Creative Construction Conference 2016

Acceptance of Construction Scheduling Visualizations: Bar-charts, Flowline-charts, or Perhaps BIM?

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Abstract

Four-dimensional Building Information Modelling is widely viewed as the next evolutionary step in construction scheduling. Linking scheduling information to parametric object models is believed to assist a more intuitive understanding of what is to be built when. We explore how 4D BIM, as a new method of visualization, compares to other pre-existing forms of visualization like bar- and flowline- charts. Based on a series of individual and focus group interviews, this paper reports construction professionals' perceptions of the utility of the different visualization methods. Simultaneously exposed to three types of scheduling of the same building, construction professionals evaluated their ease of use and usefulness. This was done based on the Technology Acceptance Model, which explains how individuals develop an intention to use technology. Based on this work we found the three scheduling methods having strengths and weaknesses. Gantt provides the simplicity and responsiveness required for the day-to-day communication in projects, and was perceived as the easiest to use. Flowline was perceived as less intuitive; however, some argued that it provides a better overview when many different work activities need to be run concurrently. 4D BIM has the clarity required for conveying the bigger picture, yet was perceived as most useful for early project stages. Our contribution to the body of literature is that we compare the technology acceptance of new and existing scheduling methods in order to unearth their complementary roles. This work is important for managers deciding on a combination of planning tools, enabling them to better run their projects.

Keywords: 4D BIM, Flowline chart, Ganttt chart, construction management, Technology Acceptance Model.

1. Introduction

The Nordic countries are among the global leaders in Building Information Modelling (BIM) adoption and implementation [1]. Norway's governmental construction clients have mandated BIM use in their projects since 2007 [1]. Thus, most large construction firms in Norway have experience from working based on BIM. Initially one might expect that Norwegian construction professionals would readily apply BIM technology to support management tasks in their projects. However, it appears that even in the countries most advanced BIM project, schedules linking time with solid object modelling are not yet actively used [2]. In fact, the wide availability of BIM models did not significantly change the way in which project schedules are prepared. Classical Gantt, Critical Path (CPM), and flow-line charts continue to be the preferred tools for construction managers. The struggle project managers have with evaluating how 3D/4D technology can be efficiently applied in projects has been reported in literature [3]. Nonetheless, 4D BIM is widely viewed as an important technique for eliminating waste and increasing value for the customer in construction projects. Is the Norwegian construction industry, by not using 4D BIM, missing out on some of the advantages BIM technology has to offer [4, 5]. Alternatively, are there good reasons for practitioners to continue using the classical schedule visualizations in their day-to-day work? Are the scheduling methods complementary and used for planning different aspects of a construction project? These questions motivated the article presented here.

Considering that moving towards using 4D BIM is a 'technochange' influencing organizational work at several dimensions, then it may simply not be easy to use 4D BIM [6]. The term 'technochange' refers to situations where deploying new technology significantly affects organizational life. This is the case for the application of 4D BIM since it is influenced by and influences the features of the industry, projects, and people involved [7]. A risk involved in technochange is that people simply will not use the new technology and related processes. Scholars' report that especially 'off-the-shelf' software, developed by technical teams not familiar with the characteristics of the organizational context, is likely to be resisted [6].

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Whether individuals accept or resist using a new technology depends on whether they perceive it to be beneficial or detrimental for doing their jobs. It is important that there exists a perceived relative advantage of using a new technology over the current solution it replaces [8].

In this article, we focus construction teams' technology acceptance of 4D BIM when compared to Gantt and Flowline [9]. More specifically, we focus on the extent to which a construction team working in a Norwegian project, where different schedule tools were applied, accepted the technology. We contribute thereby to the discussion of whether and how users find Gantt, Flowline and 4D BIM technology useful and easy to use for doing their jobs. This work is important because using IT-technology on construction sites is virtually impossible without users accepting the new technology [10]. Many organizations remain skeptical about changing established work practices in response to new information systems [11]. Our research question is: *How useful and easy to use are different schedule visualization methods for construction site teams?*

To answer the research question we conducted a case study in an ongoing joint apartment and office project in Oslo where Gantt, Flowline and 4D BIM were used to schedule the works. A series of semi-structured interviews with individual construction managers, construction workers, and site engineers has been conducted to gain an understanding of how the technology has been accepted by the people using it. The theoretical approach supporting the analysis in this article is the so-called Technology Acceptance Model (TAM) [12]. The intended contribution of this article is twofold: First, we argue that research taking a TAM perspective to understand construction teams' acceptance of 4D BIM adds to the understanding of the potential that lies within its deployment. Second, construction managements' awareness that construction crews may or may not accept an on-site use of Gantt, Flowline and/or 4D BIM in specific situations can be increased by this study. The article is structured as follows: first, the Technology Acceptance Model (TAM) guiding our analysis is introduced. Second, the "joint apartment and office" project case is introduced. Third, the findings of the case study are presented based on TAM. Fourth, the discussion of the technology acceptance is presented. Last, we present the conclusions of our work and answer the research question.

2. Theoretical lens

There exists a broad spectrum of theoretical models explaining technology adoption and acceptance (e.g. Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology, Actor Network Theory, and Diffusion of Innovations). These theories also inform construction informatics and management research [13] (Merschbrock and Munkvold, 2012). The technology acceptance model (TAM) has informed research on the user acceptance of building management systems as well as research on individual beliefs about the outcomes of BIM use [14, 15]. A graphical depiction of TAM can be found in figure 1. The model depicted in figure 1 builds on the original TAM model introduced by Davis [9]. and the theoretical extensions (e.g. TAM2) suggested by Venkatesh and Davis [16]. Diverging from the original TAM and TAM2 models, the construct names 'intention to use' and 'usage behavior' have been rep laced with 'behavioral intention to use' and 'actual system use' respectively. This has been done in accordance with what has been proposed by Venkatesh et al.[17].

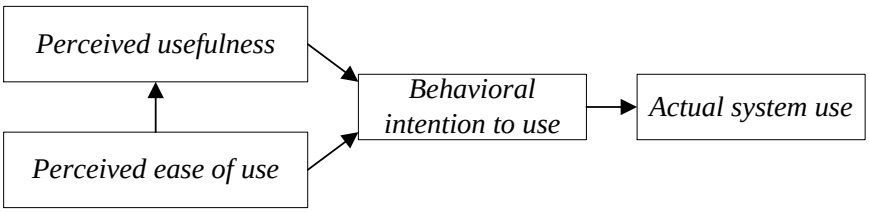

Figure 1. Technology acceptance model [9, 15, 16]

TAM has proven its value for explaining how users come to accept and use new technology, making it a good fit for our study. TAM posits that perceived usefulness and perceived ease of use will determine an individual's intention to use. TAM places a strong emphasis on the users and places the construct 'behavioral intention to use' as a mediator of actual system use. The main TAM constructs are: (1) Perceived usefulness – "the degree to which a person believes that using a particular system would enhance his or her job performance" [p.320, 12]; (2) Perceived ease of use - "the degree to which a person believes that using a particular system would be free of effort" [p.320, 12]; (3) Behavioral intention to use - users intention of use of the system in the future [17]; (4) Actual system use - users 'real' use of the system for performing work tasks [17].

3. Method

A case study was considered appropriate since it allows for exploring "sticky practice based problems where the experience of the actors are important and the context of the action is critical" [p.370, 18]. We decided to conduct our case study in a

Norwegian mixed use (apartment/office) construction project. The project included two buildings and a joint parking area beneath the buildings. The project is located near the center of Oslo. Our data was collected through semi-structured interviews with seven construction professionals working on site. Using interviews as the means of data collection served as a way to access the interpretations of informants in the field [19]. The interviews were conducted in February 2015, at a point in time when the design and construction had not been finalized. Table 2 provides an overview of the interviews conducted. Three interviews took place at the designers` offices and five in or near the contractor`s field office. Interview guides were designed based on the Technology Acceptance Model. The Gantt diagram was prepared using Microsoft Project ®, the flowline diagram by exporting the data from Microsoft Project® into Vico® Schedule Planer, and finally the 4D BIM model was prepared based on Vico® Schedule Planner and Synchro®. Eventually the Gantt-diagram, the flowline diagram and the 4D BIM model were presented for the individual interviewees on-screen. Informed consent was sought in advance of all conducted interviews. All interviews were voice recorded, transcribed, and coded by using the qualitative data analysis software NVivo10. Categories were derived from the data assigning nodes to notions, which could be related to the core concepts of the Technology Acceptance Model.

Table 2. Interviews conducted.

Affiliation	Service provided	Interview technique and duration
Contractor # 1	Superintendent (construction)	Face-to face, 25 min
Contractor # 2	Superintendent (construction)	Face-to face, 35 min
Contractor # 3	Project manager	Face-to face, 25 min
Contractor # 4	Assistant Project manager	Face-to face, 35 min
Contractor # 5	Superintendent (construction)	Face-to face, 20 min
Contractor # 6	Health and safety engineer	Face-to face, 35 min
Contractor # 7	Carpenter	Face-to face, 20 min

4. Analysis

The analysis follows the structure suggested by the Technology Acceptance Model presented in chapter 2. First, the contractors` perceived usefulness of Gantt, flowline and 4D BIM scheduling for carrying out their work is presented. Second, the perceived ease of use of the schedules in the context of on-site construction work is. Third, the behavioral intention to continue using Gantt, flowline and 4D BIM for construction works as an indicator for actual system use in other projects is depicted.

4.1. *Perceived usefulness*

Throughout the interviews, several factors were found influential for construction professionals' perceptions of usefulness. For instance, Gantt has proven its value in many projects over the years and has become the industry standard instrument for scheduling. Thus, it is maybe not surprising that contractor #1 found: "This is all very 'cool'…I mean this new visualization systems [4D]… but I am a bit old-fashioned and maybe narrow minded; the schedules that we use today [Gantt] work very well for me." (contractor #1). Thus, some perceived the relative advantage of using the new four-dimensional technology over the existing Gantt solution as marginal. Schedule visualizations prepared in Gantt were perceived as easy to understand when compared to Flowline and four-dimensional BIM: "Gantt is so much easier to look at" (contractor #3). Apart from being easy to understand the interviewees stressed that Gantt charts allowed for depicting the critical path of project activities which none of the others did: "…you have the critical path which is really useful to have for figuring out which activities need careful attention for the project to turn out well." (contractor #1). In essence, all interviewees viewed Gantt as a superior tool for assessing, discussing, and understanding the status of a project. Contractor #1 summarized this in the following way: "To work properly [in a construction project] I think that Gantt is and continues to be a brilliant instrument" (contractor #1). This opinion was echoed by contractor #5's statement: "Yes, this [Gantt] is what we are used to doing and it works very well for us."

The flow line chart was widely perceived as being a useful instrument for planning, too. However, all interviewees stated that given the choice, they would rather go for using a Gantt schedule. A reoccurring theme was that Flowline charts would need an alternative way of thinking and thereby would lack the intuitive understanding provided by Gantt charts. However, some stated that, once properly understood, Flowline charts could help providing practitioners with a solid understanding of possible scheduling conflicts: "When you are used to it (flowline) I believe it could be easier to see the collisions", (contractor # 3). One of the interviewees pointed out that Flowline could work well as a complementary visualization method used in combination with Gantt: "It is maybe a good idea to prepare the main schedule in Gantt and then use Flowline to explain some of the more detailed assemblies." Moreover, some interviewees perceived flowline as particularly useful when different work activities would need to be run concurrently.

Four-dimensional BIM was perceived as a good complementary instrument for scheduling and as a "…cool visualization technology" (contractor #1). It was mentioned how 4D BIM would provide a more complete and consistent overview when

compared to a paper schedule: "A picture says more than a thousand words for us out here [on the construction site]" (contractor # 6) and "[…] one gets an overview of how it could look when it is finished" (contractor # 7). Four-dimensional BIM allows for an easy understanding of the project and its assembly which is why it was viewed as a good instrument for training new construction site personnel "In our last project we had introductory courses for new people and then this is great to have" (contractor #3). However, apart from being found useful for introductory courses the interviewees were critical towards four-dimensional BIM's value for day-to-day construction management. This observation is backed by the following two statements: "It does not really provide value for us [in construction management]" (contactor #5) and "I don't see how this can be really helpful throughout the construction process" (contractor #3). Nonetheless, it was considered useful for "getting the overall process in ones' head" (contractor #1).

4.2. *Perceived ease of use*

While Gantt was widely viewed as the scheduling visualization easiest to use, several concerns were voiced. Gantt charts were considered most easy to use when depicting few activities in conjunction with an easy readability of activity names. However, there is a tendency for these charts to become large, displaying several thousand activities and rendering Gantt less easy to use: "What did we have in our last project? Two thousand activities […] it was impossible to even print that schedule." (contractor #1). However, practitioners have developed ways to cope with large schedules by subdividing them in several smaller sub-schedules: "I am not any good at using MS Project, but I manage to make little plans. I just draw up parts of it by hand, I leave out most of the lines and then I have something to work with." (contractor #2). Reflecting on why the interviewees found Gantt easiest to use contractor #1 stated: "it is so that people find that which they always use safe and easy".

"In any case, I was not used to this [Flowline] from before" (contractor #1) was one practitioner's response when asked about his view on Flowline's ease of use. Moreover, he continued to state "I think it is very difficult to get an overview from this, at least at first glance. My first impression was that I found this to be very chaotic". Contractor #2 elaborated that "The thinking is very different, this makes it hard to understand for construction site personnel, this has to do with habit." However, when receiving a brief introduction by the interviewer one of the interviewees stated that "Ok, now I see, it is in fact well structured, maybe this is usable" (contractor #5). "This could make it easier to recognize scheduling collisions" stated another (contactor #2). However, contractor #2 doubted the practical applicability of this type of schedule visualization: "My opinion is that we are not ready to take this [Flowline] into use in our projects".

Despite wide interest and acknowledgment of its visualization capabilities by all interviewees, four-dimensional BIM was widely viewed as being difficult to use for supporting on-site construction operations. This follows from the following statements: "Having such a model requires proper design early on in the project […] moreover, schedulers would need the required IT capabilities before being able to use this on the job." (contractor #1). A limitation of four-dimensional BIM for operational day-to-day use was that only a few IT-literate people would be able to create and edit schedules. Moreover, the practitioners viewed a non-paper based solution as limiting their ability for interacting with schedules in their day-to-day work. The contractors found four-dimensional BIM too static and work intensive for supporting operational construction work.

4.3. *Behavioral intention to use*

The behavioral intention of the interviewees of using the different forms of schedule visualizations in their next construction projects is presented here. All of the interviewees stated how Gantt is likely to remain their preferred instrument for construction management. The interviewees were more skeptical about using Flowline charts in their next project, while some pondered using it complementary to a Gantt chart. While many viewed 4D BIM a promising tool for communicating the overall project schedule logic, the contractors viewed such a system as difficult to implement: "It would be great to have this. This is something we should have used in all projects. Everyone working in the project can see what is happening. It can be difficult enough for us that are managing the building process to understand what we are going to build before building it. With such a visualization, it is much easier to see it clearly. But such a model would require lots of scheduling in an early stage" (contractor # 1). The contractors found 4D BIM useful for early project stages, however they did not anticipate it as easy to use: "I believe in 4D BIM, but it must be quite hard to learn how to use and especially to explain it to others" (contractor # 2).

5. Discussion

Technology Acceptance Model served well as an analytical tool for explaining user choice of technology in the context of construction projects. An overview of the main findings related to the concepts of perceived usefulness and ease of use can be found in table 3. The findings indicate that visualization forms were viewed as useful for different aspects of the building process.

Table 3. Perceived usefulness, perceived ease of use and behavioral intention.

	Perceived Usefulness	*Perceived ease of use*	*Behavioral intention to use*
Gantt	➢ Organization of activities along a critical path	➢ Messy when many activities	➢ 'All-round' management tool
Flowline	➢ Organization of concurrent activities	➢ Difficult to understand	➢ 'Complementary' scheduling instrument
4D BIM	➢ Instruction of new site personnel	➢ Requires strong IT capabilities	➢ 'Complementary' scheduling instrument

Gantt was viewed as the 'all-round' tool facilitating day-to-day operations throughout the entire construction supply chain. This finding does not come as a surprise since Gantt is well institutionalized among construction professionals worldwide. An unexpected finding is that Flowline charts were viewed to be somewhat 'exotic' and that the interviewed Norwegian construction professionals struggled with understanding this form of visualization. This explains why the application area of Flowline schedules remains limited. Today they serve as complementary scheduling instruments in projects with many concurrent activities. The explanatory power and clarity of four-dimensional BIM was acknowledged by all interviewees. However, 4D BIM was considered difficult to use in day-to-day construction operations and management. Construction professionals felt constrained by having to use computers for viewing and interacting the content displayed in 4D BIM. Thus, people wanting to engage with the digital content would need solid enough IT/BIM capabilities. Research indicates that it is not until teams develop such capabilities that project performance improves significantly [20]. For now, 4D use is prioritized only in early project stages to, for instance, train new site personnel not yet familiar with the construction site. Thus, despite a wide availability BIM models in Norwegian construction projects, 4D BIM's utility remains low. Moreover, this is unlikely to change quickly since learning to operate four-dimensional BIM was perceived as difficult. Thus, four-dimensional BIM continues to lack technology acceptance even in advanced BIM projects. For now, practitioners view 4D BIM and Flowline as 'nice to have' complementary scheduling tools. Nonetheless, our findings would need to be validated beyond the case presented here. Thus, we recommend further research analyzing 4D BIM's acceptance in other projects and in different national contexts.

6. Conclusion

This paper has presented a case study of a construction project where Gantt, Flowline and 4D BIM were used. By comparing professionals' acceptance of the different scheduling methods for facilitating their day-to-day work based on TAM, it became possible to answer the research question: *How useful and easy to use are different schedule visualization methods for construction site teams?* Our findings illustrate that Gantt remains the most important scheduling tool for arranging the day-to-day activities in projects. Flowline was viewed as a useful system when scheduling many concurrent activities. However, some of the practitioners found Flowline to be difficult to understand. While four-dimensional BIM was acknowledged as a powerful visualization tool, it was at the same time perceived as difficult to use. The fact that practitioners' interaction with this digital scheduling method requires sophisticated IT skills represents a hurdle for its practical application. This is unlikely to change unless practitioners succeed in increasing their IT capabilities. Thus, even in advanced construction projects where BIM models are widely available, 4D BIM is viewed as little more than a complementary scheduling instrument. Future research should inquire into how the utility of 4D BIM can increased.

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