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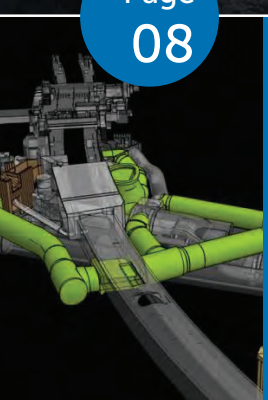
Drill & Blast into the future

Page 08



Digital Domain

TJ delves deep into the digital world focussing on the inevitable rise of BIM

Page 20

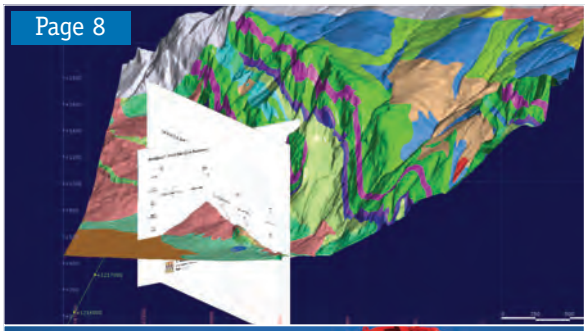
Slurry Designs

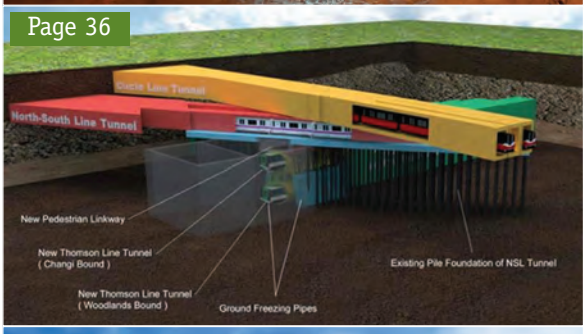
Comparing the Japanese and European approach to slurry TBM design

Page 30

Stemming the flow

Pre-excavation grouting - proving that prevention is most definately better than cure





Contents

Editor's comment - page 5

News from the web - page 6

Diving into the digital future? 08

Does digital technology have the power to disrupt the way we do things underground? Kristina Smith investigates the rise of BIM and its impact.

15 minute interview 18

15 minutes with David Salisbury - Project Manager, Sha Tin Central Link - MTR Corp, Hong Kong.

Slurry TBM development and design 20

Richard Lewis, YL Associates Limited, makes a detailed comparison between the Japanese and European approach to slurry TBM design.

Stemming the flow 30

Pre-excavation grouting techniques, perfected in Scandinavia, are now spreading around the world. But getting it right isn't always easy.

Metro tunnelling in Singapore - the Thomson Line 36

Shaik Sha Marican, Land Transport Authority (LTA), Director (Thomson East Coast Line, Civil Team 4), Ow Chun Nam, Land Transport Authority (LTA), Director (Tunnel, Thomson East Coast Line), and Andreas Raedle, Arup, Tunnel Leader Singapore, Tunnel Skills Leader Australasia here describe some of the challenges of tunnel works on Singapore's Thomson Line, focussing on Packages TSL-A and TSL-D

In the mountains 42

Squeezing ground and rock bursting are two of the biggest challenges that remain in tunnelling, Desiree Willis of the Robbins Company explains.

Drill & Blast development 46

Exciting developments are taking drill and blast to new levels of productivity, delivering highly effective solutions with increasing levels of 'intelligence' and automation. A key trend has also been an emphasis placed on 'clean-air' technology, as well as developments by manufacturers not normally associated with the tunnelling industry.

Contacts - page 54

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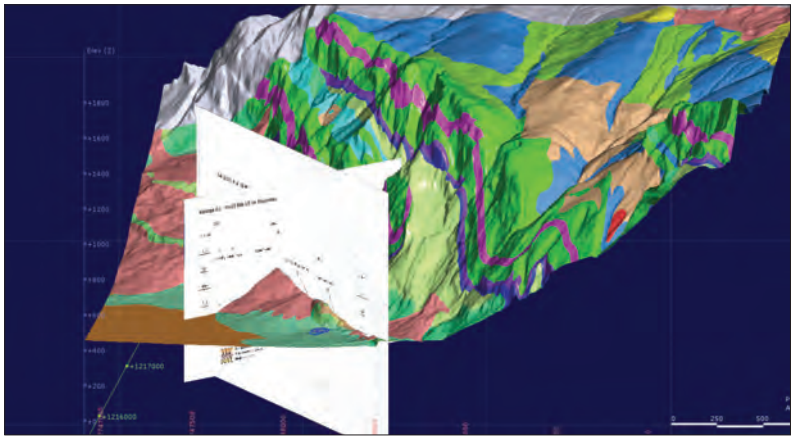
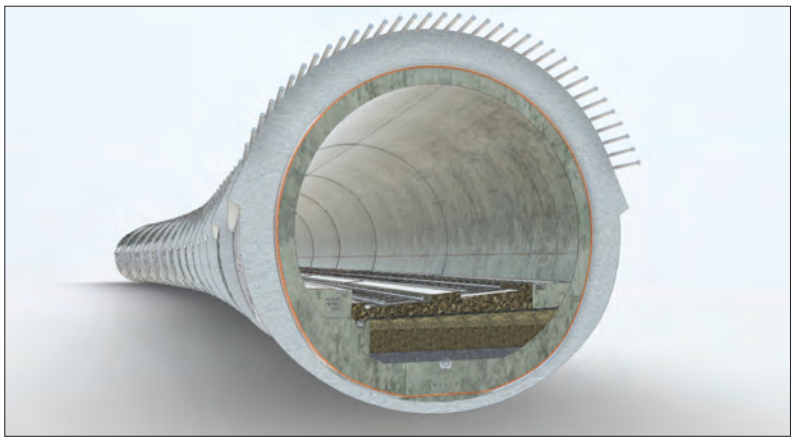
Diving into the Digital Future?





Does digital technology have the power to disrupt the way we do things underground? Kristina Smith investigates the rise of BIM and its impact.

3D Geology
This is Amberg's model of the geology of the Hagerbach Test Gallery

Amberg's BIM Model of the Bîzberg Tunnel

One day we were running down the street, arms waving frantically as we tried to hail a Black Cab with its light on. The next we were standing quite still, just looking at our smartphones, watching the dot of the Uber driver getting closer and closer on our screen.

Well, perhaps the change wasn't quite that fast. But you get the picture. Digital technology has the potential to alter the way we behave quite radically. And sometimes it feels like it's happened overnight.

Can digital technology bring the same kinds of disruptive change to the world of tunnelling and underground construction? The answer is almost certainly yes. What those changes might be is a little harder to say – disruption is, by definition, unexpected.

Digital technology in construction, of which BIM is a part, is already changing the way people work together. It is rearranging the order in which we do things, demanding different skills sets and creating new ways for organisations to engage with each other.

Digital construction is already starting to change the way we manage risk. Ultimately it offers the opportunity to reduce the capital and operational costs of underground space, while improving the way that space operates for the people and systems within it. But the journey to that point will probably we a rather bumpy ride for many.

Is BIM dead?

Though BIM may seem like a relatively new concept, the idea has been around for some time, says Paul Clark-Edwards, BIM practice leader for Mott MacDonald's transportation business.

"The software vendor's business model suggested the idea of 'BIM' 15 years ago," he says. "They wanted to extend the functionality of their core graphics engines, into something smarter allowing the author to assign attributes and behaviours to the 3D geometry."

BIM gained traction in the UK back in 2011 when the Government mandated that all central Government departments had to work in 3D and in a collaborative way from April 2016 on. The players in a project didn't necessarily have to be working from the same 3D model, but the same information had to be used and exchanged between them.

There's a certain amount of confusion over what BIM is. There's a tendency to think of BIM as the 3D model, but that's not right, says Emil Rudegran, rock mechanics engineer at WSP in Sweden.

"It's important to really see what 3D is and what BIM is and to distinguish between the two," says Rudegran. "Many people think that 3D is BIM. But they have nothing to do with each other."

A BIM, or building information model, could just be a spread sheet with a list of components, or objects, and some pertinent information in a format that everyone can use. Information linked to each object could include who designed it, what stage the design is at, when the last review was done, manufacturer, operation and maintenance information.

"There are no limits to what information we could include," says Rudegran. "It's up to the client and the end user. We have only scratched the surface of possibilities."

In the UK, there's a push to get away from the term 'BIM' altogether. In 2015, the UK Government

published a report called 'Digital Built Britain' and a year later launched a task group of the same name which aims to link a multitude of digital technologies including big data, telemetry, the internet of things and data driven manufacturing.

Since then we have seen job titles changing to reflect this change of focus. People are no longer 'head of BIM', they are 'head of digital technology' or 'digital construction'. Partha Sarkar, who is head of BIM and allied technologies at Arcadis in India predicts we will soon see some new titles emerging.

"We see there are so many influences poised to disrupt the construction industry, all these digital technologies," he says. "Maybe next year or the year after, the BIM guys will become 'digital disruptors 'or 'digital transformation leaders."

Reducing risk

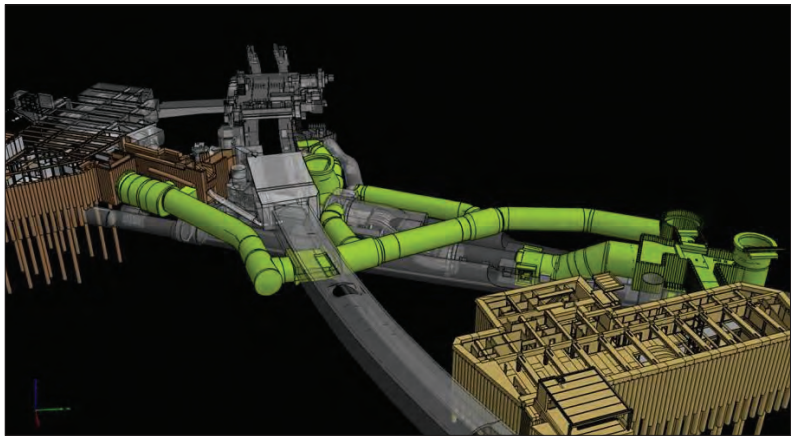
Perhaps one of the best examples of what 3D modelling, and the integration of data from multiple sources, can do is London Underground's Victoria Station Upgrade and in particular the ground improvement work carried out there. Specialist contractor Keller, working for Taylor Woodrow-Bam Nuttall (TWBN) JV, installed over 2,200 jet grout columns, working from an area of congested London streets, to improve the gravels so that a SCL tunnel could be dug through the ground.

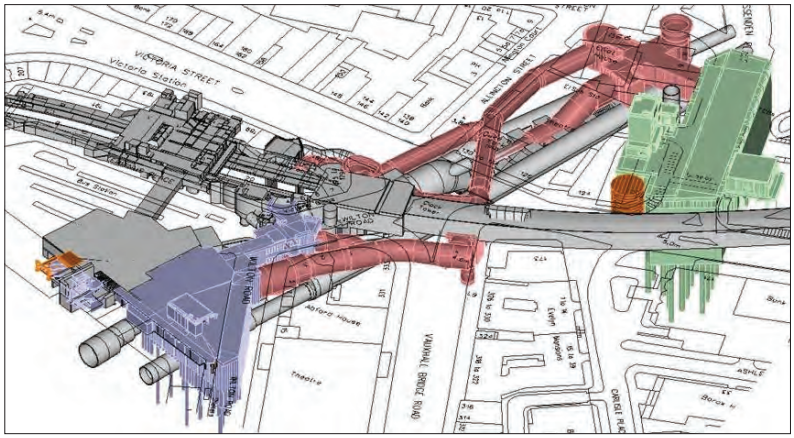
Clark-Edwards, who worked on the project as London Underground's information manager before he moved to Mott MacDonald, says that London Underground started modelling for Victoria Station Upgrade 15 years ago when the project was first conceived. "There was so much complexity with the existing underground assets – an operational railway, foundations, utilities – that it had to be modelled in 3D."

> "We see there are so many influences poised to disrupt the construction industry, all these digital technologies. Maybe next year or the year after, the BIM guys will become 'digital disruptors 'or 'digital transformation leaders."
>
> *Partha Sarkar, who is head of BIM and allied technologies at Arcadis in India.*

By piecing together information from multiple sources, Mott MacDonald's engineers built up a 3D model of the underground space beneath with the ground-level road layout layered on top of it. Specialist contractor Keller then overlaid the position of every column and used the model to plan installation, including sequencing and road closures, in 3D.

"We used the BIM model to pre-plan everything, right down to the movement of traffic," says Dr Anmol Bedi, of Bedi Consulting, a sub consultant to designer Mott MacDonald on the upgrade, and heavily involved with the BIM model.





Forensic use of survey and utility information around Victoria Station meant that the positioning of grout jet columns could be carefully planned, with information from the drill rig used to create as-built drawings that then informed the tunnelling activities beneath.

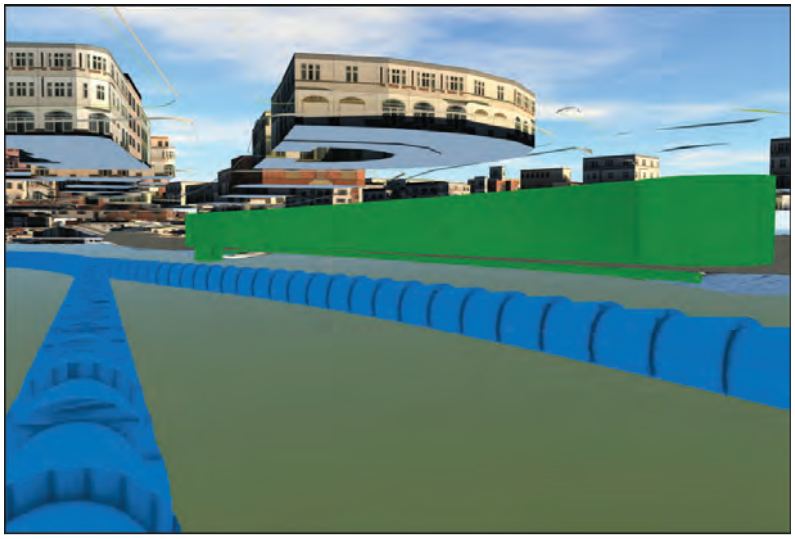
The transformational step came when Keller was able to take parametric data recorded from the drill rigs for each of the columns they had installed and feed that back into the 3D model to create an as-built record.

"We built risk review into the model," says Bedi. "We could highlight the as-built column profiles in the 3D model so it showed all the gaps where the ground could not be treated. We knew on each advance that we were coming up to a risk area. We could stop the tunnel a safe distance from the known gaps, probe drill to find the loose ground and treat it from a safe working environment in the tunnel before we moved on."

The model proved to be a good predictor of where the untreated ground would be, and as people on site gained confidence in its usefulness, they became more engaged with it, says Bedi. Knowing what was coming up allowed TWBN and Keller to prepare labour and resources and the tunnelling crew to plan other activities while the remediation was going on.

Bedi Consulting was able to apply the same process of mapping the underground to inform a contractor's bid on the Sydney Metro where a big cavern was proposed through a faulted area adjacent to Sydney Harbour. The plan was to enlarge the cavern from TBM tunnels using SCL. Inflows of water would have been disruptive and potentially dangerous for site staff, so a pre-grouting plan had to be devised.

"To evaluate the fault and the treatment we put together information from previous surveys, studies, outcrop mapping and fault areas," explains Marco Invernici, tunnel design engineer at Bedi Consulting.



Comparison of possible alignments under the city of Geneva. (Amberg)

"We had survey data from around 2km in either director from projects done in 2009 and we had some points where there were outcrops on the surface. We put that with core logs undertaken in this area and south of the project areas."

Overlaying the pattern of streets from Google Earth, Bedi Consulting could then optimise the ground improvement sequence, devising an approach that didn't require road closures, reducing disruption for the city's inhabitants and commuters.

There is a wealth of information out there which can potentially be used to create these models. "With the model you have the capability to put everything together in layers," explains Invernici. "Even if we are not totally sure of where the information is coming from – for example we might want to use information from Google Earth – we can assure ourselves that it is good enough by cross checking with survey information."

> "With the model you have the capability to put everything together in layers. Even if we are not totally sure of where the information is coming from – for example we might want to use information from Google Earth – we can assure ourselves that it is good enough by cross checking with survey information."
>
> *Marco Invernici, tunnel design engineer at Bedi Consulting.*

This digital overlaying of information, enriches its collective value, says Invernici. "It's time-consuming but worth the effort. It expands the benefits you can get from all surveys and information collected for different reasons."

In Switzerland, Thomas Jesel, director of the tunnelling department for Amberg says that this ability to re-purpose existing data is helping clients and designers with decision making at the feasibility stages.

"We have quite a few projects where we are at a very early stage. There is all this GIF data that is owned by cities and countries, most of it public, that we can download and include it in our model. When we discuss alignments, it is a very strong first tool to show which buildings we pass under, whether there are any waste water pipes, sensitive gas pipelines or fibre optic cables under the road and what kind of parties would be affected by this alignment."

In Geneva, says Jesel, the underground geology can be downloaded in 3D, speeding up early phases. "We can find out quite fast in early stages if we are below or above water table and compare different alignments.

"Previously it took us weeks to get all this information and more weeks to get the right information into drawings. Then we had to produce longitudinal sections, cross sections, you needed a lot of imagination. 3D was only in the head of engineers. Now after two or three weeks you have the first models and you can run them."

But what is a bonus for one group of engineers might be a negative development for others. Jesel outlines how this faster access to underground geology could impact on geologists.

"Geologists sell experience," says Jesel. "They have huge archives from the last decades which are not public. If this information is integrated into a huge 3D model of a city or an area for a large infrastructure project, it will spread quite easily and most probably be used for other neighbouring projects. This will challenge the collaboration between civil engineers and geologists."

In other words, the geologists could lose the part of their income stream that comes from selling data.

Benefits emerge

Communication is perhaps the best-understood benefit of working in 3D. It's far easier for an owner or a member of the public to appreciate what a structure will look like if they can see it and even walk through it.

Augmented reality (AR) adds another dimension. WSP has an app which allows a planned structure to be seen in the existing landscape, says Rudegran, so everyone can see how the tunnel portal or shaft will impact visually.

3D and AR becomes more useful again when those who will use a facility can really interrogate how what will be where and how things might work. "Maintenance staff can see how to walk around and how it will be built and maintained. They can see things that a designer would probably never know," says Rudegran.

Clash detection is another often-quoted benefit. Details and interfaces that can be fudged or avoided in 2D drawings are exposed in 3D. Engineers sitting round a table can simply see an interface issue or a clash, rather than all trying to visualise it in 3D inside their heads.

For Rudegran, working with 3D and BIM is helping to create more effective work flows. It can cut down on design time during some phases because changes and impacts can be more quickly communicated and calculated he says.

"Say a constructor is already on the works doing rock excavation and you have a last-minute change. The workflow for getting out new data is much faster," he says. "With the coordination process being

in 3D, it minimises design flows."

Feeding back real-time construction data can inform the design of later elements of the work, he says: "During construction, those on site can send back 3D scanning... so we could see, for example, that we had a wedge failure that caused the concrete amounts to go up because they had to do cast-in-place work there. Then the structural engineer already knows that, and can take it into account for the structural design of the rebar.

"Looking even further we will be able to use scanning and even photogrammetry to take a picture of the wall before and after concrete is applied. As well as being a good check, it feeds into as built drawings later on, rather than have to work from hand-sketched drawings that you can barely read."

Amberg is already working with point clouds created by laser scanning, most often to create 3D drawings of existing structures. For example, it is making as-built 3D drawings of a motorway in East Switzerland which is to be built over to create space for above-ground development.

"Real time is just around the corner," says Jesel. "The challenge in using it for checking the thickness of shotcrete, for example, is that we need high levels of accuracy to check the tolerances are right and that means we need a lot of data."

Where scanners were previously mounted on vehicles, surveyors now have the options of using drones.

What the collection, sharing and utilisation of all this digital data should mean is less risk. Ultimately this should offer more cost certainty, and the ability for clients to reduce the size of the contingency pot.

"It will allow us to reduce the cost, because a lot of the escalation factor you put into a price is for unknown elements where there is a risk involved," says Sarkar. "Some of the other benefits related to clash detection and resolsution, clarity and visibility should also allow the contractor to reduce the price."

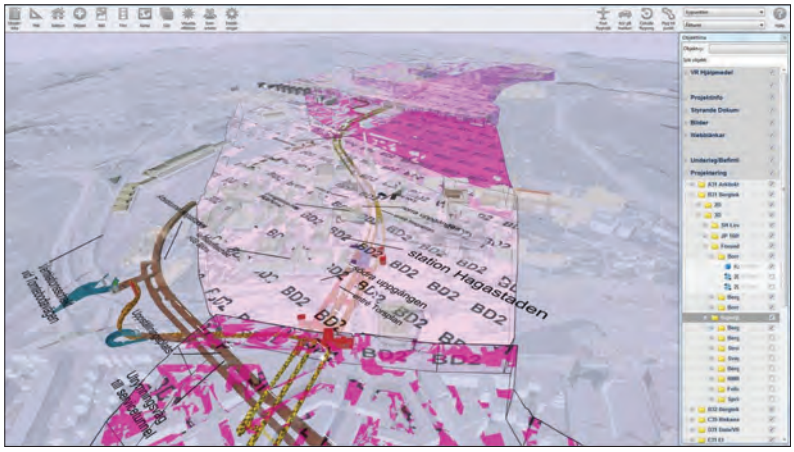
Clark-Edwards doesn't think we should be focussing solely on capital cost reduction, reminding us that cost in operation is an important consideration for the owner. "Capex represents a small percentage of the overall cost for the operational lifetime of the asset. Having a structured approach to information management during the design phase can leverage this extra value," he says.

However, the reality for many organisations is that capex and opex are very separate budgets, owned by different and unconnected parts of an organisation. "The biggest benefit of really going through the BIM process comes over the lifecycle mainly in the phase where you use your infrastructure but, in almost every project we have been involved in, construction and maintenance are separated," says Jesel. "They are two different budgets. This makes things difficult, because no one really has the big picture."

Leading the way

Looking around the world, there's a patchy picture of adoption of BIM and digital technologies. Clark-Edwards, whose role as BIM lead for Mott MacDonald takes him around the world to projects and conferences says:

"My view in terms of maturity of process and standards, is that the UK is leading. In terms of open standards, the Nordics are leading. The Nordic countries conceive of their data as open standards rather than any proprietary file format."



WSP's Northbound Metro Line Extension to Arenastaden in Central Stockholm

Some use open standards called IFCs (Industry Foundation Classes), for BIM data exchange. COBie (Construction Operations Building Information Exchange) is a data format, more focused on asset handover data than geometry, invented in the US and then developed in other countries including the UK.

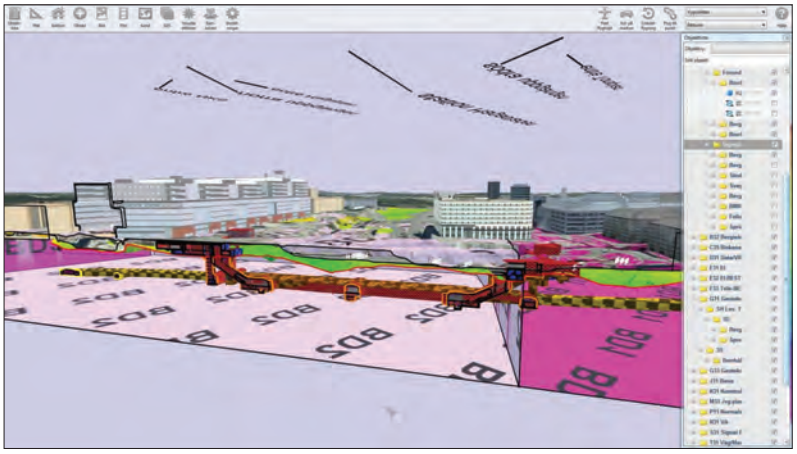
> "Real time is just around the corner. The challenge in using it for checking the thickness of shotcrete, for example, is that we need high levels of accuracy to check the tolerances are right and that means we need a lot of data."
>
> *Thomas Jesel, director of the tunnelling department for Amberg*

In most countries, it is the building rather than civil construction sector that is furthest ahead with BIM. The Swedish Transport Administration, Travikverket, has been pushing hard to encourage the uptake of BIM, mandating that it should be used in all big investment projects from 2015. In the UK big infrastructure owners such as Highways England, Network Rail and Transport for London are working towards a digital approach to data. But these are big beasts, and change cannot happen overnight.

Sarkar sees the UK, parts of Scandinavia and some Middle Eastern countries as the most-advanced in their use of BIM. "It's also in demand in Singapore, Kuala Lumpur, Hong Kong and Australia," he adds. "There are bits and pieces in the US, although the focus there has been primarily on the building side."

Sarkar has worked on a number of utility projects in the Middle East, including the Doha Expressway Project, Qatar Rail and Yas South in Abu Dhabi, where the owners had a clear vision for using BIM right through from design and construction into operation and maintenance. Though he is based in India, he says that most of the projects he currently works on are in the UK.

In Switzerland, says Jesel, the move to digital data is slower with the impetus for change coming from Scandinavian projects. Amberg's first BIM project



WSP's Northbound Metro Line Extension to Arenastaden in Central Stockholm - an alternative view

was in Sweden around 2011. "That was at a very low level, compared to engagement now-a-days," says Jesel, of Stockholm Western Bypass. "We had huge plans for what we wanted to do with BIM but the whole industry was not ready at that time and in the end, it was not much more than 3D modelling and the extensive exchange of datafiles. We had to add conventional documents."

Today Amberg uses elements of BIM, frequently, but not for an entire project. "We do not have one project where everything is 100 percent BIM," says Jesel. "On most projects we use BIM in some way, even if it is just for visualisation." It's important for Amberg to keep building the digital competencies of its talented young engineers, he adds, and to keep them interested and invested in the company.

In Sweden, WSP is working on two projects: Slussen, a new bus terminal in Stockholm and the Northbound Metro Line Extension to Arenastaden in Central Stockholm, which Amberg is working on too. All the CAD geometry for these projects must be in 3D, even the description of the rock excavation. "There are a few others going on in Sweden, but not to the same extent that I know of," says Rudegran.

Interoperability

Five years ago, people often cited interoperability – or rather the lack of it – as one of the biggest practical barriers to wider uptake of BIM. Different software packages couldn't easily talk to each other and firms further down the supply chain felt that if they invested in one particular software package for one project, they might find themselves with the 'wrong' software on the next one.

Software houses Autodesk and Bentley both offer solutions for underground construction. "I have worked with both the technologies and they both have pluses and minuses," says Sarkar, a civil engineer who worked as a senior developer consultant for Autodesk before joining Hyder Consulting which was later acquired by Arcadis. "Network Rail and Crossrail are big customers of Bentley in the UK. But for most of the upcoming rail projects, we see a lot of Autodesk technology making an inroad."

Is it "not that easy" to work between the two technologies, says Sarkar. "Both have developed their own data structure. And while, at a basic level the data is interoperable, as you add complexity – the 'I' or 'information' part of BIM - it becomes more challenging to seamlessly share data between these two platforms."

Jesel agrees: "It is difficult to exchange data between different design tools," he says. "We don't have one AutoCAD tool that can do everything including geotechnical calculations. We want to make different specialist tools talk to each other without issues."

There have been various initiatives to create standards that allow operability. International organisation buildingSMART (formerly the International Alliance for Interoperability) is creating specific IFCs. Those for tunnelling are under development. Rail sector ones already exist.

There used to be an ambition to have everyone working off the same model. And though the software houses would still have us believe it's a good plan, the concept of a one-size-fits-all BIM model doesn't work for Clark-Edwards: "As we get more comfortable with the idea of a more data-centric process the notion that you can use the same piece of authoring software from feasibility through to operation and maintenance is less credible. The power and the value will be in how we connect the data."

What the UK Government and buildingSMART want is a greater focus on the data rather than the 3D model. "We want to move to a more data-centric approach," explains Clark-Edwards. "Part of that is 3D geometry that can be co-ordinated between multi disciplines for critical space proving. We must include all aspects of the supply chain in a more genuinely collaborative approach to project delivery: designer, manufacturer, assembler, contractor and operator.

"The digital data is originally conceived to describe the design, to ensure it complies with the relevant code, standards and specifications. Further data is needed to support procurement, and more again to support fabrication, assembly and construction. Again more data is needed to support operations and maintenance. To make this process more manageable we connect – or federate - our disparate data sets to leverage this value rather than view this information model as a single entity."

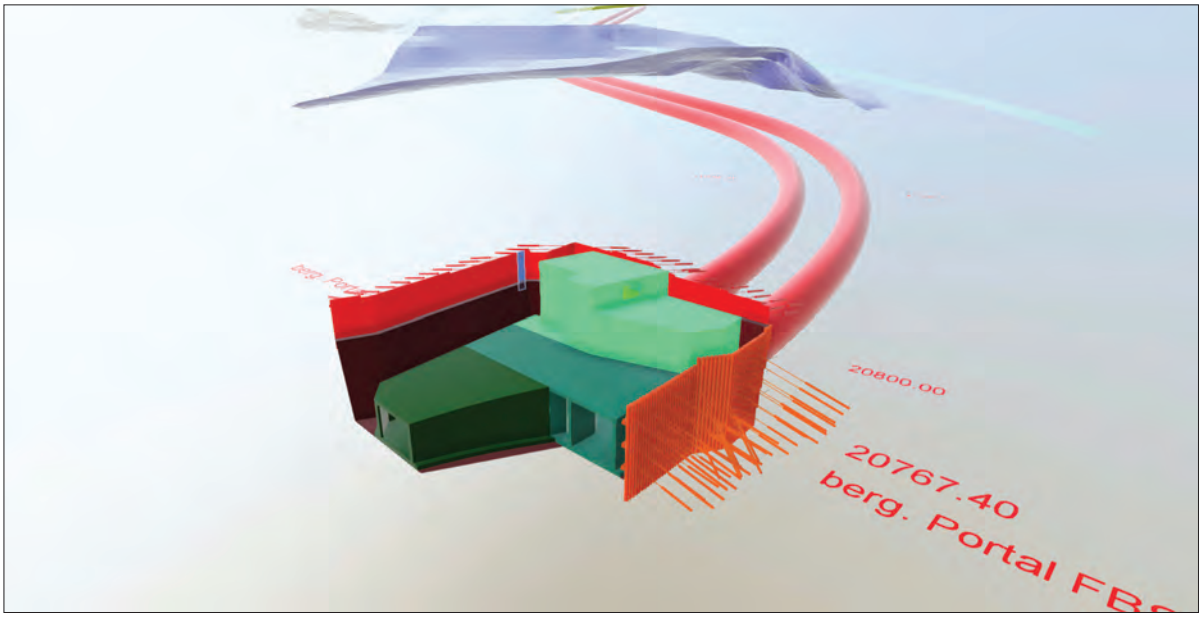
All that said, there are ways to get around interoperability problems. Both Rudegran and Invernici are quite relaxed about this issue: yes, it's a bit of a pain, but it can be done.

"We have developed a work flow that is proficient and can integrate both smart objects and the information in each object, and it involves many programmes," says Rudegran.

"In the rock engineering discipline, we start in Bentley Microstation which is our base platform. Other disciplines working here use software such as Tekla, Revit, Civil 3D which all have the common AutoCAD format DWG so everyone can export to that. So we can build the model in Microstation and export it to DWG. Inside that, in Civil 3D, you can do all the coding, add all the BIM stuff and then export to Navisworks or another collaboration platform."

For Rudegran, the biggest barrier to wider uptake of BIM and digital technologies is not practical but political: clients must demand it.

"The first step is for clients to put it in the tender,"



Amberg's model of the Lucerne highway bypass

he says. "And recently they have started to do that. If they are not ready, it doesn't matter how many beautiful 3D models or examples you can do, if they don't see the time profit or the economic profit, they won't do it."

Change is coming

Perhaps the biggest hurdle yet will be the switch to collaborative ways of working. "The philosophy in markets with a confrontational approach will have to change," says Jesel. "BIM is very collaborative, very open and very transparent. On a daily and weekly basis, everyone can see what you do."

While the roles of engineer, surveyor and geologist will be different in a few years' time, Jesel predicts that managers face the biggest upheaval. "In countries where management is hierarchical, where it is always the boss who makes the decision, managers will have to change dramatically because the designers looking at the models will have much more weight. Managers will have to give them freedom to work, trust them and guide them with methods other than hierarchical ones."

Earlier involvement of the wider supply chains will become the norm, as structures and systems are designed around the components, rather than the other way around. "It will change completely how clients buy data and the information that describes a design," says Clark-Edwards. "It will completely disrupt how contractors take that data and buy the bits they need to build the asset. It will disrupt the manufacturers and the component suppliers in how they deliver not only their physical components but the data related to their components."

Invernici sees a future where site engineers interact directly with models and information, rather than dealing through a surveyor. This means that they will need surveying skills and drawing skills. In Italy, says Invernici, education for engineers is already quite holistic, including all these skills, whereas in the UK roles tend to be compartmentalised.

As more functions become automated, whether that is carrying out repetitive design tasks or surveying an as-built tunnel lining and feeding back the data, engineers should have more time to analyse and manage.

"The site engineer will be able to supervise and make sure the quality and the control is adequate and they can do that in real time," says Bedi, contrasting that with the situation now where a site engineer surveys the tunnel, takes the results to a senior engineer and – if anything is wrong – has to take the bad news back down to the miners at the work face.

"Parametric design allows for 50 design iterations in the time it would take an engineer to do two," says Clark-Edwards. "However, the engineers must remain at the centre of the process and own the rule set for the algorithms that the computer uses to develop the design."

As for when we can expect these changes, everyone gave the same prediction: within three to five years. Artificial intelligence, big data, analytics, robotics drones; all these technologies are out there already and they will become commonplace overnight.

Mott MacDonald has an ambitious programme for transformation with its 'Go Digital' initiative which has a deadline at the end of this year. "We recognise these tools, processes and technology are not going away," says Clark-Edwards. "We cannot put the genie back in the bottle. We recognise that we have been in the design business for 150 years and want to build on that by using the best tools for the job and to integrate them into our common way of working."

Going digital is a daunting prospect for some, particularly those who have not grown up with computers. Clark-Edward's advice is to take control of the technology and process and make it serve your predefined purpose: "You have to consider the technology as a tool set and treat it as such. Don't be a slave to the technology, put demands on the technology and state exactly what you want it to do."

The challenge of course is that, like the Black Cab drivers, we may not know what wonderful new thing we want the technology to do until someone else has actually done it. Our 'Uber moment' could be just around the corner...