TOTAL BIM PROJECT: THE FUTURE OF A DIGITAL CONSTRUCTION PROCESS

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TOTAL BIM PROJECT: THE FUTURE OF A DIGITAL CONSTRUCTION PROCESS

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ABSTRACT: *Although the construction industry strives to implement Building Information Modeling (BIM) to improve efficiency and quality, adoption in the actual construction phase is still limited. However, in Scandinavia, recent years have seen the rise of an idea known as Total BIM - An approach where the BIM is the legally binding construction document and no traditional 2D-drawings are used on-site. In this paper we present a case study of a successful Total BIM project. We investigate the prerequisites for – and outcomes of – implementing the Total BIM concept, where commonly found individual and isolated BIM uses is turned into an all-inclusive approach to achieve a more efficient design and construction process. Our analysis shows that the success was contingent on factors from within several different areas, including strategy and innovation, organizing, and technology, but also on the commitment shown by the construction management company responsible for the project. In addition, three key elements were identified; BIM as the legally binding construction document, cloud-based model management, and user-friendly on-site mobile BIM software.*

KEYWORDS: *building information modeling, Total BIM, digitalization.*

1. INTRODUCTION

Building Information Modelling (BIM) can be seen as a strategic methodology that can innovate the construction sector (Fox 2014; Renz et al 2016). Indeed, the growing use of BIM has led the construction industry to move towards a digital construction approach by which it is possible to work on 3D data providing complete information to the stakeholders. The use of 3D models and BIM is widely reported in research, identifying numerous benefits (Azhar 2011; Volk et al 2014; Kumar et Bhattacharjee 2020). In particular, previous studies identify that using 3D models instead of 2D drawings facilitates communication ensuring clearer information, such as clash detection (Zaker & Coloma 2018). Nonetheless, barriers in BIM implementations still exist, such as issues surrounding the legal status of the BIM in construction projects (Englund & Grönlund 2018).

With BIMs often having unclear legal status, it is instead common to see the BIM methodology applied as a parallel process to conventional 2D drawings. BIM is far from becoming a standard because the current rules, regulations and contracts still require 2D drawings as the legally binding documents. As such, despite extensive resources being spent on providing 3D models, the potential in implementing them is not realized and the simultaneous provision of 2D drawings hinders the leap forward to a more extensive utilization and a digital process in the construction phase.

In this paper we present a case study in which the demand and requirement of 2D drawings as legal document is finally superseded. Indeed, a "Total BIM" concept where BIM (recognized as the contractual document) was used in all phases of the project by every actor. This paper offers a unicum in the literature where 3D models are fully implemented and is also used on-site by the construction workers where on-demand information and measurements are created and extracted directly from the BIM. The paper aims to investigate the prerequisites for and outcomes of implementing a Total BIM concept where the 3D model is legally binding and used in the construction phase on-site.

2. BACKGROUND AND THEORETICAL CONSIDERATIONS

Previous studies present some examples and attempts at pushing towards a full implementation of BIM, but no project seems to have reached the objective to eliminate the 2D drawings from the construction phase. Already in 2014, Czmock and Pękala (2014) reported a case study of an office complex in Warsaw based entirely on BIM, while 2D CAD drawings were secondary. The design process was estimated to be 10% faster and 80% more accurate. The authors concluded that BIM promotes simplification and saves money and time. Nevertheless, the use of BIM was limited to the design phase, because on the construction site they used paper drawings, which were required by Polish law. In 2017, in the Thames Tideway Tunnel project (a large sewage system in London) the designers assumed a challenge to eliminate 2D drawings and to work with information derived uniquely from the BIM model (Gaunt 2017). Indeed, they considered the 2D drawing production process unsuccessful, but in any case, it was legally binding for the project. Limited to the design phase, they prepared both 2D drawings and a 3D model to identify the benefits of a 3D model-based method and discovered that BIM could save money. Thus, even if in the cases presented the use of BIM could be translated into advantages, the request to produce parallel 2D drawings caused additional effort for the stakeholders that nullifies the business value of BIM. Indeed, currently most designers create 3D data models rich in information that does not reach the construction site.

Recently in Scandinavia some projects were realized using the 3D model as the legally binding document on the construction site. In the Norwegian Randselva Bridge project (due for completion in 2021), IFC models were uniquely used, defining it as a “drawingless” or “drawing free” project. The information was derived from the 3D model and used on the construction site. However, at the same time 2D drawings were requested from the client to have “an overview of general information”.

In the case of the Röfors bridge, 2013 – a project realized entirely without traditional drawings – additional agreements were established that gave the BIM the same status as “specifications”, thereby placing it above “drawings” according to the General Conditions of Contract. Construction workers then had direct access to the BIM on tablets for an easy overview and understanding of the project. However, due to limitations at the time in the BIM-viewer software, it was difficult for construction workers to extract accurate measurements and specific information from the model. In order to solve this issue, the project regularly had a structural engineer on-site to create so-called Production-Oriented Views (POV) from the BIM in consultation with the construction workers. These views were essentially enhanced screenshots typically containing color-coded elements, specific measurements and dimensions, object information, 3D-sections, or any other information the construction workers considered was necessary to perform the actual work on site (see Figure 1). After creation, these views were uploaded as images to a shared model repository and could then be accessed and used as a complement to the complete BIM on the tablets.

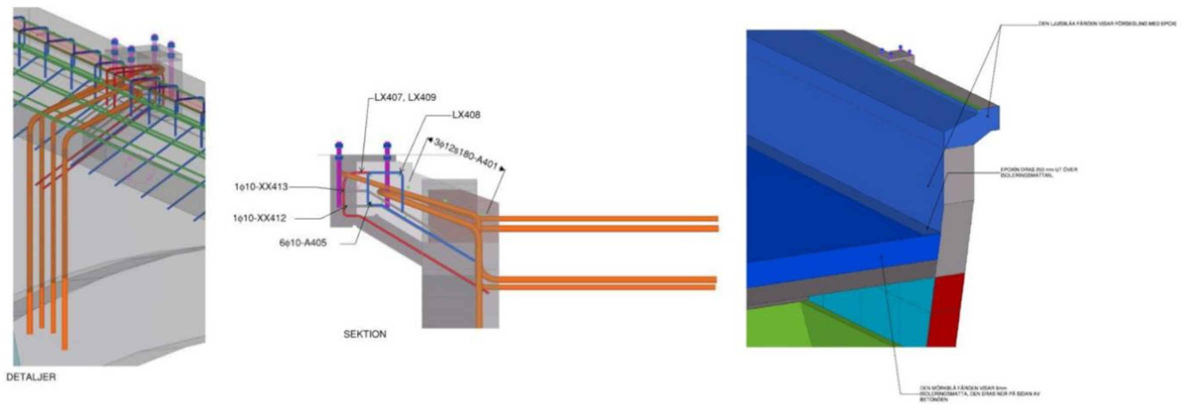

Fig. 1: Illustration of Production Oriented Views (POVs) in the Röforsbron case (Johansson & Roupé 2019)

In the Norwegian Oslo airport expansion project, completed in 2017, due to a large number of estimated paper drawings they decided to use a BIM approach on site, but only for placement of the reinforcing bars (Mershbock & Nordahl-Rolfsen 2016). It is noteworthy as this also occurred in the Röforsbron project where they decided to use the POVs to facilitate the work on site.

The Slussen project, in Stockholm, is the rebuilding of the junction between Södermalm and Gamla stan (Cousins 2017). The project started in 2019 and the completion date is scheduled for 2025 (Nohrstedt 2017). It was decided to use only 3D models in the project and to not use 2D drawings because the creation and handling of the latter wastes time.

In the Smisto project, a hydropower station in Norway, the consulting firm collaborated strictly with the contractor to reach the goal of only using the 3D model. They also used the model-based approach in the construction phase (Gaunt 2017) and only delivered one 2D drawing. The drawingless execution increased progress monitoring and interaction among stakeholders both during the design and the construction phase (Multiconsultgroup 2016).

Considering the cases found in the literature, to understand how BIM could be fully implemented even in the construction phase, it is necessary to highlight both its social and technological nature.

The BIM approach is based on technological and processual factors (Mondrup et al 2012) that influence information management along the supply chain and the overall business concept (Sundquist et al 2020). Nonetheless, the ability to tackle and manage complexity in the project has encountered many challenges due to the different needs and incentives of various stakeholders. Furthermore, the BIM environment has not been mature enough to adopt a Total BIM approach. In fact, different maturity models have been proposed to assess and evaluate the level of BIM implementation within organizations (Sacks et al 2018). Using these models, the level of BIM maturity (that could find its maximum stage in a Total BIM approach) can be evaluated accordingly to a socio-technical perspective, considering the simultaneous application of technological (e.g., 3D model) and social factors (e.g., synchronous collaboration).

Finally, because BIM entails interdependencies between technological, process and organizational aspects, to capture the implementation of a Total BIM approach, in this research we apply a holistic method where ecosystem, strategy and innovation, organizing, and technology categories are used (Sundquist et al 2020). By applying a socio-technical holistic point of view, this paper wants to investigate and analyze a project that has embraced the Total BIM approach during the entire project from design to construction phase.

3. METHOD

Due to the nature of the research, a qualitative approach was employed. The data consists of qualitative semi-structured interviews with the Virtual Design Construction (VDC) manager and the VDC on-site coordinator for a total duration of 10 hours. The semi-structured protocol allowed the interviews to be organized according to a pre-established structure and to keep open-ended questions as to collect more comments from the respondents (Dicicco-Bloom & Crabtree 2006; Yin 2009). Before commencing the interviews, the VDC manager provided an extensive project presentation. According to the framework firstly proposed by Bosch-Sijtsema et al. (2016), (see Figure 2) data was grouped according to the following categories.

- Ecosystem: Environment of new developments; standards, laws, regulations; requirements.
- Strategy and innovation: Business value of BIM in terms of costs, productivity, performance.
- Organizing: Methods, processes, and ways of working with BIM; Cooperation with BIM between firms.
- Technology: Technological components of BIM, interoperability (type of software), technological platform and framework for collaboration, standards (structure info, naming the objects, BIM guidelines).

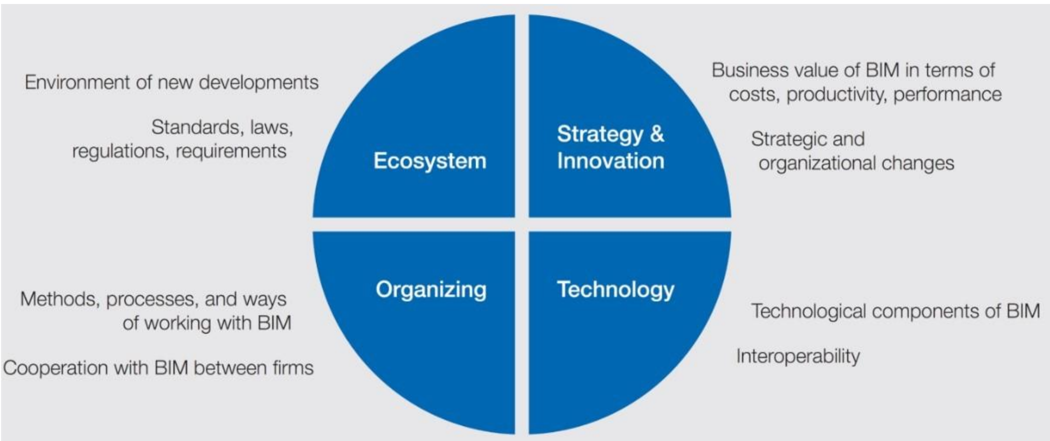

Fig. 2: Holistic research framework to BIM implementation. (Bosch et al 2016; Sundquist et al 2020)

3.1 Total BIM case study

The Celsius building located in Uppsala Science Park, is in an attractive area for new innovative science companies in Sweden (See Figure 3, Right). Design work on the project started in 2017, construction began in

2018 and work was completed in November 2020. The project is a new construction of an advanced laboratory built by a leading Swedish real estate company, consisting of 12 000 square meters over 7 floors. The project budget was roughly 45 million Euro, and the building has been certified with LEED Platinum, with highly advanced energy, water and waste systems. The CM company behind Project Celsius won the 2020 international buildingSMART award for their innovative and digitalized process in construction. In the design phase BIM-models were live-linked between BIM-applications and firms to produce high-quality open BIM models, that eased communication between stakeholders to solve more issues in this phase than previously possible. The bidding process was streamlined by providing bidders with custom IFC-models and extracted quantity data, with only information that was relevant to them, which was aimed at reducing their workload and attracting more bids. In the construction phase the 3D IFC model was the legally binding construction document. The model had to be used by all workers during construction as no paper drawings were produced. Everything was built on-site from the 3D model by using mobile devices and large screens operating StreamBIM to view the model and for tasks such as taking measurements, checking object attributes, and communicating administrative items (see Figure 4).

Fig. 3: Left: Use of StreamBIM on-site. Right: View of the Celsius project during construction

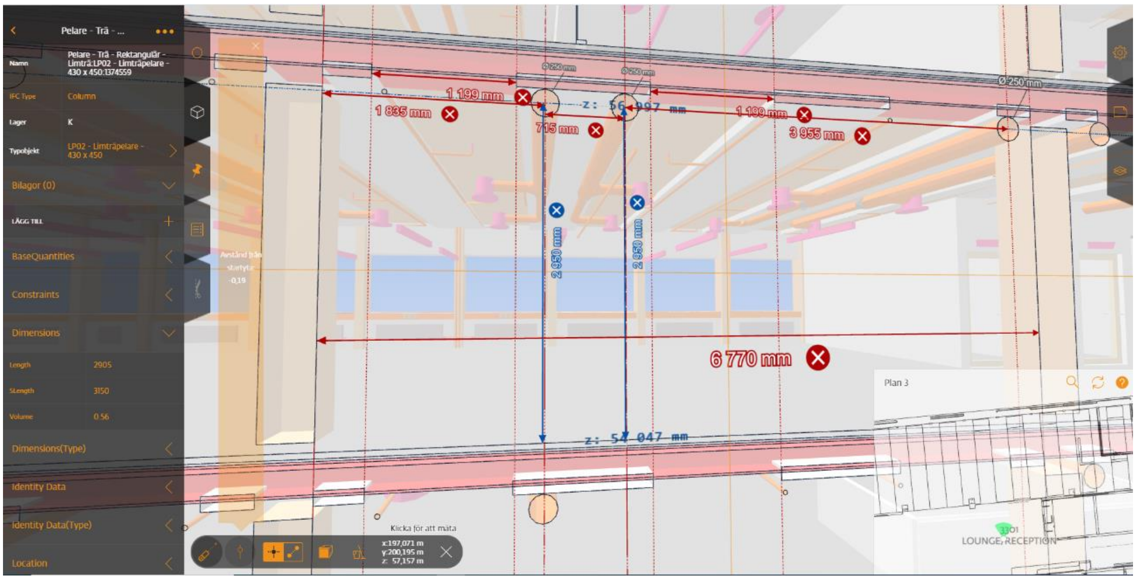

Fig. 4: In the Celsius project the construction workers took their own measurements and extract information directly from the BIM using StreamBIM the phone or tablet on construction site.

4. RESULTS

In the Celsius project, the CM company was responsible for implementing digitalization and BIM by using a model-based approach where BIM carried all the information, thus, no drawings, i.e. a Total BIM project. The project strategy is unique and novel in the sense that the vision was to utilize digitalization and BIM to enable a new approach and way of working with digitalization of construction, and in so doing achieve a more efficient construction process by simplifying and improving project quality, information handling, communication and administration (self-monitoring, case/issue management, quantity take-off, bidding and cost management, etc.). The gains and outcomes of this implemented strategy in the Celsius project are categorized in Table 1 in accordance with the previously presented category framework.

Table 1: Gains/outcomes in the Celsius Total BIM Case Study

		Total BIM Case Study, Celsius **Gains and Outcomes**
Ecosystem	***Standards***	**Standardization for codes/names** in BIM (e.g. BIM object) added in design and used in pre-production and production phases. Flexible way of information flow and working for enabling innovations and feedback from production and design.
		BIM and digital model as information carrier.
	Laws, regulations, requirements	**BIM legally binding** and forcing sub-contractors to use digital tools. Legally 3D BIM is richer about what is to be done.
		Clear structure of who is responsible for supporting BIM on the construction site and a change order process for production where the BIM and StreamBIM is used for error-handling, e.g. design change for hole punching during construction.
Strategy & innovation	***Costs***	**More design cost:** the implementation of Total BIM costs more money than a traditional design process. The focus was to create high-quality BIM and production orientated model-based design that are more thoughtful instead of making drawings.
	Productivity, performance	**Eliminated unbudgeted changes:** high quality BIM and use on the construction site eliminated unbudgeted changes.
		Single source of information and efficient process: the vision was to achieve an efficient process by removing any duplication work and use of a single source of information that emanated from BIM stored in the cloud. Information in description and drawings is not an efficient process e.g. interpretation errors, search for information and guess work of the design.
Organizing	***Methods and processes***	**Education and technical support:** local VDC and technical support on site from the management for construction workers/sub-contractors. Clear structure of who is responsible for supporting BIM on the construction site.
		Cost for BIM education taken by the construction process, support provided and knowledge transfer for new construction workers/sub-contractors on the construction site.
		No conflicting information: as all information delivered from or linked to the model. 3D-model is the construction document in the project and 2D PDF is handled as a complement for details that are hard to describe in 3D.

		By not giving the workers the opportunity to use traditional drawings, they were forced to use the new digital working methods.
		High quality of the model and the linked information, as it was the construction document and used on the construction site. A templates system was used to organize the data contained within the BIM-model.
		Bidding process using BIM: the project was a Design-Bid-Build process with 40 sub-contractors in the project. Sub-divided IFC and quantity take-off lists from BIM were used for the bidding process. Possible losses of some sub-contractors during the bidding process due to competencies when moving to digital models.
	Cooperation with BIM between firms	**Information transparency** among different contractors as everything was derived from cloud-based BIM, which gave better coordination on the construction site.
		Engagement of users using Total BIM through the process: StreamBIM supported mobile phone and camera, which simplified and improved question-answer handling, communication, coordination, information handling, administration, self-monitoring, case/issue management on construction.
		The CM-company helped the clients on how to implement BIM and stated demands and BIM-guidelines.
		Cost taken by project: StreamBIM license cost connected to construction project which supported new users and sub-contractors (+300 users in the project).
		Clearer routines and BIM-guidelines focus on constructability and the use of the digital models on the construction site. The detail level in the model was flexible and developed according to the construction site needs.
Technology	*Technological components*	**Cloud-based BIM** that supported a single source of information, which was accessible from mobile devices.
		WiFi Support: installed construction site WiFi to support internet connectivity.
		StreamBIM in the construction phase supported a user-friendly interface for measurement, sectioning and creation of 3D-views in mobile devices, which supported single source for information on the construction site.
	Interoperability	**Interoperability through cloud-based BIM:** using Autodesk 360, which supported automatically synchronized BIM-coordination and information.
		Sub-contractor discipline and custom fitted filtering of information for BIM objects depended on the sub-contractor's interest.

4.1 Ecosystem

BIM was the legally binding construction document in the project, and the only information carrier from design to construction as no printed drawings were used. To develop a high-quality detailed model was thus crucial. Standardization for codes/names of objects in BIM were added in the design phase and used in both pre-production and production, with a strong focus on how the information would be used, thus usability was a key concern. Clear routines and structures, but at the same time maintaining a flexible approach enabled development and innovations when it came to BIM and its information uses. Since the 3D model was legally binding and no paper drawings were produced, subcontractors were also forced to use the digital tools provided to carry out construction. The CM company was responsible for supporting and transferring knowledge to subcontractors on site about how to use BIM and StreamBIM, which were also used for error handling in cases such as a design change for hole punching during construction.

4.2 Strategy and innovation

Working with a Total BIM concept changed the focus from the delivery of drawings towards creating high quality BIM and more thoughtful design in 3D, which in turn led to a more production orientated model-based design. In this way, “information islands” and disconnected information sources that often occur in traditional construction design and production projects became obsolete. To accomplish this, extra human and financial resources had to be allocated to BIM and IT, adding to the overall design cost. However, the high-quality BIM greatly reduced the number of unbudgeted change requests on the construction site, thus invested money in the design phase improved production performance at site. As the vision for the project was to only have one single source of information that emanated from BIM stored in the cloud, the construction workers had to align to model-based production. Information was delivered via BIM as this was a more efficient process than when descriptions and drawings are used, and errors and guess work are common.

4.3 Organizing

Due to the model being the legal construction document and being used for construction it was ensured that a high-quality model was created, and all the information required by the subcontractors was linked. Templates were generated to organize the data in such way that users could quickly find the information relevant to them with just a single click. On the construction site local VDC and IT-support was present. The CM-company was responsible for BIM implementation and education of all new construction workers/sub-contractors. Workers arriving at construction site for the first time were introduced to the digital model-based work method and tools with an introductory education. The cost for this was covered in the budget for the construction process, as well as software licensing costs. The CM company also guided the client on how to implement BIM. The bidding process for subcontractors to work in the project also involved BIM. The project was a Design-Bid-Build process where 40 contracts were tabled. Each contract was sub-divided into IFC and quantity take-off lists, created from the BIM and distributed to the bidders. The result was a greater number of bids than in comparable projects with less variance. However, some sub-contractors may have lost out due to lacking competencies when moving to digital models.

There was no conflicting construction information as the BIM was the construction document, but 2D-PDF was used as a complement to 3D when details were hard to describe in 3D. By using a single source of information that emanated from BIM stored in the cloud, the construction workers had to organize their work based on the model and use the new digital methods. The creation of “drawings” was pushed to the construction site, as the construction workers themselves created their own “drawings”/production-views from BIM in StreamBIM (e.g. measurements and information). By doing this, time was saved as only relevant drawings were created instead of the common approach of drawing overload that has no function on the site, and the construction-workers got the measurements, information and views they need to conduct their work. The workers turned out to be positive to this change and did not want to revert to the traditional way of working. Also, by doing this, all the information became transparent among stakeholders, as everything was derived from the cloud. Commonly, the respective sub-contractor only has "need to know" for their own discipline and cannot easily understand other sub-contractors' work or information. Here, coordination on the construction site between the different sub-contractors was improved significantly.

At the beginning of the construction the project invested in buying BIM-kiosks with large TV screens, which were placed on the construction site. However, as the project continued the construction workers started to use mobile devices, such as tablets and mobile phones, instead. As the mobile phones had cameras they also started to communicate and document with photos in StreamBIM’s case/issue management tools. Using this approach facilitated improved communication and coordination between the different sub-contractors.

4.4 Technology

To accomplish the project vision, it was recognized early in the design phase that a cloud-based design process would be used. As most of the members in the design team worked and designed in Autodesk Revit, they recognized Autodesk 360 as interoperability and collaboration platform. Consequently, almost any file-based exchange was carried out during the design phase and automatic processes for merging, color-coding, cleaning and publishing updated IFC-models to StreamBIM were developed. The updates were done during nights and saved a lot of time compared to a traditional file-based BIM-coordination process. For one of the designers working in Trimble Tekla (e.g. pre-concreate fabrication), the model was exported once a week into an IFC file. The file was then subsequently imported into Revit and Autodesk 360 to facilitate coordination with the design team. During the construction phase the model was kept up to date and accessible by mobile devices from the cloud, thus, providing users with a single source of information rather than having to locate the most recent drawings. For this to work WiFi had to be installed and made accessible across the construction site. This single information source was supported by StreamBIM, which provided a user-friendly interface for measuring, sectioning and creation of 3D views in mobile devices. Information in StreamBIM was custom filtered so that subcontractors could immediately locate the data relevant to their discipline without having to browse through multiple tabs/windows.

5. DISCUSSION

When looking at the Celsius case from an individual/isolated BIM usage perspective (e.g. model-based quantity takeoff, shared cloud-based model repository, etc.) there are few applications that are fully unique to this specific project. Although many of them are certainly exotic, such as having the BIM as the legally binding document as well as excluding traditional 2D-drawings (both physically and digitally), there are previous examples from practice of such applications, although still mainly within Scandinavia. Instead, what specifically sets the Celsius case apart from other projects is that the CM company has managed to incorporate all of these applications within a single project, thus embracing the Total BIM approach to its fullest. In relation to this, it is generally accepted that each consecutive step on the "BIM-ladder" (e.g. going from BIM-Stage 2 to BIM-Stage 3) is an increasingly challenging task for all involved stakeholders (Succar 2009). Furthermore, it is commonly advocated, and the de-facto standard, to mix traditional – albeit digital – 2D documents and BIM to ease the transformation. This is also reflected and operationalized in mobile BIM-viewers, such as Dalux and BIM 360, where 2D documents and BIMs are used together. However, by essentially going all-in on BIM, the project can focus solely on a single representation, instead of having the burden of keeping two representations continuously up to date – the BIM, as well as the traditional 2D construction documents. Not only will this have an effect on the design organization, but also during actual construction, where conflicts between two different representations are no longer an issue. Taken together, this approach does put a higher relative cost on the design phase, which in the Celsius case was increased from approximately 11 to 13 percent of the total cost (compared to previous projects of a similar type), but at the same time these investments also allowed for other applications, such as automatic quantity takeoffs, ultimately simplifying the bidding process and cost estimations in general. Obviously, this high-end BIM use requires more from the design organization, but at the same time it allows the designers to focus on and prioritize a single representation to deliver. As such, it stands to reason if a Total BIM project is more challenging than a (semi–Total BIM) "mixed-mode" BIM project.

Furthermore, concern is often raised that small firms might get excluded in high-end BIM projects, due to lack of general BIM competence as well as resources to put on various BIM software and technology (Lam et al 2016). This may still hold true for the consultants (i.e. designers) in the Celsius case, considering the high demand regarding model quality. However, for the subcontractors, the opposite applies. In fact, more bids were actually received compared to other similar projects, therefore inclusion rather than exclusion is present with the Total BIM approach. Still, this should not really come as a surprise. Instead of having to spend time and resources on extracting quantities from 2D-drawings, before even being able to place a bid, the subcontractors were given detailed lists of quantities provided by the CM company. Moreover, with the on-site software as well as training and support provided by the CM company, subcontractors essentially had no extra costs in relation to the BIM-use.

The results show how the CM company have managed to transfer and redistribute costs and resources differently from traditional as well as BIM-based projects. Although the design phase was more expensive, it allowed for automatic and accurate quantity takeoffs to be used during procurement, which in turn made the bidding process less expensive for the subcontractors. With the task of extracting quantities from 2D documents being far from non-negligible, subcontractors typically must be strategic on which project to bid on (which was made easier in this case). Similarly, instead of having to make strategic choices around internal education, software investments, or digital innovation in general, the subcontractors could take part in this highly innovative project simply by taking advantage of the software and support provided by the CM company on site. Thus, in many ways, the Celsius case challenges the general understanding on how high-end BIM projects affect the different stakeholders.

In comparison to more traditional BIM projects, perhaps the most daunting concept employed by the CM company was to use the BIM as the legally binding construction document. Although this has been done previously on a few projects in Scandinavia, there are still no turn-key solutions as far as contract and legal aspects go. This meant that additional resources had to be spent on (realizing this) modifying the standard contracts. However, this part appears crucial (for the Total BIM concept), as it essentially makes it impossible for the project to fall back on traditional, non-BIM ways of working, which is otherwise common during times of high pressure. In fact, similar conclusions can also be drawn from the Röforsbron case, where the legally binding properties of the BIM ultimately led to new and improved working methods. Still, it must be acknowledged that this concept might not even be legally possible in many countries due to local regulations. On the other hand, the Celsius case does highlight the need for these issues to be raised and reconsidered by authorities. In order for BIM to be taken to the next level, and hence, making it possible to embrace the Total BIM concept, and allow for more efficient and less inaccurate construction, it must be possible to make the BIM the legally binding construction document.

Another key component for the success of the Celsius project can be seen in the use of the StreamBIM software on-site. As discovered in the Röforsbron project, functionality and user-friendliness is crucial in order to be able to actually build directly from a BIM, and it is typically not sufficient to only be able to "view" the model. What mainly sets the StreamBIM solution apart from other available software solutions is the simple, but powerful, filtering and measuring functionalities. Thus, in many ways, a similar concept to that of the production-oriented views could be adopted, but instead created on-the-fly by the construction workers themselves (see Figure 3). In addition, StreamBIMs issue management system was used to handle and keep track of all the issues throughout the project.

All in all, important success-factors are identified within each one of the four categories of the BIM holistic research model. Although some of them (e.g. BIM as a legally binding construction document, ecosystem), may appear more crucial than the others, it is, in fact, when taken into consideration the strong interdependencies among them that enables reaping the benefits. The Total BIM approach is thus only as strong as its weakest link. By being strategic and investing more resources (up-front) during the design, the bidding process and the cooperation with subcontractors was improved, at the same time as production costs where reduced. Still, without clear methods, processes, and routines in place for support, responsibilities, information management, and issue management (i.e. organizing), it becomes difficult to utilize BIM cost-efficiently throughout the project. Furthermore, without access to a user-friendly and powerful BIM-viewer software (i.e. Technology), a high-quality BIM would become difficult or even impossible to use and build after on-site. Consequently, we see that all these factors and BIM-uses have merits on their own, but it is the fact that they are all used and incorporated together that makes the Celsius case so successful.

6. CONCLUSIONS

In this paper we have presented and analyzed the Celsius case, a rather unique project that has embraced the Total BIM concept to its fullest with a number of successful outcomes. In many ways, the high-end BIM use has put additional demands regarding commitment and competence on both the CM company as well as the members of the design team. However, contrary to what one might expect, it has actually fostered inclusion rather than exclusion with regards to the subcontractors.

By applying a holistic, socio-technical view we identify strong interdependences among factors of ecosystem, strategy and innovation, organizing and technology and a successful Total BIM project is thus contingent on the alignment between them. In fact, when looking at isolated BIM uses and applications there are few of them that are as unique as this case. Instead, the strength comes from combining all of them within a single project, thereby finding even more "leverage" from each one of them.

Still, we identify three main factors that have played a crucial role in the project's success:

- BIM as the legally binding construction document
- Shared cloud-based model management
- User-friendly and powerful mobile BIM-viewer application on-site

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