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Construction Research and Innovation

ISSN: 2045-0249 (Print) 2475-6822 (Online) Journal homepage: http://www.tandfonline.com/loi/tcri20

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To cite this article: Stephen Cousins (2017) Total BIM: How Stockholm's £1bn urban transformation project is going 100% digital, Construction Research and Innovation, 8:2, 34-40

To link to this article: http://dx.doi.org/10.1080/20450249.2017.1334940

CONSTRUCTION RESEARCH AND INNOVATION, 2017
VOL. 8, NO. 2, 34–40
https://doi.org/10.1080/20450249.2017.1334940

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Total BIM: How Stockholm's £1bn urban transformation project is going 100% digital

Stephen Cousins

The £1bn New Slussen urban transformation project in Stockholm is aiming to become one of the first in the world to deliver all its design information digitally, based on a highly evolved BIM strategy, virtual reality simulations and a range of other digitally enabled processes. Going 100% digital is expected to improve design coordinatwion and eliminate the need for over 15,000 paper or PDF drawings. The project is still in its initial phases. This report contains interviews with the City of Stockholm's BIM strategist, the project's technology consultant, Tikab, and the head of visualisation for the masterplanning architect, Foster + Partners. It explores their objectives, how the BIM approach has been set up, and documents some of the early experiences.

BIM (short for building information modelling) is often referred to as the "holy grail" of construction, holding out the promise of a richly detailed, well structured and collaborative approach to the way buildings are designed and delivered. In practice, however, take-up has been patchy as project teams continue to struggle to understand and implement BIM processes and achieve buy-in from the supply chain.

One project striving to embrace BIM in its totality is the SEK12bn (£1.05bn) New Slussen scheme in

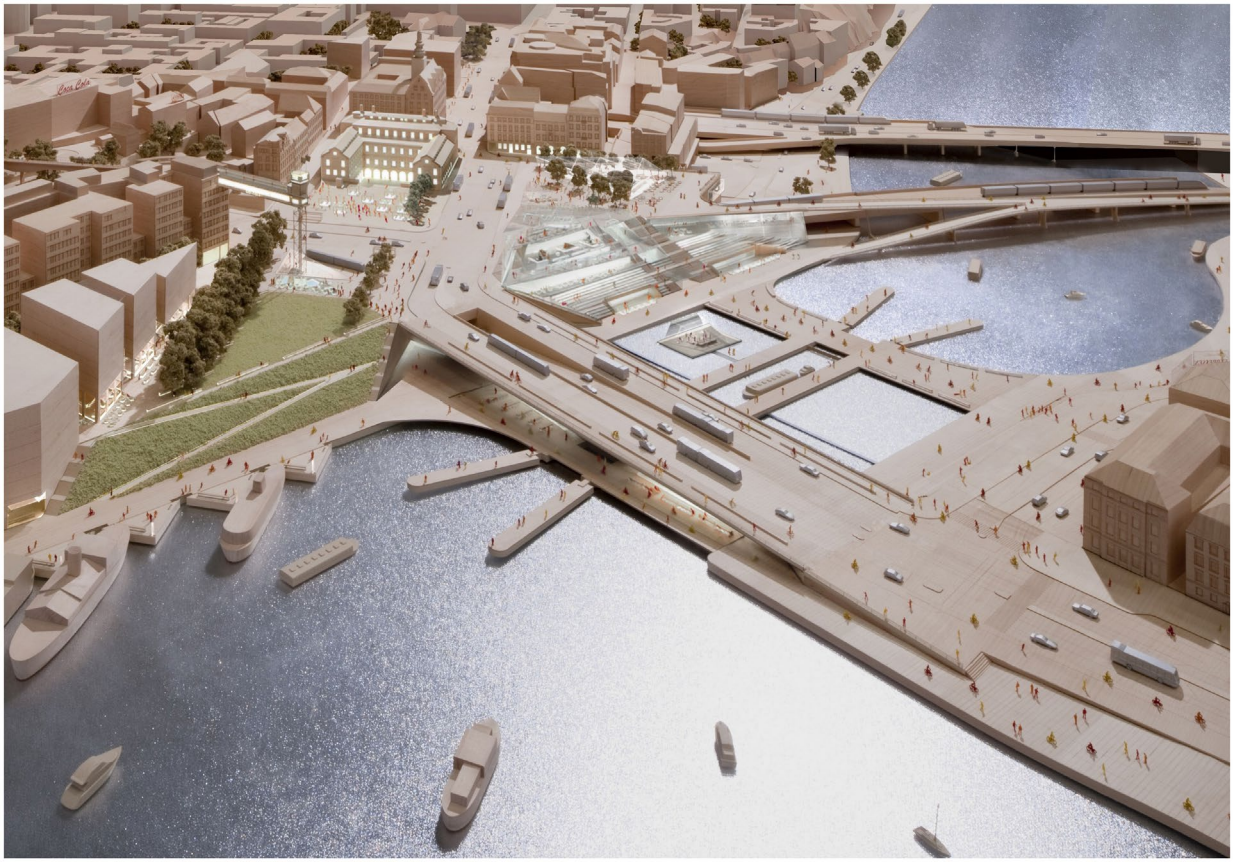

Figure 1 Render of the new layout, masterplanned by Foster + Partners (Credit: Foster + Partners).

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Figure 2 The Slussen cloverleaf in 1939 (Creative Commons).

Stockholm, one of the largest urban transformation projects in Europe, which has ambitions to become the first in the world to produce all its design information digitally, from early design through to handover, with no paper documentation at all. It is an ambitious goal, given the project's size and complexity. Covering 70,000 square metres, its aim is to create a new pedestrian-friendly urban quarter at the heart of the Stockholm archipelago, next to the navigation lock joining the Baltic Sea and the freshwater Lake Mälaren. The area's topography will undergo dramatic change, with the removal of a decrepit "four-leaf clover" road interchange built in the 1930s. Lasting until 2025, the project is split into more than a thousand discrete delivery packages, many of which are being designed in parallel with live construction work on site. At least 40 different contractors are involved.

The client, the City of Stockholm, employs a dedicated design team lead by engineer ELU-Konsult and comprising over 150 designers. Each company within the team has a Virtual Design and Construction (VDC) Coordinator (the equivalent of BIM Coordinators in the UK), overseen by VDC Managers from technology consultant Tikab, who pull together data and graphical models, including over 500 BIM models, covering disciplines such as architecture, structures, landscaping, MEP, ventilation and traffic.

High tech applications on the project include several detailed virtual reality simulations created to give the client and other non-technically trained stakeholders an immersive understanding of the scheme. Some 3D models are used to run machine-guided excavators, which, in combination with positioning technologies, helps to boost their efficiency. There are plans to deploy "BIM kiosks" on site to provide access to Navisworks and virtual reality (VR) scenarios on a big screen at the coal face of construction.

Going 100% digital is expected to improve design coordination and eliminate the need for over 15,000 paper or PDF drawings, significantly reducing administration costs. All VDC elements are being managed by technology consultant Tikab on behalf of the project's lead consultant, the engineer ELU. Johan Stribeck, Business Area Manager for BIM/VR at Tikab, told CRI: "Not a single crown has been spent on photocopying costs. Instead of having to carry reams of drawings, the team fine tunes the models and interrogates them together in meetings. Some models contain BIM data, others contain only geometry for surveying and measurements. Many are being developed over time and will include an increasing number of objects at each stage of delivery."

City reconnected

The Slussen was originally built in 1642 as a lock separating the Baltic Sea from the freshwater Lake Mälaren. An extensive update in 1935 saw the area covered by a concrete "four-leaf clover" structure of roads curling around a cylindrical office building, over an underground bus terminal and alongside the massive locks that regulate boat traffic between the lake and the ocean.

By the mid-2000s, the concrete was dangerously eroded and in such a bad state of that repair the City of Stockholm decided to demolish and rebuild it. The re-design, by renowned architects Foster + Partners, and local practice White Architects, aims to provide a "new civic quarter for all" that will make the area more friendly to pedestrians and cyclists, and knit the city back together again. New public spaces, a quayside, and pedestrian and cycle routes will restore connections between the islands of Södermalm and Gamla Stan, the Old Town of Stockholm, which were previously separated by a maze of roads and concrete passages.

The navigation lock will get a five-fold increase in capacity to minimise the threat of flooding. The realigned quayside will have restaurants, cafes and cultural amenities. A new road and pedestrian bridge will be constructed and, on the Södermalm side, the space around the existing City Museum will be extended over a new underground transport interchange and shopping mezzanine to create a series of public spaces.

The complexity of the development is reflected in the construction programme, which runs until 2025 and is split into over a thousand discrete delivery packages, many of which are being designed in parallel with live construction work on site.

When the project was procured, the client had a BIM Strategy but the actual requirements were "rough" for BIM, says Stribeck. It stipulated the need for structured information and the use of 3D apps for visualization, reviewing, coordination, procurement, 4D Sequencing, and 5D Calculation. However, details were not supplied as to how BIM processes should be implemented or the level of detail required in the models.

Stribeck saw in the city's strict requirements an opportunity to embrace BIM in its totality. "When this landed on my lap I realised it would be vital to get everyone to

Figure 3 Demolition of the four-leaf clover proceeds in July 2016 (Credit: Holger Ellgaard/Creative Commons 4.0).

design and produce the scheme without drawings," he said. "It would have been impossible to write a manual for hundreds of workers explaining how to simultaneously deliver standard drawings and high quality 3D models carrying data. With everyone working in just models and databases we could get everyone onboard much faster."

Tikab advised the client to keep all information structured in models, and they agreed. The prospect of improved efficiency and reduced administration costs was a key draw for the client, explains David Möller, BIM Strategist for the City of Stockholm: "On traditional projects a huge amount of work is required to make drawings look good, many of which are never used. On New Slussen we have tried to present information in a different way that enables staff to focus their time on technical design issues, not drawing."

However, this innovative approach was not set in stone from the outset. Around five percent of the project comprises small, early enabling works that were designed before the model-based platform was ready. These are currently being carried out using 2D printed drawings.

Land, water, rock

Construction of New Slussen is split into three areas covering construction on or under water, construction on or under the land, and construction within the rock substratum. The land and water zones cover the majority of works and are being delivered by an ELU-led team of 12 design consultants, including the local architect, M&E, heavy mechanical (lock ports), signal, plumbing, sprinklers, landscape land, landscape water, traffic design. The "rock" element is being delivered by

Fun and games

A team of game designers was hired by project master planner Foster + Partners to create a 3D interactive model of the New Slussen to help refine its design.
The three experts were hired to produce a comprehensive 3D geometric model of the scheme in the games engine CryENGINE, created by German game developer Crytek. CryENGINE was initially launched in 2002 to run the console game Far Cry and remains at the forefront of gaming graphics technology. The system was adapted to run exported versions of Foster's 3D architectural models, produced in Autodesk Revit and Bentley MicroStation, and expanded to include the wider context of the site and the city of Stockholm.
Gamma Basra, Partner, Head of Visualisation, Foster + Partners told CRI: "When we approached Crytek, around five years ago, the costs to use the engine were astronomical, but we managed to agree a sum for its use in a non-games world."
The 3D environment was projected onto a large screen during design review meetings to enable the client and the architects to add or remove objects and assess the quality of light, materials and finishes. A joystick was used to navigate through spaces, including the bridge, the lock, or through the new bus terminal.
A key function of the engine was its ability to quickly swap out different colours and finishes to match building materials being developed by Fosters' Materials Research Centre.
Ricky Sandhu, project partner in charge at Foster + Partners told CRI: "We had a very interactive way of working internally at Fosters. The Materials Research Team was finding these great materials, the architects would explore them and write specifications, then our visualisation team would put them into the model to view and navigate on the big screen."
According to Sandhu, the ability to make live changes made it easier to engage the client. Rather than have to mark up drawings, the team could make design decisions on the fly. "That level of inclusion was quite brave. As architects you don't want to give the client too many options to make changes as all of a sudden it can become a free for all," he concludes.

Figure 4 New Slussen aims to provide a "new civic quarter for all" that will knit the city back together again (Credit: Skanska).

a team led by engineer WSP and principally involves the construction of a new bus terminal formed inside an excavation blasted out of the ground with dynamite.

All design information for New Slussen is being collated and coordinated using a model-based delivery platform, devised by ELU/Tikab to foster collaboration between design consultants and contractors. Many of the same principles were also adopted by WSP's team.

The platform is a strategy for delivering information, rather than a piece of software. A typical construction project in Sweden is normally delivered using three main "information carriers", namely, drawings, technical specifications and quantity lists. The delivery platform for New Slussen exploits 10 information carriers, and no drawings. These include:

- A BIM model in Navisworks, including things like geographical information, material qualities and contract details;
- A geometric surveying model in CAD, from which contractors can extract coordinates and take measurements;
- A graphical erection sequence model, also known as 4D sequencing, for every delivery situation in a package of work;
- A series of static "model views" as digital PDFs that describe aspects of the package that cannot be conveyed in other model formats;
- A components list, exported data in Excel or in synchronised databases;
- A bill of quantities, exported data in Excel.

An overview and coordination model, referred to by Stribeck as a "coordination model on steroids" pulls all other model information together, alongside "sharp" data, used by the contractors to identify and locate each small, delivered BIM-model in its context. The iConstruct plug in for Navisworks enables the team to automate many processes and filter project information. For example, different colours can be selected to filter the model to display the status of each object, if it is under construction or under review, which zone of the project it belongs to, the technical discipline the object was created by, or the construction contract it belongs to.

Each of the several thousand separate delivery packages will have 10 information carriers, but requirements will vary depending on the nature of the package and the needs of designers delivering it.

Stribeck comments: "The [geometric] surveying model is important to the structural guys to display all coordinates and surveying information. In contrast, the electrical consultant relies more on other models on the delivery platform because they don't need to know the precise coordinates of every cable tray."

An asset model, for use post-handover by the client's facilities management team, is not currently a deliverable due to the fact that, by 2025 when the project is completed, the client's software and information requirements may have changed. However, it is not being ruled out at this stage.

3,600 piles, and not a single drawing

Skanska is the key main contractor on the construction framework responsible for two contracts worth a total SEK1.95 billion. It is currently deep into excavation and piling work to create foundations for the new locks.

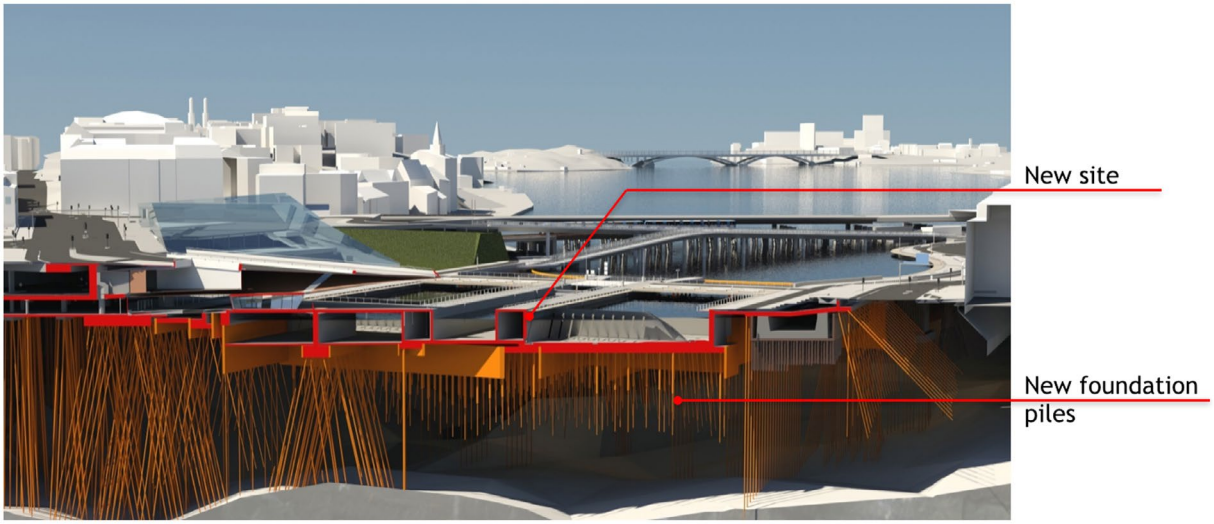

Figure 5 Visualisation of cross-section of the New Slussen (Credit: Tikab).

High tech history lesson

A VR simulation of how the Slussen probably looked in the mid-to-late 18th Century was developed to give stakeholders a feel for the heritage of the site. This "time capsule", which users experienced using HTC Vive goggles, started out as a BIM model of relics and torn down buildings considered likely to have an impact on foundation and excavation works.

The discoveries were analysed, together with documents in the Stockholm Archive, including old colour illustrations, drawings and even paintings and copperplates, to build a realistic historic portrayal of the site in VR. The simulation features cobbled streets, virtual locals in period dress, a wooden quay and a version of the Blå Slussen, a wooden bridge that used to open up to allow boats to enter the lock.

Users get to wander around the famous "Green Walk", a wooden promenade situated just north of the ancient Polhemslussen (lock/sluice). The name was subsequently given to one of three pedestrian tunnels that pass through the modern Slussen, rebuilt in 1935.

The virtual environments were developed by the project's lead consultant ELU, using a mixture of AutoCAD, Autodesk Revit and 3ds Max, then brought together, textured and made interactive by Tikab in the games engine Unity.

A key challenge was to verify the authenticity of the archive material, says Dan Svensson, Head of Unit at ELU: "We worked to the principle that if we had four sources, including drawings, illustrations, paintings and literature, from different ages, showing, or confirming the same thing, then we assumed that the area or the object looked like that at the time."

According to Svensson, the site has evolved considerably since the 16th Century, when all that existed was a narrow "tongue" of land between Södermalm and the Old Town. The character and function of the area has changed, from early fortification, to a place of commerce and crafts in the mid-1700s, to an area that mainly serves as a traffic interchange today.

"What unites the area, throughout the ages, is its strategic location relative the capital, it is only a couple of hundred meters from the royal castle," he says. "As it turned out, many of our assumptions and estimations are being confirmed during ongoing archaeological excavations in the area."

Figure 6 VR simulations showed how the Slussen looked in the 18th Century.

This job will take until 2022 to complete, will consume around 20% of the total project budget and require some 3,600 steel piles, each driven down 70 metres to reach solid bedrock on the seafloor.

The cloud-based data management platform BIMeye is being used to plan and execute the works, combining information from several different information carriers. Every pile is unique and costs around 20,000 euros to produce. To avoid the need to produce 3,600 sets of drawings, the piles were modelled first as basic 3D elements in the project's various BIM models, with information on the specific pile number, location coordinates, orientation and length. This was synched to BIMeye, where Skanska inputs detailed information on every pile, covering 80 separate parameters needed by the design team, and 30 parameters for its own use.

As each batch of 50 piles is drilled and installed, Skanska feeds the as-built data into BIMeye to enable ELU to check progress against the design. As-built parameters include the final X, Y, Z coordinates, depth, the number of extra steel sections that had to be welded, and technical data on ground pressure.

The software syncs all data back to the Revit and Navisworks models to give users real time access to BIMeye. "It means we can have one team entering information online, without the need for knowledge of BIM, while the design team still has all the information available at its fingertips in Revit and Navisworks," says Stribeck. Having a single source of data in several locations – in BIMEye, in Revit models and in Navisworks – helps guarantee accuracy and removes the possibility of information gaps that can occur traditionally, when information in paper drawings is sometimes not entered into spreadsheets.

It is an early success story in the project's efforts to eliminate drawings: six months since piling work began and not a single drawing has been produced for the work.

Challenges lay ahead, however. People are getting "a bit nervous" about forthcoming concrete and reinforcement works, says Stribeck, as staff at the concrete contractor are not all familiar with working in BIM software. Virtual reality (VR) technology may provide part of the solution. During production planning, each small concrete delivery package will be reviewed by managers who will wear a VR headset to examine rebar arrangements and get a clearer, 1:1 scale understanding of the layouts by walking around inside the foundations.

The rebar for the new bus terminal raises other issues. Exploding the rock with dynamite creates uncertainty around the final profile of the surface and therefore the precise layout of rebar in the walls. "We might not model all of the rebar because we don't know precisely how the dynamite will affect the rock," says Möller. "As with everything here, we are trying to be smart and efficient about how we approach the task at hand, it might not be necessary to model everything."

Real and surreal

VR technologies are being used in various ways to help improve decision making and "democratise" the design process by ensuring that every stakeholder, not just the design experts, have access to the most relevant information.

In one surreal scene, a uniformed fire protection engineer from Greater Stockholm Fire Department donned a pair of HTC Vive VR goggles to carry out a 1:1 scale safety review inside the lock channel. Using a joystick he was able to "walk through" and examine how ambulance personnel would enter to carry a person out after an accident, and to check corridor widths and stairway angles.

"Drawings wouldn't have been able to give the same mental understanding of the spaces," says Stribeck. "In less than a minute he understood how to move around and had started his review; in 30 mins he had finished his work and was quite impressed by the technique." The use of high quality design models makes it possible to generate and update VR scenes just before a review. The client now has its own VR set up to review design changes when required.

Master plan architects Foster + Partners has an ongoing role ensuring that its design intent is being delivered on site. In October it was commissioned to design another large building for the project, outside the original scope of work, which is being interrogated in regular VR-based design reviews in Stockholm.

"Although many issues could be uncovered using drawings and a physical model, VR makes it easier and more immediate," says Ricky Sandhu, project partner in charge at Foster + Partners. "For example, we had an internal debate at Fosters about a roof garden on the building. I wanted to create a form of allotment, others wanted a thick forest. When I was in the VR model I realised the trees would obscure beautiful historic views of Gamla Stan. We turned off the trees and all of a sudden we could see the vista, that kind of thing is really powerful."

Efforts to engage the supply chain with BIM are an ongoing challenge for Stribeck and his team, particularly due to the scale of the project, which involves 40 different contractors, and employees that will come and go during the extended programme. "Some people get it straight away, others don't get it at all," says Stribeck. "We are currently talking to Skanska to fine tune the system so their surveyors and others can use our models. One issue is we haven't appointed an MEP contractor yet, so we have had no one to exchange ideas and refine the details."

The need to run design and production processes in parallel complicates matters. "It's not the nicest environment to work in, it's much easier to finish the design upfront, review it, and then move into production," he adds.

The model delivery platform helps streamline the process, for those unable to interrogate 3D models,

the "model views" information carrier was developed to convey information as a multi-page PDF viewed on tablets and laptops. The PDFs include up to 50 different static 3D and plan views, taken from BIM, with notes and embedded hyperlinks to related information.

With the first above ground works not expected to begin for around six months, there's still a long way to go, but the prospect of paper-free delivery is on track so far. "If we had tried to complete the project with drawings it would have been impossible, far too complex and time consuming," Stribeck concludes.