Fixed Asset Sensing Technologies

Background

Problem Statement

The use of sensing technology within the construction and infrastructure industry is of great appeal to i3P members due to the expected improvements in productivity, quality and safety that can be achieved. The use of sensing technologies and the benefits they could bring to the construction and infrastructure sector are still in the infancy stage and have not yet been fully explored. However, there have been some promising results to date.

This discovery poster is intended to clarify what technology is available to enable asset monitoring in construction and infrastructure, as well as the benefits it could bring and the barriers to its adoption.

Observations

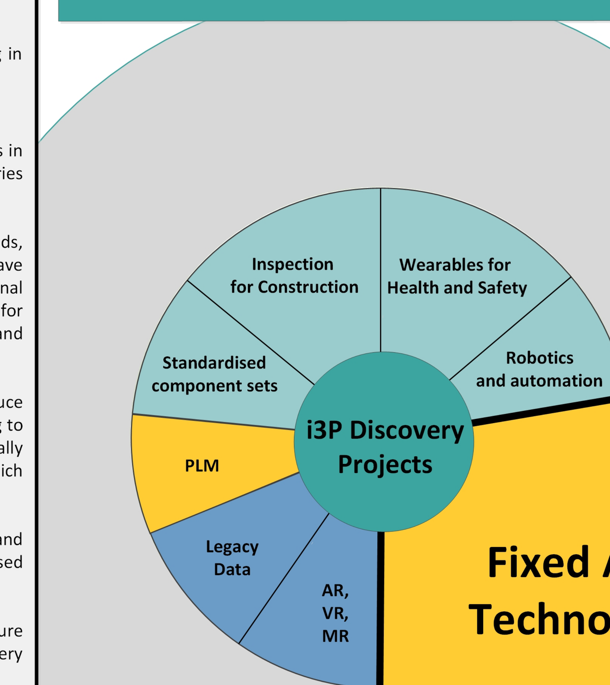
Throughout all sectors the construction industry had the highest number of fatal injuries to workers in 2016/17. The rail industry provides a key example of this issue. Railway infrastructure worker injuries accounted for ~10% of all railway injuries in 2016/17 (Figure 1a&b).

Traditional infrastructure maintenance requires surveying in risky environments such as live roads, railway lines, near live equipment, at height as well as in confined spaces. All of these activities have inherent risks associated with them. For example, viaducts and tunnel sumps have confined internal areas that require periodic inspections, while bridges and tall structures require special access for inspections at height (Figure 1c to 1e). Sensing technologies have the potential to reduce injuries and fatalities, primarily by reducing the need to work on-site.

In addition to improving Health and Safety, asset monitoring technologies have the potential to reduce the environmental impact of conducting onsite surveys. At present c. > £20million[1] is spent travelling to sites to gather data on assets. Sensing technology could reduce the need for personnel to physically visit these sites. For example, for one company surveyed, installed an asset monitoring system which reduced fuel consumption by 1136 litres per week.

Implementing sensor technology can also provide a mechanism for asset data collection, analysis, and 4D modelling of assets which has the potential to reduce through life costs and ensure assets are used to their full.

However, sensor technologies have had limited adoption within the construction and infrastructure industry to date (see survey results below). There are many challenges to adoption; this discovery poster work highlights these challenges as well as the benefits of adoption.



i3P Survey Results

Data Interface and Storage

- 75% of respondents use a mobile app for manual condition monitoring
- Data collected by sensors is used principally by engineers for all responding companies
- Respondents are already using data visualisation methods, such as dashboards
- 100% of respondents use a cloud or centralised server
- 75% of respondents use or plan to use publicly available weather data

Barriers to Adopting Asset Technology

- The main barriers to adopting asset technology are cost and technical risk, however there are also a number of drivers for adopting asset technology

Sensing

- The majority of monitoring is done during construction. The frequency of monitoring depends entirely on risk, which is assessed by engineers
- Sensors are used in a range of conditions, including above ground, below ground and underwater
- 75% of respondents use sensors to monitor ground movement. Other sensor applications include force and flow monitoring
- The majority of monitoring uses surveying methods and manual inspection, rather than sensors
- Sensing is not currently used for condition monitoring after construction of assets

Analytics

- 75% of respondents already use data analytics:
  - Microsoft Power BI
  - Qlik
  - Bespoke
- The majority are deployed on cloud or central servers, which raises security concerns
- Current analytic solutions are not specific to asset monitoring, therefore lack predictive insights

Power

- 95% of power is supplied by the grid
- All respondents are concerned about cost and the green credentials of power sources
- There is a demand for temporary power supplies which have high density storage at a low cost

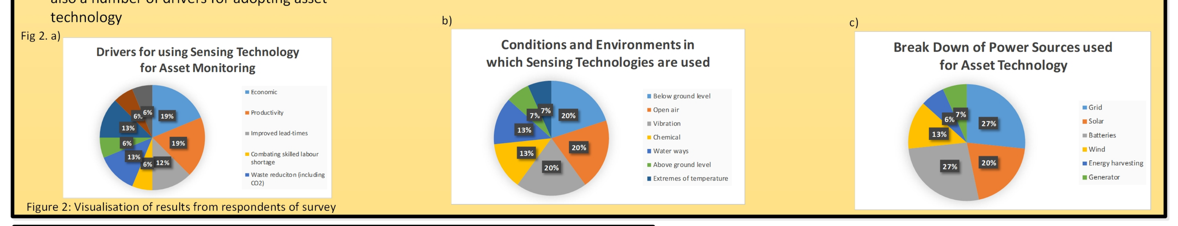
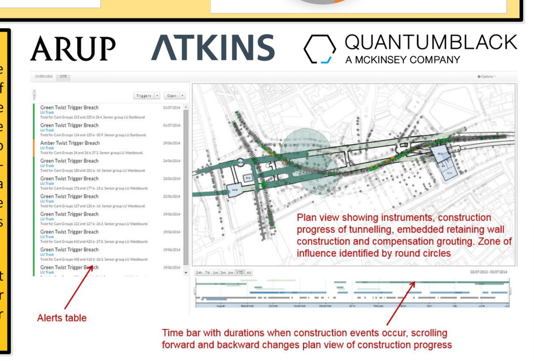


Figure 2: Visualisation of results from respondents of survey

Case Study: Data Analytics

Description: Arup, Atkins, and QuantumBlack have developed and tested an adaptive instrumentation and monitoring (AIM) application to undertake analytics on large volumes of data. The data is from manual and automated sensors that monitor any movement of the ground/assets/structures, occurring as a result of underground construction projects. The analytic methods extend upon traditional Gaussian models with spatio-temporal correlation, to enable automated analysis that can be interrogated by an engineer or project leader, via a web-based app. This data is presented alongside monitoring and construction progress data. The data is used to predict future movements, identify anomalies, issue alerts and make predictions of movement at the earliest possible opportunity.

Benefits: The success of the project gives confidence that implementing applications that combine monitoring and construction progress data alongside the use of data analytics can offer significant savings for monitoring programmes and reduce the risks of significant ground or structural movements being missed.



Case Study: Sensors and Connectivity

Description: To facilitate maintenance whilst also offering its customers new services, Cofiroute (VINCI Autoroutes), in partnership with Orange, developed a connected rest area prototype in Boutroux, on the A10. Hundreds of wireless sensors using the LoRa communication technology were installed. Among other functions, they can alert the teams when rubbish containers are full or when soap distributors and toilet paper need replenishing. They can also detect occupancy of parking spaces, record water and electricity consumption, and measure the temperature of the pavement to anticipate the risks arising from formation of black ice.

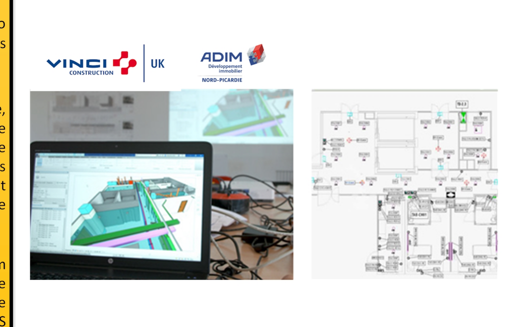
Benefits: After a nine-month trial, the prototype proved to be fully satisfactory. It enables remote access to information usually collected on the ground by a road operative. Being immediately informed of the level of cleanliness and availability of consumables makes it possible to optimise upkeep of the rest area whilst also improving customer satisfaction. The system could then be rolled out on the 268 rest areas and 189 service areas in the VINCI Autoroutes network.

Case Study: Data Interface

Context: Adim Nord-Picardie proposed that the building information model be handed over to the client after construction is completed. The client refused due to an unpleasant previous experience.

Description: Convinced that the use of the BIM model could be valuable in the operating phase, the Adim Nord-Picardie teams, in liaison with Sogea (VINCI Construction), decided to adapt the digital model to its future user. After a first phase devoted to explaining the potential uses of the elements already available – models, plans, as-built file – to the client, the BIM model was enriched by adding its own property data. Special work was also carried out to make the as-built file documents – the building's "health card" – accessible from the intuitive interface of the digital model

Benefits: By adapting the content of the digital model to the specific needs of the client, Adim Nord-Picardie was able to demonstrate very clearly the practical merits of using BIM in the operating phase. By creating trust in this way, the company will be better equipped to anticipate the operator's future needs in terms of updating the model and creating interfaces with CMMS applications, etc.



Implications of using sensing technology on fixed assets

Theft: There is a history of theft of valuable items and resources from sites e.g copper, sensors etc. Whilst sensors are a potential target of theft, they may also serve as a deterrent if setup correctly.

Security: Cyber security is a real threat. Connected sensors could be hacked to prevent the detection of malicious activity, to manipulate data, or to steal the generated data. To combat this, smart sensors should be capable of data encryption with time and origin stamping to detect fraudulent or replayed messages from sensors.

Ethics: There is a risk that some sensor types (e.g. cameras) could collect personal data of people's faces, gaits, etc and this info held without consent. It is recommended that the usual codes of practice are followed for surveillance cameras.

Regulations: Any electrical devices that may pose risk to health by failure (e.g. fire) will require testing to ensure they are fit for purpose. Wireless communication will need to conform to local regulation. General data protection rules may need to be followed if personal data is collected.

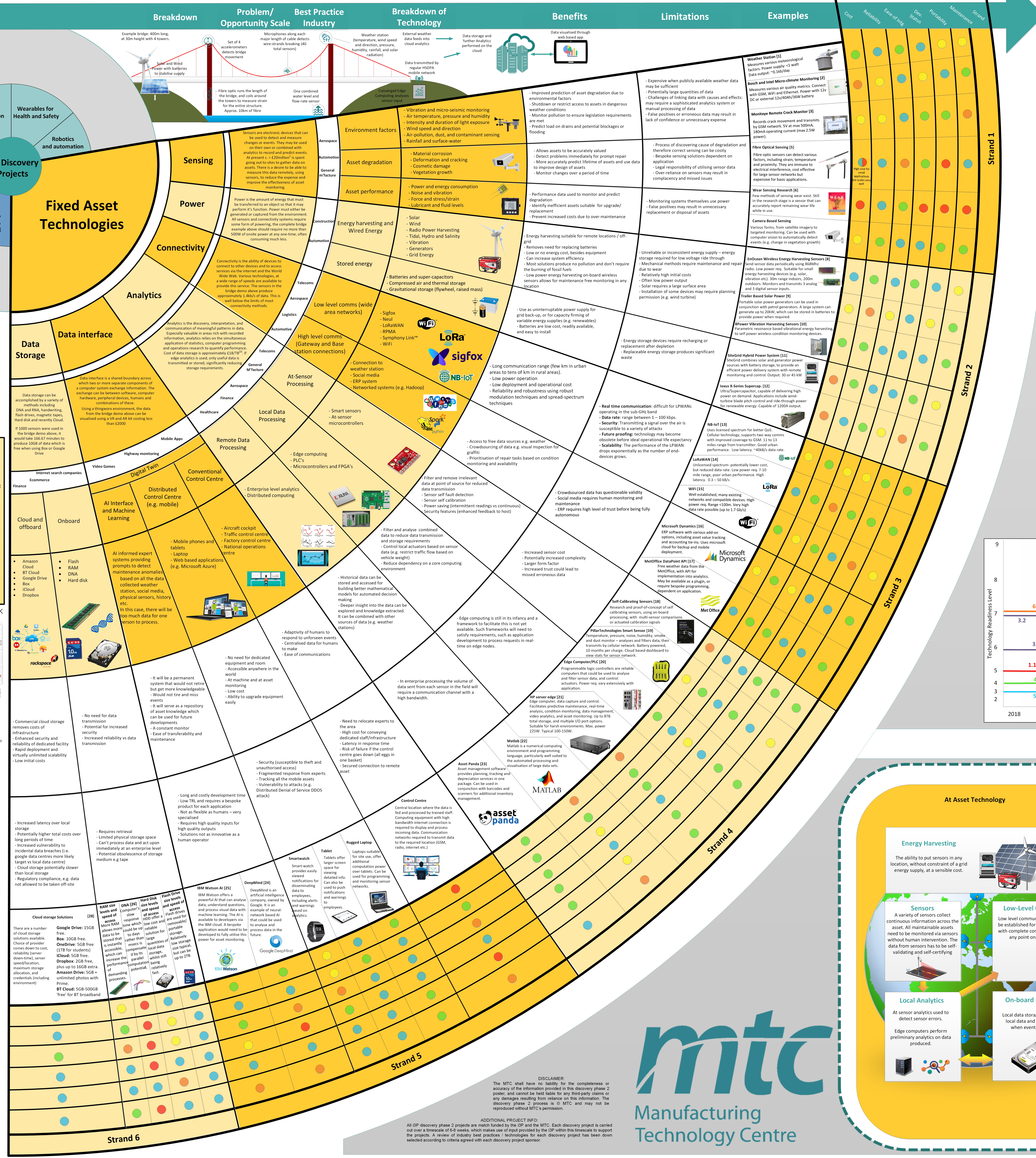
Spectrum of sensing (Continuous vs Discrete): It is possible to cover an asset entirely with sensors so that data is collected at every point on an asset's surface. This is called Continuous sensing. This type of sensing offers a high resolution with the ability to get finely grained data. The problem is with the amount of data that will be generated by the sensor network. How will it be stored? How will it be transmitted? How will it be processed? How much will it cost to store it? Perhaps a more practical solution is to use discrete sensing which is the placing of sensors at set distances from each other. This will lead to more economical data volume. However, it raises the problem of missing a fault in the space between two sensors.

Qualitative vs Quantitative: Traffic cameras give a user at the base station a qualitative assessment of the road condition and traffic levels. With video analytics, a quantitative assessment can be achieved – e.g. the number of cars that pass through in a given time period.

HD Cameras looking at the bottom of the bridge can be viewed by an operator at a base station to assess if corrosion is taking hold, paint is peeling off or if there is something structurally wrong with the bridge. The operator could potentially use around 10 minutes to inspect each bridge. With this approach, it will take an operator ~55 hours (10mins * 330 (no. of bridges in the UK) to assess all the bridges in the UK.

Measurement System accuracy and calibration: It should be considered whether a sensor system is for reference only or if they should be used for real life/death decision scenarios. An exceptionally low total uncertainty is required for these scenarios, in which self-calibrating, fault detecting, and backup sensor networks are required.

Liability: Asset owners are liable for their property and any damages caused to 3rd parties in the event of a failure. What is the potential liability case if physical inspection is replaced with off site monitoring? What impact does discrete data have if a failure occurred between sensor points e.g. cracking?



ADDITIONAL PROJECT INFO:
All i3P discovery phase 2 projects are match funded by the i3P and the MTC. Each discovery project is carried out over a timescale of 6-8 weeks, which makes use of input provided by the i3P within this timescale to support the projects. A review of industry best practices / technologies for each discovery project has been down selected according to criteria agreed with each discovery project sponsor.

Manufacturing Technology Centre

Development Strategy

Strand 1: Sensing

Used for on-site monitoring/data acquisition. The applications are dependent on the individual use cases, and are likely to require accompanying equipment to provide a full solution. The vast majority of asset monitoring solutions will require some form of sensing.

Next steps:

1.1) I3P to collaborate to define common challenges and to consolidate demand

1.2) Potential for a low cost sensor demonstrator project to validate commercially available technologies

1.3) I3P to work across supply chain against common sensor types/commodities to standardise across industry

1.4) I3P rollout of sensor technology on new projects with a collaborative approach

1.5) There are specific projects needed to validate new sensor technologies, this will be application dependent and will call for development and demonstration of new technologies as needed by industry (e.g. very high frame rate cameras)

Strand 2: Power

Required in various quantities for all applications. Future developments are increasingly requiring off-grid energy harvesting, and clean/renewable energy solutions, to enable the use of wireless devices and reduce the use of fossil-fuel burning power supplies. This technology will be driven by consumer goods and renewable technology development. The construction industry will deploy the technology as it becomes commercially available. Validation of energy harvesting technologies to be incorporated into steps 1.2 and 1.5.

Strand 3: Connectivity

Used for linking asset monitoring devices on-site and to a larger national or international network, where the data can be processed remotely. Future developments are likely to be in low power connectivity, for self-powering wireless sensors and increased efficiency; and in decreasing latency and increasing bandwidth for enhanced real-time monitoring of multiple data feeds. I3P already influence government strategy with regards to 5G deployment and industrial communications.

Next steps:

3.1) I3P need to develop security protocols and testing standards. This is likely going to be ongoing work.

3.2) I3P to investigate connectivity mapping based on project experience to determine areas where investment is needed. I3P to partner with telecoms providers to build new business models to support investment in infrastructure in areas of low coverage.

3.3) There is a requirement to fuse data from various sources such as operational and user data, for example social media and asset data. This needs to add to the output of sensor data to give a full picture of asset performance. Demonstration of this to be included with steps 1.2 and 1.3, through fusion with data from social media.

Strand 4: Analytics

Analytics performed on-site at the 'edge' or at a remote data centre. Future developments will see more detailed and predictive outputs, through the use of much larger data sets and enhanced processing capabilities. Other developments are in the area of smart sensors increasing reliability over conventional sensors, with on-sensor analytics.

Next steps:

4.1) I3P need to define use cases where historical data can be analysed to support ongoing asset maintenance, this should also include using analytics to establish cause and effects of quality failure. Demonstrator project to implement root cause analysis on assets.

4.2) A demonstrator project should be completed on an I3P case study to use historical data over the life time of the asset. This project will prove the concept of using analytics to achieve predictive maintenance and inform planned maintenance.

4.3) Roll out to other I3P examples identified in 4.1.

Strand 5: Data Interface and Digital Twin

Data interfaces used for communicating data across devices and presenting it to a human operator. Digital twin is used for modelling systems virtually, allowing for changes to the system to be tested before implementation. Future developments are likely to see digital twins being easier to create and integrate.

This work needs to link to the metrology discovery project to ensure that assets are captured as built so that digital twins can reflect reality.

Next steps:

5.1) I3P to support BSI on data format for digital twins for infrastructure

5.2) A project is needed to define an agnostic data format based on JSON (JavaScript Object Notation) and IFC (Industry Foundation Class) to support commercial classification of data followed by roll out.

It is assumed that once 5.1 and 5.2 are achieved there are no technical blockers to prevent immediate rollout across I3P consortium.

Strand 6: Data Storage

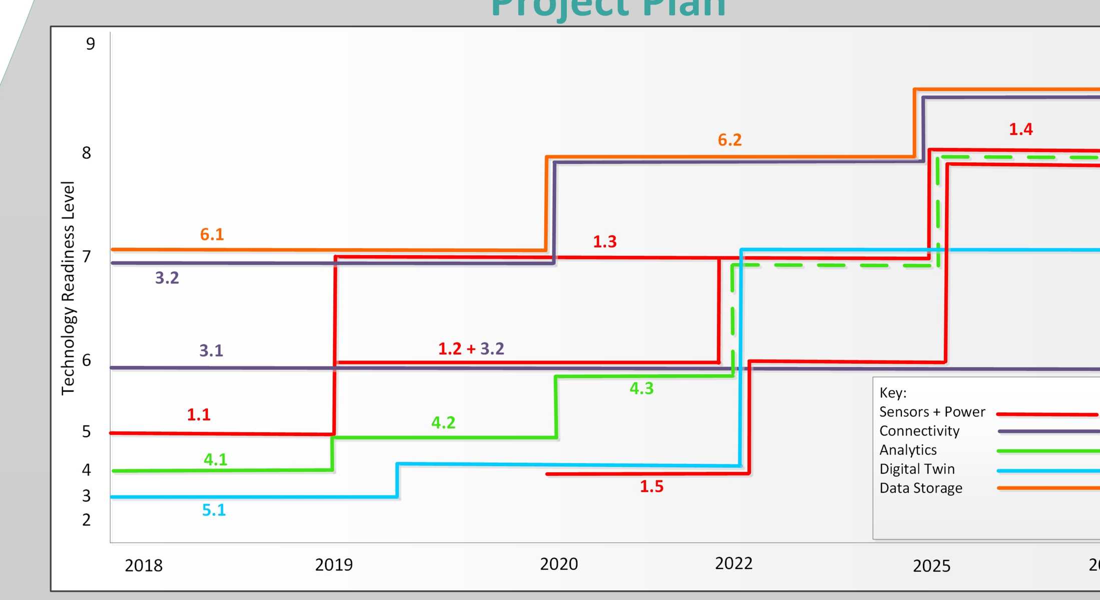
Future developments in data storage aim towards increasing storage capacities without increasing physical space occupied by storage drives. Increased storage allows more data to be captured, which can improve the quality of information produced by analytics. Novel storage methods are also being developed, such as DNA based storage.

Next steps:

6.1) I3P to support the development of best practice for data storage and technology direction to enable strategic decision making.

6.2) I3P to explore the feasibility of a national central repository to store data from all assets across all I3P.

Project Plan



Future State