. System level integration with other sensor systems could also be carried to exploit data fusion and advanced analytics to create "trusted" (high Safety Integrity Level (SIL)) decisions from varied networked sensor inputs (low SIL).



The use of optical fibres for Structural Health Monitoring (SHM) is now well established across a wide range of industries. There are many fibre sensor types and the choice for a given application depends on the best-suited underlying physical sensing mechanism. Distributed Acoustic Sensing (DAS) in optical fibres is particularly attractive technology as it can enable high sensitivity sensing of acoustic vibrations over many tens of kilometres with spatial resolution of few metres thus turning entire length of the fibre into effectively thousands of discrete sensors. In addition, unlike discrete sensors, a single interrogator unit can remotely monitor an entire fibre length. The classification and quantification of specific acoustic vibration event types is carried out post-detection using state-of-art signal processing and pattern recognition techniques. Another advantage of distributed sensing is that it avoids the need to pre-

determine sensors' positioning. These attributes make DAS in fibres very attractive for the RCM of railway infrastructure assets.

The use of DAS technology is well established in Oil and Gas industry for remote monitoring for applications such as intrusion detection and leak. More recently, DAS Own Equipment Manufacturers (OEMs) have started developing DAS technology for railway applications. Early, results show that DAS is particularly well suited to address applications such as

- Train location, travel direction, speed and length detection;
- Track and Train condition monitoring, e.g. rail breaks, wheel-flats etc.;
- Detection of people, animals and vehicles near the tracks and at level-crossings;
- Earthworks failures e.g. land slips, subsidence, etc.;
- Rock-fall, tree-fall, ice-fall and other track-side fixed-structure falls on or near the tracks.

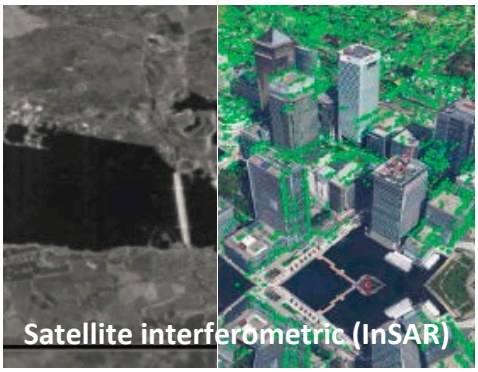
The challenge for the OEMs is to develop algorithms optimised for rail applications which can reliably detect events. This requires deployment of DAS in operational rail environment to enable development and optimisation of algorithms to reliably differentiate and classify different events. This will require collaborative R&D between rail asset and technology experts and DAS technology OEMs.

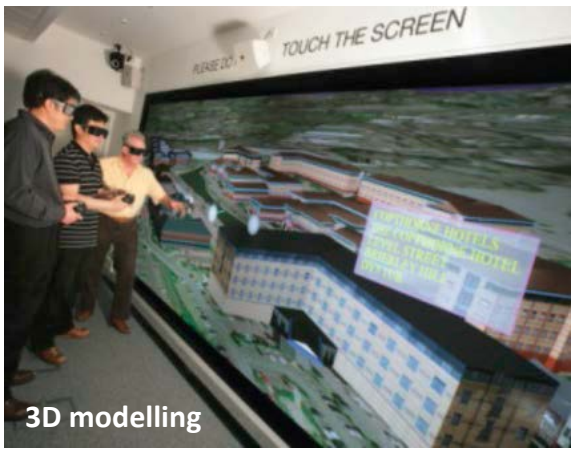
A9: Modelling and satellite data for condition monitoring

Contact: Rocky Gaur, Principal Engineer – Technology & Innovation, Transport for London

BIM and satellite technology for condition monitoring

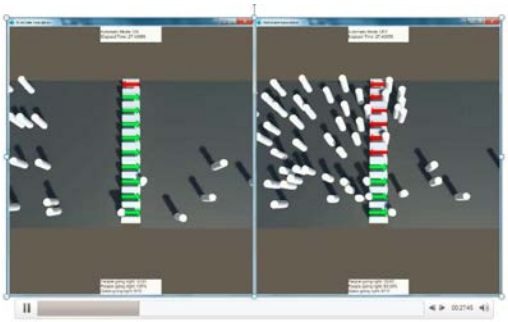
TfL's Engineering R&D department are working in a joint partnership with Telespazio and a number of SMEs in order to trial the use of satellites, combined with civil structural analysis and 3D BIM to predict structural health issues in bridges, structures, road and tunnels before they are visually revealed. This novel use of satellite technology could remove the need of in-situ sensors and data can be collected at night or in high risk weather. The consortium of partners was carefully chosen to ensure the best technical domain experts who can contribute their individual specialism to the vision. The proof of concept that the consortium are aiming to develop could have a hugely positive impact on reducing the downtime of routes due to routine maintenance, overrunning of engineering works or failures.





Dynamic modelling to support operations

Managing the gatelines on London Underground stations is currently a highly manual intensive activity and the gateline is often a source of capacity pinch-point. TfL's Engineering R&D department has formed a consortium in order to develop an 'intelligent gateline' which can dynamically self-configure (eg. Direction, timing, push of API feeds) combining sensors, CCTV and context knowledge of the wider station. The aim of the project is to move from laboratory trials to a mock-station facility which TfL has specifically created to enable transfer of ideas to the operational environment.



A10: Efficient construction and operation through BIM

Contact: [name.redacted] HS2

During Phase 1 Hybrid Bill we provided a Common Data Environment (i.e. a Building Information Modelling (BIM) Platform), configured to a set of consistent and standard processes to ensure an efficient and accurate exchange of information for all parties involved. This allowed the multi-disciplinary teams to share and coordinate information in a timely manner and allow information to be re-used as appropriate. For us in HS2, BIM is essential to make the vital shift from a traditional document management approach to more dynamic real-time data driven environments where 3D modelling and technologies such as Virtual Reality and Augmented reality can be exploited to drive efficiencies through design and construction to see positive business results.

Our vision for BIM is to develop a Virtual Railway, everything about that railway is first being created digitally. To HS2 this means a complete digital representation of the physical railway, how it functions as a system of interconnected assets and representing the different states during its life-cycle , along with information on its functionality and utilisation held in an integrated environment in which high quality, reliable and accurate graphical and non- graphical data is made available through a secure, role based, user – focused interface for exploitation.

This will realise benefits not just in efficiencies and accuracy – through the ability to test and fix in a virtual environment, for example, assuring the design quality through identifying potential risks and design clashes resulting in reduced re-work and decreased waste, but also in linking other digital information to the model; adding, for example, schedule information that enables better planning of construction sequencing and rendering images that can be used with stakeholders to show the exact effect HS2 will have. Health and Safety will also be improved with decreased time on site during design, in pre-fabrication and off site manufacturing and in better identification of risks that can be flagged in our virtual models.

BIM is a way of ensuring that we have consistency in our data development and that our supply chain can access and interpret the same core data sets. This is important because it enables us to understand and deal with the huge volumes of data we will be getting back through design and construction. Our ability to interpret and evaluate that data quickly is going to be critical and having consistent inputs enables us to optimise our processes. We see BIM as a precursor to big data principles and associated technologies, the internet of things and smart cities, which are the next big drivers to achieve a true digital era.

We have not been prescriptive about what systems or technologies the Supply Chain should use. Our overall approach is to be system agnostic, this ensures we do not put any additional burden on our supply chain now. But also, as we move into operation and maintenance this digital information will need to transition with the physical assets. What we build, operate and maintain is for the next 150 years, so we ned to ensure our data will fit whatever technology comes along.

There is still some way to go to achieve a true digital transformation, to capitalise on the power of procuring and working with data, particularly in the Infrastructure sector. Mature open data standards will help us to achieve this and we continue to work with a number of bodies to really test the processes, technologies and resources available to understand if there are any gaps and if there are, what it would take to fill them.

A11: Additive manufacturing

Contact: [name_redacted}.Network Rail

Additive manufacturing is an important contributor to effective and efficient management of existing railway assets. It comprises a set of technologies to support the layered deposition of material. It has the potential to change the performance of assets and to enable more flexible approaches to their repair or replacement including automation.

Network Rail is one of ten Founding Members of Shift2Rail, the first European rail initiative to seek focused research and innovation (R&I) and market-driven solutions by accelerating the integration of new and advanced technologies into innovative rail product solutions. Network Rail leads the infrastructure innovation programme under which a project is being commissioned to design, research, develop and demonstrate an additively manufactured rail crossing to enhance the performance of cast crossings. This is one example of the application of additive manufacturing technology where the objective is to improve the reliability and resilience of the crossings part of the track system.

Cast Austenitic Manganese steel is currently used for rail crossings due to high hardness to resist wear and high toughness to resist cracking. However, the steel is prone to fatigue cracking due to inherently low fatigue strength and the difficulty of producing castings free from defects. The indicative cost of failure and replacement of cast crossings exceeds £24M per annum so this application alone for additive manufacturing is targeting a substantial opportunity.

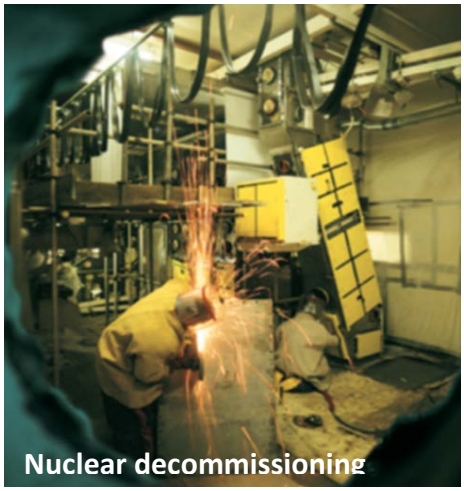
A further significant additive manufacturing opportunity exists through the application of induction welding to address track defects, in particular a type of defect known as a squat that constitutes the largest proportion of rail defects on the GB rail network.

A12: Robotics to automate output and remove people from hazardous environments

Contact: [name_redacted]..Network Rail

Robotics are already being applied using drones for survey and inspection and automating manual inspection with the DIFCAM tunnel inspection system to reduce the time, cost and repeatability of survey.

Robotics will transform the reliability and repeatability of maintenance and inspection activities and allow infrastructure managers to undertake inspections and maintenance that will be non-disruptive to operations and increase workforce safety and productivity. This will enable safe works in areas that are difficult or time consuming to access, such as at height, around water, in enclosed spaces and around live power supplies. Ease of access will in turn enable more regular data to be collected to provide better information on degradation rates and condition and lead to better predictive maintenance. Robotics will be driven by the extensive use of monitoring and diagnostic systems transforming huge quantities of data into engineering decision support information. Artificial intelligence systems will enable us to identify the root cause at a time to enable us to plan an appropriate intervention with minimum traffic disruption.



Network Rail has already participated in the Autonomous Intelligent Systems Partnership (AISP) with EPSRC, Innovate UK and other industrial partners from the nuclear, oil & gas, defence and space industries to build an understanding of potential applications. Key challenges shared by these sectors are:

- Safety – moving the operative away from the hazardous part of the task, reducing incidents.
- Risk – reducing the risk budget from the baseline plan by reducing the risk of human error.
- Productivity – increasing productivity by automating repetitive tasks, linking technologies to remove non value adding tasks and increase tool time.
- Quality – improving quality by introducing automated intelligent systems to measure, monitor, adjust and aid decision-making

Sharing the challenges is enabling the definition of a mutually beneficial cross-sector collaborative programme.

Nuclear	Space – Planet exploration	Space – Orbit Activities	Rail - Transport	Oil & Gas	Aerospace
Robotics for Enhanced Teleoperation (robotically-enhanced operatives)	Human Machine Interface, Communication optimisation	Human Machine Interface, Communication optimisation	Remote maintenance, inspection and survey.		
Robot Assistant			Development of self-calibrated robotic arms/assistants.	Accurate grasping, localization, decision making, vision, control and planning techniques	
Robotic Access to Workface		Lining up, docking Grasping/berthing			
Autonomous robots for Monitoring, Inspection and Survey	Human-Machine Interface, Real-time planning, resource management and utilization techniques.	Human-Machine Interface, Real-time planning, resource management and utilization techniques	Low-cost sensors and sensing technologies, 3D perception, data fusion algorithms, data categorization and classification, analysis techniques for continuously enlarging data set		Knowledge extraction from data streams, rapid data compression, de-compression, data fusion and encryption.
Autonomous Robots for Maintenance, Decommissioning and Waste Management	Sampling during motion, Platform to enrol mission managers with vision and manipulation algorithms, Real-time planning, resource management and utilization techniques	Adaptive guidance, navigation and control, High-performance data-handling systems designed for simple circuitry, low power consumption and low-error rate.	Low-cost sensors and sensing technologies, 3D perception, data fusion algorithms and data categorization, classification and analysis techniques for continuously enlarging data set	Drilling during moving, Target localisation.	Knowledge extraction from data streams, rapid data compression, de-compression, data fusion and encryption

Rail Delivery Group

National Rail BRITAIN RUNS ON RAIL

Sent by email to: TechnologyEvidence@nic.gsi.gov.uk

National Infrastructure Commission
11 Philpott Lane
London
EC3M 8UD

15 September 2017

Dear Commission,

This note comprises the rail sector Technical Leadership Group's response to the National Infrastructure Commission (NIC) technology study call for evidence, published 27 July 2017, seeking views on the ways in which new technology can improve infrastructure productivity through input to specific case studies.

The Technical Leadership Group (TLG) brings together senior stakeholders from the rail industry's technical community to enable the rail industry to deliver its agreed plans efficiently and effectively through the use of technology. TLG owns the industry's Rail Technical Strategy and associated Capability Delivery Plan which describe how technology can deliver a higher capacity, higher performing and lower cost railway over a 30 year time horizon.

TLG is co-sponsored by the two rail industry leadership bodies: the Rail Delivery Group, which is the GB rail sector's client leadership body, and the Rail Supply Group, which is the GB rail sector's supplier leadership body. This response incorporates contributions from Network Rail Infrastructure Ltd, with a particular focus on intelligent infrastructure, the rail sector's Digital Railway programme and it has been developed in collaboration with the Transport Systems Catapult.

Its scope covers two of the four studies:

- Better asset management
- Big data

This response builds on evidence already provided to the NIC in response to the consultation on 'The impact of technological change on future infrastructure supply and demand'; and the technology study call for evidence, published 15 February 2017, seeking views on the ways in which new technology can improve infrastructure productivity including rolling stock. It builds on the evidence generated through the process of establishing the rail sector's industrial strategy and the Rail Technical Strategy Capability Delivery Plan (RTS CDP). In particular picking up on the opportunities presented through the idea of 'digital twins' to routinely explore opportunities in a more open and connected way in a virtual environment –throughout the infrastructure lifecycle -in advance of applying to the physical environment.

The core response references a complementary set of case studies that are attached as a separate document.

Yours sincerely

[name.redacted]
[title.redacted]

BETTER ASSET MANAGEMENT

1. ***What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?***

The railway is a complex system in which the reliability of all infrastructure assets including rolling stock is critical to the running of passenger and freight services. Passenger numbers have doubled over the last 20 years requiring more services to be run on an already congested network. As a result, infrastructure failures such as faulty switches, crossings, signals or trains can cause significant delays and disruption over large parts of the network. As a result the rail industry is developing and implementing more sophisticated approaches to monitor asset condition to support predict and prevent maintenance – an intelligent infrastructure.

Operating and managing existing assets. Current in-service approaches are achieved through the overlay of systems to monitor specific failure modes and measure condition. For the national railway infrastructure this is focussed around: A dedicated track monitoring fleet of trains; analytical and visualisation tools brought together under an information services programme (ORBIS); and sensor-alarm systems applied to the operation of the most performance-critical assets including rolling stock. Moving forward, there is an opportunity to utilise data acquired using wholly or largely pre-existing assets to manage other railway assets. Examples include:

- Equipping assets to monitor other assets such as instrumenting train pantographs to monitor the performance of the overhead electrification system, summarised in Annex A5.
- Using telecoms assets to monitor a potentially wide variety of asset use and performance through distributed acoustic sensing technologies summarised in Annex A8.
- Modelling for condition monitoring and operations such as the dynamic modelling for rail passenger revenue protection gate lines, summarised in Annex A9.

A key aspect of masonry arch bridge maintenance is the automation of condition assessment to reduce the cost and improve the consistency of condition data. The capability to achieve this is under development through the Digital Imaging for Condition Asset Management (DIFCAM) project, summarised in Annex A7.

Simulation technology proofs of concepts relevant across transport have been developed by the Transport Systems Catapult, summarised in Annex A2, and offers the means to link better asset management with the opportunities unlocked under big data through a digital twin.

Potential role for Government. The Department for Transport as principal funder and specifier for the GB railway has a strong interest in ensuring the rail network operates efficiently and effectively. It is also well placed to ensure that asset management is considered from a whole system perspective, for example by encouraging or requiring train operators and Network Rail – one of DfT's arm's length bodies - to collaborate in monitoring and improving asset condition. Asset management should be driven by clarity on service expectations under a range of circumstances such as asset resilience to extremes of weather. Government is well placed to set these expectations, determine priorities and affordability, together with a framework to incentivise appropriate industry behaviour that should include recognising the value of a digital version of assets to sit alongside the physical assets.

Enhancing existing assets. In a rail context, a key aspect for cost-effective, non-disruptive and environmentally sensitive whole life asset management is to have the capability to enhance existing

assets. The ability to do this is driven by data to understand and push the limits of what can be achieved. For masonry arch bridges that means enabling the clearance to rail traffic to be increased with minimal disruption and at low cost – for example to facilitate electrification or to enable the passage of increased loading gauge rolling stock. The technical capability to achieve this without demolishing existing overbridges and constructing new assets has been developed and successfully demonstrated through the Avoidance of Bridge Reconstruction project [link to project sheet].

Modelling and simulation enables the improved design and specification of enhancements to infrastructure including new rolling stock – examples are provided by Transport for London in Annex A3.

Looking more broadly at assets, the Digital Railway programme is automating the design process to manage unit rates which, although focussed on signalling design, has the potential to drive savings across the railway. This was set out in the 10 February 2017 NR Digital Railway response to the NIC's consultation on the impact of technological change on future infrastructure supply and demand.

Creating new assets. We flagged in the 15 March response that digital technologies have the potential to reduce costs, disruption and improve safety for project implementation which then goes on to support through-life management. These are achievable through survey, design, test and manufacturing by maximising the use of digital models, automation, BIM[1] and Lean production processes as well as through railway applications operating on standard hardware and software using automated design and assurance. A step improvement in the efficient construction of railway assets is under development, a substantive example being in the delivery of HS2. This is being progressed as a key enabler for efficiency during construction and also as the backbone that will drive a more efficient railway during operations and is summarised in Annex A10.

2. ***What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?***

We flagged in our 15 March response that applying rapidly evolving modelling and simulation technologies could deliver the capability to support a transformation in the speed, resolution and ease with which planning scenarios can be tested and understood. This is a key enabling technology to enable and exploit the Digital Railway and Intelligent Infrastructure. Modelling and simulation technologies will exploit already abundant data to allow options to be explored, compared and traded off to maximise the impact of scarce resources (people, skills and funding) and avoid disruption to the operational railway from low impact interventions.

Taking already rich data sources and generating value through better decision-making mean that supercomputing and advanced whole system modelling should be prioritised to drive simulation; and artificial intelligence to underpin optimised planning, management and operation of the whole railway system and support faster, more effective decision-making. This must be enabled by security technologies for people, information and systems.

In terms of delivering planned maintenance, renewals and enhancements, key technologies required are:

- Additive manufacturing (3D printing) to enable renewals, maintenance and enhancements to be achieved at lower cost with substantially shorter lead times, summarised in Annex A11.

[1] BIM applied to HS2 construction, for example, is estimated to potentially lead to around £200M savings

- Robotics to increase output and remove people from hazardous environments for inspection, maintenance and renewal of assets, working collaboratively across sectors with hazardous environments. The opportunity is summarised in Annex A12.

  For operations, key technologies required are traffic management including driver advisory systems. To enable more transformational change optimisation tools and methods, applications, algorithms, artificial intelligence decision support systems and demonstrators are being developed under two programmes: Developing Integrated Tools to Optimise Rail Systems (DITTO) and Developing and Evaluating Dynamic Optimisation for Train Control Systems (DEDOTS) aim to deliver.

3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

Whilst the technologies to generate data and test scenarios for sophisticated cross-system optimisation have the potential to be delivered within the medium term, the technologies will only deliver benefit if embedded in an appropriate asset management process and culture. Optimisation across systems presents a substantial challenge in terms of workable approaches to accountability and for incentive and reward structures. So, as well as development of the technology, simultaneous development is required within and between organisations with asset management responsibility to exploit the potential of the technology. This includes:

- **Aligning planning & delivery capabilities**, understanding and aligning the core process for decision making, planning and delivering asset management activities both for specific infrastructure systems and across systems. The plan needs to be owned and optimised in the full context of providing services for the end user.

- **Developing appropriate culture, competencies, leadership and organisation**. Culture needs to shift from the primary focus on improving assets to better managing assets as a system. At one level this can be addressed by providing competency tools and training materials underpinned by ISO55001 which should be a consistently required by clients including Government. However the step change required in process requires dynamic collaboration, within and across organisations, facilitated through connected models

- **Asset information systems and data driving intelligence** to support an aligned, end-to-end process to monitor asset condition, analyse service critical performance and predict incipient failure in sufficient time to enable efficient pre-emptive action. Thereby either preventing a service affecting failure or unduly costly remedy

- **Management review** based on the performance of the asset management system as a whole, increasingly with assurance against system level risk and opportunity. The aim is to drive improvement in the most efficient and effective way and by the parties best placed to do so and to learn, and embed learning, through automation.

Potential role for Government. To demonstrate the effectiveness of optimisation, the Government will need to facilitate collaborative decision-making to include taking a leadership role in addressing the barriers to sharing data outlined under question 11. The Government could commission pathfinders for optimisation, facilitated by the catapults, that explores the application of new modelling technology under a cross-departmental leadership and collaborative delivery team. This would be strongly supported by the Transport Systems Catapult. Additionally, specific opportunities can act as pathfinders

such as the aspiration to pull together operational and passenger data to realise both operational benefits and passenger experience improvements on HS2, summarised in Annex A

4. ***What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?***

Establishing a digital twin breaks down the barriers to understanding and demonstrating the potential for ideas which creates opportunities and risks. It improves creativity to contribute to the optimisation and enhancement of the system; whilst supporting the development of ideas to target disruption to the system.

A key use of digital twins would be to create a shared space to test, share and promote opportunities quickly and at low cost. Multi-modal technologies, services and systems within a common architecture which enable end to end seamless journeys to be undertaken by transport users such as autonomous vehicle interface with railways and mobility as a service. Technologies also open up opportunities to plan infrastructure enhancements, renewals and operations as part of the national infrastructure, not just as part of a transport system but, to improve the wider economic benefits available from rail.

The capability of a digital twin must therefore be to enable demonstration of value whilst not undermining security of the system. The digital twin should also enable public and non-technical engagement with proposals as well as enabling technical functionality and features to be explored.

5. ***How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?***

Getting technology into use in the rail sector is disrupted by two 'valleys of death'. The first valley of death arises from the cost and logistical challenge of achieving a suitably meaningful demonstration of the product or system; and the second valley of death arises from market conditions not being sufficiently developed to pull the product or system into use.

The costs and risks of developing and introducing technology, and in particular these two valleys of death, can be managed through the rigorous application of readiness level frameworks. A technology that has been effectively managed through this type of framework will have been systematically de-risked as it progresses so that, by the time it has been demonstrated its deployment carries comparable risk to conventional solutions. A readiness levels framework has recently been developed by the rail sector for the rail sector as part of the suite of tools underpinning the RTS CDP. Embedding this is key to unlocking effective innovation. The framework, and its application in Network Rail for product development, is summarised in Annex A1.

BIG DATA

10. ***What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?***

There are many factors that need to be considered. The first is having a Common Information Model for the industry. This will help define a common language that is used so that the data can be shared and understood by multiple organisations. This will require precise definition and agreement throughout the

industry, not only on what the terms mean, the units they are stored in (e.g. metres) and the accuracy that is required. The BIM (Building Information Modelling) initiative is laying a good foundation for this in the construction of new assets and buildings. We are looking to support this with an industry wide information architecture model. There is the need for the development of Information Asset Registers by the individual business units and businesses where key supporting information is stored including the accountabilities and sensitivity of the information. The rail industry is establishing an Information System Interface Committee to govern these principles across the rail sector. These principles need also to be extended across infrastructure sectors, for example initially across road and rail which could be facilitated through the Transport Systems Catapult.

We should consider which technology partners we want to work with to support this large data environment. The expertise is unlikely to reside within the main business areas. In the past some of the technology companies have suggested using open source techniques, but have then found they could not support them. A key part will also be with regard to what security requirements are required for the different data items that are required. We are struck by conflicting drivers of the need to be open and transparent versus "only providing access on a need to know basis". This will be key in determining what technology platforms can be considered.

11. ***What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?***

The barriers include:

- Lack of trust and a cultural willingness to "protect empires" or potential liabilities
- Lack of alignment with goals and incentives
- Lack of common definition and language
- Lack of unique identifiers and published metadata
- Disparate technology standards
- Clarity on ownership and accountability including what data is deemed sensitive and should not be shared and licensing requirements where data is owned by suppliers
- Lack of integration of policies and standards
- No Common Information Model
- Lack of an Information Strategy

The Common Information Model and Information Strategy will then form the bed-rock for further development. This will also help us to understand the value of our information and data along with its sensitivity, providing a basis as to what can be shared externally.

A further issue with the sharing of data is again the lack of trust of our "industry partners". Again there is the issue of what data could be of commercial value to organisations. Progress has been made through a data transparency agenda – examples include Darwin, the train running information engine, and operational data feeds from Network Rail. This needs to extend into working practices to share project data in a way that is software agnostic – a principle being adopted by HS2 – to manage the cost and complexity arising from SMEs otherwise being required to utilise specific proprietary products.

Potential role for Government: Government should continue to support the development of industry wide standards and working practices to maintain the dialogue. There might be the possibility of providing a secure platform that hosts the industry information that should be shared. The traditional means of funding the railway, including rewards and incentives, focuses on valuing physical assets. The virtual and enabling assets that support value being achieved through collaboration to exploit physical

assets are less well recognised or explicitly funded by the Government. This will need to change if we are to exploit the opportunities provided by these assets to improve the efficiency of the railway.

12. How can a national digital twin help to manage infrastructure data as an asset?

A digital twin could help manage infrastructure data by establishing the value of specific data streams. A digital twin would make infrastructure data available in a more usable form, providing data already related to reflect the real-world environment to complement data streams that are already available. A key example is with the commercial management of technical interfaces which could be embedded within a digital twin to underpin more agile commercial relationships and potentially generate exportable intellectual property. As well as improving the planning and co-ordination of maintenance, renewals and enhancements to improve safety and operational efficiency, it would enable the combined impact of plans to be explored and optimised, particularly in respect of the impact on end users. This is illustrated through HS2's ambitions to improve the passenger experience through operational data, summarised in Annex A4.

Annex A – Case study summaries – see separate document

Case study	**Contact_.[all.names.redacted]**
A1: Rail Industry Readiness Levels (RIRL) and the Network Rail product development framework	
A2: Insights and case studies for modelling, simulation and visualisation	
A3: Modelling, simulation and visualisation to design and specify infrastructure	
A4: Improving the passenger experience through operational and passenger data	
A5: Instrumenting train pantographs	
A6: Avoiding the Reconstruction of Bridges	
A7: Digital Imaging For Condition Asset Monitoring system (DIFCAM)	
A8: Distributed acoustic sensing for infrastructure monitoring	
A9: Modelling for condition monitoring and operations	
A10: Efficient construction and operation through Building Information Modelling (BIM)	
A11: Additive manufacturing	
A12: Robotics to automate output and remove people from hazardous environments	

THE ROYAL SOCIETY

15 September 2017

Submission to the National Infrastructure Commission New Technology Study: Second Call for Evidence

The Royal Society is the UK's national academy of science. It is a self-governing Fellowship of many of the world's most distinguished scientists working in academia, charities, industry and public service. Its fundamental purpose is to recognise, promote, and support excellence in science and to encourage the development and use of science for the benefit of humanity. The Society draws on the expertise of its Fellowship to provide independent and authoritative advice to decision makers, including advising how to realise the potential of new and emerging technologies.

We welcome the National Infrastructure Commission's initiative to explore how new digital technologies can improve the productivity of the UK's infrastructure, and hope that this can inform government activity going forward to ensure that new and emerging technologies can be harnessed to better plan and maintain the country's infrastructure network.

The Society has undertaken a number of relevant pieces of work in this area, outlined below, and separately will identify individuals with relevant expertise among our Fellowship and partners who can helpfully inform the Commission's work.

How can new technologies improve the productivity of infrastructure?

Cybersecurity

Cybersecurity delivers important economic benefits, both by underpinning the digital foundations of UK business and trade and also through innovation that feeds directly into growth. These benefits have already been substantial, but they remain at risk. Protecting the benefits and minimising the risks requires reliable and robust cybersecurity, underpinned by a strong research and translation system. The Government can help to support developments in this area in four key ways: by encouraging the development of systems that are trustworthy and resilient, and by supporting research and the translation of research. Supportive government policy and a strong research base make the UK particularly well-placed to realise the benefits of the emerging digital society and the Government may benefit from guidance from an independent body acting in the public interest, to cover the principles, standards and practices for state of the art cybersecurity.[1]

Machine learning

Machine learning shows promise of supporting potentially transformative advances in a range of areas, and the social and economic opportunities which follow are significant. Recent years have seen exciting advances in machine learning, which have raised its capabilities across a suite of applications. These include, and are not limited to:

healthcare	Support doctors' decision-making and help doctors to give more accurate or effective diagnoses
education	Support new ways of delivering teaching materials and can help teachers to create personalised learning plans for individual students

[1] The Royal Society, Progress and research in cybersecurity, https://royalsociety.org/~/media/policy/projects/cybersecurity-research/cybersecurity-research-report.pdf

transport and logistics	Supporting the development of autonomous vehicles and make existing transport networks more efficient
public services	Target support from public services more effectively to those in need
finance	Support banking and finance by detecting unusual spending activity or responding to customer queries
pharmaceuticals	Increase the efficiency of the pharmaceutical industry by increasing the efficiency of the drug discovery process, by identifying drug candidates more quickly and predict how well patients will respond to different drugs
energy	Optimise energy infrastructure by designing systems that respond more effectively to peak demands, or by improving the efficiency of power plants
manufacturing	Automate manufacturing processes or make them more efficient, or enable predictive maintenance functions such as anticipating when assests may fail
retail	Make increasingly personalised product recommendations or design more intensively-automated shopping experiences
law	Provide advice and analysis on simple legal queries and predict compliance with the law

There is a vast range of potential benefits from further uptake of machine learning across industry sectors and the UK is well placed to take a leading role in the future development of machine learning. Ensuring the best possible environment for the safe and rapid deployment of machine learning will be essential for enhancing the UK's economic growth, wellbeing, and security, and for unlocking the value of 'big data'. The UK will need to support an active machine learning sector and the Royal Society's report on machine learning outlined a number of recommendations to achieve this including creating an open data environment to support machine learning, building skills in machine learning at every level and continuing to undertake engagement activities to raise the profile of machine learning in public dialogue.

During the report the Royal Society conducted research to understand the views of members of the public towards machine learning. The extent of engagement consisted of 500 practitioners, over 1000 members of the public involved in dialogue activities and over 15,000 attendees at public events across the UK. There was not a single common view, with attitudes, both positive and negative, varying depending on the circumstances in which machine learning was being used. Context is key, as the nature or extent of public concerns, and the perception of potential opportunities, are linked to the application being considered. Ongoing engagement with the public will be important as the field develops.

There are a number of other considerations needed to be made within the context of machine learning, such as its societal and ethical impacts and the Royal Society is supporting work in this area through its wider data programme, for example through its upcoming fast-track discussion meeting on the growing ubiquity of algorithms in society in October 2017. This event will highlight opportunities and challenges in this rapidly changing landscape, bringing legal and ethics experts together with technologists to discuss implications, impacts and innovations.

Data Governance

There is an enormous amount of data generated from the world around us and the uses of data-enabled technologies, such as the aforementioned machine learning, promises benefits from improving healthcare and treatment discovery, to better managing critical infrastructure such as transport and energy. There is great scope for benefit here, but also great challenges, and to realise the benefits of these technologies, society must navigate significant choices and dilemmas and manage any risks. The

Royal Society and British Academy's report on data governance[2] recommends two essential governance arrangements for data management and use: First, a renewed governance framework needs to ensure trustworthiness and trust in the management and use of data as a whole, and this need can be met through a set of high-level principles. Second, it is necessary to create a body to steward the evolution of the governance landscape as a whole. This stewardship body would be expected to conduct inclusive dialogue and expert investigation into novel questions and issues, and to enable new ways to anticipate the future consequences of today's decisions.

Satellite Technology

The Royal Society's "From satellite to soil" report documented findings from a high-level conference which brought together individuals to discuss space and environmental observation technologies and their potential in agriculture. Advances in satellite technologies and terrestrial computing – the so-called 'Big data' - are examples of new technologies which have the potential to improve the productivity of infrastructure; in this case agriculture infrastructure. The report highlighted that advanced technologies that improve prediction, productivity and resilience in agriculture, for example environmental observation data from satellites, offer the potential to revolutionise 21st century farming. The UK is well placed to become a world-leader in the adoption of these new technologies and the opportunities to harness 'big data' and the associated downstream technologies is rapidly improving.

The Internet of Things

Over the past decade the Internet of Things (IoT) has seen a huge growth in interest, due to its extensive applications and potential to rapidly increase productivity and change lifestyles. The Royal Society's Industry Team is supporting work in this area and is hosting an upcoming Transforming Our Futures event on IoT in October 2017. This conference will describe the state of the art of the field, and highlight key issues which pose a challenge to the translation and adoption of technologies that fall under the umbrella of the IoT.

Transport

As technology evolves society will be met by a number of new opportunities to help keep transport safe, but also a number of new threats to our security. The Royal Society is working with the Department for Transport (DfT) to challenge the UK's brightest minds to apply their science to the future of transport security: the challenges that may face our transport systems, how these may be addressed, and how to make the best of potential opportunities.

For further information please contact [redacted] on
[redacted]

[2] The Royal Society, Data management and use: Governance in the 21st Century – a British Academy and Royal Society project, https://royalsociety.org/topics-policy/projects/data-governance/

Response to NIC – New Technology Second Call for Evidence

15th Sept. 2017

1. About Sensus

Sensus, a Xylem brand, helps the world's public service providers do more with their infrastructure by providing technology and data-driven insights that deliver efficiency and responsiveness. It is a leading utility infrastructure provider offering smart meters, resilient FlexNet communication systems, and software and services for the electric, gas, and water industries. Sensus technology helps utilities drive operational efficiency and customer engagement with applications that include advanced meter reading, data acquisition, demand response, distribution automation, home area networking and outdoor lighting control.

In 2013 Sensus was selected alongside its partner, Arqiva, to supply solutions as part of the UK government's DECC program to install smart meters in millions of homes and small businesses by 2020. Sensus technology will support the rollout of electric and gas smart meters to ten million locations in the Northern region of Great Britain.

Customers worldwide rely on the innovation, quality and reliability of Sensus solutions for the intelligent use and conservation of energy and water.

2. Summary

A smart utility infrastructure offers numerous direct and indirect benefits to the UK. Sensus believes that these benefits will both enable greater use and efficiency from the country's existing asset base, and with sufficient security and protection, allow for the exchange of data across different infrastructures on a regional and national scale, opening up the possibility of new services, greater knowledge transfer, dissemination of best practices and enhanced insight to be established.

We do not believe that technology is a barrier to this objective. The core technology exists today to provide reliable sensor/metering data alongside robust and secure network communications. New advances in technology and increased competition mean that solutions will continue to be developed which will increase efficiencies, reduce costs, and provide much more advanced data analytics to turn this data into real, tangible benefits to the industry and the nation. The National Infrastructure Commission (NIC) is well positioned to drive and accelerate this process, and help recommend initiatives to government to help break down the barriers and silos that prevent the wider use of smart technologies. Sensus believes that the market must be left to decide the most optimal technologies for the individual utility sectors and the applications within those sectors, especially in relation to sensor and communication technology.

Sensus believes that there should be greater emphasis on the sharing of best practice across all the infrastructure sectors in order to maximise the benefit brought through innovation. The government can assist, either directly or via its regulators, to accelerate adoption of new technology by addressing the key issues that form barriers to adoption. To meet the best standards we believe the regulators will need to set more targeted and specific requirements to the utilities, and that greater use of incentives should be used to accelerate implementation by the utilities in order to ensure that the U.K's national infrastructure is considered among the most efficient and resilient in the world.

Better Asset Management

1 What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

No information to provide on this question.

2 What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

Sensus believe that the immediate technology priority is:

- Ensuring existing infrastructure (meters, sensors, data loggers etc.) are accounted for with up-to-date test information and maintenance programs and the information is sufficiently accurate.
- Older meters are replaced by more reliable smart meters with integrated communications and that have no mechanical moving parts, as this will significantly help to reduce the overall maintenance requirements over the long term.
- Use of software tools and analytics to highlight characteristics that indicate if an asset is operating sub-optimally or may be due to fail.
- Use of “big data”, AI and “analytics” to correlate weather events vs threats to infrastructure and use this ability to reprioritise assets to respond to the threat.
- Ensuring that critical control assets, such as pumps, valves, circuit-breakers and key sensors/meters, can be accessed 24/7, 365 days a year.
- Maintain security and efficacy of the assets through consistent, regular monitoring and the ability to upload software upgrades remotely if required.

Older assets may not have the ability to provide these capabilities, and the utility should be incentivised to replace these assets based on regulated assessment criteria that includes whether the asset has the ability to support ongoing optimisation (e.g. remote upgrades etc.), reduced power usage, and improved maintenance requirements (i.e. less maintenance visits or calibration required).

3 What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

No information to provide on this question.

4 What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

No information or comment to provide on this question.

5 How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

No information or comment to provide on this question.

Smart Traffic Management

6 What are the latest developments in intelligent traffic systems, and what technologies underpin them?

No information or comment to provide on this question.

7 What barriers do local authorities face in deploying these systems, and how could these be overcome?

No information or comment to provide on this question.

Water Efficiency

8 In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

Sensus believes that accurate water flow measurement at end-customer premises, in conjunction with District Meter Area (DMA) metering and detailed mapping of the distribution network, are a necessity in order to implement effective leakage control that meets the best world standards.

In addition, pressure sensors can be used to control pumps to reduce pressure. As the amount of leakage is a function of pressure in the network, managing it more dynamically provides a more optimal network that reduces leakage while maintaining customer satisfaction with the water supply.

Another very important and emerging requirement is the need for high-level analytic software in the Head-End System (HES) to sift through the large data sets collected and provide more direct information to operators on possible leakage areas, risk of pipe failure data, maps of pressure anomalies and other potential network problems.

There has been a move away from using just volumetric percentage performance indicators towards an Infrastructure Leakage Index (ILI) methodology defined by senior professionals within the International Water Association (IWA). While there is a debate in the industry as to the best way forward, Sensus believes the use of effective performance indicators (PI's) and regulatory targets will accelerate leakage and efficiency improvement projects.

The UK is one of the only major regions within Europe without a complete metering program established and driven by a national regulatory body, and is lagging substantially behind in the comprehensive uptake of smart metering in the water network. Sensus believes that this lag is mainly due to a lack of direct pressure on the water utility companies from Ofwat to bring in new technologies. Initiatives, such as PR19 help, but Sensus believes that the regulator should consider becoming much more actively involved in driving the adoption of new technology by the utility companies and also in offering tangible incentives to them to help de-risk this approach.

9 Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

Sensus strongly believes that there are efficiencies to be gained from the greater use of metering and other sensor technology in the water sector. Metering and wireless communications technology exists today that can provide a long-term, 15 year or more battery life per meter, and a communication network that can reach underground meter assets and meters that would be out-of-range of even the latest 3GPP cellular technologies

Currently the water utilities fix leaks when the cost of the water lost is greater than the cost of the repair. Unless the water company has a demand vs supply deficit, such as those in the South and South East Regions, they have little internal incentive or pressure to install water meters proactively to help find leaks in their network.

However, smart water metering is an integral part of identifying leaks that have previously gone unnoticed, for example, where there is no surface evidence of a leak. This has been clearly demonstrated in a field trial carried out with our partner, Arqiva for Thames Water, consisting of 3.6 million households and businesses in London and the Thames Valley, using our resilient FlexNet technology.

To-date the use of reliable remote meter data reads has lead to, ~4,200 leaks being identified, saving on average 930,000 litres of water per day – the equivalent of ~10,000 baths!

Despite the benefits of having a network of robust and sufficiently accurate meters it is evident that not all the water companies have an imperative to invest in a comprehensive water meter program to fulfil their own leakage management purposes.

We believe that more analysis needs to be carried out at the national level to, not only consider the benefits to the individual water companies of smart water metering in improving the efficiency of their networks, but also to establish and quantify the wider benefits that can be achieved. These benefits may include; savings through improved synergies with other utility industries, greater use of data across industry and ability to help meet wider national climate change targets to reduce waste and power usage. Water consumption and quality is also a particularly good indicator for social and health research. In addition, because of the high energy and climate costs moving water, there are potential benefits from using smart meters to change water consumption incentives to times where energy is cheapest, or when it is most green i.e. coordinated with wind and solar power availability.

The need for a mandated rollout will still depend on the overall business case across the nation, which is complicated by the fact that the demand and supply situation varies substantially across water company regions. Some regions with heavy rainfall may experience consumer resistance to a compulsory program, while other regions are likely to be much more open to a compulsory element to the program. An overall target on leakage reduction, as suggested by Ofwat in Water2020, is likely to drive better analysis of the needs in each water region, and is a good start point. However, we believe that more specific measures and incentives may be required to improve uptake of smart meter technologies within all the water utilities, in order for the U.K to achieve the leakage levels and efficiency of the world's best and where there is a consistent level across all the different regions and nations that comprise it.

Big Data

10 What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

No information or comment to provide on this question.

11 What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

No information or comment to provide on this question.

12 How can a national digital twin help to manage infrastructure data as an asset?

No information or comment to provide on this question.

techUK response to the National Infrastructure Commission

Second Call for Evidence | New Technology Study

September 2017

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techUK | Representing the future

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About techUK

techUK represents the companies and technologies that are defining today the world that we will live in tomorrow. The tech industry is creating jobs and growth across the UK. 900 companies are members of techUK. Collectively they employ more than 700,000 people, about half of all tech sector jobs in the UK. These companies range from leading FTSE 100 companies to new innovative start-ups. The majority of our members are small and medium sized businesses.

Summary

Smart infrastructure offers numerous benefits to the UK. We believe that these benefits can loosely be described as in the short-medium term getting more for less from our existing asset base, and in the long term allow for the near real-time exchange and analysis of data across different infrastructures, enabling new services and insight to be delivered.

There are barriers to realising both the short and long term benefits. The National Infrastructure Commission (NIC) is well-positioned to help overcome these barriers. In particular, establishing a framework for the harmonisation of IP-based processes such as collecting, transmitting and storing data for local and national assets, could start to overcome these barriers and help drive up-take of existing solutions in these areas.

The Institute of Civil Engineers, in analysing the necessity for smart infrastructure, have also outlined the not inconsiderable task facing the sector in undertaking its digital transformation. One such barrier is a mix of capital cost and an understandably conservative risk environment. In State of the Nation 2017: Digital Transformation[1], it advocated for more focus on whole life costs within both the industry, procurers of infrastructure and the regulatory framework. We support this call, believing that it would help to enable more focus on value beyond up front cost and would help unlock a variety of digital solutions in both the short and long term.

techUK also believes that there should be greater emphasis on the sharing of best practice in the infrastructure sector to quicken the pace of innovation. We see the benefit, particularly in the utility sector, of an overall system architect position[2] which could have a wider remit.

Response

Better Asset Management

1. **What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?**

[1] Institute of Civil Engineers, State of the Nation 2017: Digital Transformation

[2] See Institute of Engineering and Technology, The Future Power System Architecture Project

2. **What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?**
   The immediate priority is to establish the framework for sharing of data between different organisations and industry sectors. Please see answers 10 and 11 for how this could be realised.

3. **What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?**
   The collation, transmission and subsequent analysis of data are linked but it is useful to think about the challenges that face both areas as separate to each other. Please see our answers 10 and 11 for a framework allowing the sharing and analysis of data.

   Regarding the collation of data, the UK benefits from a vibrant digital infrastructure sector which has been built predominantly with private funding. Different communication technologies may be suited to differing use cases. However, regardless of the communication technology to deliver the level of coverage desired, the sector requires a business case to invest. Helping to provide market clarity and even starting to aggregate demand would help to improve this business case.

4. **What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?**
5. **How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?**
   Digital twin technology – at its simplest a virtual model of a service, product or space – can be incredibly powerful. For complicated, albeit it confined use cases, such as jet or race car engines digital twins have delivered substantial benefits. The computational power of the cloud now allows us to model more complicated systems, monitoring their performance in near real-time as well as indicating potential future states, allowing planners to explore alternative scenarios by introducing new data into the digital environment. Digital twins can also allow for greater collaboration between design, build and operate/maintain phases of infrastructure assets.

   Highways England are currently putting efforts into building up pictures of assets which could be used as an input into a digital twin. Similarly, Connected and Autonomous Vehicles (CAVs) could be an input and beneficiary of this digital asset. Universities are also currently exploring this area; Cranfield have active projects to understand infrastructure from the perspective of protecting resources during excavation and maintenance, whilst the Infrastructure Transition Research Consortia and its National Infrastructure Systems Model (NISMOD) take a system of systems approach to infrastructure modelling.

   Smart Traffic Management
6. **What are the latest developments in intelligent traffic systems, and what technologies underpin them?**
7. **What barriers do local authorities face in deploying these systems, and how could these be overcome?**
   We welcome the Government's ambition for the UK to become a leader in the research and testing of CAVs. Smart Traffic Management is a very important part of that ecosystem and will be integral for managing the transition between smart and legacy technologies. However, we caution against focusing too much on one technology at the risk of ignoring potential macro developments such as a wider move towards multi-modal transport systems. This is because partly technology should not be used solely to drive efficiencies resulting in more traffic but also about moderating demand.

Water Efficiency

8. **In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?**
   techUK believes that technology can play a greater role in helping to ensure that we live in a more sustainable, productive and ultimately healthier society. Within the water sector there is clearly the potential to deliver benefits around all three of these goals by ensuring that water companies are better able to monitor and manage their networks and assets.

   The Economic Level of Leakage (ELL) mechanism has an aim that matches ours but has a questionable track record in delivering the desired outcome. Ofwat appear to be moving away from this methodology, proposing in their Delivering Water 2020 consultation document that for PR19 water companies will be judged against other targets such as a 15% reduction by 2025 or upper quartile performance on leakage per property per day. We welcome these changes but believe that more can be done to de-risk the adoption of technology that can reduce leaks and improve performance.

9. **Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?**
   techUK believes that there are efficiencies to be gained from the greater use of sensor technology in the water sector, not just in smart metering. Within metering it is important to differentiate between those that hold interval data, and automated meters that purely record consumption over longer billing periods. Resilience is the ability to cope with future demands for water whilst at the same time protecting the natural environment. Smart water metering could identify leaks which would have previously gone unnoticed without a meter being installed which helps to improve resilience. This has been demonstrated most recently from Thames Water whereby a 50,000 litre a day leak was detected and fixed due to the installation of a smart meter.

   However, currently, water companies approach resilience by providing water efficiency advice to reduce consumption and reduce leakage by currently fixing leaks where the cost of water lost is greater than the cost of the repair (ELL). Unless a water company has a demand vs supply deficit it is very difficult for water companies to make the case to install meters let alone make them smart given this strict economic case. We want to continue to encourage water companies that are already installing smart meters but believe that we need to look beyond water efficiency to other positive externalities. Water consumption is, for instance, a particularly good indicator of occupation of properties, so the data can be used for social and health research, as well as security applications. In addition, because of the high energy and climate costs moving water, there are potential benefits from using smart meters to change water consumption to times where energy is cheapest and/or is most green. More work needs to be done to quantify these benefits but we believe that when taking this additional benefits into account then we believe that there is a business case to mandate a rollout of smart water meters, noting that this may require subsidy in some form.

Big Data

10. **What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?**

As the amount of information being created, processed, shared and stored by organisations continues to increase in this new era of big data highlights the importance of data governance. All organisations across both the public and private sector must ensure the ongoing management of data throughout its lifecycle including data's availability, integrity, confidentiality, privacy and security. By applying well established data governance principles, underpinned by data protection law, data governance has a key role to play in helping organisations to bring order and standardisation of data when it is collected, classified, managed, accessed, protected, shared and used. These principles can also help support and guide organisations on when and where it is appropriate to deploy the use of data technologies, such as predictive data analytics and APIs, to ensure the availability, integrity, confidentiality, privacy and security of data. Data governance can also act as a competitive advantage for organisations that can demonstrate to partners and customers (through for example the use of existing industry standards) that data is being appropriately managed and secured.

As we look to the future and consider the implications of a world where organisations and humans live and work alongside intelligent machines it is important to ensure that data governance thinking keeps pace with technological innovation. We are now entering a new era where the use of machine learning and Artificial Intelligence is raising legal, social and ethics questions around how data is being used that go beyond the legal protection of personal data. Robust mechanisms must therefore be in place to ensure effective data governance over intelligent data driven machines. techUK has welcomed the recently released report by the Royal Society and British Academy on Data Management and Use: Governance in the 21st Century and contributed to its development. The report recommends a set of high level principles to guide the governance of data use in the 21st century and the establishment of a new Data Stewardship body. Developing consistent and effective answers to ethical questions being raised about data use will need to be at the heart of data use governance moving forward. We strongly believe in the creation of such a body that would bring together leading experts to build the capability and capacity needed to answer and address these questions and believe that the NIC should play its part in accelerating the bodies delivery.

11. **What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)?**

Providing greater access to and indexing data can in itself help deliver value. The more data is made available, the greater understanding people will develop about to what uses they can put the data – it is a self-fulfilling scenario which will lead to the value of data being understood and a marketplace created.

The ability of organisations to share data internally between business functions and externally with business partners where appropriate is a key enabler of increased collaboration, operational effectiveness and efficiency as well as a driver of data driven creativity and innovation. It is vital therefore that barriers to data sharing are identified and addressed to ensure organisations can realise the full potential of data. techUK has identified the following as key barriers that can prevent data sharing from happening within organisation and between business partners. These are:

- Data protection and privacy legal concerns - employees may be concerned and fearful about what data they can, and cannot, share with colleagues and outside their organisations with customers

and business partners. With the introduction of the new General Data Protection Regulation (GDPR) next year organisations should be encouraged to provide employee GDPR training before it comes into force on 25 May 2018.

- Data portability and interoperability - Realising the full power of data comes from the ability to bring together different datasets and use data analytics technologies to find hidden insights and knowledge to make real time data driven business decisions. A common barrier to this is the lack of standardisation in the way data is collected and recorded and the degree of interoperability that exists between different data systems. This means that datasets may not be easily be portable and might not be interoperable with other data system when shared.

- Lack of an organisational data strategy - A key enabler of increasing data sharing, particularly internally, is having in place a board level agreed company strategy focused on data driven innovation and growth that encourages greater data sharing amongst business functions. This can also develop a culture of data confidence that could lead to increased data driven creativity and innovation by employees.

techUK supports the open data movement and measures that encourage public and private sector organisations to voluntarily publish non-personal or commercially sensitive data. For example in the infrastructure industry this could include technical data generated by intelligent web sensors on a network which could then be used by others to increase efficiencies and also drive digital innovation. However, it should also be remembered that there will be situations where organisations will not be able to publicly release data that relates to individuals or commercially related company specific data relating to the delivery of a product or service. These circumstances where data may not be able to be made open should not be seen as a barrier that needs to be addressed. The introduction of mandated open data access requirements for proprietary commercial related company and business data would not be welcomed. Such as requirement could stifle companies willingness to invest in innovative data collection which could prevent the emergence of data driven business models and increased data sharing.

What can the government do to support the secure sharing of data in the infrastructure industry?

For many organisations digital data is becoming the core assets to how their business operates. However, data is also increasingly a key target of cyber criminals in the ever-evolving online threat environment. It is therefore vital that organisations put in place appropriate cyber security policies, procedures – including incident response plans for when breaches do occur – and technologies to ensure data is secure and protected whether it is at rest within an organisation or on the move and being shared.

Government has a key role to play in helping to raise greater awareness amongst organisations across all sectors of the importance of put in place an effective data and cyber security strategy. This strategy should include having in place data privacy and cyber security policies and procedures, the deployment of appropriate security tools and technologies and up to date training to ensure all employees have relevant data security skills needed. The National Cyber Security Centre is a key asset that provides advice, guidance, support and information to organisations on how to protect their data assets. It is suggested that the infrastructure industry should look to work closely with the NCSC to ensure organisations have the most relevant and appropriate cyber security policies and procedures in place to protect data when it is being shared.

12. How can a national digital twin help to manage infrastructure data as an asset?

Please see answer 4 and 5.

Transport Systems Catapult (TSC) response to the National Infrastructure Commission's 'New Technology Study, second call for evidence' https://www.nic.org.uk/wp-content/uploads/New-Technology-Study-Second-Call-for-Evidence.pdf

This call for evidence asks for input into detailed case studies, which will inform our final report, to be published by the end of 2017. Through these case studies, which are described below, we will be looking at how efficiency gaps can be closed in different sectors (energy, water, transport, digital, waste and flood defence) through the application of new technologies which use data to optimise the operation and maintenance of infrastructure systems. We will be considering the implications of viewing "data as infrastructure" and assessing security and resilience as critical requirements of a future interdependent infrastructure system with data at its core. And we will be looking at models such as digital twins and assessing how coordination at the national level can help us manage this data for resilient outcomes.

BETTER ASSET MANAGEMENT

1. What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

Presently, those responsible for the maintenance of individual infrastructure types, overlook the importance of the drainage network, and the challenges it faces, including; efficiency, reducing disruption, protecting communities from the risks of flooding and avoiding environmental damage.

SmartClean - The Smart Clean project is a collaborative R&D project part funded by InnovateUK and NERC and focuses on creating SmartWater; a system that delivers a step-change in the quality and quantity of data available from our urban water infrastructure. The information that the innovative SmartWater solution can provide, transforms our understanding of how best the network can be maintained, by providing accurate data, real time alerts, predictive data modelling and clear, user friendly visualisations.

This innovative IoT sensor-based predictive maintenance solution has been shown to deliver a potential 80% reduction in cleaning for drainage assets while also helping to deliver real-time status information for the drainage network, minimise the risk of flooding by ensuring appropriate gullies are cleaned when they stop performing as intended (https://www.intouch-ltd.com/smartwater).

TrackWater - will take the existing highways product and transfer the knowledge and experience for use within drainage management challenges within the rail sector.

These will in some small part address elements of the asset management challenges around resilience and leakage, providing a greater level of understanding how a system of systems approach to capturing, analyzing, and managing of data and assets in needed to make the best of the wide variety of different infrastructures within UK PLC's geographical boundaries.

Government and the NIC could utilise its reach and oversight responsibilities for national infrastructure, of whatever type(s), to ensure it uses its best efforts to transfer, deploy and integrate UK and world best practice for, and with the benfits of all UK infrastructure types.

2. What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

One of the biggest technical challenges relates to the challenges of retrofitting sensors and extracting the key information from low-integrity and noisy data sources. This requires the integration of disparate data sets and use of machine learning techniques. These techniques need large scale, long-time-baseline data sets and ongoing operational data, hence collaboration with infrastructure partners is essential.

Currently available technologies, such as LIDAR, infra-red, optical etc., could provide benefits to support better asset management if they were utilized correctly; providing more information, coverage, and often with a better level of detail than at present.

Added to that new lower-cost sensors which are IoT enabled provide new and innovative ways of obtaining network coverage and generating data on asset condition, use and utilisation. These sensors can generate significant amounts of information which will require machine learning techniques to monitor and analyse. Machine learning techniques and algorithms also allow the potential for developing predictive capabilities which will help with monitoring asset performance and degradation and enable pro-active management strategies to be implemented based on condition and expected residual life of the asset.

3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

Identifying who is responsible for managing the infrastructure and ensuring interoperability is vitally important to improve asset management. For example, the TSC learned from working with Network Rail, that responsibilities for managing the Permanent Way, Signaling, and Telecoms and Overhead Electrification assets are split between three distinct parts of the organisation and technical disciplines, which run their own asset management systems, without a common referencing system and little overlap in terms of asset management activities. This siloing of responsibilities can, and has led to issues of lack of clarity of accountability and responsibility particularly when dealing with planned renewals and enhancements to the network. This highlights the issue of asset management responsibility being shared and divided across siloes and between asset owners.

4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral, or national digital twins? What would be the main uses of such digital twins?

A national digital twin could enhance the predictive capability using existing datasets and models, providing the relevant organisations are brought together. For example, one could consider bringing together the knowledge and skills of the Environment Agency; Ordnance Survey mapping and topological capability; British Geological Survey with its sub-surface knowledge; and the meteorological factors from the MetOffice to provide complementary datasets and analytical systems to strong predictive capability. However, since these are independent organisations with different capability and business models, there would be challenges to bringing the capabilities together to provide a powerful digital twin.

The TSC have undertaken some work in this area, developing a national 'twin' of HE's Strategic Road Network (SRN). This was hosted in a cloud based high performance distributed computing environment. Although focussing on traffic and operations initially, it is recognised that this 'twin' has the potential to incorporate all asset and operational data pertaining to the operation and condition of the complete SRN.

5. How can Government, infrastructure providers, researchers, and SMEs work together to leverage rapid innovation occurring in this space?

Catapults could play a significant role as the neutral trusted entity that combines and builds on the strengths of independent organisations to develop new and innovative solutions. Initiatives such as the Transport Systems Catapult's IM Data Hub is a trusted neutral enabling capability and open data platform for innovation, i.e., IM Data Hub can be part of transport sector's critical infrastructure for big data. The grand vision is to have an 'API First' approach to build a robust pipeline for data ingestion and efficient storage of either raw data or aggregated data. The IM Data Hub offers advanced data curation and data analytics capabilities to address any real-world transport problems like predictions, situational awareness, network resilience to name a few. It provides a framework in which data providers, researchers, and innovators could collaborate to create services for the infrastructure sectors.

More details of the IM Data Hub can be found here: https://ts.catapult.org.uk/innovation-centre/imdh/

SMART TRAFFIC MANAGEMENT

6. What are the latest developments in intelligent traffic systems, and what technologies underpin them?

There are several main enablers needed to underpin the success of intelligent traffic systems operations:

- Intelligent infrastructure: where infrastructure systems companies complement existing offerings with new intelligent services and additional capability;
- Systems that incorporate digital information gathered from vehicles (especially pertinent for connected and autonomous vehicles), leveraging IoT technologies, with relevance for the automotive and adjacent sectors:
- Systems that gather crowd-sourced information, both in terms of people movement and sentiment to determine stress on transport infrastructure;
- Technologies that facilitate data processing on mobile platforms, and the anticipation of future ubiquitous and resilient mobile data connectivity (5G terrestrial/ satellite integration);
- Technologies that provide secure means of ensuring transactional (e.g. blockchain) and data integrity (artificial intelligence for information signature analysis);
- Technologies, particularly sensors, which provide data in real-time to enable more pro-active management of transport networks, particularly when combined with Artificial Intelligence/Machine Learning (AI/ML) techniques to provide predictive power for active management of the networks. This highlights the further benefits of integrating sensors with AI/ML.
- Vehicle to Infrastructure (V2I) technology introduction of simpler 'bottom-up' rules at Traffic light to enable cars to control the lights rather than the other way around, enables the system to achieve an emergent (dynamic) equilibrium by itself. Existing UK examples of real-world deployment and implementation of C-ITS are COMPASS4D and ACCRA.

7. What barriers do local authorities face in deploying these systems, and how could these be overcome?

There are number of barriers associated with the exploitation of such systems by local authorities, which include, but are not limited to:

- A lack of understanding of the economic benefits of such systems and the value they accrue to the citizen;
- Challenges with regards to budgetary mechanisms and the need to invest at scale prior to the impact being obtained;
- Difficulties in transforming internal processes and transitioning from existing operational practices;
- A lack of collaborative frameworks that allow National and Regional Government organisations to work with professional services companies to share and exploit new information sources;
- Ensuring common standards and language are necessary to enable interoperability which will allow a more integrated response to the information acquired.
- Local Government has a workforce shortfall of suitably skilled staff who can design/deploy/manage and operate these new types of systems. Whether these are budgetary or skill/capability driven will vary across local authorities. Nevertheless, the impacts of not having the resources to meet the demand is a very real, and near-term challenge.
- Economic value models (WebTag, Green Book) for economic development proposals need updating to allow for more accurate forecasting and value return mechanisms developed to deliver the needed efficiencies to extract and amplify the potential gains these technologies can provide.

BIG DATA

10. What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

a) The new governance arrangements needed for the huge amount of data is all about being agile and proactive. This includes proper profiling of data, understanding what it will be used for and then determining the required level of governance. Interactive governance of data will ensure appropriate controls without inhibiting the speed and flexibility of innovative big data technologies.

b) Big data ingestion in massive scale needs an automated mechanism. API first is such an approach wherein robust data pipelines can be built with automated feed ingestion though read/write APIs. This will ensure data ingestion from trusted and reliable sources and an automated workflow.

https://hortonworks.com/solutions/data-ingestion/

https://www.gsma.com/iot/iot-big-data/iot-big-data-api-directory/

Transport Systems Catapult's IM Data Hub is a trusted neutral enabling capability and open data platform for innovation, i.e., IM Data Hub can be part of transport sector's critical infrastructure for big data. The grand vision is to have an 'API First' approach to build a robust pipeline for data ingestion and efficient storage of either raw data or aggregated data. The IM Data Hub offers advanced data curation and data analytics capabilities to address any real-world transport problems like predictions, situational awareness, network resilience to name a few.

More details of the IM Data Hub can again be found here: https://ts.catapult.org.uk/innovation-centre/imdh/

11. What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

Effective data sharing is critical to establishing the UK as the global leader in integrated, efficient, and sustainable transport systems – what we call Intelligent Mobility (IM), estimated to be worth £900bn per annum globally by 2025.

Sharing data in the transport sector and combining it with data from other sectors, is key to delivering the Transport System Catapult's mission of enabling new and innovative mobility solutions to be developed in the UK that will play a leading role in tackling some of our biggest challenges from uneven economic development, a growing and ageing population, and the depletion of traditional energy sources.

Working with Deloitte and the Open Data Institute, we have found access to data across the industry to be limited. Organisations are dissuaded from sharing data due to significant actual and perceived risks, high costs and closed cultures. Allowing these barriers to persist means the UK will fail to secure the full benefits of new mobility solutions and not develop a strong presence in an exciting, global sector.

This Briefing Paper on data sharing which puts forward our recommendations on how government can support the industry to address these challenges from today. We have discussed these recommendations with a diverse range of stakeholders and are confident they can accelerate and enhance existing industry-led initiatives to shift incentives across the sector from not sharing data towards sharing by default.

Please refer to Data Sharing report by Transport Systems Catapult: https://ts.catapult.org.uk/intelligent-mobility/im-resources/opendata/

12. How can a national digital twin help to manage infrastructure data as an asset?

The Digital Twin allows you to have access to all archive and real-time data associated with the national asset within a single environment, opening-up access to that data and insight across the asset owners' business. This is a significant benefit as at present HE and NR do not have this strategic overview due to the regionalisation of their control systems. Whilst this allows control of the asset/network to be undertaken close to the operational frontline, it does not easily cater for cross regional issues which need to be managed or dealt with.

The digital twin is also the ideal receptacle for real-time data from new and existing sensor technologies. This will allow the asset owner to maintain a real-time operational overview of asset performance and capability. The benefit with being a 'twin' though is the ability to incorporate modelling and predictive technologies and algorithms to enable future scenarios to be evaluated that are 'forked' from a point in time. In the high-performance computing environment that was investigated by the TSC, this would enable real-time operational decision making to be supported by being able to rapidly run 'what-if' scenarios in real-time, e.g. for identifying the best way to deal with an incident on the SRN, e.g. in terms of number of lanes closed/speed limits imposed/diversion routes used etc.

The digital twin also allows for longer term strategic planning to be undertaken based upon having available all asset information in archive format. From this data, predictive algorithms can be developed and implemented to enable forecasts of asset condition and usage to be produced. This can be used for planning future asset renewals, enhancements, and additional/new infrastructure.

Digital twins will become essential assets for monitoring, managing, and planning of national infrastructure assets.

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NATIONAL INFRASTRUCTURE COMMISSION – TECHNOLOGY STUDY EVIDENCE
Second Call: September 2017

Executive Summary

The Forum is delighted to respond to your second call for evidence on how new technologies improve productivity of infrastructure. Your questions complement our initial response.

Latest developments in intelligent traffic systems provide new policy tools (such as reducing emissions), make the most of new data (especially from vehicles) and exploit new technology to reduce whole life costs. Above all, they give an integrated tool that could bring benefits to the UK of £2.5B from increased productivity.

UK traffic management systems are now offered "as a service", so authorities do not need to physically host or in some cases even operate them. This improves productivity through asset sharing, increases security and availability to reduce risk. Internet and wifi communications allow easier interoperability, as does "plug and play" of different vendors' products, increasing competition and UK exportability. On motorways, Smart Motorways deliver additional capacity at far lower cost and delay than construction can and where the UK is working with international partners that will enable export of skills and products.

The rise of data from vehicles and smartphones means more ability to monitor journey times, travel patterns and queues. This will mean reduced roadside equipment, aiding productivity of limited funds. Links into vehicles also support new services to drivers, such as the speed to drive at to go through signals at green. This can reduce emissions and wear & tear both on the vehicle and road, and saves fuel – all aiding productivity.

Other key developments are smarter parking, allowing drivers to find spaces without causing extra congestion, and then paying for parking automatically using their smartphone. This reduces costs to businesses of parking. Further technical innovations include better cyclist safety, pedestrian countdown timing and intelligent control for bus priority. These are underpinned by cellular & wireless communications, cloud storage, new roadside devices, in vehicle communications & sensors (both line fit & retrofit), big data and smartphones.

The barriers that local and national authorities face in deploying these are the lack of revenue funds to maintain investments, unclear business cases for new technologies, lack of resources skilled in areas such as data, and local political pressures such as potholes. There is also an understandable risk aversion to procuring new technology. They could be overcome by government valuing the benefit of data as it does infrastructure, by smarter procurement shared across authorities, by easily available evidence of benefits in a common framework and by more of a government focus on connected rather than autonomous vehicles.

Whilst this response focusses on traffic management, our work sits across other questions. Data from vehicles is a key input to both better asset and traffic management, saving at least £300m a year on maintenance costs. Data volumes from the UK's connected vehicles lend themselves to big data approaches. Hence traffic management must not be a silo, it is part of a smarter integrated approach to productivity of existing roads and vehicles, and is fundamental to highly autonomous vehicles. Traffic management will be key to effective safe transition to automation, as a mixed vehicle fleet will be a challenge and take many years to recede. Managing the evolution of current technology is as important as including disruptive ones and an area where UK industry and government in partnership can lead.

About our response

This response has been prepared by the Transport Technology Forum, looking at more effective and efficient management of existing and new roads as a national productivity opportunity. With pressures on public funding, there is an ever-increasing need for better transport at lower cost by making the most of the infrastructure we have. Roads will remain a key to how people and goods move across the nation, not just on strategic roads.

So the core aim of the Forum is improving road transport to achieve economic and social benefits through technologies. The Forum is a neutral meeting place for senior public and private sector policymakers and investors (government, industry and network operators). They want effective commercial and operational solutions to challenges and opportunities faced by roads. The Forum promotes collaboration to unlock opportunities and address fragmentation and caution that have impeded efficiency and innovation.

The Forum has produced the first national business case for roads technology and is publishing a guide to the value of connected vehicles in managing UK roads.

The latest technologies

The latest developments in intelligent traffic systems build on the UK's foundation as a world leader by bringing in technology ideas from outside traffic to:

- Provide new policy tools (eg reducing emissions through telling drivers about signals),
- make the most of new data sources (especially from vehicles and smartphones),
- enable more cost effective and scalable services using wireless communications; and
- lever cloud data approaches to reduce whole life costs via asset and data sharing.

These give an integrated tool for road management for an authority. The customer emphasis is moving from technology for minimising delays to vehicles to a more balanced "mobility "toolkit. TfL has led new ways to optimise traffic for productivity of London though its SITS programme, building on its prior investment adding new ideas from the wider IT industry about use and exploitation of data and new algorithms for optimisation.

To reduce costs, many UK traffic management systems are now offered "as a service", so authorities do not need to physically host or in some cases even operate them anymore. This improves infrastructure productivity through asset sharing and enable use of cloud storage. It also increases security and systems availability to reduce risk of loss of an important asset for many cities. Internet and wifi communications now allow easier rollout and interoperability, as does the UTMC standard which allows "plug and play" of different vendors' products in a system. As well as allowing the piecemeal change of technology that limited resources often allow, this is increasing competition and UK exportability.

On motorways, smart motorways deliver additional capacity at far lower cost and delay than construction can and where the UK is working with international partners that will enable export of skills and products. Enforcement, queue detection and smart use of data are all part of the CHARM system bringing developed jointly with the Netherlands which also helps the move from bespoke traffic control software to off the shelf configurable products.

A link to big data

The rise of data from vehicles and smartphones means more ability to monitor journey times, travel patterns and queues. This could lead to a reduction in the need for roadside equipment by using vehicle data, aiding productivity of limited funds and new policy tools. Using data direct from vehicles also allows new approaches to older problems, for example setting traffic signals effectively and detecting slow moving queues. Data from vehicles also allows weather monitoring, detection of asset condition and hazard reporting.

Links into vehicles also support new services to drivers, such as advising them the speed to drive at to go through signals at green (Signal Phase and Timing -SPAT). This can reduce emissions and wear & tear both on the vehicle and road, and saves fuel – all aiding productivity. However, it does rely on adoption by the driving public and investment by local authorities which can slow deployment.

Other key developments are smarter parking, allowing drivers to find spaces without causing extra congestion, and then paying automatically using their vehicle or smartphone. This reduces costs to businesses of parking and parking fines. Further innovations include better traffic management for cycles safety, pedestrian countdown timing and intelligent control for bus priority. As well as systems, the UK leads on intelligent road studs, bus real time information and queue detecting radar as just 3 examples. All help movement of people and goods for the productivity of the UK. These are underpinned by cellular & wireless communications, cloud storage, new roadside devices, in vehicle communications & sensors (both line fit & retrofit), big data and smartphones.

The benefits for productivity

We quantified the benefits mentioned above in our previous submission – attached as an appendix, and include further examples in the appendices. In summary, we see our area of technology as adding £2.5B benefits just in productivity.

However, whilst technology develops and become available in the market or at high levels of technology the confidence to invest in them and the skills to adopt them in the UK public sector at large are low. Most are also easy to deploy in physical terms – for example as apps on smart phones, or piggybacking of other services such as fleet management for HGVs and rely on little physical change. We now focus on these challenges.

Principal challenges and barriers to deployment

Barriers that local and national authorities face in deploying these are:

- the lack of revenue funds to maintain investments once installed (capital revenue is relatively easy to come by from competitions) This also discourages procurement of "as a service" approaches as they are not capital items but need revenue funding.
- the need for revenue can impact decisions – eg making parking payment easier may reduce overall revenues for an authority yet parking is a key generator of funds
- unclear business cases, eg SPAT is widely seen as a potential tool to reduce emissions but has only one UK trial with results, although others are in deployment.

- a lack of resources skilled in areas such as data and IT in local authorities, and a general lack of resource per se for anything above the current operational priorities.
- local political pressures such as filling potholes mean an understandable intuitional risk aversion to procuring new technology.
- the way local authorities are often set up and operate can inhibit integration. Parking and traffic management are traditionally separate teams, so deploying smarter parking can mean working with different systems, people and processes.

However, many authorities are recognising that smarter traffic management can make a contribution to three key goals:

- economic growth of a town or city, not just by reducing congestion for commuters and deliveries but also be enabling better parking, more reliable park and ride services, encouraging tourism and reducing costs of work – for example smart parking solutions can save businesses many thousands of pounds. Smarter traffic management has a role in a "smart city" concept but is also fundamental to enabling freight deliveries.
- enabling other activity. Managing traffic well allows road capacity for vehicles to be shared with other road users, such as cyclists and pedestrians. This enables a more attractive city, and healthier travel that for example could reduce the cost of obesity to the NHS. Traffic management can also gibe better priority to buses and using approaches like SPAT ensure that the reliability of the bus is protected.

Other barriers

- Regulations and standards are required for safety – for example of how traffic signals work but also to support procurement and enable interoperability and consistency. The "localism" agenda of previous government meant the centralised role of DfT as a standard setter has diminished. Approaches such as UTMC are technically now becoming aged, but the principles that drive them are still relevant today (open data, interoperability, ease of procurement).
- There is confusion in the market between a cellular approach to connecting to vehicles and a beacon based approach. Cellular offers benefits – notably not requiring roadside beacons – but is not as mature. Beacon based communications may have better performance. This "VHS vs Betamax" means many investors are wary of making decisions now.
- Intelligent Transport Systems (ITS) is a term long used but which does not sell itself well. When ITS works well it simply becomes "better transport".
- The interest in autonomous vehicles and hype about their benefits and timescales mean many people now see congestion as a short-term problem. In fact, various studies show benefits may not occur until a high level of penetration. Managing a mixed fleet of human driven and autonomous vehicles will be a challenge.
- In contrast, our work has shown the value of data from and information to connected vehicles. These can be new highly connected vehicles, or older ones with smartphones and other devices. Whilst not as headline grabbing as autonomous

vehicles, connected vehicles of all types could offer significant benefits in traffic and asset management, being enabled through smartphone and pay as you go insurance devices. Various projects are using this data to manage traffic better or improve traffic control. This is an area where the UK leads and has strong export opportunity.

Mindset change

There is a need to move away from an engineering-led approach to an outcome-driven approach. Many pilot projects are "technology tests" where the user and the services they need are not the focus. With many new systems like SPAT, these require active buy in by users (as opposed to being mandatory like traffic signals). Hence a common way to assess outcomes rather than technology is needed. This will also help with evidence for investment.

The Forum's workplan focuses on creating an environment for investing technology for policy and business outcomes, rather than technology itself.

1. **Network operator collaboration**. Road operators need to work together to develop common requirements, share knowledge and risk, build confidence, promote critical R&D, develop and share skills, and engage collectively with industry chain.
2. **Public sector investment decision-making**. The strategic value and importance of road technology needs to be better reflected in investment appraisals / decisions. This could be overcome by government valuing the benefit of data as it does infrastructure, by smarter procurement across authorities, by easily available evidence of benefits in a common framework and by more of a government focus on connected rather than autonomous vehicles as a source of rapid benefit
3. **Connected and then autonomous vehicles**. There is a key role in promoting wider economic interests and interests of road network managers and policy makers alongside well-established automotive interests. We see connected vehicles as a much more deliverable benefit short and medium term than autonomous ones.
4. **Innovation.** Promotion of new technologies and business models to improve effectiveness and efficiency; and targeted innovation to address key weaknesses.
5. **Procurement.** Improving efficiency, agility and innovation in procurement is a recurrent theme, needing collaboration and better procurer/supplier understanding.
6. **Specifications and standards.** A refreshed UK approach to development and promotion is important in aiding efficiency, promoting innovation and exports.
7. **Exports.** This is currently underdeveloped and a clear understanding of the market is required, followed by a coordinated approach to international opportunity.

Avoiding siloes

Traffic management does not stand alone. Whilst this response focusses on traffic management, our work also sits across the other questions you pose.

Data from vehicles is a key input to both better asset and traffic management. The same devices that detect driving behaviour for insurance can report on traffic queues and detect potholes. Connected vehicles can report on poor road friction, heavy rain, rapid braking and

other impacts that damage assets, so we see better asset management as a key benefit from smarter traffic management.

This is an area currently underexplored as it is not as exciting as self-driving cars, but has huge value to the UK. Our initial estimates show a conservative saving on asset management costs of £300m a year just from data collected for traffic management. There may be far bigger savings but this needs research and deployment outside the core business of many of our members. It is a "Cinderella" area but not as attractive as self-driving vehicles so lacks research funds.

Data from connected vehicles also lend themselves to big data approaches – eg data from vehicles can be used in a big data approach to monitor rain on roads and hence flood risk.

Hence traffic management must not be seen as a technology silo. It is now part of a smarter integrated approach and hence the productivity of existing roads and vehicles. It is fundamental to using data from connected vehicles effectively to support highly autonomous vehicles.

The future

Traffic management will be key to effective and safe transition to automation of vehicles, as a mixed vehicle fleet of human and automated vehicles will be a challenge and take many years to recede. Many presentations showing a road of the future fail to think about pedestrians, cyclists or older vehicles. Managing the evolution of current technology to support new innovation is as important as including disruptive ideas, and is an area where the UK can take a global role for the good both of UK towns and cities and many of our industries and service providers. Industry and government can work together in partnership.

The key is that the data and communications surrounding a road and its users are now as important as the concrete and steel supporting it, and are developing far faster than roads infrastructure ever can.

Contact

The Forum will be pleased to be engaged in future discussions following from this evidence. We have far more material and evidence than 5 pages will allow and would be delighted to add further insight. In the first instance, please contact:

[names redacted]

Appendix: Delivering benefits

The current value to the UK from improved transport as a result of applying technology in the roads environment is about £7.3bn per year as indicated in the table below. This value is derived from the Forum's own analysis based on a review of other published data and evidence gathered over many years of traffic management and new service benefits evaluation.

Most of this current value is derived from well-established infrastructure-based technology such as traffic control, motorway management, incident detection and warning and the use of data from existing connected vehicles. This helps to makes the most of existing infrastructure and vehicles, and without it congestion for example would be much worse. This value can be gained with conventional infrastructure and any new build required and can also be "retro" fitted to existing roads and vehicles.

Adopting further technologies (exploiting ubiquitous data, highly connected vehicles, enhanced communications, Mobility as a Service, etc) gives potential for an additional £6.5bn of value to the UK. This is not dependent on future technologies (such as autonomous vehicles) but can be realised in the immediate and near future if appropriate measures are taken.

Benefits from vehicle automation are not included below, as they are not as well proven as these well understood opportunities shown below. However, it is likely they could offer a further level of gain if delivered in co-operation with road operators. Also, the average age of a UK vehicle is around 7- 8 years, and with 38 million UK vehicles and less than 2 million new vehicles a year, it will take a long time to move to the levels of penetration needed to gain significant benefits.[1]

UK roads - benefit from technology spend		Value to UK (£bn per year)	
		Now	Additional potential
Productivity gains	Reduced congestion	2.0	0.2
	Improved economic capacity of UK cities and towns	2.5	2.5
Cost savings	Reduced cost of travel	1.2	2.5
	Reduced asset management costs	0.0	0.3
Non-financial gains	Improved safety	0.8	0.2
	Reduced emissions	0.8	0.8
TOTAL UK BENEFIT FROM IMPROVED TRANSPORT		**7.3**	**6.5**
UK trade	Exports	0.1	4.7

As well as providing excellent value for money for the UK as a business, investment in road transport technology also provides a strong platform for exports. The UK is a great showcase for reducing congestion and improving safety on roads networks. UK industry led the world in roads technology in the 1970s and 80s, but stagnation in the home market and active competition reduced this lead.

So, the value to UK businesses of exports is underdeveloped - probably no more than 25% of the size of the UK market, around £0.1bn per year. If UK businesses were to capture just 5% of the world network management market, estimated at £94bn per year by 2025[2], this would be worth £4.7bn per year.

[1] Atkins study for DfT on Capacity Impacts of CAVS, January 2017
[2] Intelligent Mobility Market Breakdown - Transport Systems Catapult

Productivity gains

- **Congestion management.** A wide range of estimates put the annual cost of road congestion in the UK conservatively at £10bn or more. Hence technology is to date heavily focused on congestion reduction, but there remain opportunities to increase effectiveness and reduce costs through, for example, using new data sources and improved responses to travel disruption.

  To date, productivity gains have focused on increasing capacity of roads to makes our cities and towns more usable (urban traffic control, parking management, etc). In the future, improved productivity will relate more to managing and influencing demand to gain more efficient and effective overall use of available national infrastructure capacity.

- **Cities and major towns** contribute disproportionately to the UK's £1.8tn GDP. Unlike the geographically limited impact of nearly all transport infrastructure schemes, applying technology to road transport increases the ability and capacity of <u>every</u> UK city and major town to support more economic activity, deal with population growth and mitigate new travel demands.

  It increases the economic capacity of the UK with little or no infrastructure cost. This wider economic benefit is additional to the above congestion savings.

Cost savings

- The overall **cost of UK road travel** is over £100bn per year so even a small proportional reduction is of considerable value. Variable signing, parking guidance and satnavs already improve routeing, and bus priority enhances the efficiency of movement in people terms. However, optimising travel still has significant potential, for example, to improve fuel economy through reducing stop-start driving, to ensure fewer missed connections to other modes and to better connect freight and network management systems to improve delivery vehicle utilisation and efficiency.

- **Asset management costs.** The UK spends between £2bn and £3bn per year maintaining and renewing road infrastructure. In addition, there is a backlog of maintenance valued at up to £10bn. Routine asset management costs need to be reduced – Highways England, for example, aspires to cut these by 30-50% over time. Much of this improvement will come from improved materials and practice, but technology also has a significant role in making infrastructure more sustainable.

  Improved sensing (both within the infrastructure itself and from other sources including satellites, vehicles' own in built sensors, and retrofittable devices) can enable focussed targeting of interventions. Traffic management and control strategies can reduce also stress on the asset and improve asset life (eg reducing stops at traffic signals reduces road wear.

Non-financial gains

- Significant **safety** benefits are delivered by current technology applications. Traffic control, driver advice and enforcement significantly reduce collisions and their severity, so Britain now has some of the safest roads in Europe. There is particular benefit from technology applied for vulnerable road users such as cyclist detection and warning for HGVs.

But there remains scope for new applications of technology - for example to reduce driver error, to incentivise behaviours through insurance, to better understand accident causality and to respond more quickly to rural accidents.

- **Emissions** are the forgotten problem in road transport. Unlike a road accident, people are not killed suddenly and so they do not grab headlines, but current work suggests at least 29,000 people are killed in the UK from particulates every year. Of these deaths, around 25% can be attributed to transport - around 7,000 deaths per year.

  Existing traffic control techniques reduce harmful emissions by smoothing traffic, reducing damaging stop/start driving and encouraging efficient routeing. There is considerable potential for improved technology to go beyond this, eg to monitor emissions more effectively, implement smarter parking that reduces circulating traffic and aid uptake of electric vehicles.

Further benefits come from:

- Making the most of existing physical infrastructure, for example increasing the capacity of traffic signals using new data from vehicles and new control approaches and by smart motorways maximizing lane use, and hence reducing new infrastructure investment;
- Optimising the design of new planned infrastructure, for example by using mobile phone data to understand demands on the road network; and
- Future proofing new build, for example by incorporating features for automated vehicles.

The speed of technology means new ideas will develop and be deployed (and even die out) in the timescales for planning physical infrastructure. Apps on smartphones and social media have developed in the planning lifetime of many as yet unbuilt roads. New phones turn over every 18 months, vehicles every 5-8 years but road design life is 30 plus. Hence technology delivered benefits can be flexible to change in policy, the economy and market forces in a way that infrastructure cannot.

Further detailed appendices to be added following discussions with the NIC team.

Turner & Townsend

Report

National Infrastructure Commission- New Technology Study

Second call for evidence

- **Turner and Townsend response**

1 BETTER ASSET MANAGEMENT

1.1 What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

1.1.1 PROBLEM

Good asset management requires strong asset information and the challenge we face in the UK is two-fold:

- A lack of common standards which encourage stakeholders to capture and analyse data in a repeatable manner;
- Limited appreciation of the potential and value of rich data among stakeholders.

These are barriers to data collection, sharing, analysis, transferable learning and optimal asset management. In the context of national infrastructure assets – and on the accepted basis that approximately 80% of the whole life cost in an asset is in operation and maintenance – the lost value from fragmented and inconsistent data is likely to be on a scale that has a material impact on both public finances and the economy as a whole.

1.1.2 SOLUTION

Government should either mandate a British or International Standard or facilitate an industry SSO (Standard Setting Organisation) which encourages technology solutions which are more effective at sharing data. For example, a common GIS and whole system approach to modelling a city so that all parties can offer up their asset information to enable each other to make optimal decisions. The move towards BIM Level 3 and Digital Built Britain is an opportunity in the context of this bigger picture. An appropriate standard will also factor in research into relevant new technologies and examine the development of new skills and processes.

1.1.3 EVIDENCE

History is full of examples where common platforms and standards have driven not just industrial but economic progress: think of W3C and the web's development of HTTP, HTML and URLs; more recently the role of SSOs in the development of mobile technologies. One SSO, known as 3GPP, was responsible for a common technology approach to both 3G and 4G networks despite the presence of many powerful, competing technology vendors. In this context, there are also lessons to be learned from initiatives like ORBIS in the rail industry which aims to drive value from rail asset data.

This is not about Government investing in technology, but in setting and mandating the standard.

1.2 What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

The immediate priorities should be fit for purpose data and the Digital Twin concept. These should allow organisations to share quality data which supports optimal decision-making and deliver technologies which enable organisations to collate as much data as possible from within their own activities.

This should go hand-in-hand with encouraging organisations to use high quality data as the basis for advanced modelling and analytics to ensure we make balanced decisions across asset portfolios.

It is critically important to make clear that better asset management will come from a combination of not just new technologies and data, but also improving organisational capability (through process re-engineering, data engineering and improved analytics skills/capacity). Focusing on culture and behaviours also plays a critical part in driving adoption of new ways of working so that the new tools and data are adopted. These are the factors that will collectively drive better asset decision-making.

1.3 What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets and how can these be addressed?

1.3.1 PROBLEM

Besides the lack of common standards referred to above, we also have to consider the impact of contractual boundaries and relationships between asset owners, asset managers and asset stewards: without appropriate contractual arrangements, the necessary data will not pass across boundaries. We are aware of prominent instances in which asset registers for large estates have been lost because there was no provision in the facilities management contract for them to be retained by the asset owner on termination. It may also be that an owner is unaware of the condition of their asset base as the steward does not see condition information as part of their responsibility.

This is also a cultural issue within some organisations which does not place individual or collective emphasis on the value of collecting, analysing and learning from data.

1.3.2 SOLUTION

Besides the mandating of common standards, there has to be a drive to place a value on data related to national infrastructure assets; one that is identified at an appropriate contractual level. This is likely to incentivise the prioritisation of data capture, storage, curation, management, analysis and accessibility to agreed standards. In turn, this should also encourage a view within organisations that collecting rich data and taking ownership of it is a fundamental professional responsibility.

1.3.3 EVIDENCE

The UK Fintech and Proptech sectors provide powerful examples of sectors built on the capture, analysis and deployment of data to drive the development of valuable products. For example, earlier this year, the ISO announced a new technical advisory group intended to drive common data and technology standards across the Fintech sector globally, supporting growth and regulatory compliance.

1.4 What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of digital twins?

1.4.1 PROBLEM

Despite advances like Network Rail's ORBIS programme, we generally lack data which enables us to understand infrastructure assets at a granular level. We think of asset data broken down into the what, where, condition, utilisation, work, cost, schedule, performance and capability. Information is fragmented,

often incomplete and inconsistent (particularly when it comes to underground assets in the water sector). Asset data is often difficult to capture and not maintained.

1.4.2 SOLUTION

A meaningful digital twin would cover the journey from concept to design and construction through to performance, maintenance and degradation, and capture (near) real-time dynamic data (activity / event / operational / process) in the context of the static data (design / as built / as operated). This is, though, a vast undertaking if done in one step. A more pragmatic approach may lie in aggregating and aligning elements of a digital twin that already exist in relevant asset owner / operators. This would, over time, creating a comprehensive model for sharing high quality data among stakeholders by region, by sector, and then nationally. The outcome encourages cross-organisational visibility of assets. Starting with, say, rail and road would be the first in a series of incremental steps towards having in place structures and processes which would eventually support the creation and maintenance of a genuine national digital twin.

Once the 'static' digital twin was created (i.e. what assets are where and how are they connected, plus their capability), it would act as the 'framework' for capturing dynamic data. This would include data from monitoring and diagnostic sensors capturing the utilisation, performance and condition of an asset. Work, schedule and cost data can then be mapped to give a more complete picture. It could be the 'beating heart' of a new approach to optimised performance and control of whole life costs. It is also consistent with a wider vision for Smart Cities where citizen experience is optimised.

1.4.3 EVIDENCE

We have already seen the benefits of digital technologies like BIM, which has yielded some significant cost savings across the industry (£840m identified in 2013/14). While 3D BIM essentially captures a moment in time, a digital twin could be a dynamic model which unlocks significant performance improvements and whole-life operational cost savings.

1.5 How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

1.5.1 PROBLEM

Whilst innovation does take place in the infrastructure space, there are differing levels of innovation 'maturity' across sectors and businesses. Much of it also takes place in silos, carrying the risk that it may not be transferable or generates a solution already found elsewhere. Innovation is also seen as a high-risk activity and valuable Intellectual Property is less likely to be shared.

1.5.2 SOLUTION

Government needs to both recognise and incentivise innovation in procurement and across the supply chain, where tiers 2 & 3 need to be seen as part of the operational innovation chain. Innovation should be rewarded and celebrated, while standards bodies can enable and even mandate sharing of innovation in learning, process and product.

1.5.3 EVIDENCE

Government has already recognised the value of innovation in infrastructure through Innovate UK's innovation in infrastructure systems rounds at a critical services level - https://www.gov.uk/government/publications/funding-competition-innovation-in-infrastructure-systems-round-2/competition-guidance-innovation-in-infrastructure-systems-round-2 . We would suggest another round with a specific focus on the development of collaborative systems and processes likely to bring infrastructure innovation to market more rapidly.

2 SMART TRAFFIC MANAGEMENT

2.1 What are the latest developments in intelligent traffic systems and what technologies underpin them?

2.1.1 PROBLEM

Intelligent Traffic Systems (ITS) should be seen as an operational rather than purely technological tool. These systems will be more likely to achieve their full potential if they are also informed by commercial, creative UX and data analytics expertise applied across a whole multi-modal network. There is also a temptation to develop proprietary standards specific to the transport sector whereas there is actually a great deal of benefit from aligning with mainstream technology and adopting an open, collaborative and standards based approach.

2.1.2 SOLUTION

'Deep Learning' is one machine learning (ML) technique that has found application in traffic management. It uses multi-layered neural networks which can be applied to live video data. They can be trained to recognise different objects, flows and speeds (pedestrians, cyclists, types of vehicles etc) in a live location video feed. This real-time view of road utilisation can be used to optimise traffic management (e.g. traffic light phasing or even as open data to improve satellite navigation systems performance). Access to this data also feeds into improved city planning and design.

While ML opens up the opportunity to alter traffic light phases, improve flows and mitigate congestion, the bigger opportunities are its use in dynamic multi-modal routing and access to accurate (anonymised) origin-destination data from smartphones or autonomous vehicles. This has the potential to significantly improve performance at the multi-modal network level.

Collaboration between network planners, ML tracking systems, mobile networks and mapping providers could generate live data which can be deployed to:

a) dynamically inform and manage end-to-end journeys at network and user level;

b) inform the design and development of smart networks through data analytics.

Logically, such a system would interact with individual mobiles (as location beacons), potentially generating information on point of origin, in-vehicle, during car parking (where sensor-driven lighting can identify empty spaces), and cross-modally.

These systems should be seen from the citizen perspective, where the most successful mobile technology adoption rates have been driven by 'low friction' user convenience.

2.1.3 EVIDENCE

Evidence of potential is provided by a Vivacity Labs trial at London Bridge Underground Station, where these cameras are being used to optimise pedestrian flows during construction works: https://dftdigital.blog.gov.uk/2017/01/17/station-to-station-passenger-information-trials-at-london-bridge/ . This start-up firm has also been working with TfL to explore the opportunity to optimise traffic light phasing: https://www.standard.co.uk/news/london/london-in-frame-for-traffic-lights-that-prioritise-cyclists-and-buses-says-schemes-boss-a3540021.html Highways England has also engaged in collaborations with mapping technology providers like TomTom and Garmin. In this context, we should also note the steady growth of in-vehicle technologies which are centred on smartphone apps rather than separate devices and of course the potential for autonomous vehicles to provide a wealth of data to support optimal infrastructure operations and asset management.

2.2 What barriers do Local Authorities face in deploying these systems, and how could these be overcome?

2.2.1 PROBLEM

Systems are likely to deliver more effectively if they are allowed to operate across highway organisational boundaries. For example, Highways England is following an efficiency model predicated on journey time

speed & reliability. But it is responsible for only a small (albeit high volume) proportion of the network, and achieving Highways England targets in isolation has implications for traffic flows downstream on major or local road networks managed separately by other authorities**.** It makes no sense for multiple authorities to 'reinvent the wheel' in terms of traffic management and smaller Local Authorities do not have the capacity to do so. Indeed, many face difficulties recruiting technical specialists, who find private sector careers more attractive. Public sector resource constraints also mean that capital cost has become a barrier to adoption of existing technologies, such as SCOOT adaptive traffic control systems.

2.2.2 SOLUTION

In the current financial environment, innovation is most likely to be driven by private sector smartphone journey apps for volume end-users. There is therefore a need to examine how these solutions could be integrated with, or contribute to, network-level intelligent traffic management. This requires intervention at ORR or DfT level. Such shared or integrated data and technology solutions could enable cross-network improvement. Mechanisms to share strategic advice/strategic models with smaller Local Authorities might mitigate limited resource/capacity. We should consider making data available to community developers, such as the TfL REST API, even crowd-source solutions.

We must also continue nudging people into behaviours likely to mitigate congestion by making alternative modes more visible, attractive and accessible. Rich data insights into public attitudes, such as that available from the annual National Highways and Transport (NHT) Survey - http://www.nhtnetwork.org/nht-public-satisfaction-survey/findings/ - should inform this approach.

All stakeholders in the traffic management space need educating to consider data as a valuable asset which is critical to the performance and enhancement of infrastructure. Stakeholders also need to consider the skills requirements of a sector in which the expertise of data and decision scientists, modellers and UX designers should play an increasingly prominent part.

2.2.3 EVIDENCE

The integration of smartphone journey solutions into vehicles and transport provision continues apace. Highways England has engaged with providers like TomTom, Garmin etc, to make its data available to them in an attempt to drive journey time improvement. Sharing information with LA highway authorities about potential increases in traffic volumes/flows downstream would help them to develop more effective strategies/budgets.

3 WATER EFFICIENCY

3.1 In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

3.1.1 PROBLEM

Rising consumer demand, climate change and regulatory pressures are making resilient water supply an ongoing challenge for an industry with ageing infrastructure which yields limited performance data. Adding to the complexity is a shift towards a TOTEX costing model. Some water companies face greater demand than others, while physical geography and network shape also pose differing challenges for system integrity. All of these factors can impact on leakage performance.

3.1.2 SOLUTION

A raft of practical and technological innovations could drive change here:

- Introduce a legal obligation on pipe manufacturers and installers to include a metal element on new/replacement pipes which would make them easier to detect;

- Introduce smart networks with snap-shut valves driven by sensor networks in District Metering Areas. These valves can be driven by solar power or flow-drive dynamos and would be connected to SCADA control and data systems;
- Drones are already in use, for example, in the Anglian Water area, using thermal imaging cameras to identify leaks on low-lying farmland;
- In-pipe sensors monitoring flows and feeding back data via wifi and NFC connectivity.

There should be a comprehensive examination of these and other technologies in terms of the contribution they can make to improved asset performance, data capture, regulatory gain etc – generating data which can feed back into the creation of an Intelligent Water Network which leverages the Internet of Things to enable dynamic management and fast leak response.

The oil and gas industry already make extensive use of Real Time Systems (RTS) to monitor performance but this is built on the foundations of a high value and hazardous commodity. RTS may be viable only for problem catchments in the water industry and its potential needs to be understood in the context of the shift to a TOTEX model. Nevertheless, the potential to use RTS to generate data and isolate and reroute supply when leaks occur should be explored. The need to link water supply zones to enable rerouting where there are linear 'single course' networks has been highlighted by the Consumer Council for Water in a National Infrastructure Commission submission consultation earlier this year - https://www.ccwater.org.uk/wp-content/uploads/2013/12/National-Infrastructure-Assessment-Call-for-Evidence-February-2017.pdf

While the industry is good at recording information it is less effective at using it to inform future investment or building maps and profiles of performance and failure that could inform proactive day-to-day asset management. The move towards a TOTEX environment should drive improvement here, but a framework is required for data handling.

3.1.3 EVIDENCE

The UKWIR initiative - https://www.ukwir.org/ - dates back to 1993 and now needs further support and development. It encourages effective delivery of innovation by sharing investment and management of research. Making projects and results more visible would encourage progress. One focus might be on developing sensor and instrumentation technologies robust enough to operate in the wastewater treatment process – a harsh environment unsuitable for sensitive precision instruments. It should also be aware of the research related to Robotic Autonomous Systems and 'swarm sensing' being carried out by the Twenty65 universities research consortium, which has particular relevance to water system integrity - https://twenty65.ac.uk/research-themes/robotic-autonomous-systems-for-water-infrastructure-inspection-and-rehabilitation . There is also value in studying the way water systems are managed and operated elsewhere in the world (the leakage performance of Tokyo's Bureau of Waterworks is a notable example - http://www.c40.org/case_studies/tokyo-world-leader-in-stopping-water-leakage).

3.2 Do you feel that a national and compulsory roll-out of smart meters would have a positive or negative impact in driving and delivering water efficiency and resilience within the water sector and why?

3.2.1 PROBLEM

Though the industry needs to reduce consumption, the evidence from Waterwise (*June 2017 Water Efficiency Strategy* http://www.waterwise.org.uk/data/resources/67/Waterwise-UK-Water-Efficiency-Strategy-full-report.pdf) suggests a lack of capacity among water companies to drive behavioural change among consumers, and a lack of awareness among those consumers about how to reduce consumption. Installing smart meters in isolation is therefore unlikely to deliver an optimum result unless accompanied by other strategies to reduce consumption. There is also related evidence that some consumers are resistant to the whole concept of smart meters (*research by Cambridge University into energy smart meter perceptions suggested 22% of consumers would not want their usage recorded. It's reasonable to infer they may have the same attitude towards water*).

3.2.2 SOLUTION

Smart meters hold significant potential to encourage consumers to consider the relationship between consumption and cost and adopt strategies to reduce both. Meters with simple IHDs, potentially linked to smartphone/tablet apps delivering advice and information (similar to South West Water's iPad app - https://itunes.apple.com/gb/app/south-west-water/id501170486?mt=8), are more likely to do this. But their installation should be accompanied by a drive to raise knowledge and skills within water companies about behavioural change, a campaign to increase awareness among consumers, and a programme to install devices which will help reduce consumption – a scrappage scheme for older white goods & large-volume cisterns; free water-saving nozzles for taps and showers; home water mass balance; free water butts (which may collectively reduce flooding); different tariffs.

3.2.3 EVIDENCE

As Waterwise has noted, there are lessons to be learned from the work carried out by the International Water Association on ranking the top 50 cities for water efficiency, and from examining water efficiency best practice in countries such as Spain, Denmark and Singapore.

4 BIG DATA

4.1 What governance arrangements are needed to a) manage the huge amounts of data being generated and used in the infrastructure industry, and b) encourage the effective deployment of data-based technologies in the infrastructure industry (eg., need for agreed APIs)?

4.1.1 PROBLEM

While the industry generates huge amounts of data, quality can be low, semi-structured and confined to silos. It is hindered by contractual boundaries, limited cultural appreciation of its value, and a lack of common standards which support its collection, retention, analysis and availability.

4.1.2 SOLUTION

A huge amount of data is available in the construction sector and with the advance of IoT and BIM, and the increasing instrumentation of the built environment, we are on the cusp of a tidal wave of data.

The solution is to channel it through standards governing its fitness for purpose, APIs aiding visibility and adoption, and contractual arrangements which break down barriers to sharing.

This will work best as a three-pronged people / process / system strategy, supported by governance which identifies data as a tangible asset, defines its value by linking to the actions taken and decisions made, and which therefore requires professional handling and identified responsibility.

As mentioned under Question 1, Government should either mandate a British or International Standard or facilitate a Standard Setting Organisation to drive progress in a common approach to collating and analysing data related to national infrastructure.

4.1.3 EVIDENCE

The retail and manufacturing industries routinely record and deploy data at scale. There are lessons to be learned about the way in which organisation like Amazon use algorithms to leverage the information contained in transaction data warehouses. The financial services industry also went through a significant phase of implementing Data Governance as part of the implementation of its Basel II regulations. GDPR legislation also demands practices often associated with Data Governance. A similar approach could be applied across the whole DfT 'family' of transport organisations and infrastructure providers. DfT is currently undergoing a project as part of the Transport Infrastructure Efficiency Strategy where data is collected and transformed into actionable information which can be used to drive efficiency in transport infrastructure delivery.

4.2 What barriers are there to sharing data a) internally within systems and organisations, and b) externally – for example, through making datasets available to realise indirect value? What can government do to support the secure sharing of data in the infrastructure industry?

4.2.1 PROBLEM

Contractual boundaries, and commercial sensitivities about cost data and Intellectual Property hinder the sharing of data in the infrastructure industry. Difficulties in translating data across project phases, participants and functions is also a barrier to systems integration, with differing data structures and purposes.

4.2.2 SOLUTION

Common standards founded on the identified value of data in improving asset performance, and contractual arrangements which emphasise collaborative responsibility across supply chains (while providing safeguards for IP), should drive gradual change. As mentioned earlier, opportunities may come from a common GIS / whole system approach towards modelling a city so that all parties can offer up their asset information to enable each other to make optimal decisions; and viewing the move towards BIM Level 3 and Digital Built Britain as an opportunity in the context of this bigger picture.

4.2.3 EVIDENCE

There are examples of collaborative contracts and shared pains, notably London Bridge: a great example of where sharing across the supply chain has enabled more timely reporting. Government's role in all this is to recommend those areas where a sensible approach can liberate data.

4.3 How can a national digital twin help manage infrastructure data as an asset?

4.3.1 PROBLEM

Rich data which gives a comprehensive single view of national infrastructure assets is either absent or not available in a form which enables optimal whole life cost and whole system performance. This is likely to lead to substantially higher whole-life costs and reduced asset performance as well as negative impacts on public finance and the economy as a whole.

4.3.2 SOLUTION

A national digital twin can be a standard for describing assets through rich data which gives a single view. If we apply the Network Rail ORBIS (Offering Better Rail Information Services) approach to all infrastructure, it is about creating a database of information about the assets as a whole system, so you understand how different assets link together, how they operate and a wealth of other data: what, where, condition, utilisation, capability, performance, work, cost and schedule.

This is also a question of analytics and action – we need to build skills, awareness, and processes around this capability to enable it to achieve its potential. For example, you may be aware that a section of rail track has cracked and needs replacing, but have you got information about the condition of sections nearby in case it makes economic sense to replace them at the same time?

Even social media is relevant to this equation: for example, a dynamic system should identify Twitter posts about user experience and faults. This helps layer up third-party data to make predictive action and maintenance more responsive. Best practice links asset management with operations and citizen experience.

4.3.3 EVIDENCE

A national digital twin can provide richer insight into end-to-end planning, strategy, construction and operation of infrastructure in this country as a whole system. It can drive better decisions, massive productivity benefits, total cost of ownership, safety and citizen experience. It requires concerted effort,

significant investment and a large-scale business change programme. There have to be common and agreed protocols for collection and maintenance, standards for sharing, privacy safeguards, but a default assumption that data is open (or at least shared).

Several infrastructure owner / operators have parts of this digital twin already (e.g. Network Rail, Highways England). Their use is already demonstrating significant value within those organisations. Work is needed to aggregate and align them into a digital twin as well as put in place the platform and processes to maintain, improve and provide access to the data.

5 ENDS

From: [name and email redacted]
Sent: 09 August 2017 23:04
To: Technology Evidence <TechnologyEvidence@nic.gsi.gov.uk>
Cc: [name and email redacted]
Subject: NIC new technology study call for evidence

Colleagues

I have completed the survey as [name redacted] proposed. I am now taking up your invitation to comment further on the issues that arise in maintenance and use of national infrastructure. My expertise is in the area of transport, so my comments stem for that area though might well apply in varying measure to other areas of your concern.

The transport system consists largely of public infrastructure – roads, railway networks, public transport systems. This is used by individual members of the public to further their interests and pursue their lives through livelihood, living requirements and leisure. But it is increasingly used by private concerns for their commercial benefit – more or less directly. We understand that taxi operators and even privatised public transport operators have been doing this for a long time. But more recently, private operations such as Uber have become appreciable users of the public networks in terms of vehicle-km of travel for this commercial benefit. This has impacted others through road congestion, which is an externality that their operations impose on others without either charge or recompense to those affected. This seems an established current practice where use of technological advances in convenient pairing of travellers with drivers and their vehicles has led to use of public infrastructure that is detrimental to other members of the public. I believe that the advent of services such as this and these effects were not foreseen and are now subject to investigation and the possibility responsive action.

An increasing concern that I wish to express here is the prospect of autonomous vehicles operating on public road networks. These vehicles could, depending on their operation, regulation and deployment, lead to substantial changes in the travel behaviour and consequent patterns of members of the public. But this usage will impact on the operation of our transport systems which are based on public infrastructure including the road networks. Manufacturers of autonomous vehicles have a principal interest in sales of their vehicles to individual users. The satisfactory operation of the road networks when populated even partially by autonomous vehicles therefore remains a matter of public concern. The opportunities to manage this road networks under this prospective mode of operation seem to fall to regulation, and in short the requirements on the design of autonomous vehicles and their operation on the road. This might include requirements on interactions with other road users – from pedestrians, cyclists and other unprotected road users to other autonomous vehicles. There might also be requirements for cooperative usage, including sharing of data on current disposition, actions (such as braking, acceleration and turning) and intentions such as destination and calling points. This cooperation could include among vehicles using the road and between these individual vehicles and the management systems such as signal control. Although this cooperation could, if managed effectively, lead to efficiencies in road usage in the sense of increased capacity for vehicle-km of travel, that will not necessarily happen without appropriate design and requirement. On the other hand, decreased average occupancy of road vehicles arising from transfers from high occupancy mass public transport (buses, trams, trains) to autonomous vehicles, and even zero-occupancy autonomous vehicle-km could lead to decreased person-carrying capacity of road

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Yours faithfully

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Centre for Transport Studies
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NIC Case Study: Smart Traffic Management

Response by [redacted] Centre for Transport Studies, University College London

State of the art urban traffic management in the UK takes the form of traffic signals coordinated using SCOOT, which automatically adjusts signal timing to adapt to traffic conditions, using data from traffic sensors. Transport for London plans to further develop its system to improve incident management and coordination of road works, and to develop predictive capability in order to smooth traffic flow over a greater geographic area.[1]

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Surveys of road users, as well as feedback from commercial road operators, indicate that the main concern arising from road traffic congestion is the uncertainty of journey time, rather than the longer duration of the trip. Accordingly, utilising digital technologies to provide good predictive journey time information at the outset of the trip is very likely the most cost-effective means of tackling the detriments arising from congestion.

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A similar source of route guidance is Waze, which was acquired by Google in 2013. Waze uses crowd-source data, collecting map data, travel times and traffic conditions from signed-up users. Waze also offers a car-pool option to allow sharing with other users.

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The efficacy of these systems depends on the response of road users to information provided, which needs further research. Regular users may prefer only information about incidents and other unusual events, while infrequent users may prefer route guidance. Driver diversion rates in response to information received is likely to depend on a number of factors, including the driver familiarity with the network, trip purpose, expected delay, the nature of information received and driver confidence in the system. In practice, about a quarter of users of the Strategic Road Network in 2016 employed digital navigation, but very few re-routed once they set out.[10] The economic case for investment in such digital technologies depends on quantification of user benefits, for which some approaches have been developed.[11]

Conclusion

The main problem for surface transport is road traffic congestion. Increasing road capacity is no answer: it is undesirable within urban areas, and futile beyond, in that traffic grows to fill the available carriageway, as we know from experience and understand in theory. Hence costly investment in new civil engineering infrastructure is unlikely in general to offer value for money, as a means of tackling congestion.

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1 September 2017

From: [name and email redacted]
Sent: 09 August 2017 23:04
To: Technology Evidence <TechnologyEvidence@nic.gsi.gov.uk>
Cc: [name and email redacted]
Subject: NIC new technology study call for evidence

Colleagues

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1 September 2017

National Infrastructure Commission Call for Evidence
New Technology Study
United Utilities' Response

We welcome this study on the potential application of new technologies which use data to optimise the operation and maintenance of infrastructure systems. We consider that there is scope for innovation to deliver future improvements in efficiency and service performance.

We have responded below on the questions relevant to the water industry.

BETTER ASSET MANAGEMENT

Q1. What initiatives are currently underway to collate and analyse data on infrastructure assets? How can these initiatives be joined up and supported by Government?

UK Water Industry Research (UKWIR) has developed a National Sewer and Water Mains Failure Database that will enable its subscribers to compare and analyse sewer failure and water mains failure data with anonymised data from other participating companies.

UKWIR has also carried out a number of projects involving collection and analysis of data on infrastructure assets, most recently a project on "Long-term Investment in Infrastructure". The primary objective of this project was to assemble a body of evidence to determine whether an increase in rates of renewal and/or rehabilitation in water and wastewater infrastructure might be needed for long-term stability. This was intended to provide a basis for an informed discussion around the options for long-term investment.

Government and regulatory support and involvement in such UKWIR studies will encourage further work in this area.

Q2. What should be the immediate technology priorities to support asset optimisation and better targeted maintenance across the infrastructure sectors (transport, water, energy, digital, waste and flood defence)?

Further development of databases to share information could be beneficial. When projecting future asset investment there is considerable uncertainty in forecast failure frequency, due to the very small number of failures recorded for certain asset types. Sharing of these to create a larger data set would improve reliability modelling considerably.

Q3. What are the barriers to rolling out new technologies to collate, analyse and utilise data on infrastructure assets, and how can these be addressed?

The regulatory framework needs to encourage innovation with long-term benefits, rather than focus on the current regulatory period. This can be done for the water industry through use of outcome delivery incentives with rewards for delivering long-term benefits.

Q4. What are your thoughts on the capability of a national digital twin? What are the first steps to developing regional, sectoral or national digital twins? What would be the main uses of such digital twins?

We welcome consideration of whether there are potential benefits of this area. There may be limited benefit from a national approach in the water industry, given limited network connectivity.

A first step would be common specifications. In the water industry, the creation of the non-household retail market revealed that companies were using different definitions for standard terms, such as the definition of "a premise".

Q5. How can Government, infrastructure providers, researchers and SMEs work together to leverage rapid innovation occurring in this space?

UK Water Industry Research could be used to enable all stakeholders to work together in this area.

WATER EFFICIENCY

Q8. In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

There is potential scope for reducing the Economic Level of Leakage (ELL) by using new technology to find leaks more quickly. (It is finding leaks more quickly, rather than repairing more leaks, which could bring the ELL down). Collecting and analysing real-time data on flows and pressure within the network could pinpoint leakages more quickly. A leak could be identified and located accurately as soon as it breaks out and repaired promptly. Also, artificial intelligence could be used to adjust pressure flows in response to demand changes (pressure management can also bring leakage down).

These technologies require significant investment in additional infrastructure and IT systems. Approaches using current leak sounding techniques are currently the most cost-effective method of leak detection. However, water companies are already exploring these new techniques. As these technologies become cheaper the economics of leakage could significantly change.

These approaches will become more economic over time, but there is an issue about whether more could be done to encourage early adoption. For an individual company, innovation may be uneconomic because:

- Justifying investment may require a financial return beyond the current regulatory 5-year period, and it may be unclear whether the regulatory framework will provide for continuing returns.
- Benefits may be achieved nationally from innovation, which an individual company will not take into account.

This may suggest that there could be national initiatives to develop new approaches, or that regulatory incentives could be strengthened to encourage innovation with long-term benefits.

Q9. Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

Increased smart metering could maximise the potential for demand management. Better insight into customer consumption patterns would enable smarter, more appropriate targeting of water efficiency campaigns. It would also allow for better quantification of the actual savings achieved and more robust cost-benefit analyses. Having more metered data will allow us to develop new, more

attractive tariffs for customers that will enable them to financially benefit from wiser water consumption and be more conscious of their water usage.

An increase in customer meter penetration will also help in leakage management activities. As leakage is not directly measured, its accuracy depends on the accuracy of the components used in the leakage calculation, of which consumption is one of the key ones. Improving accuracy and frequency of consumption data will enable companies to calculate and target leakage more effectively.

However, the benefits may not be sufficient to justify the costs because:

- The relatively low cost of water, compared with energy, diminishes the incentive on customers to monitor their consumption. It is clear that installation of a meter leads to a reduction in water use but the additional benefit from smart metering may be relatively small.
- There is a high cost for smart meter installation.

Therefore the costs and benefits need to be carefully assessed, and the experience from energy smart meter installation taken into account.

It may be that smart metering should be targeted on areas where there is the greatest imbalance between future demand and supply is highest, and incremental costs are high, rather than applying a national policy.

BIG DATA

Q10. What governance arrangements are needed to a) manage the huge amount of data being generated and used in the infrastructure industry and b) encourage the effective deployment of data-based technologies in the infrastructure industry (e.g. need for agreed APIs)?

Governance involves developing the standard specifications and then monitoring compliance. Once that is in place agreed APIs can be developed.

One issue that needs to be addressed is the need to buy address sets and “blocks” of location-based information for a company’s operational area. So often data is paid for that will never be used. An alternative approach would be for government to provide a data portal where companies could access just the information they need via an API.

Q11. What barriers are there to sharing data a) internally within systems and organisations and b) externally (e.g. through making data sets open to realise indirect value)? What can the government do to support the secure sharing of data in the infrastructure industry?

Common specifications are needed, and a secure portal.

There is some conflict between the potential benefits from sharing of data and the regulatory comparative competition framework, which means that companies may see some benefits from retaining their own data and analysis. They may then be able to demonstrate better understanding and analysis, and therefore a better case for future investment. A clear government and regulatory direction would be needed on this.

Q12. How can a national digital twin help to manage infrastructure data as an asset?

In the water industry, there may be limited value from a national digital twin of individual assets. This is because there is currently very little connectivity between company networks. So performance information on a specific asset has very little value outside the company that owns and operates it. More useful would be data on specific asset types (*e.g. Ultraviolet Disinfection Units, Masonry Arch Bridge, etc.*). Sharing of this data would provide a larger data set for more accurate forecasting and could be shared across industries.

NIC CALL FOR EVIDENCE – VIVACITY LABS

HOW CAN THE DEPLOYMENT OF INTELLIGENT TRAFFIC SYSTEMS HELP TO OPTIMISE THE ROAD NETWORK?

1. INTRODUCTION

Vivacity Labs was founded in December 2015, and specialises in the use of Machine Learning (ML) and Artificial Intelligence (AI) to solve transport problems. The concept of a Smart City or Smart Road Network had been around for many years, but incumbent sensor technologies are too expensive to deploy at a wide scale, and cannot generate sufficiently detailed data to be used in reactive and proactive network control.

The first problem Vivacity set out to solve was rectifying this lack of detailed hyperlocal data. We developed a low-cost camera device, which uses ML to recognise, classify and track different road users (including cars, vans, HGVs, buses & vulnerable road users such as pedestrians and cyclists) within the field of view. Our core concept is that the amount of detail captured by a camera cannot be matched on cost by any other method. The challenge is extracting this data from the video captured – which is where recent advances in Machine Learning & mobile compute capabilities allow results which were unthinkable 5 years ago.

Beyond this, we are using ML on the data sets we are generating to predict the location of vehicles at junctions in the coming seconds, traffic volumes and travel times in the coming minutes, and also begin to develop interfaces with control systems. Our ultimate goal is to allow AI to optimise the road network.

2. MACHINE LEARNING IN SMART CITIES

Key findings of a literature review we have been carrying out on the use of Machine Learning in Smart Cities:

Research has consistently sought the ability to predict traffic accurately, robustly, and adaptively, but the complex nature of road systems is poorly suited to using deterministic models for real-time purposes. Traditional statistics-based models have been widely used for several decades, with ARIMA-based models providing acceptable performance. However, such approaches are less able to capture the spatial nature of road systems, or the impact of external events such as traffic accidents, weather variations, and road works. Further, the traditional reliance on induction-loop sensors has hampered smart city efforts due to a general lack of spatial granularity, and the incomplete description they provide about traffic conditions.

A significant shift has occurred over the past 10 years towards Machine Learning, fuelled by the increasing volume of data available from connected devices, decreasing costs of computational power, and a maturing research and practitioner community in this space. A wide range of Machine Learning model types and problem formulations have been experimented with in both urban and motorway networks for traffic prediction. A general consensus has emerged over the past 5 years that deep recurrent neural networks using long short-term memory (LSTM) cells offer a significant improvement over the prior state of the art. Much research has explored derivatives of these models, by including external data such as weather or social media sentiment, or by assembling LSTM models with others to produce a 'best of both' hybrid, or by using convolutional networks to capture the spatial nature of traffic systems. This work has paved the way for intelligent traffic systems which can leverage more complete, accurate, and reliable data about the future.

3. VIVACITY'S TECHNOLOGY

In April 2017, Vivacity won an Innovate UK First of a Kind contract to deploy the world's first "city-wide smart sensor network" in Milton Keynes, deploying 450 road sensors covering 900 carriage ways across 150 junctions in the city, and a further c.1,800 car parking sensors to cover the city's 13,000 parking spaces. Once fully deployed in March 2018, this network will provide a more detailed dataset on how a city's road networks are

being used than has ever been available before. Using this dataset, we are developing predictive algorithms, again using Machine Learning techniques, which will predict junction busy-ness levels and travel times across every possible route in the city at predicted arrival times – not just based on current traffic levels.

Beyond this, Vivacity have started investigating how to use data from our sensors to communicate directly with traffic signals and Connected and Autonomous Vehicles (CAVs). In both these areas, we are aiming to disrupt the industry through taking a modern, Machine Learning approach to control, ensuring any system is fully adaptive to changing demands without need for human input. We expect to have market ready products in these two areas over the next three years. Our efforts are now backed by a combination of VC investment and a strategic investment from Tracsis PLC.

4. OUR EXPERIENCE SO FAR: POSITIVE ASPECTS

Innovate UK have been an essential part of Vivacity's technological development and growth. During the first 12 months of the company, we delivered a SMART Grant funded project, during which our first Machine Learning software able to detect cyclists was developed. Their new First of a Kind initiative also addressed a key barrier to entry in infrastructure technology markets – the client fear of being the first mover.

We have had a long relationship with Milton Keynes Council's Innovation Team. They have developed a strategy for the city which recognises the need for smart sensors to help balance the use of their road network in future, and therefore facilitate and support rapid growth in the city. The Innovation Team have always demonstrated the ability to think outside the box, and have facilitated trials to bring our technology to market.

The UK's labour market structure between late 2015 and now has been extremely important in helping new technology companies grow. Access to European Union labour markets, along with London's reputation as a fast-growing, tech-focused and open city has helped us attract 5 of our 20 highly qualified and experienced staff from other EU countries. As Machine Learning is a very new field, and as the likes of Apple, Facebook and Google are doing everything they can to attract and hire anyone with experience in these areas, having access to a market of 500m people has been essential as there is a dire shortage of new recruits.

Vivacity have designed our system with data protection in mind. By extracting anonymous data from a video feed, and then deleting the video at source, no personal data is ever generated. We have been pleased to see recent announcements from the UK Government that they plan to introduce regulation identical to the EU's GDPR for data protection in the UK post Brexit. Having identical regulation between the UK and the EU is important for a small business to ensure that design decisions made in one country will hold true elsewhere. Our ability to export our technology will be substantially impacted if regulation diverges, and thus care needs to be taken to ensure that interpretation of regulations do not diverge over time. This means that decisions made in the European Court of Justice must continue to carry weight in the UK.

5. OUR EXPERIENCES SO FAR: NEGATIVE ASPECTS

FRAMEWORK CONTRACTS

The single biggest road block to our progress in the past 18 months has been the poorly constructed framework contracts for road maintenance, epitomised by our experiences in Milton Keynes. While the Milton Keynes framework contract makes sense for well-understood, commoditised works carried out directly for the Council, Vivacity are also obliged to use the same supplier on a large-scale technology trial, such that we cannot put the works out to the wider market. The results have been disastrous. The contractor knows we cannot fire them, and while the framework contract states hourly rates, it does not force them to work efficiently. As such, costs risk spiralling out of control on a project which is ultimately funded by the taxpayer. Furthermore, the contractor is being incompetent, turning up to works without tools, without keys to gain access to areas of road protected by bollards, or with old equipment which breaks down halfway through the day. This behaviour is a direct result of the contracting method being used between the Council and the Contractor.

text redacted - confidential

7. RECOMMENDATIONS TO REMOVE BARRIERS

We see a number of key areas in which improvements could be made:

1. Encourage the procurement of modular systems, and define framework contracts in such a way that intelligent, innovative elements can be procured separately from the commodity of lights and wires. This will allow new entrants to develop competing intelligent systems, and move away from the situation that occurred after the development of SCOOT, where the algorithms and the control systems were vertically integrated, so one could not be replaced without also replacing the other.
2. Improve the link between national investment in technology, localised trials and the route to market for this technology. Systems are currently disjointed, leading to conflicts between national investment strategies (Innovate UK) and local government procurement. Where central government funding is provided for innovation projects, it should clearly state whether the awarding process has competitively evaluated the suppliers in the award of the funding, and therefore what the expectations are on the role (or lack thereof) of local government procurement in the project.
3. Ban anticompetitive framework contracts from having a monopoly over the deployment of new technology on old infrastructure. If a private company is given long term ownership or control over an asset, there must be mechanisms for this asset to be used, altered, tested, added to in a way which reacts to the emergence of new technology. While the framework holder should be given a say on how these changes may impact their ability to maintain the asset, they should not be given an effective veto over the works, or the irrevocable right to lead works to install the new asset.
4. Design procurement programs for mature intelligent traffic control systems in a way that:
    a. Encourages further investment / development by using paying under a subscription model, rather than a lump sum up front
    b. Allows continued competition, by ensuring new entrants can easily enter the market
    c. Does not encourage high marketing expenditure or generate large tender response costs for suppliers, as these act as a barrier, drive up prices and lead to poor value to the tax payer
    d. Understands that technology takes time to deploy
5. Ensure that regulation is clear, stable, internationally consistent and agnostic of the “intelligent system”. Decide what aspects of the system should be standardised, and which aspects are likely to develop quickly. Some aspects of traffic control should be standardised, such as the meaning of traffic signals (green go, red stop) and the communication protocols between smart infrastructure and connected vehicles. Other aspects should be outcome driven, rather than method driven, such as “ensure vehicles do not crash”, rather than specifying there must not be two simultaneous green lights. To extend this example, consider a road where most vehicles are connected and centrally directed, where there is no need for red lights unless a non-connected vehicle is approaching.
6. Ensure that technology companies can easily access external job markets. At a minimum, Machine Learning needs to be added to the shortage occupancy list. From our experience of getting a Visa for a role on the shortage occupancy list, however, the process is too slow for new companies. Any immigration control system needs to be capable of making a decision in hours (maximum 24), not months. The easiest solution here is to maintain freedom of movement with the Single Market.

www.waterwise.org.uk

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15 September 2017

National Infrastructure Commission
TechnologyEvidence@nic.gsi.gov.uk

Dear Sir or Madam,

Re: National Infrastructure Commission- New Technology Study Second Call for Evidence

Waterwise is pleased to respond to the National Infrastructure Commission's call for evidence on new technology, including water efficiency. Waterwise was founded in 2005 and is the leading authority on water efficiency in the UK and Europe. We are an independent, not for profit organisation, receiving funding from supporters across and beyond the water sector and wider sponsorship and research projects. We like to be at the front, leading and supporting innovative efforts to realise our mission; that water will be used wisely, every day, everywhere.

Water efficiency is a key contributor to resilience, and water companies are currently carrying out large-scale retrofitting and customer engagement programmes. Ofwat and Defra are keen to see greater ambition on water demand management. The Waterwise Water Efficiency Strategy for the UK sets out a range of actions to improve water efficiency in new developments. Waterwise support a national and compulsory rollout of smart metering to provide benefits for customer engagement and water efficiency. We have set out barriers to new technologies as well as a range of new technologies identified by Waterwise and in research internationally.

Attached are our detailed responses to your evidence questions and we would welcome the opportunity to discuss these with you.

Yours sincerely,

[name and contact redacted]

www.waterwise.org.uk

Response to evidence questions on Water Efficiency

The call for evidence sets out areas for case studies. The narrative for the water efficiency case study is below. In our response we answer the key question on metering and set out wider information in relation to the case study outline to support the NIC New Technology Study.

WATER EFFICIENCY

How can new technologies support the water sector in delivering and driving efficiencies, in terms of operational cost and reduction of leakage and wastage? How can we use new technologies to increase resilience? This case study will look at use of sensors, meters, thermal imaging and drones in the water sector to increase efficiency. It will also compare and contrast different practices amongst the water companies to see how new technology, benefits and understanding can best be shared and tested across the sector. We want to identify the key barriers to rolling out new technologies regionally and nationally.

9. Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

Waterwise feel that a national and compulsory roll out of smart meters would have a positive benefit in driving and delivering water efficiency and resilience within the water sector. The UK is one of the few countries in the developed world not to have either full water metering or a clear programme to implement universal metering. At present 50% of households in England and Wales are metered and this is projected to increase to 61% by 2020. In England, water companies can compulsorily meter customers if they have been designated as being in an area of water stress (by the Secretary of State based on evidence from the Environment Agency). Otherwise, they can't. In Scotland there are some meter trials but the current level is close to zero, whilst in Wales the Welsh Government is looking at the benefits of smart meters.

Southern Water's Universal Metering Programme (UMP) has shown that domestic metering can save 16.5%. If people do not pay for the amount of water they use, there is no financial incentive to use water efficiently - alongside social norms and other behavioural incentives, which do still exist. For unmetered customers, it is important to seek alternative ways to incentivise the efficient use of water. We are proposing a water meter in most homes in England and Wales (some can't be metered) by 2030, supported by water efficiency and

political commitment and tariffs to protect vulnerable customers and based on a wider cost-benefit analysis.

The Water Efficiency Strategy for the UK (Waterwise, 2017) recommended:

- Allow water companies to introduce full metering for benefits beyond areas of designated water stress status
- Fit water meters in almost all homes in England and Wales by 2030, supported by political commitment and tariffs to protect vulnerable customers and based on a wider cost-benefit analysis
- Increase the proportion of smart water meters at company level

As part of a wider cost benefit analysis to enable metering in areas not currently designated as in water stress, smart metering benefits for customer engagement should be considered. Water companies are currently considering the level of smart metering they need to introduce. From a utility perspective it may that drive by readings are sufficient to support billing and detect large leaks. However, for customers to change behaviours they require greater access to their water data and the investment in a fixed area network can provide this.

Managing peak demands and linking with new technologies such as decentralised water management (rainwater harvesting, third pipe systems) can also be supported by roll out of smart metering technology.

Wider response

Innovation in both technology and behaviour change/ engagement approaches are required to deliver and drive water efficiency in the UK.

Variation in water companies delivering technological innovation for water efficiency

There is a wide level of variation in water company use of innovative technology for water efficiency. Those with innovation programmes are more likely to be implementing smart metering and sensors as well as feedback through apps and websites to customers to improve water efficiency. Many companies are still using standard retrofit packs of devices (aerated showerheads, tap aerators etc.) that could be improved upon with greater innovation in water efficiency.

A few examples of current innovation in water efficient technology being implemented by water companies are below:

- Thames Water - propelair toilets, incentives programmes (Green Redeem)
- Anglian Water - smart metering and behaviour change platform
- SES Water - behaviour change platform (Advizzo)
- Dwr Cymru Welsh Water - WISDOM project to deliver smart metering and network optimisation

www.waterwise.org.uk

Key barriers to rolling out technologies regionally and nationally

There has been a lack of investment in water efficiency innovation to date in the UK. Although water is a key risk to businesses and lack of resilience would impact on households across the country, investment in new technologies has remained focused on energy when it comes to Smart Cities. The EU ICT4Water Cluster programme has involved many partners in the UK. However, UK based organisations are having difficulties accessing new rounds of EU funding and participating in these projects to help innovation in the UK.

A lack of reliable field trials has been raised as an issue within the ICT4Water cluster programme (2016 report). Water companies tend to be conservative and won't invest in technologies that have yet to mature. However, technologies can't mature and demonstrate their effectiveness without larger scale field trials in the water company setting. Further investment is required in the UK to support "incubator" programmes for water efficiency and to enable field scale trials so these can form part of water resources management and business plans.

Examples of new technologies

The first Waterwise Water Efficient Product Awards were held in 2017. This enabled us to identify a range of innovative technologies and products for water efficiency. The results are summarised below and links are provided to case studies.

Table Waterwise water efficient product awards 2017 with links to case studies

Category	Winner/Runner-up	Product name	Organisation Name
Kitchen/White Goods	Winner	Whirlpool Supreme Clean Dishwasher – WiO 3T123 6PE	Whirlpool UK
	Runner-up	Whirlpool Supreme Care Washing Machine FSCR 10432	Whirlpool UK
Bathroom	Winner	Propelair 1.5 litre flush toilet	Phoenix Products
	Runner-up	Hydrao	Smart and Blue
Plumbing	Winner	Waterblade	Waterblade
	Runner-up	AquaReturn	AquaReturn
Garden	Winner	Watflo Dual Flow Water Diverter; Filter Unit + H2O harvester brainbox	Watflo
	Runner-up	Watering Pipe	Wateringpipe
Water Storage	Winner	Platin/Minimax Pro rainwater harvesting system	GRAF UK Ltd
	Runner-up	Flushrain	Flushrain

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Industrial / Business	Winner	Heatsavr	Brenntag
	Runner-up	Programmable Sensor with Handheld Programmer	Dart Valley
Innovation	Winner	BrighTap	Bwareit
	Runner-up	Aqualogic Aquarius Fixed & Mobile Leak Detection System	Aqualogic
IT / Communications	Winner	Hydrao	Smart and Blue
	Runner-up	Advizzo behavioural customer engagement	Advizzo

A report by the Institute for Sustainable Futures for several water companies in Victoria, Australia, has identified a wide range of water efficient technologies that should be require further consideration. These include[1]:

- Showers - a range of innovative water-efficient showers are hitting the market that potentially offer significant water-savings as well as associated energy savings.
- Showers - other relatively low cost water-efficient shower products are readily available via retailers and online shopping including: shower shorteners, timers, displays and alarms which target reducing shower length; and aerators that focus on reducing flow rate
- Highly efficient clothes washers that incorporate new sensor technologies
- Nylon bead washers in the commercial setting can use up 80% less water
- Supercritical washing machines that use zero water are being developed
- Steaming wardrobes are on the market and can provide an alternative to washing
- High efficiency toilets are available, along with alternative waters that use almost no water
- High efficiency taps with sensors have been developed, along with taps that combine soap
- A range of leak detection devices that can shut off water flow remotely are now available
- Highly efficient dishwashers could use less than 10l/ wash.

[1] Liu, A., Turner, A., and White, S., 2017, Assessment of Future Water Efficiency Measures. Report prepared for City West Water, Yarra Valley Water, South East Water, Melbourne Water, Barwon Water and Department of Environment, Land, Water and Planning by the Institute for Sustainable Futures, University of Technology Sydney.

WSP Response to Call for Evidence – New Technologies

TO	National Infrastructure Commission	**FROM**	[name redacted]
DATE	**15 September 2017**	**CONFIDENTIALITY**	**Public**
SUBJECT	**New Technology Study Second Call for Evidence**		

Water Efficiency – Second Call for Evidence

WSP is delighted to respond to the NIC's second call for evidence. While colleagues responded directly on the smart traffic management aspects of the consultation, this submission focuses exclusively on the Water Efficiency angle. We would be delighted to engage the NIC on either of these submissions.

Question - In your view, how can we use new and emerging technologies to address and reduce the Economic Level of Leakage (ELL) to make it more financially viable to repair more leaks?

There are 2 main aspects to successfully reducing the calculated value of ELL either of which, or both, will support a lower target providing space for incentives to reduce leakage.

The costs of detecting, scaling the amount of leakage and resolving the issues appropriately and accurately need to be lower and this can of course be supported by innovation around technology. The benefits accruing from leakage reduction also need more innovative assessment with a longer term view of the benefits taken; if such a view of benefits can be adopted there will be more incentive to develop technological solutions for what are currently considered marginal opportunities.

In terms of detecting and scaling leakage, the advent of new, small and relatively cheaper sensors has helped to develop new techniques and to refine existing techniques. It is to be expected that such sensor technology will continue to be developed as the demand for them rises. A few years ago Veolia suggested embedding cheap sensors into pipe sections so that pipe condition, movement and leak noise could be monitored allowing risk assessment to be performed routinely and precisely.

This was in support of the concept that companies such as Veolia could offer a "service" of water delivery to utilities, owning the pipes and the solutions, and charging for metered delivery.

Whilst this was "blue sky" thinking, as at the time such sensors were not available and the long term powering of them was some way from being developed, it does indicate clearly that

companies are aware that they can make better decisions when supported by appropriate information, that there are different business models which could operate, and that the obtaining of such information is more of the barrier than the desire to collect and use it.

Given that leakages and seeps from water systems are characterised by pre-existing asset condition, geographical dispersion (ie in different locations around the system), geographical range (ie over a wide scale as networks are very expansive) and are environmentally diverse (ie subject to different and often unknown support conditions, loading types, temperatures, chemistry, etc) as well as usually being buried it is clear why obtaining sufficient appropriate and useable information has been the barrier.

Data collected have been sparse, probably imprecise and often inferential: the use of DMAs to support leakage detection and resolution is inferential in that the inputs and outputs of a defined area are measured (to varying degrees of accuracy) and the net loss determined after making an estimated allowance for real use. Clearly greater discrimination of information – such as on-line usage monitoring at all demand points and more intermediate meter points – will allow less reliance on guesswork; and a greater flow of data both on detection and on the process, options and costs of leakage resolution would allow better decision making, probably supported by machine-learning and other such technology.

An example of where such data and techniques have been used in a slightly less complex arena is detecting and resolving leakage from dams. Numerous techniques such as temperature, conductivity, vegetation differences at the surface or near sub-surface have been used to support decision making, but adoption of advanced geophysical measurement and analytics have provided some significant advances.

The WillowstickTM system from US allows rapid data acquisition over wide area and to depth (c 1km), and with great discrimination. The data collected semi-automatically are satellite fed to an analysis suite and the analytics are heavily automated with “data cleansing” to allow for the effects of potentially unhelpful signals from existing utilities, metal structures and the like and with 2-D and 3-D rendering of flow paths, with the ability to discriminate between active flows, seepages, damp patches.

There is still more room to develop such a system, using machine learning, adopting an online fully monitored system to collect and analyse data on a continuous basis to provide trends, trigger points and warnings of assert deterioration.

In a similar way, the application of better data flows and analytics in the more complex environment of buried networks must develop to provide more on-line and direct measurement and analysis to allow more precise and pro-active investment.

Use of piloted Pressure Reducing Valves helps to maintain pressure in networks at the optimum to meet demand as it changes, thus tending to minimise pressure effects on leakage; if the PRV is operated using rules based on real time information on demand, real time operation of the PRV and intermediate valves so optimal flow routes are preferred then this should provide further

benefits. The data from flow and pressure monitors could come from monitors installed for other purposes and trends and events analysed to provide greater control and speed of intervention.

On the benefits assessment side a longer term view of the benefits available should be established with the potential for expanding the assessment to consider less easily monetised aspects such as social return on investment, resilience modelling borrowing from insurance product economic models to establish wider ranges of costs avoided, which could be weighted to account for difference of “feel” at national, regional, community or household level taking account of actual or indicated vulnerability of customer groups at these various levels; use could be made of company specific data as well as the wide range of publicly available information sets released by central Government.

Question - Do you feel that a national and compulsory roll out of smart meters would have a positive or negative benefit in driving and delivering water efficiency and resilience within the water sector? And why?

Overall if water company directors had information from metering, smart meters or otherwise, they would be in a better position to manage efficiently their systems; in other words if, like practically every other water company in the world, there was a tradition of having meters and water charged by volume customers would not be outraged by the idea and would accrue benefits from being able to make informed choices about how and when they consume water, based potentially on differential costs associated with resource and supply/sewerage costs, and thus allow better and more economic operation of the system.

In essence it is not whether having meters or not is a bad idea, it is merely the transition cost – both the financial cost and the customer dissatisfaction cost – that prevents the more rapid uptake.

Having smart and connected meters at each demand point allows a much more focussed effort on demand management and leakage management. Added to which smart meters allow the potential for differential tariffs such that the efficient deployment of the “nega-litre” – that water not required at peak period because people have deferred demand – can save capital and operational costs when all the real time data are used to manage network operations.

The benefits of not spending new capital on new equipment allows tighter control of prices and better use of scarce funds to optimise use of existing assets, which in turn can lead to more cost savings from reduced headroom supply and equipment and to improved supply resilience.

[name redacted]

WSP Response to Call for Evidence – New Technologies

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[name redacted]

Smart Traffic Management

How can the deployment of intelligent traffic systems help to optimise the road network? Adaptive systems are already deployed in parts of the UK, e.g. SCOOT, and new technologies are driving their evolution and increasing their effectiveness. This case study will consider how deployment of more advanced traffic systems could support both better use of the existing road network, and future developments in road use, such as the transition to connected and autonomous vehicles.

Latest developments and technologies that underpin them

WSP's notice-processing software, Taranto helps to ensure that the road network is safe and free from congestion.

Taranto is the result of 4+ years of development and over £3million worth of investment to re-develop the legacy software solution previously used in parking environments by numerous Local Authorities across Britain. It is now the number-one enforcement solution for tolling and congestion charge enforcement in the UK.

Taranto processes over 4.5 million parking penalty charge notices in England annually, with over 1.5 million notices issued for tolling and road user charging enforcement.

Vehicle details can be passed into the Taranto system from Automatic Number Plate Recognition (ANPR) equipment capable of capturing Vehicle Registration Marks (VRMs). This information can be passed into Taranto either automatically, without any user intervention, or after any manual review should further clarification be required. Taranto's flexible design means it can then interface with any ANPR camera or review client interface, demonstrating its suitability to be used in any tolling scheme. If the road-user charge is not paid, then Taranto can be used to help tackle evasion for UK or non-UK drivers. Enforcement measures are used to recover the outstanding charges, including postal PCNs and statutory documentation, or the use of a European debt recovery agency to support the recovery of outstanding charges from non-UK vehicles.

Taranto assists the Operator in pursuing this debt in numerous ways:

- The web-enabled Taranto software can be used to find and view case details using a variety of search methods. Users can log enquires, generate incoming/outgoing correspondence, hold or cancel cases, re-issue associated documentation, schedule tasks and alter the charging structure of any case.

- Taranto provides the ability to adjust timescales between stages in the statutory process or ticket charges/tariffs, allowing the unpaid case to progress appropriately in line with any tolling scheme.

- 'Batch tasks' such as DVLA Vehicle Keeper Enquiry generation and DVLA Vehicle Keeper Enquiry response processing are automatically scheduled and executed, freeing up users to carry on working while tasks are being performed by the system.

- Optical Character Recognition (OCR) enables incoming correspondence to be scanned and categorised automatically according to the case status, passed to certain individuals or teams, offering a virtual work allocation tool.

- All types of outgoing correspondence can be generated from the system, including email. When generating correspondence the interface is designed to be as streamlined as possible, allowing users to choose from a number of standard templates, add merge fields and photographs specific to that case. All templates are fully customisable and can be edited for each individual piece of correspondence making the process as quick and easy as possible.

- Eventually, unpaid cases can be allocated to a bailiff for further enforcement. There is no limit to the number of bailiffs that can be used and Taranto can even integrate to the European debt recovery agency enabling enforcement of non-UK vehicles.

The efficiencies delivered through the software help to maximise enforcement for non-payment and ultimately drive compliance through reduction in repeat-offenders. This has various benefits for others users of the road-network. The recently opened Dartford Free Flow electronic tolling system uses Taranto which saves an average of 13 minutes each day for road users using the crossing in both directions which has considerably reduced pollution and carbon emissions.

Barriers faces by local authorities

Public opinion; of utmost importance is the customer interaction with any scheme introduced. High-standards can be reached through the selection of trusted technology providers. Pros and cons can be offered for selecting one provider to manage the full scheme, or several each delivering "the best in class".

Partners; having the technology partner capable of delivering such functionality is critical. Such schemes often require multiple organisations (or at least divisions within large organisations) working together, so by ensuring that each partner has the flexibility and capability to integrate with all relevant third-parties, in a secure manner, is paramount.

Technology available; any type of scheme must be underpinned by necessary technology to allow pre and post-payment, whether this be accounts for repeat users, or ad-hoc payments for occasional use. Crucially consideration should be given over how the solution is enforced and rules can be upheld against those users that refuse payment for the journey. Since this can be large volumes, tools need to be utilised that can automate much of the manual process required to enforce payment.

Cost; whether considering hardware investment, or the IT solution to underpin the scheme – often investment is needed and when considering development costs of any legacy systems then these can be prohibitive.

Smart Traffic Management

How can the deployment of intelligent traffic systems help to optimise the road network? Adaptive systems are already deployed in parts of the UK, e.g. SCOOT, and new technologies are driving their evolution and increasing their effectiveness. This case study will consider how deployment of more advanced traffic systems could support both better use of the existing road network, and future developments in road use, such as the transition to connected and autonomous vehicles.

Latest developments and technologies that underpin them

WSP's notice-processing software, Taranto helps to ensure that the road network is safe and free from congestion.

Taranto is the result of 4+ years of development and over £3million worth of investment to re-develop the legacy software solution previously used in parking environments by numerous Local Authorities across Britain. It is now the number-one enforcement solution for tolling and congestion charge enforcement in the UK.

Taranto processes over 4.5 million parking penalty charge notices in England annually, with over 1.5 million notices issued for tolling and road user charging enforcement.

Vehicle details can be passed into the Taranto system from Automatic Number Plate Recognition (ANPR) equipment capable of capturing Vehicle Registration Marks (VRMs). This information can be passed into Taranto either automatically, without any user intervention, or after any manual review should further clarification be required. Taranto's flexible design means it can then interface with any ANPR camera or review client interface, demonstrating its suitability to be used in any tolling scheme. If the road-user charge is not paid, then Taranto can be used to help tackle evasion for UK or non-UK drivers. Enforcement measures are used to recover the outstanding charges, including postal PCNs and statutory documentation, or the use of a European debt recovery agency to support the recovery of outstanding charges from non-UK vehicles.

Taranto assists the Operator in pursuing this debt in numerous ways:

- The web-enabled Taranto software can be used to find and view case details using a variety of search methods. Users can log enquires, generate incoming/outgoing correspondence, hold or cancel cases, re-issue associated documentation, schedule tasks and alter the charging structure of any case.

- Taranto provides the ability to adjust timescales between stages in the statutory process or ticket charges/tariffs, allowing the unpaid case to progress appropriately in line with any tolling scheme.

- 'Batch tasks' such as DVLA Vehicle Keeper Enquiry generation and DVLA Vehicle Keeper Enquiry response processing are automatically scheduled and executed, freeing up users to carry on working while tasks are being performed by the system.

- Optical Character Recognition (OCR) enables incoming correspondence to be scanned and categorised automatically according to the case status, passed to certain individuals or teams, offering a virtual work allocation tool.

- All types of outgoing correspondence can be generated from the system, including email. When generating correspondence the interface is designed to be as streamlined as possible, allowing users to choose from a number of standard templates, add merge fields and photographs specific to that case. All templates are fully customisable and can be edited for each individual piece of correspondence making the process as quick and easy as possible.

- Eventually, unpaid cases can be allocated to a bailiff for further enforcement. There is no limit to the number of bailiffs that can be used and Taranto can even integrate to the European debt recovery agency enabling enforcement of non-UK vehicles.

The efficiencies delivered through the software help to maximise enforcement for non-payment and ultimately drive compliance through reduction in repeat-offenders. This has various benefits for others users of the road-network. The recently opened Dartford Free Flow electronic tolling system uses Taranto which saves an average of 13 minutes each day for road users using the crossing in both directions which has considerably reduced pollution and carbon emissions.

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