Building Information Modelling (BIM) – A Route for Geological Models to Have Real World Impact

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Abstract

The rapid rise of Building Information Modelling (BIM) represents a major opportunity for Geological Survey Organisations (GSO) to make their data and in particular three-dimensional geological models accessible to the civil engineering and construction industry. The paper presents how GSOs and the private sector are preparing themselves for a possible paradigm shift with the vision of a 'live' ground model becoming a possibility, leading to real efficiency gains and risk reduction during construction and throughout the life time of an asset.

Introduction

Three-dimensional geological models are now routinely used in within geological surveys and to some extent in the development of groundwater models (Royse et al 2010, Berg et al 2011). Uptake in the construction and civil engineering sectors however has lagged behind (Kessler et al 2008). This situation might be about to change rapidly with the uptake of the concept of Building Information Modelling (BIM) within the geotechnical industry. BIM is a process involving the generation and management of digital representations of physical and functional characteristics of a building or places. The BIM process will facilitate the sharing of data and models such that isolated teams can work together in a much more integrated and collaborative manner. This will enable much better decision-making about the design, construction, management and the eventual decommissioning of the building or structure as depicted in Figure 1.

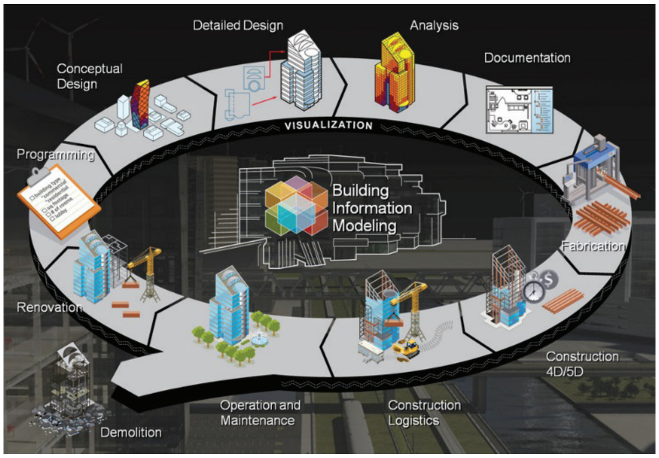

Figure 1. BIM lifecycle (image courtesy of Autodesk)

BIM is becoming increasingly important in the UK; the UK government has stipulated, for example, that all public sector funded work must be carried out to BIM level 2 by 2016. Given that the global construction sector is forecast to grow by 70% by 2025 (HM Government 2015) interest in BIM is likely to increase. In the UK, projects such as Crossrail, High Speed 2, new nuclear builds, electrification of railways and major upgrades to the road network and flood defences will all require major ground investigations and are all to be delivered BIM compliant. Since most construction happens to be placed on or in the ground, the implications for Geological Survey Organisations (GSO) and their data and models are huge.

Implications and opportunities for Geological Survey Organisations

The main themes of BIM are collaborative working, data sharing and full life cycle of data management – all of which are core principles of any GSO. Consequently GSOs have been on a very similar journey over the past few decades, Figure 2 illustrates how the stages of BIM maturity closely match the stages of the evolution of a GSO (Kessler and Mathers 2006).

The transition for GSOs from mapping geology in two to three dimensions, required a fundamental reconsideration of acquisition methodologies, data management and dissemination mechanisms. In times of reduced resourcing, geological surveys need to be more open to keep pace with the continuously evolving understanding of the subsurface, which is driven by the acquisition of new data by external parties in particular the construction sector as mentioned above. As a national survey it needs to be able to create and maintain authoritative models nationally and convey uncertainty, particularly where data is sparse, clustered or of varying quality, and it needs to be sufficiently flexible to allow the generation of outputs at a wide range of resolutions. To resolve these challenges, the British Geological Survey, as well as many other leading GSOs, are developing infrastructure that allows geologists to make interpretations and models that can easily be incrementally updated as more data becomes available. It is therefore paramount that data and models are as accessible as possible to the user community and integrate seamlessly with the methodologies and software tools used in the construction sector.

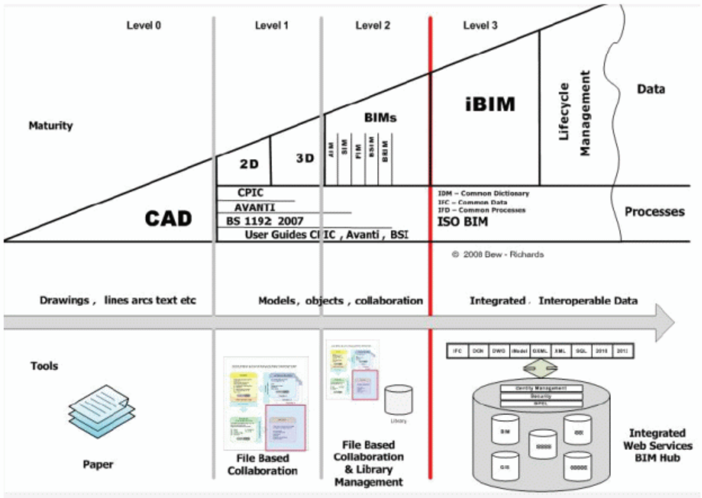

Figure 2. BIM levels and associated methodologies and technologies (BIM Working Party 2011)

Involving the end user community – BIM for the Subsurface

Geology is still absent from most BIM models but technology together with data transfer standards such as the AGS format (Association of Geotechnical and Geoenvironmental Specialist http://ags.org.uk/data-format/) are already available to allow the fast access and visualisation of factual geotechnical data in standard software tools used by engineers. These standards currently allow project based factual geotechnical data to be managed and visualised, generating high-quality output of geotechnical logs, sections and 3D visualisation. However this needs to be taken to the next level to allow engineers to fully collaborate and utilise the wealth of existing knowledge and share both factual and interpreted data throughout all construction projects; this is the intention of the BIM for the Subsurface project (http://www.keynetix.com/bimforthesubsurface/). This two year project is funded by Innovate UK under its Digitising the Construction Industry initiative and is due to be completed in April 2017; the project partners include Keynetix, BGS, Atkins and Autodesk. (Grice and Kessler 2015)

The aim of the project is to significantly advance current technology, HoleBASE SI and the extension for AutoCAD Civil 3D, and deliver a geotechnical BIM solution through the development of a cloud based repository that will allow the storing, sharing and re-use of subsurface data, including interpretative data and access to the wealth of BGS historic data, throughout the supply chain. The project will integrate the BGS proven 3D geological modelling methodologies within the AutoCAD Civil 3D extension (a prototype is shown in Figure 3), with the aim of generating detailed 3D site models from local geotechnical data together with data from the BGS National Geological Model (Mathers et al 2014). The ultimate aim is for geotechnical engineers to use and create more detailed site models and for these to be shared, where possible, to enhance the national knowledgebase.

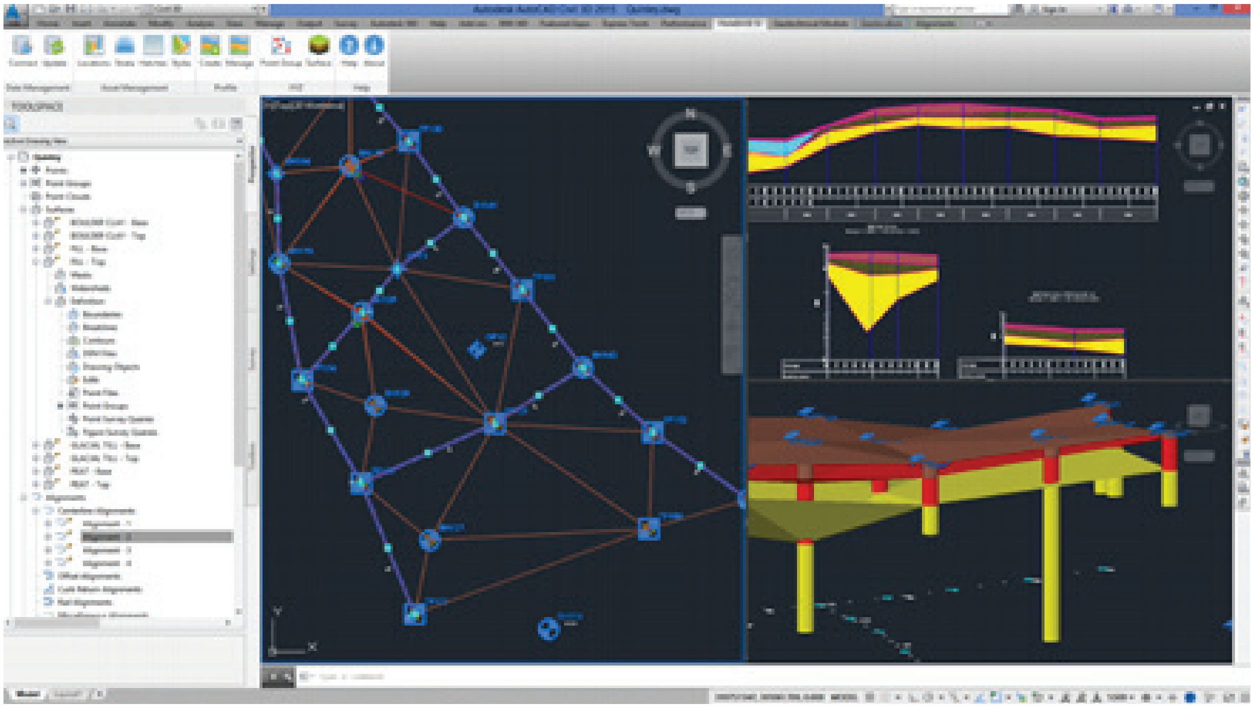

Figure 3. BIM software showing 3D geological objects (courtesy of Autodesk)

An emerging BIM strategy at CH2M

As mentioned the process of fulfilling BIM objectives in industry has certainly been more straightforward in some markets than others. Strong focus has been placed on the construction, operation and maintenance of new structures, and consequently the teams rooted in the design of these already have a suite of BIM-complicit software products at their disposal. In the geotechnical sector, where relatively traditional, 2D methodologies are still commonplace, the production of an integrated 3D information hub has been noticeably more difficult. Achieving this is crucial in major infrastructure schemes where effective and integrated management of 'Big Data' significantly enhances project efficiency.

CH2M have recently undertaken a research and development project to explore the feasibility of 3D subsurface modelling as a technical solution to this challenge. It was identified at an early stage that 3D modelling provides a fully digital interface to store, visualise and interrogate ground conditions. In a manner that is coherent with BIM ideologies, this information 'hub' can house all subsurface data and interpretation across the project site (see Figure 4). This may be used to identify areas of uncertainty or risk at an early stage to focus subsequent ground investigation to these locations, which at a commercial level maximises the investment into GI while reducing down-the-line costs associated with 'unexpected' geotechnical issues during construction.

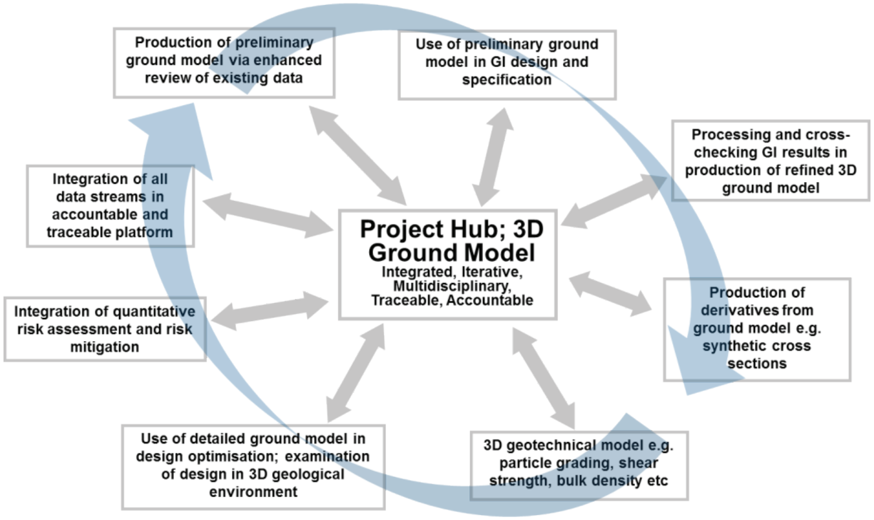

Figure 4. 3D model as the nucleus of a typical interactive project workflow as per BIM philosophy (from Fitzgerald and Dabson 2015)

The use of 3D geological models in real world engineering projects

Farringdon station project – benefits of a ground model in reducing construction risk

Crossrail is currently Europe's biggest construction project creating a 42 km long east-west rail connection beneath London. Most of the tunnelling was carried out in London Clay which is a perfect tunnelling medium and, with thicknesses reaching above 40m, is widespread beneath London. However, at Farringdon, the ground conditions are more complex as the station was excavated below the London Clay in the Lambeth Group. Additionally, Farringdon Station is the first application of sprayed concrete lining (SCL) to a tunnel excavated almost entirely in the Lambeth Group. Due to these geological and construction complexities an early decision was made to exploit the existing BGS 3D geological model (Aldiss et al, 2012) and integrate it into in the site supervision workflow. The main geotechnical risks arose from the presence of randomly distributed, water bearing sand lenses, interbedded within the clays of the Lambeth Group and the presence of multiple geological faults. The 3D model was progressively developed by being fed geological data recorded following each step of tunnel excavation. As a result ground conditions could more reliably be predicted ahead of subsequent tunnel excavation.

Using this method the 3D geological model forms the hub of a cycle of risk reduction (see Fig 5). It uses data from in-tunnel probing and face mapping to progressively increase knowledge of ground conditions, enhance the accuracy of and confidence in predictions and ultimately

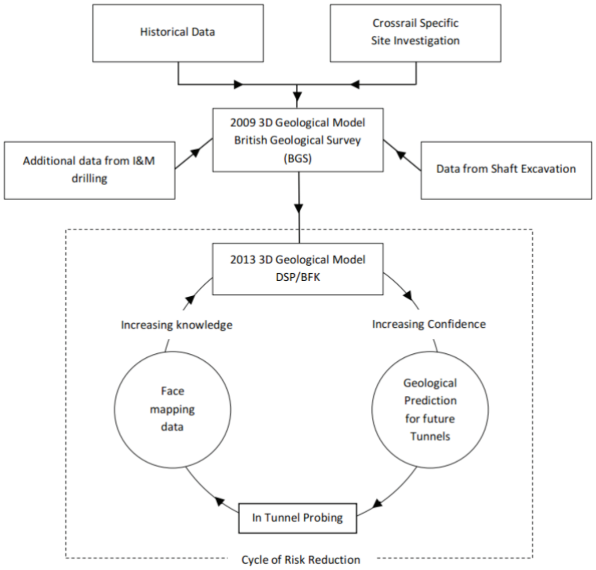

Figure 5. The cycle of risk reduction (from Gakis et al 2014)

reduce geotechnical risk to the project. As per the BIM principle of life-time asset management all the geotechnical data from the excavations have been stored in the 3D model's database and will be handed over to the BGS to be used by Crossrail and others for future purposes.

A 3D geological model for Railway Electrification between Leeds and York

Recently the BGS undertook a 3D modelling project along 28 km of railway line between Leeds and York on behalf of Tata Steel Projects (Burke et al 2015). The model was constructed using 1:10,000 scale digital geological map data and 102 borehole logs. The final conceptual ground model (CGM) indicated the top and base elevations of the geological units and weathered rockhead and major faults were defined as separate surfaces. The purpose of the work was to identify areas where targeted ground investigation could be undertaken in the early assessments of the design of deep or shallow mast foundations for the electrification of the route. After overcoming substantial challenges with projection systems, the model was delivered as CAD files and the client was able to integrate the CGM within their in house BIM workflow as shown in Figure 6.

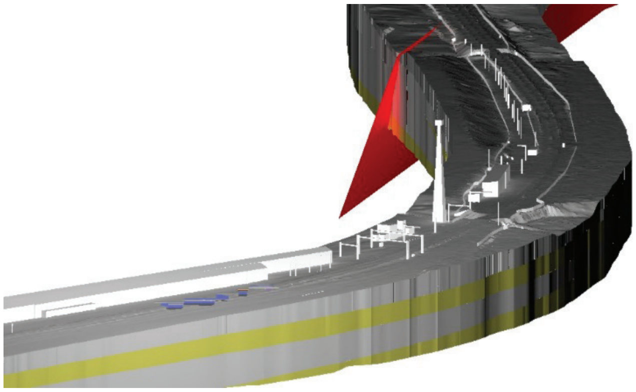

Figure 6. BGS Conceptual Ground Model (sandstones and mudstones in grey and yellow plus a fault in red) of a site near Leeds (UK) with existing and proposed overhead line electrification and building infrastructure

Conclusions

Current and future growth and investment in national infrastructure in the UK is providing a perfect storm of new data and opportunities for collaboration and technical advancement. Furthermore, government commitment to the application of BIM strategies to publically funded projects is providing a driver for digitization of the construction sector, and will enable the sharing of construction models. Unforeseen ground conditions continue to be a major source of project delay, and ambitious schemes and testbeds are underway to explore ways of incorporating geology into real projects via geotechnical BIM workflows to minimize cost and risk. GSO's are key players in this arena and need to step up to the challenge of delivering their data and models seamlessly into BIM workflows. In the future, provision of BIM-compliant data services and software will be routine. The ability to seamlessly incorporate and share subsurface data within construction projects will ultimately lead to the realization of 'live' ground models, where pertinent data is available on-demand in suitable formats and can be easily shared throughout the project lifecycle.

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