UNDERGROUND ASSETS CHALLENGE

DEEP DIG OUTPUT

The Challenge: How can we better manage underground assets in Britain?

We held the Underground Assets Deep Dig on 22 June 2016 at the Geovation Hub in London.

From this, **30** people (including energy suppliers, transport providers, utilities and data providers) who were familiar with issues involving underground assets identified **55** raw problems.

We've summarised these into **27** problems, explaining why they matter and have grouped them into four themes:

1. ASSET LOCATION
2. ASSET MANAGEMENT & MAINTENANCE
3. STAKEHOLDER IMPACT
4. PREDICTING ASSET FUTURE

1. ASSET LOCATION

1.1
Dusty archives ignored

PROBLEM

Around a third of utility mains underneath London are more than 150 years old. In addition, the privatisation of utilities since the 1980s has caused huge organisational, management and supplier changes across the industry, resulting in disparate information sources (House of Commons, 2014). Today, many records are not digitised and only exist in paper or PDF format which aren't easily accessible.

WHY IT MATTERS

This means vital information on utility assets such as potential hazards or state of repair may be missed by those who need it, such as asset managers and stakeholder planners. Manually processing paper records is expensive and takes time. Digitising records can increase productivity in the utilities sector by 15% (Booth et al, 2016).

1.2
Oldies are best?

PROBLEM

As a result of poor digitising methods, human error and poor quality control, complex but important historic data is often lost when hand-drawn records are converted into digital format. A specification exists for achieving accurate levels of underground utility detection, verification and location data capture (PAS 128), but this doesn't address standards in digitising existing asset records (Beck et al, 2007).

WHY IT MATTERS

Knowledge of missed historic asset data can help inform better management and maintenance decisions. Digitising this data, and making the information more usable, can contribute to better asset management from improved operations, and can increase profitability by 20-30% (Booth et al, 2016).

1.3
Locating assets accurately

PROBLEM

Locating and identifying assets properly can minimise unnecessary upheaval and inconvenience to utility companies, customers and wider stakeholders. Around one in 10 excavations are for exploratory purposes, but these could be avoided with advanced, no-dig technologies (Roberts et al, 2006).

WHY IT MATTERS

Locating assets inefficiently or incorrectly can bring risk of injury to workers, damage to the asset itself, power outages, unnecessary costs and indirect problems such as traffic and pedestrian congestion.

In 2011, 40% of incidents (asset strikes and injuries) were caused by inadequate excavation practice. It's estimated that the impact of disruption on society from asset works in streets, including congestion caused, totals £5.5 billion per year (Metje et al, 2015). Based on extensive studies of utility strikes, for every £1 spent on direct costs it's estimated that £29 is spent on indirect and social costs (Makana et al., 2016). As cities expand, efficiencies could improve quality of life, and reduce delays, costs and customer bills.

1.4
Too much chasing

PROBLEM

Local government spends a lot of time getting data on underground assets. It's also difficult to get cross electoral boundary asset data to help see the wider contexts of utility networks. Stakeholders recognise that data sharing across utilities is slow and hindered (Mayor of London, 2013; GLA, 2016).

WHY IT MATTERS

Delays gathering the right information can lead to hold-ups in roadworks approvals needed for utilities asset management. Going ahead without enough data can result in ill-informed decisions and risk to life or the asset. The government forecasts that greater cross-sector collaboration with infrastructure networks across GB could save the economy £3 billion (HM Treasury, 2013).

1.5
Poor record data

PROBLEM

Utilities hold insufficient data on their underground assets. Using a manual process may not capture the right data and may compromise the detail, scale and quality. Location data in particular is usually missing. When excavation reveals a utility is wrongly placed, the utility record data is not always updated, so problems persist.

WHY IT MATTERS

Not knowing what's buried where causes significant disruption, including wasted time and delays in street works, possible damage to utilities, health and safety risks, and extra design and construction costs. Lack of complete and accurate information is a primary reason for utility strikes occurring (Metje et al, 2015). For example, London's Heathrow Airport has many underground assets serving more than 180,000 visitors per day. Assets include 45,000 manholes, 115km of water mains and 130km of fuel pipelines. Yet in 2002, only 40% of their underground assets were mapped to within half a metre. Major mapping work between 2002 and 2011 has seen strike incidents fall six fold (Zeiss, 2014).

1.6
Improving accuracy nationally

PROBLEM

There is no comprehensive asset location mapping at national level that's entirely accurate. Improving the mapping of underground utility assets has been needed since the 1980s (New Scientist, 1985; University of Birmingham, 2012). Many assets are more than 100 years old and either aren't recorded or if they are, lack the level and accuracy needed today. Patchy data exists across utilities because of differing software used, differing priorities in data capture, as well as major organisational changes since utilities were built and privatised (University of Birmingham, 2012; House of Commons, 2014).

WHY IT MATTERS

A national level of accurate maps could increase productivity and save costs. International examples of improving the accuracy of underground asset location data reveal the return on investment can be as high as a 1:21 ratio (Zeiss, 2014).

1.7
The third dimension

PROBLEM

It's recognised that flat plans on underground asset location exist and are shared, but don't have depth information. While some data exists, there's great inconsistency across the utility data providers – particularly with the relatively recent use of GPS in utility surveys. This variation also causes greater discrepancy (Beck et al, 2007).

WHY IT MATTERS

Lack of depth knowledge and understanding of underground assets makes them difficult to manage – and to meet regulation requirements. It's also costly to utilities, stakeholders and consumers. For example, whether maintenance jobs are carried out largely depends on the depth needing to be worked at. Stakeholders realise the value in better data capture of asset attributes, and appropriate visualisation including their 3-dimensionality, which can lead to more efficient decision making (Mayor of London, 2013). The national 25 year Mapping the Underground and Assessing the Underground initiatives aim to locate 100% of underground assets (Mapping The Underworld). Greater London Authority has also committed to provide accessible, 3D mapping of all London's Underground assets by 2020 (Mayor of London, 2013).

1.8
What's there? Where?

PROBLEM

It's difficult to get a comprehensive view of assets, including private assets and third party data within an area of interest. Utility and underground asset data is held on multiple platforms and there's no central repository for finding this information. When information is used from disparate sources, some relevant organisations may be missed. Information is not all logged digitally and often doesn't include enough key information such as depth of asset, extent and number of assets, and maintenance plans. Gathering third party data from disparate sources also makes it unclear, time consuming and costly.

WHY IT MATTERS

Easily accessible, usable shared utilities data can help inform asset maintenance such as digging operations, installing new assets and early stage planning. A third of utility construction projects that overrun are estimated to be due to limited access to high quality, geospatial data and errors in interpretation of data (Keynetix and Innovate UK, 2015). Inaccuracy of data is also attributed in 20-30% of 'dry digs' – excavations in the wrong places (Trenchless World, 2011). In London's Westminster borough, 20% of their 50,000 annual street works tend to be fruitless, costing £6 million. Shared data can support comprehensive maps of third party buried assets within areas of concern and help avoid conflict with others assets, as well as avoiding increased costs and all round brand damage. Errors can occur when decisions are based on a range of data sources and types. If there were greater cross utility collaboration, the government forecasts it could save the economy £3 billion (HM Treasury, 2013).

1.9
Avoiding strikes

PROBLEM

Damage to third party assets by utilities costs approximately £150 million to repair, with indirect costs estimated to be ten times this. London City alone has a melting pot of over 300 utilities (GLA, 2014). Wider societal impact of disruption by street works is estimated to cost £5.5 billion per year (Metje et al, 2015).

WHY IT MATTERS

If new or adapted assets are not catalogued, and reliable data isn't supplied, maintenance teams may strike and damage an asset, leading to loss of service, as well as safety risks, and brand damage to the affected company. As well as the £150 million in repair costs, and far greater indirect costs (such as impact on road and rail traffic, and citizens), fatalities are a particularly severe consequence, with approximately 12 deaths and 600 serious injuries each year from contact with electricity cables (ICE, 2015).

1.10
In what format?

PROBLEM

It's difficult to share information between utilities when there is no standard data format. Data capture and management is often technology and platform specific, and bespoke to each asset manager. There are inconsistencies in the types of software and formats used by each utility company and contractor for storing, editing, analysing and viewing asset data (Beck et al, 2007).

WHY IT MATTERS

Locked-in formats reduce the ability to connect, share and utilise data. This increases time and resources when trying to connect data across providers and suppliers. If all asset data had standard formats, sharing would be easier. It would also prevent expensive network damage and supply interruptions. A specification for best practice in data sharing is currently in development (ICE, 2015).

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2. ASSET MANAGEMENT & MAINTENANCE

2.1 Ground movement

PROBLEM

Ground movement causes pipes to burst. It can be caused by temperature, soil moisture (which triggers ground swelling and shrinking), and human activity increasing ground pressure. While utility infrastructure is becoming increasingly resilient against large-scale natural hazards such as flooding, there's less attention to impacts of incremental environmental changes such as subsidence (Pritchard et al, 2013).

WHY IT MATTERS

The most common reason for modern pipes failing is ground movement due to settlement of soil causing vertical stress. A break in a pipe puts quality of its utility supply at risk, can interrupt supply, be costly to repair, and cause other indirect damage. Ground movement causing damage to assets has direct and indirect costs of £300-500 million each year (Pritchard et al, 2013).

2.2 Groundwater asset infiltration

PROBLEM

Groundwater levels are rising and infiltrating buried assets, effectively making the asset part of a 'natural drainage system'. Higher groundwater levels mean that cable chambers and ducts, which are not waterproof, are at risk of flooding. (Cranfield University, 2013). Predicting future groundwater levels is difficult, but it's been estimated that in London levels could rise by up to 2.5 metres per year (The Geological Society, 2002).

WHY IT MATTERS

Water where it isn't wanted can be expensive to mitigate and to transfer to the right place. Climate change could make rising groundwater levels worse and lead to flooding, which would have a negative impact on assets (Cranfield University, 2013).

2.3 Agressive infrastructure environment

PROBLEM

Assets can be damaged by their natural environments, such as chemical or physical, combined with human activities that disrupt the natural state of the ground. However, these environments are not all understood in relation to assets, for example, impact on corrosion, movement and accessibility. In a global survey of electricity utilities, despite all companies considering equipment failure in their risk analysis, only around 15% considered natural disasters or human action (IEC, 2015).

WHY IT MATTERS

Many construction projects overspend and overrun because of poor planning due to lack of knowledge and unforeseen ground conditions. Scientific models often ignore surrounding built structures, yet these models point to future scenarios – such as ground water flow changes due to climate change – and therefore can affect decision making. Physical ground movement is one of the prime causes of failure in modern plastic pipes, and among other factors this is closely linked to the type of soil, surrounding vegetation growth, and soil disturbance, which can be caused by human activities such as building work. Groundwater is also a risk to assets, as groundwater flooding can damage non-waterproof cables. Ageing pipes are usually cast iron, which are highly susceptible to corrosion, while other factors which make assets vulnerable include soil type and even lightening which can strike overhead lines and consequently affect connecting equipment underground (Cranfield University, 2013). It's important to fully understand the impact the natural environment has on assets for optimum asset management. Without it, asset lifespan and functions could be compromised, causing inefficiencies in maintenance and costs.

2.4
Redundant asset management

PROBLEM

It's difficult knowing what assets are redundant, where they are and who owns them. So it's challenging to maintain or successfully close off these redundant assets to ensure their degradation doesn't affect wider infrastructure.

WHY IT MATTERS

Poor management of redundant assets can cause unexpected disruption, safety issues, and delays to other projects, as well as wasting time and resources. Lack of knowledge on redundant assets could mean missed opportunities to re use or renew them, and missed contributions to predictive and preventative maintenance.
In the water utility industry for example, a 2004 study found that no more than 2% of the UK's main sewer network had been surveyed, and that one fifth of any observations made were most likely inaccurate (Ofwat, 2004).

2.5
Not following process

PROBLEM

Best practice is not always followed when excavating, which can incur damages. Training is recommended among stakeholders to improve safety performance (ICE, 2015).

WHY IT MATTERS

Principal reasons for accidental utility strikes include lack of care by workers, improper excavation, and poor visibility conditions. More than a third of asset strike incidents happen when excavators use hand tools prone to human error. On average, 80% of strike incidents are down to human error and no common rules being followed (ICE, 2015). Better practice when excavating can improve health and safety and reduce unnecessary repair costs to utilities own and others assets. It's been shown that more coordinated practices can improve delivery by 30%, and at lower costs (TfL, 2013). Better collaboration between utilities civil engineering works has potential to unlock £3 billion in economic value (HM Treasury, 2013).

2.6
New technology, new approaches

PROBLEM

There's a lack of technology in asset management, such as surveying techniques and use of predictive analytics to support maintenance. There's a lot of exploration and experimentation in new technologies, but lack of full development and implementation on a large scale (Glickman and Leroi, 2015). Currently, utility asset managers are often restricted by using older technology than is available. Budgets and expenditure underpinning decisions to take certain approaches are handled in different silos within utility companies – usually 'capex' (capital expenditure for new developments) and 'opex' (operational expenditure for maintenance work). These work streams are not well joined up, nor do they have unaligned incentives, making it difficult to focus on achieving similar strategies. Other approaches and methods could make processes and outcomes more efficient and effective.

WHY IT MATTERS

The utility industry spends around £150 million on asset repair costs due to accidental strikes during excavation (GLA, 2014), where trenchless technology could be used.
There's growing focus on trenchless technologies for repairing and installing assets to reduce disruptive and damaging 'open cut' practices, as well as techniques to improve the quality of asset data capture (Mayor of London, 2013). More joined-up management across key asset management budgets would reduce duplication of efforts and maximise value. Since 2015, regulators are encouraging the 'totex' approach (one budget of total expenditure combining both 'capex' and 'opex'). This approach is expected to optimise asset management delivery, as well as future, long-term investments by encouraging innovation to achieve final outcomes via the best means, rather than restricting 'capex' and 'opex' budget quotas which don't always favour the most efficient opportunities (First Economics, 2016). Some water companies in the UK have already taken this approach and have saved more than £50 million in one year (Water Briefing, 2016).

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3. STAKEHOLDER IMPACT

3.1
Who owns what?

PROBLEM

There's a lack of information and description about assets once they're found. Who owns it? What's it for? Who regulates it? Where does it connect? Who is responsible for it and what's its lifecycle?

WHY IT MATTERS

The government forecasts that greater cross-sector collaboration with infrastructure networks across UK could save the economy £3 billion (HM Treasury, 2013).

3.2
When will it be fixed?

PROBLEM

There's inadequate communication of planned works, and unexpected power outages across utilities.

WHY IT MATTERS

Faster communication between utilities and contractors improves cooperation and can reduce disruption by 20% (Balfour Beatty, 2012). 24-hour news, social media and an abundance of internet information has increased the level of customers' expectation around communication (Department for Transport, 2014).

3.3
The utility thief

PROBLEM

Unauthorised access to and usage of utilities' infrastructure could result in damage, costs and fines to companies and end users, such as theft of utility supply resulting in increased customer bills.

WHY IT MATTERS

Energy stolen from UK utilities each year could heat and light all households in a city the size of Bristol or Leeds. Theft of electricity and gas supplies costs energy consumers around £300 million per year. Only 15% of these thefts are identified (IBM, 2012).

3.4
Data sharing reluctance

PROBLEM

There's a reluctance to share data on assets, including location, condition and risks, among many utilities, cross industry or inter-sector, due to commercial sensitivity or security concerns. There are no standards or best practice for data sharing.

WHY IT MATTERS

Shared information can lead to more streamlined delivery, improved decision-making and smarter investments, such as being able to plan works more effectively, improve safety, and identify opportunities for sharing infrastructure. Inconsistencies exist across utilities' data due to autonomous data capture with no need for compatibility or interoperability with other utilities' systems. Each utility company therefore records differing asset details in silos as their priority is to improve their own operational systems rather than to improve data sharing (Beck et al, 2007). The Institute of Civil Engineers (ICE) is working with stakeholders to establish a new Publicly Available Specification (PAS) industry standard for recording and sharing the location, state and nature of underground assets (ICE, 2015).

3.5
Street space competition

PROBLEM

Roads are dug up to fix problems with underground assets but a lack of coordination and communication may result in multiple ‘works’ needed in the same space, and duplication of effort. The public faces continual street work disruption over extended periods, and utility companies have to wait to complete works.

WHY IT MATTERS

Approximately four million holes are dug each year by the UK utilities industry to repair, upgrade or provide new connections to their assets (Beck et al, 2007). Utilities are charged up to £2,500 per day to carry out these works (New Roads and Streetworks Act 1991), on top of permit schemes and lane rentals. Societal impact of this disruption is estimated to cost £5.5 billion, including road closures causing congestion and downtime for businesses and homes (McMahon et al., 2006). In London’s Westminster borough each year, more than seven square miles of road are dug up almost 28,000 times (City of Westminster, 2015). 10% of congestion across the UK is estimated to be due to roadworks (Masood et al, 2016). Population and GDP per capita growth is expected to increase traffic by over 40% across roads, while the cost of congestion could rise to £36 billion per year by 2025 (HM Treasury, 2013).

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4. PREDICTING ASSET FUTURE

4.1 Underground asset conditions

PROBLEM

Limited information on the condition of underground assets can make it difficult to predict if and when they could fail, and how this can impact other assets. This lack of understanding also leads to imprecise models being created and relied on for decision making.

WHY IT MATTERS

Assets can deteriorate from a combination of their own and surrounding conditions. For example, pipes can be susceptible to cracks, holes and ineffective seals due to their material, age, construction and surrounding geology. In the UK where utilities need to replace their ageing assets, models created from improved data analytics can aid better decision making. In turn, this helps the companies prioritise their investments effectively, their assets work smarter and reduce business and customer costs. A global survey taken across utility companies in 2013 found that up to 60% do not consider big data analytics a significant opportunity to improve delivery; only 20% of have implemented big data analytics, and 40% have no foreseeable big data initiatives.

4.2 Future-proofing assets

PROBLEM

Not knowing the long-term needs of underground infrastructure and supply makes it impossible to plan for the future – which could be shaped by advances in technology and more localised sustainable solutions.

WHY IT MATTERS

The UK's population is set to grow by almost 10 million by 2040 (ONS, 2014). Stakeholders recognise they aren't considering the future (including land use and user-driven changes) when asset management planning. The design life of gas and electricity assets is typically around 50 years (Ofgem, 2010), but it's best to future-proof asset infrastructure either in the beginning, or during maintenance or upgrading (ICE, 2016). International electricity utilities consider projects that meet regulatory requirements over those driven by demand growth, as mandatory (IEC, 2015). Currently, 90% of assets are replaced using 'minimum dig' technology (NJUG, 2008).

4.3 Short-term investment paradox

PROBLEM

Expectation of short-term investment returns (e.g. Asset Management Plan period is only five to seven years for water utilities; RIIO [Revenue=Incentives+ Innovation+Outputs] period is eight years for gas and electric; and political governance periods are five years) and wanting to keep prices down to remain competitive, leads to reluctance in investing in long-term resilience, future demands and creating master plans.

WHY IT MATTERS

The UK government's definition of infrastructure 'resilience' is "the ability of assets and networks to anticipate, absorb, adapt and to recover from disruption" (ICE, 2016). There's an identified need to plan for the impacts of weather, including greater rainfall over longer periods in winters; more intense and localised rain storms; drier and hotter conditions in summer, more frequent severe storms and rising sea levels. Sea level in London is expected to rise 11-16cm by 2030 and 18-26cm by 2050 (ICE, 2016) but around 30% of gas infrastructure, 20% of rail assets, 15% of electricity assets and 10% of major roads are located in flood risk areas (GLA, 2011). Natural hazards such as flooding, winds and snow storms account for 10-35% of service interruptions to electricity, road and rail infrastructure. Recent assessment of national infrastructure rated nothing as 'fit for future' (ICE, 2016). If UK infrastructure does not meet the standard of other developed economies, by 2026 this could cause loss to the national economy of £90 billion (HM Treasury, 2013). The government recommends large-scale investment in gas technologies to maintain the UK's prime energy supply (35%) and help cut down emissions. It's thought the peak demand for electricity will increase from 63GW (2013) to 68-73GW in 2030. Replacing and upgrading electricity network infrastructure would need around £110 billion of investment between now and 2020. Water demand per household is expected to rise by approximately 35% by 2050 (HM Treasury, 2013) requiring increased resilience in infrastructure. In London, the developing Thames Tideway super sewer which aims to tackle overflows from the aging Victorian sewers for the next 100 years has an equity opportunity worth £1 billion (UK Trade and Investment, 2014).

4.4 Free for all

PROBLEM

Britain has no underground space masterplan. Pipes, cables, basements and tunnels are placed underground without a framework for how space is used, impacts, and potential wider future use of underground space.

WHY IT MATTERS

The benefits of using underground space include efficiency of land use, environmental improvement, improved urban aesthetics, energy conservation and sustainable development (Chow, 2002). Wider use of underground space to serve the amenities of urban life (from road networks to shopping malls and sports facilities) is already in place in cities worldwide including Paris, Boston, Helsinki, Montreal, Stockholm, Singapore and Hong Kong (Arup, 2013). In old cities such as London, there's a recognised need to reuse existing foundations and construct them to longer design lives, as the ability to construct new foundations reduces after several generations of development (Chow, 2002).

4.5 Too much information

PROBLEM

Many assets are more than 100 years old and due to privatisation of utility companies, historical information tends to come from disparate sources (University of Birmingham, 2012; House of Commons, 2014). There are inconsistencies across the quality and format of data, as well as poor data sharing across the utilities industry, with no official bespoke standard to guide practice (ICE, 2015; University of Birmingham, 2012; Mayor of London, 2013). As a result, collating desktop information on assets needs extensive liaising and information gathering across stakeholders. Effective predictive analytics are needed for predictive asset management and maintenance, but these can't be achieved with incomplete and poor quality data.

WHY IT MATTERS

To run more efficiently, companies and site staff need to find less cumbersome procedures for collating and interpreting large volumes of different asset stakeholder information. Yet carrying out the appropriate asset work before a job starts is vital to planning and to address safety risks. If data sharing processes were digitised and automated, this could raise utility companies profits by 20-30%, and increase staff productivity by 15% (Booth et al, 2016).

4.6 Multi asset world

PROBLEM

Assets are currently not resilient enough as there's not a full understanding of the multiple factors that impact them, while long-term factors aren't taken into account to manage them for a sustainable future. Multi-dimensional failures in assets (due to time, place, conditions, people and things) can cause complex impacts. As a city is a "system of systems" it's recognised that resilience of these systems depends on the resilience between them (Mayor of London, 2013). A complex web of factors makes asset failures difficult to predict and therefore address. For example, understanding corrosion factors of cast iron mains; knowing locations of typical combined sewer (both surface water and sewage) overflows that occur during storms, and forecasting stress points in the network. The UK population is projected to grow to over 73 million by 2025 which will increase the need for more efficient, sustainable utility infrastructure (HM Treasury, 2013). Part of the problem is the inability to predict asset failure without disruptive excavations to monitor the asset, as these may themselves trigger failures. Based on a global survey, only 15% of utilities tend to consider implications of natural disasters and long-term human activity, such as major storms and population growth increasing the utility demand (IEC, 2016).

WHY IT MATTERS

Currently, there are many asset failures. For example, 25-31,000 sewer overflows happen around the UK each year which can trigger discharge of untreated human sewage (Marine Conservation Society, 2011). There are 624,000 km of human sewers – that's almost the distance to the moon and back – but only around a quarter of the network is monitored for overflows (Defra, 2012). An estimated 250,000 properties are at risk of groundwater flooding (Defra, 2004; UK Groundwater Forum). Direct costs of excavation using trenching technologies to access assets are approximately £1 billion, with indirect costs estimated at £3 billion per year (Roberts et al, 2006). In the decade before 2002 (when the 90% of cast iron gas mains in close proximity to properties began to be replaced), 14 people died due to their failure. As a result of the first phase of the 30 year programme, between 2002-9, £200 million was saved in societal costs from gas failures (HSE and Ofgem, 2011). Ignoring the possibilities of wider impacts is costly to UK plc and society. For example, up to 30% of disruptions in electricity, road and rail infrastructure is due to unprecedented flooding, winds and snowstorms (ICE, 2016). Around 30% of gas and 15% of electricity infrastructure is in flood risk areas, and 15% of London – a city home to 300 utilities – is in floodplain (Mayor of London, 2013; GLA, 2014). Nationwide flooding in 2013 cost the rail infrastructure industry £15 million in damage and £12 million in compensation due to stakeholder impacts. Meanwhile, new drainage systems are currently designed with a 20% allowance for withstanding climate change, which includes taking the frequency of severe storm events to be only every 10-50 years (Rail Standards and Safety Board, 2016). Keeping more comprehensive and real-time knowledge of every asset can help determine, prepare, understand and manage the more indirect, secondary impacts by asset failures more effectively. A future opportunity to save £2-3 billion every year and reduce construction costs by 15% is estimated, through improved asset management by being predictive and proactive upon potential impacts throughout the asset lifecycle, rather than reactive when failure occurs, (HM Treasury, 2013).

THEME 4
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