Total BIM As a Digital Disruption

'TOTAL BIM' AS A DIGITAL DISRUPTION

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Digital technologies and information systems are challenging the construction industry. Existing literature focuses on different digital technologies in construction projects and the intricacies around technology improvement itself. However, there are limited discussions about how construction management (CM) organisations respond to disruptive change and pursue business model innovation. Drawing from emerging literature on digital disruption, we argue how the 'Total BIM' approach can disrupt the way value is created in a construction project. 'Total BIM' could be described as an approach where the design process and BIM are focused on production orientated design and BIM is used as the legally binding construction document. A construction management company in Sweden implemented the 'Total BIM' concept that embraced it to the fullest in the Celsius project This paper is based on data from in-depth interviews with construction management company practitioners from the Celsius project. It frames such improvement as a digital disruption which transforms the current traditional business models heavily based on the parallel processes of producing and maintaining 2D drawings for the construction site. Findings illustrate how the 'Total BIM' approach disturbs the existing roles, relations, and processes, creating cross organisational and systematic shifts.

Keywords: digital disruption; Total BIM; innovation; digitalisation; transformation

INTRODUCTION

Building information modelling (BIM) has long been an area of interest for construction management researchers. Much of the literature evolved around the expectations that BIM will create a transformative change and lead the construction sector to a better future (i.e., Singh 2018). To address performance and productivity issues, construction companies have long been oversold the benefits that disruptive technologies may offer, explaining why some organisations may be reluctant to fully embrace BIM (Love *et al.,* 2020). This study contributes by illustrating how an approach known as 'Total BIM' was implemented by a Swedish construction management (CM) company in a way that seems to create real organisational impact. The selected case illustrates when BIM is used as a contractual document and accepted as the single source of information during production, it can challenge the status quo by altering the roles, responsibilities, and relations among project participants, hence reconfigures the current business model. This resonates with the notion of 'digital disruption', which refers to a process that digital attributes and

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innovation shifts the established paradigms in a domain (Baiyere and Hukal 2020). Drawing on disruptive, innovative, and digital concepts, which are seen as the three properties of digital disruption, we aim to discuss how the 'Total BIM' approach can disrupt the traditional business models in the construction sector.

The paper is structured as follows. The theoretical background of digital disruption is reviewed with reference to both construction literature and the broader management disciplines. Consideration is then given to the Total BIM approach. This is followed by presenting the details of the empirical work. Given that the research is the initial part of a larger research project exploring the organisational level impacts of digital disruption, the paper is specifically positioned to encourage feedback and critical reflection.

Disruptive Innovation

In recent years, digital disruption has emerged as an important concept to discuss the profound changes resulting from the increasing embeddedness of digital technologies. Disruptive innovation theory can be accepted as the initial point of such discussions (Christensen 1997). The disruptive innovation theory offers an explanation why established companies failed to recognise the disruptive characteristics of new technologies while new entrants capture the market with either low-cost and low-performance offerings or creating a new market. Markides (2006) extended this by identifying product innovations and business model innovations as two specific types of disruptive innovations. Business model innovation is argued as the formation of a significantly different business model or reshaping the way that the service provided in an existing market or business by the impact of technology. For Markides (2006) 'business model innovators do not discover new products or services; they simply redefine what an existing product or service is and how it is provided to the customer'. To date, little attention has been given to understanding the disruptive impacts of digital technology adoptions on the current business models within the context of the construction sector. Ernstsen at al. (2018) notably adopted disruptive innovation theory to discuss whether the construction industry is ripe for disruption by presenting a comparison between the health sector and the construction sector. They emphasized that being the first mover in technological investment, identifying overserved customers and non-customers and focusing on value creation for the customer are identified as the path towards creating disruption. Chan (2020) also discussed how digital platforms, leading disruptive innovations in other sectors, are studied in construction specific research. He offered that CM research on platform business should shift from increasing the functionality of platforms to discuss the ways how platform business can impact the value creation in the broader eco-system of the construction sector.

The Properties of Digital Disruption - Digital, Disruptive and Innovative

More recently, 'digital disruption' is emerging as an alternative concept to explain the transformative effects of digital technologies. The common argument is that the decisive boundaries of 'disruptive innovation theory', emphasized by Christensen in several different publications, does not fit to explain the impact of digital innovations on existing business models (Skog *et al.,* 2018; Baiyere and Hukal 2020). This critique applies to difficulties to discuss the potential impacts of digital transformation in the construction sector, because disruptive impacts of digital technologies transcend the offerings of new entrants. Hence, we draw on the concept of 'digital disruption' which refers to:

> The rapidly unfolding processes through which digital innovation comes to fundamentally alter historically sustainable logics for value creation and capture by unbundling and recombining linkages among resources or generating new ones (Skog *et al.,* 2018: 432).

For Baiyere and Hukal (2020), digital disruption refers to three key properties as digital, disruptive, and innovative and when they are combined, they alter the traditional logics in a domain (Table 1). These properties are seen useful concepts to discuss how digital technologies have potential disruptive effects on the status quo in the construction sector. The intention of this paper is to discuss how the use of digital technologies impacts organisational aspects by disturbing the existing roles, relations, and processes, creating cross organisational and systematic shifts. More specifically, we aim to explain whether the Total BIM concept, as explained in the following section, can be seen as a digital disruption in the construction sector.

Table 1: Three properties of digital disruption (Baiyere and Hukal 2020)

Properties	Meaning
Disruptive property	'Profound alteration in a prior paradigm, an alteration in an existing logic'
Digital property	'Innovation should be created by unique attributes of digital technology'
Innovative property	'Introduction of something new into the domain through which digital disruption occurs'

TOTAL BIM

Despite the enormous opportunities BIM is said to offer the construction industry adoption has been slower than expected (Walasek and Barszcz 2017). These opportunities are often discussed in relation to BIM in the design stage but are limited when site work is still dominated by 2D paper drawings (Davies and Harty 2013). The process of creating and maintaining traditional construction drawings from BIM is costly, leads to errors and delays (Davies and Harty 2013). Two parallel processes exist where both BIM and 2D drawings are used. Recently in Scandinavia a new trend called ‘Total BIM’ is emerging where BIM is embraced in its totality, in reference to Stockholm's Slussen project (Cousins 2017). BIM is used in all project stages, including production. There is a single source of construction information, completely replacing 2D paper drawings. BIM is the legally binding construction document and developed to create a fully accurate representation of the project. Design focus shifts from creating drawings to technical design issues and trust is gained in the model (Cousins 2017). BIM is implemented in the production phase where site workers extract information directly from the model themselves on mobile devices. Typically, Swedish construction projects are delivered with three main information carriers, drawings, technical specifications, and quantity lists. In a Total BIM project, all information is connected to BIM as a central communication platform. There have been some previous attempts at pushing towards Total BIM type projects but are mostly infrastructure projects or faced other limitations, for example the Röfors bridge case, which faced technical limitations back in 2013 (Johansson and Roupé 2019). In this study we focus on the novel Total BIM approach by the CM company used in the complex Celsius project.

This study is focused on a small Swedish CM company that constructs an identity emphasizing a fully digital way of working. The company has been established for over 20 years but undergone an important transformation through adapting their

business model to a fully digital way of working. The transformation resulted in a change in the employee profiles, the leaving of senior members and employment of key actors with digital capabilities. The intention of the company was to move towards focusing on larger, more complex projects.

The driving force for digitalisation was emphasized as the frustration with traditional work methods and mistakes that occurred. For example, a glass façade was ordered from out-of-date drawings. This led the company to taking action to create value for their ecosystem and to innovate the industry. They want to remain a small company and continue to work in small project teams, rather than to grow. With the client, the CM company decided to implement an innovative, digital construction process in the Celsius project, focusing on production and building directly from BIM. According to the case company they have a self-developed CM production system that enables them to continuously improve. They are hired by the client to act as advisors for the whole construction process. This includes leading the design of the building, managing the bidding process for subcontractors and leading on-site construction, for which they are paid hourly according to a pre-determined budget.

METHOD

The empirical analysis described below draws from the tradition of case study research (Flyvbjerg 2004) to explore the impacts of the Total BIM approach, especially from the lens of 'digital disruption'. The empirical analysis presented in this paper is based on two semi-structured interviews with senior managers from a construction management company that apply the Total BIM approach in Celsius Project. The interviews were conducted following a systematic analysis of the company documents and earlier discussions with representatives from the company. The managers were asked to interpret the development of their organisation, digital shift in their business model and the transition process towards adopting a fully digital way of working (drivers, problems, reactions of the stakeholders, etc). The interviews were based on semi-structured questions which allowed interviewees to articulate their perspectives while at the same time enabled researchers to keep control of the discussion on the organisational impacts of the Total BIM approach. The data analysis followed an iterative process between the documents and the relevant literature. The discussion is designed in line with the concepts in the digital disruption literature.

BIM as a Digital Disruption

Drawing on the conceptual properties of digital disruption, this section presents a discussion on disruptive, innovative and digital aspects of the Total BIM approach.

Disruptive aspects

The empirical study highlights three disruptive aspects regarding the use of the Total BIM. First, the interviewees described how the decision to adopt a fully digital way of working initiated an 'organisational transformation' process in the company. The phrase repeated by both interviewees was that the people who 'did not really feel that they fit in with the new organisation, left'. This was followed by emphasizing the employment of people that had digital capabilities and led the transition towards the Total BIM approach. The driving force of embracing a fully digital way of working was linked to a 'dedicated leader' who was fed up with the inefficiencies of traditional work methods. Such emphasis on leadership resonates with the literature around 'digital champions' (Criado-Perez *et al.,* 2021).

One of the key issues emphasized in the interviews was the size of the company and the emphasis on keeping it small, with core teams working on each project. Interviewees said that each project has team members that come from both design and the construction site with active VDC participation. One of the interviewees emphasized that the transition towards a fully digital way of working is difficult in large companies because they change project teams in each project, and they do not have consistent teams that are keen to apply digitalisation. The emphasis on company size resonates with the discussion on why incumbent firms fail to adopt disruptive innovations (Christensen 1997).

The second disruptive aspect are the shifts regarding cost structures and the bidding process. The interviewees emphasized that the use of Total BIM resulted in higher design cost, but less production cost. In the words of an interviewee:

> [The client] was a little bit concerned about the increased design cost and the risk, … we had to convince [The client] saying that we will spend less in the construction itself because there will be less errors ... [the client] is big and they feel like that they need to help the industry to innovate, they need to take some initiative in doing something new!

The above quote illustrates how the CM company convinced the client to spend more on design to have less production cost. It also refers to the 'digital champions' narrative once more. The interviewees also described shifts in the procurement processes. For example, subcontractors bidding on the project were provided with quantity data, technical documents and the IFC model taken from BIM. Hence, they no longer had to extract quantities themselves. As emphasized by the interviewees, following such a process resulted in more bids with less variance between them. In addition, competition was more based on how smart they could carry out the work, rather than who measured incorrectly

FINDINGS

The third disruptive aspect is related to the roles and relationships among the stakeholders. The empirical material shows that working with a Total BIM approach calls for a shift in key actor's roles and relationships in a project, especially the roles of the design team and CM company. The below quote illustrates the communication between two sides:

> Designers were naturally against it, thinking it was madness, how would it work, the architect asked many times “do you mean that we should draw everything and draw it right?” Yes! He thought that perhaps in 2D you can cheat a little, normally where the detail isn’t solved beforehand, but you still get what you need later on. I tried to remind him that this time is behind us. It went relatively well.

Such reaction from the design team can be seen as resistance to the shift of their role and the business model that they are used to work with. They are called to have less control on design development by the active involvement of site people in the CM company. They were also faced with an expectation to produce an accurate BIM. The interviewees argued that production of an accurate BIM contradicts with developing a design project based on 2D drawings which requires several revisions during the construction phase. Another change is that subcontractors were expected to bid based on the measurements given by the CM company. This seems to disrupt subcontractors' business model and profit calculation. The shifts in roles and responsibilities of different stakeholders might seem small changes but they disrupt the current patterns and traditional logic of how construction projects are delivered.

Digital aspects

The digital aspect commonly refers to disruption / innovation being enabled or induced by some new or unique attributes of technology. In the most recent project of the case company, we see three main (digital) enablers; cloud-based model repository, user-friendly and powerful mobile BIM-viewer, as well as an efficient mobile communication platform. Although we have examples of previous (successfully realized) model-based projects, such as Slussen and the Röfors bridge, certain technologies have always been missing for a Total BIM project to reach its full potential.

Table 2: Digital disruption interview data from the case company

CM company	Disruptive	Digital	Innovative
The CM company used a fully digital construction process where BIM was the legally binding construction document and no 2D drawings were used on-site. Site workers extracted views, measurements, dimensions on demand. A novel construction process for creating value by using BIM as a single source of information and as a communication platform.	Organizational change Several employees left the company and downsizing happened in 2014. Some left due to retiring and others felt they did not fit in the new organization. Disruption occurred due to a shift towards digitalization and larger projects. New employees were hired to work with digital processes. Redistribution of costs Design costs increased by 18% due to the new approach, but production costs decreased compared with a similar project. The project was delivered under budget and within time. Costs structures in projects were altered that may affect typical stakeholders. The high-quality design reduces errors found in the production phase, also shifting earning potential away from late changes. Bidding process Subcontractors bidding on the project were provided with quantity data, technical document and the model. They no longer had to extract quantities themselves. Resulting in more bids that with less variance between them. Competition was more based on how smart they could carry out the work, rather than who measured incorrectly. Business model and roles Stakeholders are affected by new roles and business models. Architects are challenged with new demands and requirements. The subcontractor's bidding process is simplified, and they use new work methods on-site. Clients are faced with new cost structures.	Cloud-based BIM A single source of up-to-date construction information where designers and site workers could access the model. Information was accessed digitally on-site. Wi-Fi A dedicated Wi-Fi network was established at the construction site to ensure broad and reliable connectivity. Mobile BIM viewer software BIM was accessible on mobile devices on-site on software featuring digitalized communication tools e.g., case management and checklists. Construction information was linked to objects and filtered based on the subcontractor's discipline. Communication platform Traditional documentation and communication methods were replaced with StreamBIM's inbuilt digital platform. Surveyed workers graded the project highly for communication compared with other projects in Sweden.	Construction document BIM was the legally binding digital construction document. Designers worked to create a high-quality, accurate model, which site-workers were required to use. BIM completely replaced traditional 2D drawings. Accurate BIM All parts of the building had to be included and accurately designed in BIM. Requiring architects and designers to adopt new work methods and quality controls, to maintain an unbroken information chain and information sustainability. BIM in production No 2D drawings were used on-site. Contractors and sub-contractors had to adapt to working with a new medium and were excluded from the project if they refused. Support and training were provided for site workers to create and extract construction information they needed to carry out work themselves.

Supervisors and construction workers found it difficult to extract information and dimensions directly from the model, and the design team therefore had to put extra resources on producing additional, static, 3D-views with annotations. In contrast, the use of the StreamBIM mobile application on-site in the Celsius project essentially enabled the construction workers to extract all the information they needed directly from the BIM. With a novel and user-friendly interface - that had not been available before - even rather complex tasks, such as measuring, and dimensioning could easily be performed by the construction workers themselves. In a similar way, cloud-based model repositories and work-sharing environments have significantly matured in recent years, especially if all design disciplines work within the same software suite (e.g., Revit). What used to be a simple file-based storage and version control system can now support simultaneous model editing (i.e., work-sharing) and automated model processing tasks. With almost all design work performed in Revit, the Celsius project could take advantage of these features and enable a "live" design environment with instant work-sharing in BIM 360 Design. An exception was Tekla Structures for the prefabricated concrete elements where design collaboration was performed through IFC-files synced with a desktop connector.

Not only did the BIM 360 design environment allow the design team to have a 'single source of truth', but they could also take advantage of automated nightly IFC-export jobs that were then pushed to the StreamBIM mobile platform for use on the construction site. As already explained, the StreamBIM mobile BIM-viewer was

primarily chosen for the construction workers to be able to easily retrieve and consume the information and build directly from the model. However, during the project, the team started using more and more of the functionality in StreamBIM, such as issue reports, check lists, inspection documentation, and as-built documentation, that it eventually became the natural path of communication within and between the design and construction teams. That is, although not initially planned for, the attributes and functionality of the technology almost induced the use of it as a communication platform, or as expressed by an interviewee:

> We thought at the beginning of the project that we wouldn't be able to get as much information into StreamBIM as we eventually did. We had all cases, relationships, decisions, controls, requests in StreamBIM. Everything got a lot better, just with having all the information there in one place and being directly available to the right people. We tried to connect all information to the model, and it became a communication platform. which offered us so much more than just building without traditional drawings.

Furthermore, with so much of the communication handled electronically and all the construction documents (i.e., models) managed and stored in the cloud, a fast and secure network becomes much more important than for a 'normal' construction project. In fact, as used in the Celsius project, 5G and Wi-Fi can almost be seen as important technological enablers for a Total BIM project.

Innovative aspects

The innovative aspect is considered as the answer of what is new to whom in a digital disruption process (Baiyere and Hukal 2020) One innovative aspect of the case is the decision to use 'BIM as the legally binding document'. This disrupts the way actors communicate and take roles in the project process. Designers are expected to create a high-quality, accurate model, and workers are required to use BIM to do their daily tasks. This requires developing digital capabilities for the actors, especially the ones on-site. As described by one of the interviewees:

> It was more of a change for people working in production, our site managers and supervisor working on the field really like to take notes and do a lot of analogue note taking and communicate with the drawings. They have now also been incorporated with this way of working and there's no going back for them. We've managed to implement these digital tools that help them do their daily work in a better way.

The interviewees also emphasized the requirement for an unbroken information chain and data flow to use BIM as the legally binding document. This shows how three aspects of digital disruption are interwoven.

Another innovation is the mandate to work on an accurate BIM throughout the project. That requires designing all parts of the building accurately, which forces architects and designers to adapt new work methods and quality controls. For the interviewees, this also requires active involvement of site personnel during design development. One of interviewees says:

> We wanted to emphasize that we were doing something different. We were not going to rely on drawings. Such as "oh screw this 3D BIM, we go back to drawings." We didn't want to have that mentality. No! It's the model that's the legal construction document and you should do as much as possible in that, so skip all the 2D and only focus on that. To really focus the design teams to understand that this was serious. Then we could go forward. We had all the tough discussions early with the designers that this is what we want to do, that we deliver the 3D model as the binding construction contract document. Then they can't cheat on creating the models because the models really need to be good.

The above quote illustrates how targeting an accurate BIM disrupts the logic of working through design changes and earning from claim management. Having an accurate BIM is also seen as a key step towards achieving digital twins.

Lastly, the interviewees emphasise that the 'no 2D drawings' decision was the key to achieve production based on a model. They say that if 2D drawings are produced, they become the main communication channel and BIM becomes a secondary document, used mostly to represent 3D views and clash detection. With the 'no 2D drawing' principle, contractors and subcontractors had to adapt to working with a new medium because they were excluded from the project if they refused. This shows how the Total BIM approach brings innovation to the traditional way of working based on 2D drawings. It is important to note that the CM company provided support and training to site workers to create and extract construction information they needed to carry out work themselves.

CONCLUSIONS

This paper positions Total BIM as a digital disruption to the traditional way of working in construction projects. The empirical study has demonstrated how the use of BIM as the contractual document, not allowing 2D drawings and developing an on-site communication platform for use within and between design and construction teams, challenges the traditional business model. Drawing on the three properties of the digital disruption concept, the case study illustrated details regarding disruptive, digital and innovative aspects of the Total BIM concept.

Our case analysis highlighted the disruptive aspects regarding the use of the Total BIM approach. The empirical data describes a substantial organisational change when the company decided to pursue a fully digital way of working. More importantly, adopting this approach emerged as a key strategy pushed through by the company leader and supported by the hiring of employees with digital capabilities. Another radical shift was regarding the bidding process and the redistribution of costs. Costs for the design process increase but are lower the during construction phase and the bidding process is simplified for subcontractors. It is also seen that the traditional business model and the roles assigned to different stakeholders were challenged, for example expectations increased on design teams to produce an accurate model and collaborate with site professionals with production knowledge.

Digital technology is a key enabler for a successful Total BIM approach. Previous advanced BIM projects have been limited by, user-friendliness of software, accessibility, multiple sources of information, as well as software and hardware capabilities. In this context the CM company recognized BIM as a potential platform for a single source of information on the construction site. During the project they also recognized StreamBIM as an enabler of communication between designers and construction workers, which became the communication platform for the project. This was made possible by using cloud-based BIM and installing Wi-Fi across the construction site, granting users easy access to the most up to date construction information. By combining digital technology uses in a successful way it enabled the CM company to embrace BIM to its totality - Total BIM.

The empirical data also indicated some key innovations which was leading disruptions in the described case. One important innovation is the use of BIM model as the contractual document. This appears to create a disruptive impact on the current procurement methods and the roles ascribed to traditional stakeholders such as

architects, contractors, etc. This opens a space for further discussion on the potential impact of BIM regarding traditional procurement methods, especially towards new business models. Another innovation was targeting an accurate BIM model, which enabled expanding the active use of BIM throughout the entire project, including design and production. Also having BIM as the common data source for all parties might be seen as a means to further improve collaboration among different stakeholders throughout the whole project. Lastly, excluding 2D drawings seems to be a key innovation, especially considering the role of 2D drawings as the common language throughout the history of construction projects.

While the findings here are based on the case of a Swedish construction management company and their project, Celsius, the study aims to contribute to construction management literature in two ways. First, it extends BIM research by conceptualizing it as a digital disruption. Second, it extends the methodological debate by mobilizing the three properties of digital disruption to guide an empirical analysis.

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