Inspection for Construction and Infrastructure

Background

Problem Statement

The Construction sector in the UK is very diverse, ranging from building construction to mining. Construction output in the UK is more than £110 billion per year and contributes 7% of GDP - 60% of construction is new build, whilst 40% is refurbishment and maintenance [1].

Despite this, profit margins are very low (an average of 1.5% in 2014) [2], which leaves little scope for research and innovation which will, in the long term, increase profits. For these reasons, the MTC has been tasked with completing discovery projects in a number of areas relating to the construction and infrastructure sector. This poster focuses on inspection for construction and infrastructure, it clarifies what technology is available, the benefits it could bring and the barriers to it's adoption.

Background

Inspection is a term which comprises both metrology and Non-Destructive Testing (NDT). Metrology is the science of measurement and, in this case, usually refers to ensuring an asset is dimensionally and geometrically correct within a given tolerance. NDT is analysing the asset to ensure it is structurally sound and no defects are present which might affect the performance and integrity of the asset. Inspection generates an abundance of data, which can be leveraged for a number of benefits.

Inspection is extremely important. Failure to inspect could result in wasted materials and time, resulting in unplanned costs if an asset is the wrong size and does not fit, or lacks the required integrity. There can also be severe safety implications if a building or structure has defects present which could cause an asset to break or fail. For these reasons this poster has focused on six areas, or strands, of inspection for construction and infrastructure:

1 – Buried Assets – Focusing on technologies for the detection and assessment of underground assets, which can be comprised of a range of materials such as metals, plastics, concrete etc.

2 – Underwater Assets – Focusing on the inspection of underwater assets such as bridge piers, dam walls and off-shore platforms.

3 – Hidden Elements – Focusing on the detection and assessment of hidden elements, such as reinforcement bars within concrete, or the detection of voids behind concrete tunnel linings.

4 - Large Assets – Presenting technologies which can be used for the assessment and digitalisation of large assets.

5 – Data Use and Management – The construction industry is keen to adopt digital technologies and explore how inspection data can be better used and managed. This strand looks at making the specific inspection data more accessible, linking inspection data into a BIM to assist monitoring the assets over time and creating networks of digital assets using inspection data to guide the management of a wider asset base.

6 – Inspection of Off-site Manufactured Elements – Off-site manufacture presents many cost and time benefits. However, it is necessary to inspect the elements before they reach the site, otherwise, if the assets are not fit for purpose then not only will the material and time costs be lost, but the shipping costs will be also.

Current use of Inspection Technologies and Future Adoption of Inspection Technologies

Legend
- Uses technology / operation
- Does not use technology /operation
- No response

The Survey was answered by 12 individual respondents across 5 businesses, 2 of whom were clients and 3 contractors.

Current Use and Application

The survey shows a breadth of technologies being used (25+), including several bespoke to the user and some notable new applications e.g. Intelligent Compaction using measurement sensors.

Drones (UAV) and Ground Penetrating Radar (GPR) were commonly used, along with laser scanning. Manually performed inspections are in the minority.

The majority of respondents report encouraging outcomes by using inspection technologies, citing advantages such as improved data in terms of integrity and repeatability.

Improved risk for working at height or underground and lower costs are also noted.

Inspection Data Management

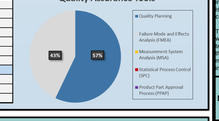
Record keeping methods are evenly distributed between paper-based, manual digital and automated digital data capture. Record retrieval is mainly digital and is mostly weekly or monthly.

Quality Assurance

All respondents use either Quality Planning or FMEA or both. See chart below.

MSA, SPC or PPAP tools are not used currently by the 5 businesses, although respondents indicated they see the value and intend to adopt in future.

Quality Assurance Tools



Case Study: Cloud-based Platform for Asset and Inspection Data Management

The University of Huddersfield, in conjunction with Network Rail, have developed a cloud-based system for asset and inspection data management for Network Rail masonry bridges [4]. This is shown in the 5 numbered images.

1 – A network of assets are shown on a map. The map can be searched and the asset of interest focussed upon.

2 / 3 – The data associated to each asset is shown on the map. Each piece of information can be opened and viewed. This includes data such as site photographs, point clouds, meshed models, BIM, images with identified defects / inspection reports.

4 – The BIM can be interrogated further. The inspection data can be linked to the specific element in the BIM in which they were identified. Comments can be associated to BIM elements along with tasks for the inspectors to carry out the next time they visit.

5 – The BIM, point cloud and meshed model can be viewed in Virtual Reality. This provides the opportunity for inspectors to examine the assets off-site. Defects may be identified which were missed by the on-site inspectors.

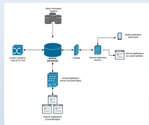
This work has demonstrated a platform for storing and using inspection data in a manner which is easy to use and access. This platform has great potential for using inspection data to manage existing assets.

Case Study: Spatial Data Infrastructure for Crossrail

During the construction of the Elizabeth line, the availability of accurate geospatial data was essential at every stage - from conceptual design through to construction [5]. Due to the scale and timescales of the project, there were significant changes in both the geospatial data itself and the technologies commonly used within the construction industry.

To ensure relevant, up to date spatial data was available to all relevant parties from the outset, a data sharing infrastructure which could be updated not only with new versions of stored information, but also with entirely new data formats and structures was developed. A robust system centred around a central repository was built allowing many different users to access information concurrently; a diagram showing this structure is displayed adjacent. This structure was capable of storing and distributing a wide variety of data, including 3D CAD and BIM data as these became available. The choice of a common coordinate system for all of these data types was particularly important for enabling interoperability between the different types of data.

The use of the SDI has yielded significant time and cost savings on the Crossrail program with a saving of 5,000 person hours being reported on one contract, and an 80% reduction in time taken to produce technical reports across the program.

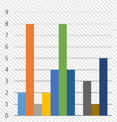


High level structure of the spatial data infrastructure (SDI) adopted by Crossrail demonstrating access to a central repository by several different nodes.

Current Trends in Inspection for Construction: i3P Survey

How is Inspection Data stored?

Barriers to Adoption of Inspection Technologies

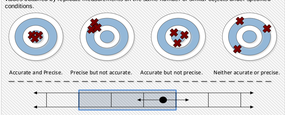


How is Inspection Data captured?

Metrology Principles – The metrology principles below are commonplace in a number of other industries. Improved understanding and adoption within the construction sector will prove beneficial.

Measurement Accuracy – Closeness of agreement between a measured quantity value and a true quantity value of a measurand.

Measurement Precision – Closeness of agreement between indication of measured quantity values obtained by replicate measurements on the same number of similar objects under specified conditions.

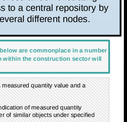


Tolerance and Measurement – for a given measurand to be in tolerance, a measurement must be made and fall within the tolerance band including the measurement uncertainty for there to be confidence that the measurand is within tolerance.

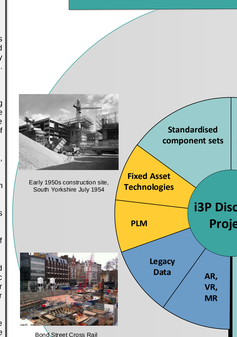
A good measurement should include the measured value, the uncertainty and the level of confidence that the true value lies within the stated value, e.g. 4.2 mm +/ - 0.02 mm with a confidence of 95%

Measurement System Analysis (MSA) – a structured procedure which is used to assess the ability of a measurement system to provide good quality data. The MSA consists of a controlled experiment to check the repeatability and reproducibility of the system, resulting in the confidence that the measurement system is fit for purpose. A gauge repeatability and reproducibility (Gauge R&R) study is a specific type of MSA used for continuous data.

Datum Strategies – Datum strategies will have the potential to affect the assembly process. For example if the 4 blue panels use a datum that prioritises the left hand side of the wall (black box) then if the wall varies in length to the design intent, then there is the potential for all of the panels to be mounted in the correct position, but this will result in the panels being in contact with each other and a large gap towards the right hand side. However, a different datum strategy may incorporate the centre of the wall and regardless of whether the wall is incorrectly sized the panels will be equally spaced and still functional.



Breakdown



Problem Scale

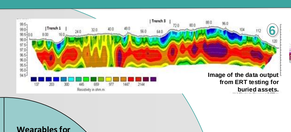


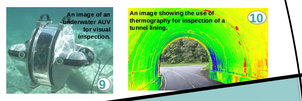
Image of the data output from ERT testing for buried assets.

Best Practice Industry

An image from CrossRail in which buried asset data is linked to a 3D model for visualisation.

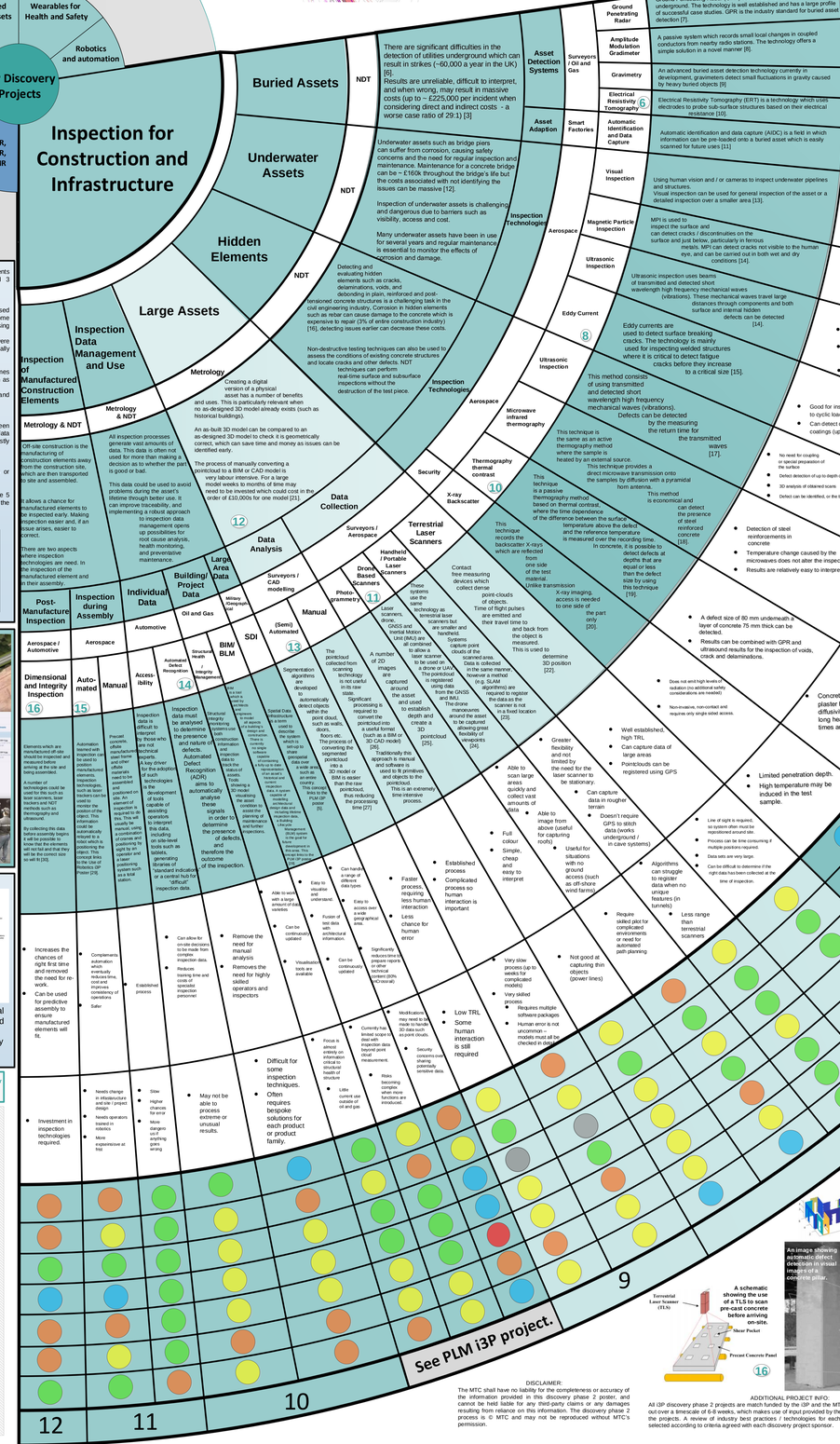
An image of a diver carrying out eddy current testing on an underwater asset.

Breakdown of Technology



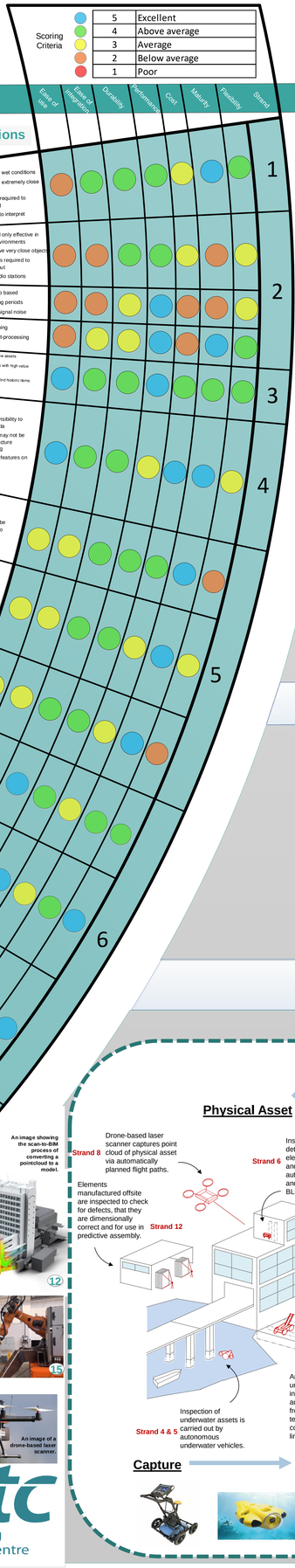
An image of an underwater AUV for visual inspection.

An image showing the use of thermography for inspection of a tunnel lining.



Findings

Scoring Criteria	
5	Excellent
4	Above average
3	Average
2	Below average
1	Poor



Development Strategy

Strand 1 – Improved Accessibility and Use of Buried Assets Inspection Data
How can the inspection data interpretation be improved and de-skilled? How can the inspection data be converted to useful formats which can be connected to BIM? How can inspection data from differing inspection technologies be combined into one output?
1.1 Understand state of the art in academic research.
1.2 Complete trial work to translate into a practical output.
1.3 Complete validation work at the MTC to prove capability (MSA, GR&R).
1.4 Package system and collaborate with supply chain and technology vendors to commercialise.
1.5 i3P deployment and standardisation including standard development.
1.6 i3P rollout.

Strand 2 – Development of High Potential, low TRL Buried Asset Inspection Technologies
1.1 Technology watch. Wait for academic research to develop technologies to a point where the MTC can offer assistance in industrialising technologies into a commercial system.

Strand 3 – Adoption of Asset Adaption Technologies for Buried Assets
Asset adaption technology exists in other sectors and can be adopted.
3.1 Technology transfer project to develop adoption approach for construction.
3.2 Development of standards, security aspects and rolled-out on development project with i3P members.
3.3 i3P deployment.

Strand 4 – Improved Accessibility of Underwater Visual Inspection Data
Undertake some work aspects of Strand 1 but for underwater visual inspection data.

Strand 5 – Underwater Inspection Technology and Automated Deployment Methods Selection
5.1 Develop technical specification for types of assets and defects. Downselect the best technology for this inspection.
5.2 Develop and test deployment platforms.
5.3 Roll out on i3P demonstration project.
5.4 i3P adoption.

Strand 6 – Improved Accessibility and Use of Hidden Elements Inspection Data
6.1 Same work as Strand 1 for hidden elements inspection data rather than buried assets.
6.2 Same work as Strand 5.1 – 5.4 for work on automated deployment methods.

Strand 7 – Development of Strategy for Backscatter Inspection Technology
This technology has shown potential but is at low TRL for this sector and applications are not well understood.
7.1 Investigate technology potential and develop use cases and technology strategy.

Strand 8 – Improving Automation and Ease of Large Asset Measurement
8.1 Investigate auto-generation of measurement flight paths from initial point cloud or as designed model.
8.2 Prove process and validate auto-collected pointcloud against manually collected point clouds.
8.3 Roll out on i3P demonstration project.
8.4 i3P adoption.

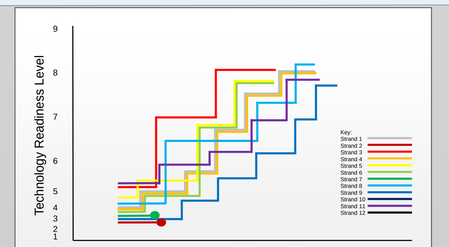
Strand 9 – Automated Digitisation of Large Assets from Pointclouds
9.1 Understand and select current best method of automated point cloud digitalisation and segmentation.
9.2 Trial methods on existing simple pointclouds.
9.3 Trial methods on more complicated pointclouds.
9.4 Demonstrate full automated large asset digitisation process.
9.5 Roll out on i3P demonstration project.
9.6 i3P adoption.

Strand 10 – Improved Accessibility for Inspection Data
This will be worked on and demonstrated in Strands 1, 4, 6. Once demonstrated for those cases it can be wider applied.

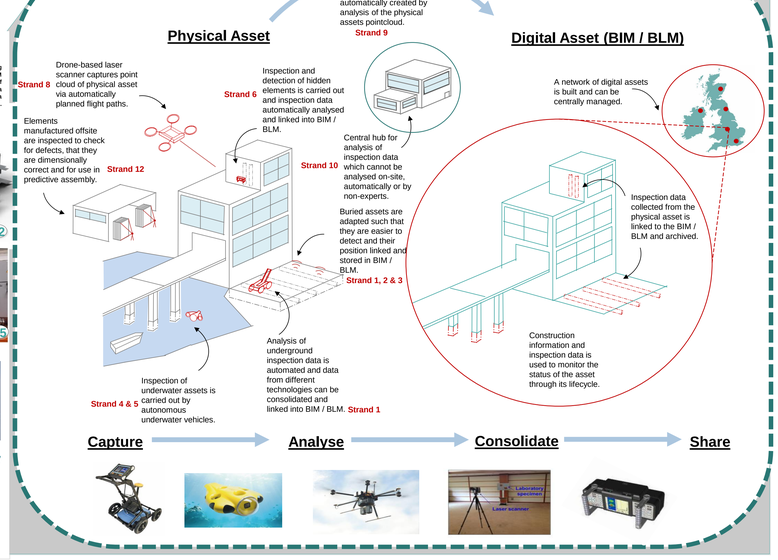
Strand 11 – Development of Increased Adoption of Inspection Assisted Automated Assembly
11.1 Prove methods in controlled environments.
11.2 Prove methods on-site.
11.3 Identify all situations where automated assembly could be used, and the site infrastructure changes which may be required.
11.4 Roll out on i3P demonstration project.
11.5 i3P adoption.

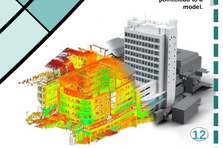
Strand 12 – Adoption of Best Practice Inspection Techniques from Other Sectors
Within the construction sector this is already undertaken to a degree, but in some cases there is scope for improvement and better standardisation across the sector.

Project Plan



Production Concept





An image showing the scan-to-BIM process of converting a pointcloud to a model.

A schematic showing the use of a TLS to scan pre-cast concrete before arriving on-site.

An image showing research using algorithms to automatically segment a pointcloud into walls and doors.

An image showing automated fitting of a window model.

An image showing automatic defect detection in visual images of a concrete pillar.

An image of a drone-based laser scanner.

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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