Institution: University of Birmingham

Unit of Assessment: UOA 14 – Civil and Construction Engineering

Title of case study: Mapping the Underworld – A research initiative to change the way we work in the streets

1. Summary of the impact

Many utility services are distributed using buried infrastructure beneath roads; inaccurate location leads to wasteful excavations and additional costs for service providers, businesses and the public. The Mapping the Underworld (MTU) project developed a proof-of-concept device to locate buried assets which can overcome problems of inaccurate mapping. This programme has acted as a crucial catalyst for the sector, leading to a series of significant actions by the industry informed by the MTU project. For instance, JK Guest, a major private sector contractor, invested £2m to establish the first vocational training centre for underground utility mapping in the UK to a specification developed by the Birmingham researchers; this centre opened in 2012 and more than 600 people had been trained there by July 2013. MTU and the industry promoted the development of an industry-standard for underground utility surveying, leading to the agreement of the British Standards Institute to develop a new standard which is being developed with sponsorship by the Institute of Civil Engineers. These, and the other impacts described in the case study, demonstrate the impact made to date on practitioners and professionals in the sector; these are the building blocks for the realisation of extensive economic impact from reduced disruption and the pro-active condition management of buried utilities.

2. Underpinning research

In 2001 the *NETTWORK (GR/R14064/01, 2001-2004)* project, led by University of Birmingham (UB), brought together academic and industry stakeholders to determine future research needs in the area of trenchless technology as its full potential was not realised. One area identified was the need to accurately locate and map existing buried infrastructure in order to improve the reliability of trenchless construction. This culminated in a workshop held at the UB on Underground Mapping Pipeline Location and Condition Assessment in 2001 attracting approximately 30 industrial stakeholders preparing the ground for MTU. This precursor to MTU started an industry debate and the *MTU initiative* (*EP/C547365/1* and *EP/C547330/1, 2005-2008*) began in 2005. This initiative combined a feasibility study to determine if different geophysical sensing technologies could be combined to develop a multi-sensor device capable of locating all buried assets in all ground conditions without the need for probing excavations, research into combining utility records from different providers, overcoming the problems of obtaining accurate positioning information using Global Positioning System in urban canyons and the development of resonant tags to make plastic pipes more visible for Ground Penetrating Radar (GPR).

The MTU initiative is a multi-university research project with the UB's work focussing on three main aspects: (1) The overall lead of the initiative by UB ensuring that all aspects of the project were delivered on time and to budget, (2) the creation of a stakeholder network to continue the collaborations established under the NETTWORK project as well as to engage with additional stakeholders and (3) the investigation of the influence of the ground on the electromagnetic signals from the geophysical sensors so that these can be tuned to different ground conditions achieving the optimal contrast.

Lead researchers at University of Birmingham have been: Professor C. Rogers, from Sept. 1998, Professor of Geotechnical Engineering; Dr D. Chapman, from Sept. 1998, Reader in Geotechnical Engineering; Dr N. Metje, from May 2005, Senior Lecturer in Geotechnical Engineering.

After proving the concept of a multi-sensor device, the *MTU Location Phase 2* (*EP/F065965/1, 2009-2013*) project commenced in 2009, led by UB. This project consisted of 8 work packages (WP), two of which were led by UB. One WP focussed on the development of a Knowledge Based System (KBS) taking geotechnical and hydrological parameters to determine geophysical soil parameters and thereby soil suitability information to indicate the suitability of different sensing technologies and it identified that information from borehole records can be used to predict these geophysical soil properties. The second WP compiled specifications for a UK national test facility. The specification of the test site sparked interest by JK Guest, so that the site was built and opened 2012 (see Impact 1). Furthermore, the UB continued the network engagement and developed opportunities to engage with different stakeholders such as politicians and civil servants through the MTU Pathways to Impact (PTI) project (*Jan. 2011-June 2011)*, the presentation of the

project to different audiences and the participation in a number of different professional initiatives.

Additional projects focus on the development of a fifth sensor technology using gravity gradient inferometers (*GG-TOP,* EP/I036877/1 *Oct. 2011- Sept. 2015)* with UB Civil Engineering leading the WP on determining the practical limitations of this technology as well as providing practical applications using the MTU test site and the comparison with the MTU sensing technologies.

Not only is the location of the buried infrastructure critical, but determining the condition of the asset is also vital for the asset owners. Therefore, Smart Pipes (*UKWIR, AWWarF and TSB,* EP/K504191/1, *~£380k, 2006-2016)*, is a parallel project to MTU developing micro- or nano-scale sensors to attach to plastic water distribution pipe walls to detect pipe material deterioration and leaks and remotely relay this information to a central server. This work extends the MTU concept as it provides condition information, but for this to be truly successful the location of the pipes has to be known in the first place, which is the aim of MTU.

3. References to the research (indicative maximum of six references)

1. Thomas AM, Chapman DN, Rogers CDF, Metje N, Atkins PR and Lim HM (2008). Broadband Apparent Permittivity Measurement in Dispersive Soils using Quarter-Wavelength Analysis. Soil Science Society of America, 72 (5), 1401-1409. (MTU1) DOI: 10.2136/sssaj2007.0319
2. Thomas AM, Chapman DN, Rogers CDF and Metje, N (2010). Electromagnetic Properties of the Ground: Part I - Fine-Grained Soils at the Liquid Limit. Tunnelling and Underground Space Technology, 25 (6), 714-722., Part II – The Properties of Two Selected Fine-Grained Soils", Tunnelling and Underground Space Technology, 25 (6), 723-730 (MTU1) doi:10.1016/j.tust.2009.12.002 and DOI:10.1016/j.tust.2009.12.003
3. Thomas AM, Rogers CDF, Chapman DN, Metje N and Castle J (2009). Stakeholder Needs For Ground Penetrating Radar Utility Location. Journal of Applied Geophysics, 67 (4), 345–351. (MTU Network & MTU1) DOI:10.1016/j.jappgeo.2008.07.006
4. Royal ACD, Atkins PR, Brennan MJ, Chapman DN, Chen H, Cohn AG, Foo KY, Goddard K, Hayes R, Hao T, Lewin PL, Metje N, Muggleton JM, Naji A, Orlando G, Pennock SR, Redfern MA, Saul AJ, Swingler SG, Wang P and Rogers CDF (2011). Site Assessment of Multiple Sensor Approaches for Buried Utility Detection. Special Issue on Noninvasive Sensing Techniques and Geophysical Methods for Cultural Heritage and Civil Infrastructures Monitoring, International Journal of Geophysics, Vol. 2011, Article ID 496123, 19 pp. doi:10.1155/2011/496123. (MTU2) DOI:10.1155/2011/496123
5. Metje N, Chapman DN, Rogers CDF and Bongs K (2011). Seeing through the Ground? The Potential of Gravity Gradient as a Complementary Technology. Special Issue on Advances in Instrumentation and Monitoring in Geotechnical Engineering, Advances in Civil Engineering, Vol. 2011, Article ID 903758, 9 pp. DOI:10.1155/2011/903758. (GG-TOP)
6. Metje N, Chapman DN, Walton, R, Sadeghioon, AM, Ward, M (2012). Real time condition monitoring of buried water pipes. Tunnelling and Underground Space Technology. 28 (3), 315-320. DOI:10.1016/j.tust.2011.11.005. (Smart Pipes)

References 1, 2 and 4 best indicate the quality of the underpinning research

4. Details of the impact

Most utility services, including electricity, water, gas and telecommunications, are distributed using buried pipelines or conduits, or via directly buried cables, and the majority of this buried utility infrastructure exists beneath roads. The difficulty of accurately locating these buried pipes and cables means that there are far more excavations taking place than should be necessary; an estimated one in four of all holes are dug in the wrong place. This increases the direct costs of maintenance to service providers and the social costs in terms of disruption to the public and businesses. In 2006 the road user delay costs alone due to streetworks were estimated as £5.1 billion per year for the UK (source 1), indicating the economic benefits that would be achieved by a reduction in unnecessary works.

The MTU project has been a crucial catalyst for the industry, leading to a clearer understanding within it about the step-changes needed to realise these potential savings. Important elements of these requirements have now been put into place as described below, with the Birmingham MTU researchers making a distinct and material contribution to their establishment and implementation.

The impact achieved to date has been primarily on practitioners and professional services within

the sector; these are the crucial building blocks for realisation of economic impact in the future.

Impact 1 - new professional training facility informed by research - MTU Centre of Excellence: A new national test and training facility for underground utility mapping, designed as part of MTU2, based on MTU1 and MTU2 research, was opened in September 2012. The design developed by the Birmingham team was adopted by a contractor (JK Guest), who invested £2million to build the site and associated training facilities in Lancashire. The Centre is designed to upskill practitioners and educate clients as well as to provide testing facilities for the MTU team and other interested researchers. MTU2 assisted JK Guest with the development of NVQ accredited skills modules, which were released in June 2012. The number of people trained on the test site by the end of July 2013 was over 600, with the initial focus on civil engineering clients and contractors (e.g. TfL and HAA). Hence, the greatest effect and benefit for the construction industry as a whole has been to allow these companies to measure the competence of the individuals and companies they employ to carry out their surveys. (source 2) This initiative alone covers a variety of the impact (**awareness, behaviour, capacity, practice and understanding**)

Impact 2 – new professional standard informed by research - BSI Publically Available Specification for underground utility detection, verification and location, sponsored by the Institution of Civil Engineers(ICE): MTU2, together with industry partners, promoted the need for a national standard equivalent to those in the USA, Canada and Australia to raise the profile of utility mapping in the UK and ensure there is a common understanding within the industry about the different levels of survey available. They were successful in making the case for this and as a result in 2012 the British Standards Institution agreed to create a new specification which was sponsored by the ICE. Dr Metje from the University represents the MTU on the Steering Committee as its **only** academic member, and has contributed, in particular, by ensuring that the standard is future proof and includes the latest MTU findings. The specification is expected to be published in January 2014. This will make a real, measureable difference to the industry which was highlighted by Nick Zembillas in *Civil Engineering Surveyor* (Nov. 2012) about national standards for utility detection stating that the advantages are "*Firstly, engineers and surveyors work within a guideline that meets a client's expectation and secondly, the client is assured that we hold full responsibility for the utility surveys we produce…and more importantly help eliminate risks associated with underground utilities during construction*." Thus, the research has resulted in a change in **policy** and **practice**.

Impact 3 – professional bodies have used research to define best practice – establishment of the Utility Mapping Association (UMA)*:* MTU1, MTU Network, MTU2, MTU PTI raised the profile of utility mapping at industry events such as NoDig Live. It helped to stimulate a debate and worked closely with JK Guest who set-up the UMA in Sept. 2011. The UMA involves some of the biggest players such as Atkins plus representatives from other large associations such as The Survey Association. This was highlighted in a CIRIA briefing in Dec. 2012. The UMA is a significant step forward as previously the industry was fragmented, and MTU had identified the potential benefits of greater co-operation. MTU is represented by Metje on the Steering Committee – a 3 year appointment to ensure the latest thinking from around the world and MTU outcomes are disseminated. The UMA seeks to "Work with all stakeholders to inform and assist in the establishment of a set of **standards** that reflect good **practice** in utility detection and mapping to help promote clear measurable accredited competence levels".

Impact 4 – professional bodies have used research to define best practice – invitations to join agenda-setting professional organisations and groups: Through Metje (MTU2), UB is represented on a number of influential, agenda setting groups such as the 'Buried Assets Centre of Knowledge' (since April 2012), the Balfour Beatty Utility Solution's 'Ground Breaking – Breaking Ground' initiative (since Dec. 2011) and the ICE Municipal Engineering Panel (since Sept. 2012) as well as the US Transportation Research Board Utilities Committee (since April 2011). The invitation to join these groups demonstrates the great value the industry in the UK and USA has placed on the MTU research and the willingness to embrace the findings of the research in the near future.

Impact 5 – Public policy and public engagement: MTU2 and MTU PTI have explained the challenges associated with buried infrastructure and how they can be addressed to politicians, councillors and civil servants. Non-traditional methods have been used to ensure wide coverage. For example, an animated video was developed (July 2011 – available on YouTube) explaining the

research and a specific workshop aimed at politicians and civil servants was held (March 2011). The MP for Solihull, Lorely Burt, stated that *"…what we all take for granted is the service that's delivered to our homes and businesses underground and I don't think you see much resistance to this type of project and it is absolutely vital*" and the Councillor Andrew Carter stating that *"… the end product of that [MTU project] hopefully will be some new technology which all the utility companies and indeed local authorities can use to their mutual advantage… and I was absolutely fascinated by the details of the project that UB is leading and it could lead to something extremely valuable*." The project also attracted the attention of BBC Radio 4 which broadcast a 30 minute programme focused on the project, *Mapping Britain's Underworld,* in May 2012 helping to raise public awareness of the issues. Robert Burns from Balfour Beatty Utility Solutions said on this programme that the "*MTU project is important to us because what it actually starts to do is to bring a lot of these [locating] technologies into one platform. It's a very complex situation and people are always looking for this silver bullet*".

Impact 6 – International reach of MTU: MTU2 (UB, Civil Engineering) has established three MSc level training modules (equivalent to 60 credits in total) for the Malaysian Association of Land Surveyors in order to train the next generation of utility surveyors. This training was delivered in the autumn 2011 (45 participants) and 2012 (25 participants) in Malaysia. This link was established as a direct result of the international outreach and dissemination of the team at Birmingham. Additionally, MTU2 provided CPD training to groups of approximately 30 Malaysian surveyors both at UB and at the national test facility for 2-3 days in 2010, 2011, 2012 and 2013. Furthermore, the Principal Assistant Director of Survey (Utility Mapping Section) at the Department of Survey and Mapping Malaysia (JUPEM) was sent to UB to read for a research degree funded by the Malaysian government. The above is evidence of the worldwide impact and reputation of MTU. Based on the developments and experience with the national MTU tests site, some form of collaboration for a new Malaysian test site is currently been explored.

Impact 7 – Development of the Smart Pipes initiative: MTU focuses on the location of buried assets, but it promoted in its 25 year vision the condition assessment of the pipes for proactive asset management to become reality. This challenge was taken up by the Smart Pipes initiative which is now in its implementation phase as a result of a TSB award in July 2013. The aim is to instrument pipes with small (millimetre size) off-the-shelf pressure and accelerometer sensors at a high temporal and spatial resolution to identify the formation of leaks and their location at an early stage, thereby saving the UK over 100Ml/d (or approx. £5000/d in water alone), with significant international applications. The TSB grant is worth £645k with £265k direct input from industry (2 water companies, 2 contractors). The key is to ensure continuous power and in-turn power efficient communication nodes. This has been the focus of research with the development of an isotopic battery capable of generation 0.8 μW and a communication node currently requiring ~7 μW.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Burtwell M.H., Evans M., McMahon W. (2006). *Minimising Street Works Disruption - The Real Costs of Street Works to the Utility Industry and Society* UKWIR 05/WM/12/8.
2. Corroborating statement from Chairman, JK Guest
3. Corroborating statement from Senior Vice President Cardno TBE,
4. Corroborating statement from Chair TRB Utilities Committee;
5. Corroborating statement from Watershed Associates (formerly Thames Water and Veolia)
6. Corroborating statement from Chief Executive, National Joint Utilities Group;
7. Corroborating statement from Innovation Project Engineer, Balfour Beatty Utility Solutions
8. Corroborating statement from American Society of Civil Engineers, Utilities Committee
9. Corroborating statement from Director, Greenwatt & Cllr. Stratford-on-Avon District Council
10. Corroborating statement from Past President, EU Water Platform; Ex-Director, UKWIR
11. Corroborating statement from Unique Production – (BBC Radio 4 programme)
12. Corroborating statement from Department of Survey and Mapping Malaysia

Web URLs: Impact 1 -http://www.construction-skills-academy.co.uk/mtuce/: -

Impact 4 - http://www.nuag.co.uk/(S(qgf2cr55k2ipasqie4eps555))/Shared/CentreofExellence.aspx)

Impact 5 : (http://www.youtube.com/watch?v=9yXgjl4MoPs; http://tinyurl.com/pjdn8kc

http://www.youtube.com/watch?v=x0mgng_dIwA);