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Circumventing obstacles in digital construction design - a workaround theory perspective

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Abstract

Building Information Modeling (BIM) has proven its value for design in the architecture, engineering, and construction industry. However, currently only a few leading firms succeed in reaping the full potential of BIM. Especially, specialist designers remain excluded from innovative practices. Reasons include the technical hurdles of BIM adoption and a misfit between human agency versus the affordances of BIM. Not all designers have the capabilities required to actively partake in BIM. Thus, BIM practice is often 'messy' and characterized by a large degree of unnecessary rework and workarounds. "How and why digital workarounds unfold in BIM design?" is at the core of the inquiry reported in this paper. Based on a 'fresh' theoretical approach entitled Theory of Workarounds, we explicate the nature of BIM related workarounds. The industrial setting involves an office refurbishment project in Oslo, Norway. Many specialist designers remained excluded from BIM in this project and a range of different workarounds have been conducted. We portray how and why digital workarounds happened. This provides valuable learning for researchers and practitioners interested in digital workarounds in construction. We contribute to better understanding of messy practices surrounding BIM and to drawing the attention of scholars to workarounds as an area in need of further research. Lastly, our work constitutes an early application of Alter's Theory of Workarounds in the setting of a construction project.

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Keywords: Building Information Modeling; case study; digital construction design; workarounds

1. Introduction

Completing today's large and complex construction projects at the necessary speed could not be done without advanced Information Technology. Especially, Building Information Modeling (BIM) systems have proven their value

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for construction design (McGraw-Hill, 2012). However, research to date has documented how many project teams struggle with how to work based on this new technology (Merschbrock, 2012; Merschbrock & Munkvold, 2012). Statistics show that all construction information needs to be re-created and/or reentered four to eight times throughout the life cycle of a project (Davis, 2007). Using BIM for integration and collaborative design remains challenging (Dossick and Neff, 2013). So far, only few, highly IT literate, and leading construction corporations enjoy the benefits of BIM technology, whereas those working in the periphery of the digital innovation networks (e.g. geo-technical, fire-protection, acoustics engineers, contractors, suppliers) are frequently excluded from the innovative practices (Leeuwis et al., 2013; Yoo, 2010). Features of the architecture, engineering, and construction (AEC) industry negatively influencing BIM deployment include its fragmented nature, the slow development of common data-exchange practices, and the lack of knowledge about the possibilities of information and communication technology (Dubois & Gadde, 2002; Howard & Björk, 2008; Linderoth et al., 2011). Thus, the current BIM design practice is 'messy' and characterized by redundant and unnecessary rework and workarounds (Dossick & Neff, 2011).

Workarounds can be defined as steps taken by practitioners faced with inadequate resources (Dalton, 2013). Researchers studying the enactment of integrated information technology (e.g. enterprise resource planning ERP) report that users respond in with inertia and reinvention in situations where technology is perceived as constraining. Users avoided system use as much as possible (inertia) or they worked around the systems constraints in unintended ways (reinvention). Reinventions are "unintended uses of technology where users compensate for their limited knowledge of the system and perceived technology deficiencies by developing tweaks and workarounds" (Boudreau & Robey, 2005 p.9). Using integrated technology requires a high degree of coordination especially when users are interdependent in their work tasks (Alter, 2014; Merschbrock & Wahid, 2013). Overcoming obstacles emerging in technology and task coordination requires users to resort to workarounds (Merschbrock & Wahid, 2013). Another source for workarounds are so-called technology misfits, situations where the new technology simply does not fit the realities of day-to-day work (ibid.).

BIM systems are intended to serve as a design space where multiple actors engage in collaborative design work. Thus, BIM systems fall within the category of integrated systems as they are designed for facilitating business transactions across organizations. Consequently BIM users are confronted with some of the same challenges users of other integrated technologies experience. For instance, many institutionalized ways of working in the construction industry need to be disrupted for making BIM work, hinting a technology misfit between BIM and established day-to-day work (Dossick & Neff, 2013). Thus, it is not surprising that researchers find BIM work to be characterized by poor communication and workarounds (Love & Li, 2000).

A review of workaround literature suggests that workarounds in organizations are both understudied and conceptualized (Alter, 2014). The author addressed this shortage by suggesting a theoretical framework called "theory of workarounds" derived from extant literature. Theory of workarounds draws from loose coupling theory in that it conceptualized workarounds along five voices (Orton & Weick, 1990). Moreover, the theory is a process theory useful for "classifying workarounds, analysing how they occur, for understanding compliance and noncompliance to methods and management mandates, for incorporating consideration of possible workarounds" (Alter, 2014 p.1041). In this paper, we put this 'fresh' theory to an initial test by exploring how well it serves for explaining workarounds happening in digital construction design based on BIM. The intention of applying workaround theory to the context of construction design is to add to the understanding of why many project teams struggle when working based on BIM. Thus, we ask the following research question:

How can workarounds happening in digital construction design based on BIM be explained?

In order to address the research question, we conducted a case study of digital construction design in an office refurbishment project in Oslo, Norway. We focused on the digital design work and present examples of workarounds conducted to circumvent challenges related to BIM. The case project is Norway's first 'green' refurbishment project to be awarded a 'BREEAM-NOR©' Outstanding score, making it a national role model for successful sustainable design. This complex project where BIM had been prioritized in design was considered a good fit for our study. Studying workarounds in the context of digital design is important for pinpointing what triggers workarounds.

2. Theoretical lens

Digital work in construction projects is a well-researched area with researchers drawing from a wide theoretical base. Theories applied in this stream of research include diffusion theory (Peansupap & Walker, 2006), technology acceptance model (Adriaanse et al. 2010), actor network theory (Linderoth, 2010), boundary objects (Gal et al., 2008), or configuration analysis (Merschbrock, 2012). What the aforementioned theories have in common is that they focus the integration, diffusion, acceptance, configuration and use of technology such as BIM. This research resembles by and large what has been suggested by agency theory in that it is concerned with how alignments can be built for maximizing an agent's conformance with a principal's goals (Alter, 2014). However, it has been argued that current research should be complemented by 'fresh' theoretical approaches exploring the messy and emerging practices surrounding digital work in construction projects (Whyte, 2011). Workaround theory "turns agency theory on its head" (Alter, 2014 p.1043) in that it suggests that agents decide with behavioural discretion whether to follow established practices. The theory provides the means for exploring emerging practices when anomalies, obstacles, and mishaps occur in digital design (Alter, 2014). This is why we argue that utilizing workaround theory in the context of BIM use in construction projects could complement the existing body of knowledge in this area.

Alter (2014) defines workarounds in the following way: "A workaround is a goal-driven adaptation, improvisation, or other change to one or more aspects of an existing work system in order to overcome, bypass or minimise the impact of obstacles, exceptions, anomalies, mishaps, established practices, management expectations or structural constraints that are perceived as preventing that work system or its participants from achieving a desired level of efficiency, effectiveness or organizational or personal goals." (p. 1044). A work system is a "system in which human participants and/or machines perform processes and activities using information, technology, and other resources to produce products/ services for internal/external customers" (Alter, 2013 p.26). Workarounds affect how a work system functions; they can be temporary or over an extended period (Alter 2014). Theoretically ingrained in the five voices of Orton and Weick's (1990) loose coupling theory (causation, typology, direct effects, compensations, and outcomes) and a structured review of the wider workaround literature, a process theory capturing workarounds is suggested. Alter (2014) identified his own 'voices' of workarounds namely: phenomena associated with workarounds, types of workarounds, direct effects of workarounds, perspectives on workarounds, and organizational challenges and dilemmas related to workarounds (see Fig. 1).

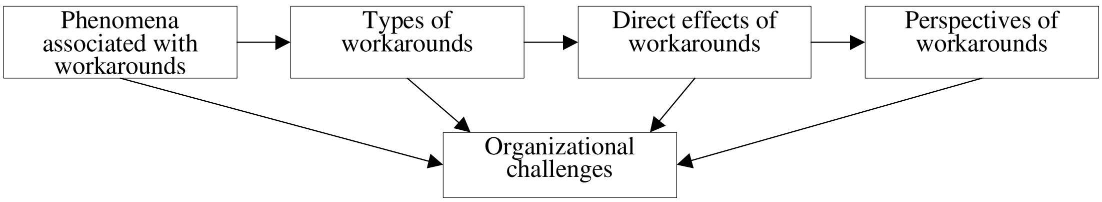

Fig. 1. The five voices of workarounds (adopted Alter, 2014).

Based on the aforementioned voices, Alter (2014) suggests the following seven steps based on which workarounds can be analysed and understood: (1) intentions, goals, interests of each work participant; (2) structure, architecture and characteristics of the work system; (3) perceived need for workaround; (4) identification of workaround by consideration of all knowledge available; (5) selection of workaround; (6) development and execution of the workaround; (7) local and broader consequences including advantages and disadvantages of the workaround.

3. Method

Identifying workarounds in digital construction design was done based on a case study approach. A case study was deemed appropriate since it allows for exploring "sticky, practice based problems where the experiences of the actors are important and the context of the action is critical" (Benbasat et al., 1987 p.370). Moreover, a case study allows for understanding the process whereby the information system influences and is influenced by the context (Walsham, 1993). We conducted a case study in the so-called 'Powerhouse Kjørbo' office refurbishment project at the outskirts of Oslo. The office building complex was first built in the nineteen eighties and covers a gross floor area of 5.200 square meters. After the ‘green’ refurbishment in 2013-2014, it features photovoltaic rooftop installations, usage of recycled materials, a super-insulated air-tight building envelope, energy efficient windows and ventilation, thermal mass, geothermal heating/cooling and letting in the maximum amount of daylight. This project in which BIM was prioritised as design technology makes a compelling context for our study.

Our data was collected through the semi-structured interviews with the eleven design professionals, aiming to gain an understanding of the phenomenon by asking those experiencing it. Using interviews as means for data collection served as a way to access the interpretations of informants in the field (Walsham, 2006). The target was to interview BIM knowledgeable key actors in the design team with the intention to identify workaround situations that had occurred in the project. Moreover, all the interviewees were part of the same higher level work system, which is why even though not all designers conducted the workarounds themselves, they influenced or were influenced by the workarounds taking place in the system. The interviews were conducted in September 2014, at a point in time when the design and construction had just been finalised. Table 1 provides an overview of the interviews conducted. Nine interviews took place at the designers’ offices, one at HiOA’s Oslo campus and one was conducted via Skype. The interview guides where designed based on the theoretical lens, namely the theory of workarounds, applied in our study. The informed consent was sought in advance of all the conducted interviews. Moreover, all the interviews were voice recorded, transcribed, and coded by using the qualitative data analysis software NVivo9. The categories were derived from the data by assigning the nodes to the notions which could be related to the steps of the theory of workarounds as presented by Alter (2014).

Table 1. Interviews conducted

Affiliation	Services provided to the project	Interview technique	Interview duration
Client #1	Project manager	Face-to-face	60 min
Client #2	Project manager	Face-to-face	75 min
Architect #1	Lead architect	Face-to-face	75 min
Engineering consultant #1	Heating, ventilation, and air conditioning	Face-to-face	60 min
Engineering consultant #2	Heating, ventilation, and air conditioning	Face-to-face	60 min
Engineering consultant #3	Fire-protection design	Face-to-face	65 min
Engineering consultant #4	Acoustical design	Face-to-face	75 min
Contractor #1	Project manager	Face-to-face	75 min
Contractor #2	Green business officer	Face-to-face	60 min
Contractor #3	BIM coordinator	Face-to-face	60 min
Subcontractor #1	Photovoltaic installations	Skype	60 min

4. Analysis

The analysis part of the paper is structured as follows. First, the workarounds occurring in the case project are identified guided by the steps of the workaround theory. The three most poignant examples are presented here as the vignettes from practice. Second, these are then classified according to the five voices of the workarounds as suggested by Alter (2014). The three selected workarounds took place in the acoustical design, the rooftop photovoltaic installations and the fire-protection design. They were chosen to put the workarounds theory to an initial test in the context of a construction project.

4.1. Vignette from practice: Workaround in acoustic design

The acoustical design work in the Powerhouse was performed by an electrical engineer specialised in audio technology having three years’ of work-experience as a specialist consultant. The intention of the acoustician was to collaborate with the architects to find design solutions fulfilling acoustical as well as the aesthetical and technical standards. The agreed work specifications were to deliver a concept for room acoustics. Complicating matters for acoustic design were open office solutions in conjunction with large areas of exposed thermal mass. Thus, the acoustician was to compensate for the relatively long reverberation times caused by exposed concrete. Consequently, for these issues to be resolved, a close collaboration among architects and acoustician was deemed necessary.

The specifications thus required bilateral design collaboration between architects and acoustician. First, the architect needed to share architectural design visualizations to provide the canvas in which the acoustical calculations could be performed. Or, as engineering consultant #4 put it: "For this project involving several unique design solutions, such as the vertical absorbers in the open spaces, it was necessary for me to have an accurate model [delivered by the architect]." Despite receiving the architectural data in good order, a workaround occurred in the design exchange prefacing the acoustical calculations. Not using an existing system for room acoustics fitted for BIM model import can be considered a workaround.

The perceived need for the workaround was as follows. While the designer was aware of and eager to utilize a more appropriate design system for room acoustics his superiors did not share his enthusiasm. This is echoed by the rejection of an application in which the acoustician asked corporate management for the purchase of an advanced room acoustics system (ODEON®) which could be run based on BIM models. However, corporate management remained sceptical as to whether the prospective benefits of the new technology would outweigh its costs and rejected the application, thus creating a need for workarounds. Despite this setback the acoustic designer remained optimistic and expected a new system to be in place by the end of the upcoming year.

The workaround procedure was as follows: first the acoustical engineer received an architectural 3D model created in Autodesk®Revit; then this model was imported into a program called EASE™ made for the assessment of venue acoustics and sound system performance but not for room sound simulation. Last the acoustician performed a manual calculation of the room acoustics as opposed to using advanced simulation technology. The acoustical engineer identified the possible workaround based on prior experience from a job in venue acoustics. The following quote illustrates how the workaround procedure was identified: "So, EASE is a program more or less used [in venue acoustics], I used it in my former job, to see how speakers will cover areas with sound […] it is not much used for room acoustics but I used it mainly to get the areas right and to see how things would look in a model" (engineering consultant #4).

The consequences of the workaround are that acoustical calculations had to be done manually. Having a system such as Odeon in place would have eased the calculation work: "Of course Odeon is better for those who maybe do not have the knowledge to calculate stuff without software doing it for you. If you know how to do the calculation yourself or how sound moves in space, then maybe you don't need to do those calculations, you know how it would be" (engineering consultant #4). Further, the acoustic design work could have been more precise: "[such software] are ray tracing programs […] they do work very good to compute the acoustics in a room." However, the acoustics designer stated that the extra precision would not have significantly improved the overall design: "maybe we could improve the reverberation time by decimals, but sound is not heard in decimals." One consequence of conducting the workarounds is, however, that management have begun to recognize the importance of new IT: "It's slowly starting to sink in that we need more tools." A negative consequence of calculating the room acoustics manually as opposed to using software was that there was no straightforward way to merge the architectural and acoustic design based on BIM. Instead, the acoustician resorted to developing a set of generic design principles rather than pinpointing particular and concrete design solutions.

4.2. Vignette from practice: workaround in photovoltaic rooftop installations

The rooftop photovoltaic elements and the solar-thermal systems for the building were designed and build by a specialist sub-contractor firm. The agreed specifications included the firm to explore where to best place the rooftop systems to maximize their efficiency. The positioning of the systems required compiling knowledge and data about the building itself, the surrounding landscape, as well as the sun's predictable movements through the seasons.

Having access to an architectural BIM model would have provided the sub-contractor with the necessary information about the buildings orientation and layout. However, photovoltaic systems have considerable lead times since they need to be manufactured to order and thus need to be commissioned early on in a project. Thus, at the point in time when the photovoltaics were designed no architectural BIM model was yet available. This created the need for a workaround circumventing the absence of architectural design data. The selected workaround procedure was to create a ‘pseudo’ architectural design model derived from a few early stage architectural drawings and sketches. The sub-contractor created a building model from scratch by using a simple modelling tool called SketchUp®. This formed a base for quantifying the installation areas of the building such as rooftops and facades. The following quote illustrates this: “The BIM model arrived very late, and many simulation programs have an interface fitted for SketchUp® data import, in cases like this [when we do not have architectural data] we quickly generate a model from SketchUp” (subcontractor #1).

Not only was this ‘preliminary’ model used to survey quantities, but it was also utilized to compute the interplay between the building’s two main heating sources, namely solar- and geothermal. Thus the SketchUp® model was successively imported into a building simulation model called TRNSYS®, a graphical software environment used to simulate the behaviour of transient systems. This provided the means for dimensioning the photovoltaic rooftop installations. When solar energy data related to the architectural model became available the photovoltaic and solar-thermal system design had been finalized and commissioned: “At some point in the process we learned that there was some sort of BIM model but at that stage we were already far advanced in our design process” (subcontractor #1).

Another workaround occurred when assessing data about the landscape surrounding the building. There existed a digital terrain model of the landscape created by using laser scanner data early on in the project, as the following quote confirms: “[…] we scanned the outside area and the buildings. I modelled the trees and the landscaping area around the house” (contractor #3). However, its existence was unknown to the subcontractor.

Thus there was a perceived need for conducting a second workaround: “When making all the energy simulations for the photovoltaic we neither knew the height of the trees in the area nor how far they were away from the façade. We just roughly estimated the situation.” From this it follows that the features of the surrounding landscape were assessed based on an ‘educated’ guess rather than available survey data. The following quote supports this: “This is very simple, when you work in the photovoltaic industry, then you go on top of a roof and you know how high the sun stands in this time of the year and then you use simple geometry to tell, ok that tree is 16m high and about 15-16m away from the façade” (subcontractor #1).

There is little evidence whether the workarounds compromised the quality and efficiency of the delivered products. However, the following quote hints that this may have been the case: “all the different ideas we exchanged with the architect were always 2D and I sometimes wished for a better kind of collaboration” (subcontractor #1).

4.3. Vignette from practice: workaround in fire protection design

The specifications of a fire-protection engineer encompass designing safeguards that aid in preventing, controlling, and mitigating the effects of fires on a building. To accomplish this, the fire-protection engineer produced a generic set of design principles and premises. Moreover, the work included providing assessments of design solutions and materials with regards to their fire-protection performance. However, the fire protection engineer possessed neither BIM nor simulation software capabilities as the following quote illustrates: “[doing BIM] would require us to have the knowledge to handle a model” (engineering consultant #3). Thus, the preferred modus operandi for this engineer was to provide assessments based on 2D drawings. Leaving traditional 2D based work routines intact while other designers operated based on BIM yielded challenges. The following quote illustrates that the engineer was left out: “BIM? I did not take part in that […] we have not been in any contact with BIM design” (engineering consultant #3). Continuing to use 2D CAD excluded the fire-protection engineer from BIM based design work. The circumventing of this problem in order to allow the fire-engineer to do her job required workarounds.

Any BIM modelling data had to be converted into 2D drawings before it could be handed over to the fire-protection engineer. This required creating 2D drawing sets in addition to BIM. Moreover, since modern fire-protection design requires running 3D simulations on the evolution and distribution of smoke, fire gases and temperature profiles the engineer needed assistance by a skilled BIM modeler. Thus, one of the project’s ventilation designers ran the smoke and fire simulations based on a BIM model. Nonetheless, most calculations were accomplished by hand by the fire-protection engineer and communicated back to the architect based on a printed report. The workarounds allowed the fire-protection designer a continuation of her work despite obstacles. However, the fire-protection engineer admitted that a participation in BIM may have allowed for a more active controlling of whether or not the fire-protection design principles had been followed by the design team.

4.4. Classification based on the five voices

An overview of the identified workaround phenomena, the types of workarounds, their direct effects, and perspectives can be found in Fig. 2. It became possible to identify the 'phenomena' triggering each workaround. The acoustic designer performed a workaround that could be traced back to organizational IT-policy with top-management restricting him from using a more appropriate system for room acoustics in the context of BIM use. The workaround in photovoltaic design resulted from the need to commission photovoltaic elements, having long lead and manufacturing times, at a very early stage in the project. Moreover, the third workaround resulted from a designer wanting to leave 2D based routines intact.

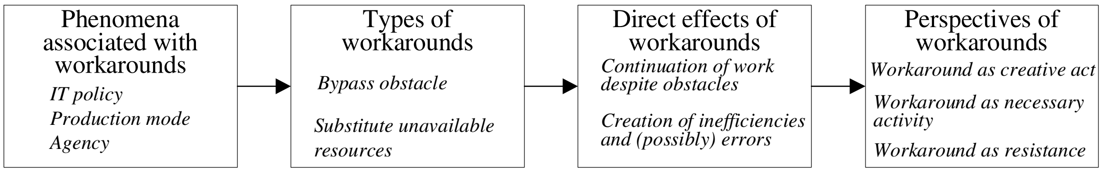

Fig. 2. The nature of the identified workarounds (adopted from Alter, 2014).

Thus, BIM was perceived as a hurdle for achieving desired organizational goals. This resembles an agency issue similar to what has been suggested by Eisenhardt (1989).

The workarounds observed can be classified into two types. Whereas the acoustician and the fire-protection designers conducted their workarounds to bypass obstacles, the photovoltaics sub-contractor substituted an unavailable resource. The direct effects of the workarounds were similar in all three cases; all designers could continue their work despite the obstacles. However, there is evidence hinting that all workarounds negatively influenced the quality of the produced design. The perspectives on workarounds differ. The acoustics workarounds can arguably be seen as a creative act since the engineer created a new way of working using knowledge and ingenuity. The photovoltaics workaround can be seen as a mere necessary activity since missing resources needed replacement. The fire protection workaround resembles a way to resist new practices. The fifth voice of workarounds namely: "organizational challenges and dilemmas" combines all aforementioned constructs (Fig. 1). The organizational dilemma for the overall construction project can be seen in that workarounds were necessary and just to keep the project going, but at the same time built quality may have been compromised.

5. Discussion

Workarounds and 'messy practices' in digital construction design are frequently observed by construction informatics and management scholars. Researchers have identified them in information exchange (Venugopal et al., 2012); in collaboration (Dossick & Neff, 2013); and in building simulation (Bazjanac, 2008). However, so far construction informatics lacked a unified, structured approach for studying and analysing digital workarounds. The initial findings of applying workaround theory to study digital construction design are promising. Analysing three 'vignettes' from practice based on this 'fresh' theoretical approach illustrated the potential that lies within further deploying the theory in the context of BIM use. The three examples illustrate that workarounds in construction design can be triggered by various phenomena including production, organization, and people related issues. Moreover, one unanticipated finding was that none of the workarounds occurred due to technical interoperability issues which are a widely debated topic area in BIM research (Merschbrock & Munkvold, 2012). However, it was beyond the scope of this study to provide an exhaustive account on the phenomena triggering workarounds in construction design. It would be an interesting avenue for further research to explore more workarounds in different settings and construction projects with the purpose of identifying their reasons. Exploring the extent to which individual and accumulated workarounds influence a building's quality is another area in need of further research. In addition, all three workarounds required some measure of ingenuity and improvisation, and designers found ways to circumvent problems in digital design. Understanding and documenting workarounds could serve as a source for inspiration for practitioners experiencing similar obstacles in their daily work. Last, we argue that studying workarounds is necessary to better understand the root causes for why BIM fails in many of today's projects.

6. Conclusion

This article has provided initial understanding of the usefulness of the workaround theory as a 'fresh' theoretical lens for making sense of the messy practices surrounding BIM. Our study extends the existing work in this area by showcasing how phenomena, types, direct effects and perspectives associated with workarounds in construction design can be assessed in a more structured way. The research question "How can workarounds happening in digital construction design be explained?" was answered by exploring the three workarounds that occurred in a construction project based on Alter's (2014) theory of workarounds. The initial data showed that a broad range of phenomena including production, organization and people related issues could all trigger workarounds. Moreover, practitioners displayed ingenuity when circumventing obstacles hindering their work. Further research is needed to provide a more exhaustive view on phenomena associated with digital workarounds in construction design. Moreover, scholars should inquire how knowledge about workarounds can be transferred to other projects where practitioners experience similar problems. What became apparent via our study is that while workarounds are often necessary to keep a project going they may negatively impact quality in construction design. Thus, the findings of the paper could be utilised to improve management in construction projects.

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