

Technical Advances Bring Digital Twin of Underground Infrastructure Closer



Mapping the underground is one of the major challenges in creating an infrastructure map at the municipal, regional, and national level, which is a key foundation for a national digital twin. Recent technical developments include: the ability to collect data at highway speeds that can be used to create a 3D model of underground infrastructure, software that can extract relevant 3D underground information from consumer digital photography, and video capture. Meanwhile, novel ways to share information about underground infrastructure, and progress on standards for sharing information about the subsurface are making mapping the underground increasingly feasible.

The uncertainty in the location of underground utilities costs the US economy at least US\$50 billion annually, with 1,906 injuries and 421 deaths over the past 20 years. A leading cause of highway construction delays is missing or inaccurate information about the location of underground utilities. To address the risk of liabilities associated with unknown or inaccurately located underground utilities, contractors regularly increase bid costs by a minimum of 10-30%. Knowing where things are underground has become important enough that in several countries around the world (France, the Netherlands, Singapore, UK and USA), initiatives to create national digital twins of above and below-ground infrastructure are already underway.

A typical example of the impact of poor information about the location of underground utilities can be seen in the Sydney Light Rail Project, which is a US\$2.1 billion PPP project for a 12km light rail extension in Sydney, Australia, to be completed by 2019. In preparation for construction, a year was allocated for identifying potentially conflicting utilities in the proposed right of way. About 500 subsurface utilities were identified and scheduled for relocation. During construction, a further 400 unmapped utility services were encountered. An economic impact study by an independent consulting firm estimated that the project could have been completed at least one and a half years sooner if a complete and reliable 3D map of underground infrastructure had been available at the project planning stage.

In the UK, about 4 million excavations are carried out every year on the country's road network to install or repair buried utility pipes and cables. Not knowing the location of buried assets causes practical problems that increase costs and delay projects - but more importantly, it increases the risk of injury for utility owners, contractors and road users. Research at the University of Birmingham has determined that the direct costs of utility strikes in the UK range from £300 to £2,800. Furthermore, the researchers found that the true costs, including indirect and social costs, associated with utility strikes is 29 times the direct cost. In the US, the Common Ground Alliance (CGA) reports that there were 390,366 documented underground utility hits in 2016. The average direct damage cost was found to be US\$4,021. The CGA estimates conservatively that the direct cost to the US economy was US\$1.5 billion. If the UK ratio is applicable to the US, it would indicate that the total estimated impact of unknown or poorly located underground infrastructure on the US economy is at least US\$50 billion.

University research has put a dollar figure on the benefits of accurate location data for underground utilities. In 2007, the Pennsylvania Department of Transport commissioned Pennsylvania State University to study the savings on ten randomly selected PennDOT projects. The study found a return on investment of US\$21.00 saved for every US\$1.00 spent on improving the quality level of subsurface utility information. In Europe, an economic analysis of a Milan pilot project to map all underground infrastructure using ground penetrating radar for the Expo Milan 2015 site found a return on investment of €16 for every euro invested in improving the reliability information of underground infrastructure.

Investment is Key

The need for investment in infrastructure is steadily growing - with an estimated US\$53 trillion investment required over the next 15 years (double this figure if the infrastructure is to be truly sustainable). Increasingly, infrastructure projects require private investment because governments simply have less and less money for capital projects. Private investment in infrastructure, which reached nearly US\$80 billion in 2016, is unlike government investment, which is primarily focused on social benefits. Its requirement for financial returns drives productivity of construction, operations and maintenance which, in turn, subsequently drives more investment in technology.

Until recently, construction has been among the lowest industries with respect to investment in research and development, but there are signs that this is changing. In the last few years, the number of start-ups focussed on technological innovation in construction has risen dramatically. As evidence of increasing investment in the underground detection sector Hexagon, which has a revenue of US\$4 billion annually, acquired IDS (Ingegneria dei Sistemi) GeoRadar, an Italian company that has developed a towed multi-channel ground penetrating radar (GPR) array that can collect data on underground infrastructure at faster speeds than previously possible. Since then, Leica has released important enhancements to the software used to create 3D models of the underground from the GPR scans and other information.

Bentley Geosystems, which earns about US\$1 billion in annual revenue, has developed software specifically for managing underground infrastructure location information. Bentley Subsurface Utility Engineering (SUE) enables users to develop 3D subsurface utility models from 2D models, resolve subsurface utility clashes, and model, analyse, and design subsurface infrastructure networks.

In 2018, two technical advancements in detection were reported that bring the cost-effective mapping of underground infrastructure at the municipal, regional, and national level closer to reality. T2 Utility Engineers, based in Whitby, Ontario commercially use an IDS GeoRadar Stream EM multi-channel GPR array towed routinely at 10-12km/hr to capture subsurface data. In a separate initiative, a successful proof of concept has been reported by DGT Associates in Mississauga, Ontario in which data collected by a Siteco rig (combining a FARO mobile laser scanner, sensors and software GPR arrays) collected data simultaneously above and below ground at roadway speeds of 80-90km/hr.

To complement the advances in detection there are several initiatives to develop ways to share information about the underground infrastructure that is captured during construction. The City of Chicago has launched a pilot to deploy a platform for collecting data and creating and sharing a 3D map of the underground. In a similar vein, Bentley Systems has experimented with a system that equips excavation equipment with four inexpensive digital cameras that are used to collect images of underground infrastructure encountered during excavation. In the UK, Project Iceberg, a collaborative project between Ordnance Survey (OS), British Geological Survey, and Future Cities Catapult, has been created to better capture, collect and share data about underground assets and geological conditions, as well as to establish a way of sharing all this information among utility and energy companies, the transport sector, street works planners, building developers, and the construction industry.

Recent developments in standards reflect improvements in underground remote sensing technology. In France, the 2012 presidential decree defines three explicit levels of cartographic accuracy for underground structures: A = less than 40cm; B = 40cm to 1.5m, and C = greater than 1.5m. In the UK, the 2014 Publicly Available Specification (PAS) 128, developed under the auspices of the British Standards Institution (BSI) and sponsored by the Institution of Civil Engineers (ICE) and others, not only includes the A, B, C, D quality levels of the US standard, but extends it with explicit precision levels B1 to B3. A process to revise PAS 128 to reflect newer technical developments has just been initiated. The Open Geospatial Consortium (OGC) has initiated a three-phase project to develop interoperability standards for underground infrastructure. The project is supported by the Fund for the City of New York, the National Center for Civic Innovation, the UK Ordnance Survey and other organizations.

Reflecting the growing public awareness about the importance of accurate location information about underground infrastructure, France embarked on a nationwide multi-billion euro project to improve the quality of the location information about national underground utility infrastructure. The presidential decree mandates that, by 2019, the location of 'critical underground infrastructure' (which does not include telecoms, sewers or water infrastructure) in urban areas will be mapped to 40cm or better. Furthermore, by 2026, the location of the nation's infrastructure will be mapped to 40cm. The decree also specifies that the liability for hitting underground infrastructure that shares the responsibility between the utility owner and the contractor depends on the precision of the information available about the utility.

In the Netherlands, in 2015, the States General passed legislation mandating a "Key Registry for the Subsurface" or Basisregistratie Ondergrond (BRO). With effect from 2018, it requires that information about the subsurface must be reported to the Key Registry whenever excavation is performed. This includes information about subsurface utilities and geology. The objective is to begin sharing the information that is routinely discovered during construction projects.

In Singapore, the Urban Redevelopment Authority is planning to have a master plan of Singapore's underground spaces ready by 2019. It will be released as part of the next Master Plan guiding Singapore's development in the medium term.

The Digital Twin

As a result of the conjunction of the release of three UK government reports, *Industrial Strategy: Building A Britain Fit for the Future*, *Transforming Infrastructure Performance*, and *Data for the Public Good*, the transformation in how infrastructure is built, managed and operated in the UK has made a national digital twin a key concept for the UK government. A national digital twin includes above and below ground assets. It is based on the foundation concept that a digital model is equally important as the physical assets.

In the US, an initiative has just been started to create a national infrastructure map which would include subsurface infrastructure. At a special summit in Arizona, leaders in public administration, infrastructure development, geography, GIS, and data integration/open data reviewed the current state of location-based information on national infrastructure (including underground). The aim was to examine efforts to integrate location-based data systems across jurisdictions, to understand stakeholder communities perspectives, to identify strategies for more systematic access to data at the national scale, and to discuss the role of government to implement such strategies.

Taken together, the public awareness of the problem, the recent technical advancements in underground detection which are making cost-efficient 3D mapping of the underground increasingly feasible, and the benefits of accurate 3D maps of underground infrastructure, have led to growing momentum to create a digital twin of the subsurface at the municipal, regional and national levels.

