ROYAL ACADEMY OF ENGINEERING

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Crossrail – improving performance of delivering infrastructure

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Background

Crossrail is Europe's largest infrastructure project. When completed, it will stretch from Reading and Heathrow in the west, across to Shenfield and Abbey Wood in the east. The new railway will comprise 100km of track and 10 new stations.

Around 24 trains an hour will operate in the central section between Paddington and Whitechapel during peak periods. Each train will be able to carry 1,500 passengers. An estimated 200 million people will travel on Crossrail each year.

During the tunnelling phase of the programme, which comprised 42km of bored tunnels, engineers had to navigate around all sorts of existing infrastructure, including railway infrastructure belonging to London Underground and Thameslink and gas, electricity and water pipelines.

The tunnel works caused settlement and ground movements at the surface, with possible impacts on existing buildings and infrastructure. In total, some 16,000 buildings, tunnels or utilities were potentially affected by the tunnelling works. As a consequence of this, a large amount of instrumentation and monitoring equipment was installed on buildings to check movement. Up to £200 million was spent on instrumentation and monitoring, representing a significant investment.

Motivation

Together with improved risk management, better cost effectiveness was one of the main drivers. At the start of the project, teams of engineers were deployed at various construction sites across the route to interpret data generated by the instrumentation. Around 30 people were deployed in total, equating to two or three people for each station. The amount of data being generated was huge. As an example, Farringdon Station was producing 100,000 data points per day from a combination of manual and automated readings.

In similar past projects such as the Heathrow Express tunnel, collapses occurred due to a failure to interpret data, so understanding and acting on large volumes of data was a key requirement. A mixture of automated devices and traditional manual techniques were used for monitoring. Manual monitoring is expensive as it requires the employment of numerous teams of surveyors so ways of using data analytics to reduce the amount of manual monitoring were explored.

Development

The software system was developed by Arup and Atkins in collaboration with Quantum Black, a data science consultancy. Its development was partially funded by Crossrail, so while the ownership of data remained with Crossrail, the system was retained by its development team. The data analytics was split into three main types:

- Anomaly detection – anomalies were analysed to judge where settlement behaviour was of concern, and where unusual behaviour was caused by errors in the monitoring data. Information about the construction process was integrated with monitoring data in order to aid interpretation of movement 'signatures' in the data.
- Sample optimisation – based on historical monitoring data and on engineering judgment, it was possible to identify where there was redundancy in the monitoring system and reduce the amount of monitoring being carried out in order to reduce costs.
- Forecasting – it was possible to predict when settlement might exceed an acceptable level, thus allowing engineers to introduce contingencies in advance, such as changing the methodology for forming the tunnel.

Results

The development team created a web-based application known as Adaptive Instrumentation and Monitoring (AIM) – See Figure 1. The program took the data from each site and, with some complex statistical analysis, produced visualisations of the information to try to understand spatial and time-dependent correlation between monitoring points, and alert engineers to issues of concern.

A method of quality assurance was introduced: for each issue that was flagged up, engineers could enter in a box that they had actually reviewed the issue and dealt with it appropriately. A higher level view was also generated, allowing project managers to assess progress without needing to look at the detailed data.

The application helped field engineers interpret and act on data, and in turn helped improve the risk management of field engineers' work.

Next steps

The data generated during this project can be used to inform the design of monitoring systems for future infrastructure projects such as HS2. Similar data analytics techniques can also be applied to other areas of civil engineering. Other applications of the software developed during this project include optimising baggage handling in airports and interpretation of data from railway assets.