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Solution selection in digital construction design – a lazy user theory perspective

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Abstract

The construction industry is in the midst of a transition with traditional design systems being gradually replaced by novel virtual modeling technologies. This transition takes place gradually rather than radically and while new systems (e.g. Building Information Modelling) become increasingly diffused in the industry, many legacy systems and practices are left intact. This leads to situations where designers have several different information systems at their disposal to fulfill their information needs. This is amplified by software vendors releasing a myriad of new design systems. How individual designers select an information system from several available options to fulfill their information need is discussed in this article. The findings suggest that construction designers will most often select a design system solution fulfilling their information needs with the least effort on their part. The theoretical approach supporting the analysis in this article is the so-called Lazy User Theory (LUT). LUT explains how users select among available solutions when there are numerous products and services possible. Preferred solutions reflect (1) a user's perceived information need (e.g. function of urgency, type, and depth) and (2) the user-state which is the situation in which the user is at the moment of information need. The findings presented in this article are derived from a case study conducted in a Norwegian construction project. The findings show that users' choice of design systems reflected local and circumstantial considerations rather than what is best for the project. This article is important for several reasons. First it contributes to an understanding of what are influential considerations for designers when selecting design solutions. Second, it illustrates how local system selection decisions may affect the digital work at project level.

Keywords: building information modelling; construction design; lazy user theory; system selection

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1. Introduction

The architecture, engineering and construction (AEC) industry struggles to efficiently share and reuse digital information. This is illustrated by construction information needing to be recreated up to eight times throughout the life-cycle of a project [1]. The annual cost of inadequate information sharing in the AEC industry has been quantified at USD 15,8 billion for the US construction industry alone (US National Institute of Standards and Technology). Novel virtual modelling technologies like BIM are widely perceived as a means to improve information sharing in AEC projects [2]. BIM use for information sharing may be necessary and desirable, but research indicates that this is not easy to achieve [3]. Despite increasing BIM uptake many of the crucial advantages this technology has to offer remain unexplored in wider practice. Costly re-design and faulty construction information could be mitigated by increasing alignment of design technologies [4].

BIM deployment is influenced by the features of industry, projects, and people involved [5]. These pieces of the puzzle do not necessarily fit well together, and in order to succeed with BIM deployment, "mutual adaptation between technology and its context acknowledging the crucial role of the people involved" will be required [6, p.344]. Consequently, the industry's transition towards sharing information based on BIM takes place gradually rather than radically. This leads to situations where organizations operate new BIM technologies alongside with older existing two- and three-dimensional Computer Aided Design (CAD) systems [7]. Design team members having a variety of design technologies at their disposal do not always pick the technology best supporting the project [3]. As a result, scholars find that BIM practice is relatively 'static' with designers creating disciplinary models or drawings that are then exchanged at meetings [8]. Moreover, working based on incompatible information technology (IT) solutions leads to inefficient digital information sharing in construction projects [9, 10].

Why then do design team members choose to work based on outdated technology in situations when BIM technologies are available? Given the importance of BIM for driving the industry's performance, such a question is worthwhile. Moreover, there is a need for fresh approaches to study digital design practices in construction projects [6]. In this article we explore the considerations undertaken by design team members when selecting information technology based on a fresh theoretical view. Our research question is: *What are the influential considerations for designers when selecting design solutions, and how do these choices affect the digital work in the design team?*

We explore the reasons behind design solution choices based on a case study run on a Norwegian construction project. One possible explanation is that design technology is selected based on the lowest level of effort. This view has been advanced by Tétard and Collan (2009) who suggested Lazy User Theory (LUT) as a conceptualization for information technology selection [11]. In this paper LUT is used to analyze how a user of IT with a (1) perceived information need (e.g. urgency, type and depth) in a certain (2) state (user situation at the moment of need) makes a choice amongst a range of available solutions. Our findings are based on semi-structured interviews with the project team of an office refurbishment project in Oslo, Norway. BIM was to some extent used in this project, with different levels of experience amongst the users. The intended contribution of this article is twofold: first we argue that research taking a LUT perspective can broaden the theoretical understanding of what happens when digital design systems are selected. Second, the practical contribution of this paper is to increase construction management's awareness of how to manage solution selection. This article presents an early application of LUT to explore solution selection in construction design.

2. Theoretical lens

The theoretical approach supporting the analysis in this article is the so-called Lazy User Theory (LUT) as suggested by Tétard and Collan [11]. There exists a broad spectrum of theoretical models explaining technology adoption in the information systems research community [12]. Examples include the Theory of Reasoned Action (TRA), Technology Adoption Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Task Technology Fit (TTF), and Diffusion of Innovation (DOI). What unites these theoretical views is their focus on technology (ibid.). There are several examples of scholars applying these theories to the study of BIM adoption in

the architecture, engineering and construction industry [13, 14, 15, 16]. Collan and Tétard developed their LUT model to develop a stronger focus on the user in technology acceptance research. The motivation for using LUT in our study is twofold: first, there is a need for 'fresh' theoretical approaches to study digital design practices in construction projects [6, 17], second, studying technology adoption from a user perspective can complement other earlier work in this area.

Lazy user theory seeks to "explain how an individual (user) makes her selection of solution to fulfill a need (user need) from a set of possible solutions (that fulfill the need)" [12, p.59]. A graphical depiction of LUT can be found in figure 1. This theory assumes that users have a tendency of following a so-called "path of least resistance" when selecting and using IT. Thus, user behavior is equated with water flowing downhill, following the path of least resistance. LUT has been applied to understand issues arising when users select from different telecommunication services [18, 19], student use of optional online learning resources [20], and for understanding choice in buying bus and metro tickets. According to LUT, IT solutions are selected based on what users perceive as the solution requiring the least effort. The core concepts of LUT are: *User need* (1) defines a goal users try to achieve by using IT. The user need is comprised of the type, depth, quality, completeness, and the urgency of information delivery. The *User state* (2) accounts for limitations of available choices and the circumstances surrounding a user when the user need arises. Relevant circumstances can be location, available devices, available resources and available time. *User need* and *user state* define the *set of possible solutions* to fulfill the user need [11]. "*Lazy users*" would choose a solution demanding the least effort, and select the solution based on the lowest level of effort (see Figure 1). Effort can be defined as a combination of time, money, and energy (physical work, mental work) necessary for fulfilling a user-need by deploying technology. In the context of a construction project, time and money represent decisive factors when companies select information technology solutions [5]. Moreover, the nature of construction projects with decentralized decision making and loose coupling foster a mindset where "nobody feels responsible for investing in technology that is best for the project" [5, 21]. Nonetheless, BIM's benefits will only come within reach for a construction project team once all members collaborate based on the new technology. Thus, a well-considered choice of BIM technology at the local organizational level will be influential for how seamlessly BIM can be run at project level. LUT serves well for the purpose of our study in that it provides a fresh, theoretical approach for making explicit what drives a construction organization to favor one design technology over another. The constructs relevant in LUT are defined by Collan and Tétard as follows [12]:

- *User need* is an "explicitly specifiable want", either tangible or intangible, that can be fulfilled completely.
- *User state* is a description of both the user and the circumstances that surround the user at the time of the need. User need includes the characteristics of the user, such as age, gender, social and cultural belonging and experience, including any type of experience that is relevant for solving or fulfilling the problem or the need in question.
- *Least effort* The solution that, according to the model, is selected as the solution that requires the least effort from the user. Effort can be defined in various forms, and is the combination of money spent, time used, and energy used (physical or mental work). Nonetheless, users' perception of what is the least effort solution depends on the knowledge of possible solutions and the efforts they require.
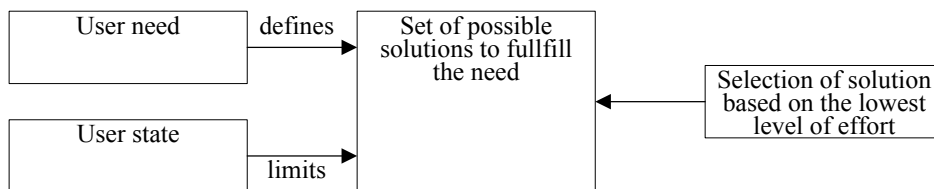

Figure 1. Lazy User Theory of solution selection [8]

3. Method

A case study approach has been selected for exploring whether BIM solution selection in construction projects can be explained based on LUT. 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, 22]. Moreover, a case study allows for understanding the process whereby the information system influences and is influenced by the context [23]. We decided to conduct our case study on a Norwegian office refurbishment project. The project is located at the outskirts of Oslo and its design made it a national role model for sustainable construction. This is signified by features like 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 prioritized by the client and used as the main design technology, was considered a suitable case for our study.

Our data was collected through semi-structured interviews with eleven design professionals, aiming to gain an understanding of the phenomenon by asking those experiencing it. Using interviews as means of data collection served as a way to access the interpretations of informants in the field [24]. The intention was to interview key BIM actors to examine the reasons for their choices. The interviews were conducted in September 2014, at a point in time when the design and construction had just been finalized. 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. Interview guides were designed based on the theoretical lens, *the Lazy User Theory*. 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 *Lazy User Theory* presented by Tétard and Collan [11].

Table 1. Interviews conducted.

Affiliation	Service provided	Interview technique and 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. After examining data on IT solution selection in the case project, the three most poignant examples were identified and are presented here as vignettes from practice. These are then classified based on the core concepts of *Lazy User Theory* presented in section 2 and figure 1 [11], namely: user need, user state, set of possible solutions, and selection of solutions. The three vignettes from practice cover rooftop photovoltaic installations, fire protection design and acoustical design.

4.1. Vignette from practice: Photovoltaic rooftop installations

User need: The rooftop photovoltaic elements and the solar-thermal panels were delivered by a specialist sub-contractor firm. The agreed specifications required the firm to explore where to best place the rooftop systems to maximize their efficiency. Positioning the system required compiling knowledge and data about the building itself, the surrounding landscape, as well as the sun`s predictable movements through the seasons. To accomplish the job the firm needed to run a solar cell capacity calculation in a system called TRNSYS©. Thus, the building data acquired needed to be interpretable by TRNSYS©.

User state: Photovoltaic systems have considerable lead times since they need to be manufactured to order. Thus, the firm was pressured for time and felt a need for conducting their calculations and design work early on in the project. At this point in time, neither an architectural BIM model nor the contractors' landscape scan had been prepared. This is illustrated by the following quote: "the BIM model arrived very late" (subcontractor # 1). How, in the time of user need, there was just 2D data available follows from the following quote: "We used 2D plan drawings provided to us in pdf. In the beginning there were almost no drawings of the structure" (subcontractor #1). Further, few data on the surrounding landscape were available at the time of need: "We made all energetic simulations for the photovoltaic systems and we neither knew the height of the trees in the area nor how far they were away from the façade" (subcontractor #1). The BIM model became available after the job had been completed: "At some point in the process we learned that there was some sort of BIM model but at that stage we were already looking at the detailed design of our façade solutions. To be precise, the energy concepts for the photovoltaics on the roof was already done." (subcontractor #1).

Set of possible solutions: The sub-contractor could have fulfilled his user need based on three different solutions:

- Modeling the building using SketchUp from 2D pdf-drawings (Site inspection)
- Modeling the building in Revit® from 2D pdf-drawings (Site inspection)
- Waiting for the architectural Revit® model and for the contractor's point-cloud scan

Selection of solution: The sub-contractor used 2D pdf-drawings from the architect and used SketchUp to make a 3D model. This information was imported into TRNSYS© where the information of the solar cell capacity was determined. The rationale for this solution selection was the following: "you can quickly generate a building model from SketchUp that is where somebody working with BIM would spend many working hours" (sub-contractor # 1). Moreover, the sub-contractor stated that: "We drew it ourselves and then we used this model to, for example, calculate the energy providing areas such as roofs and facades, and look closer into these. We studied how we could place the photovoltaic elements or other solar-thermic systems providing the energy for the building. Then we used this information and imported the model into a building simulation modelling system called TRNSYS© where we then connected the information about the photovoltaic to the geothermal simulation model, to understand how the systems would work together". In addition, the subcontractor conducted a site inspection assessing the location of trees and shadows. Using SketchUp, relative to the other options of having to create a BIM model, or having to wait for others to create a BIM model, represented the path of least resistance for the sub-contractor. Justifying his choice the subcontractor stated: "I always tell my colleagues, we have to choose our weapons right. There is a point in time when we can use very rough tools to make decisions taking us a long way. Nonetheless, later you need to step up accuracy and then we need a good BIM model and the more information we have in such a model the better." (sub-contractor #1) He stated that the business value of BIM remained unclear: "Maybe the industry in which we work has not yet understood how to use this technology right for its purpose. We talk about BIM and IFC since a felt eternity. […] if BIM would actually lead to overall cost savings […] so what we need to understand is the business value of BIM, what does it help us to use this methodology?" (sub-contractor #1)

4.2. Vignette from practice: Fire protection design

User need: The fire protection engineer developed the specifications and design for the safeguards for preventing, controlling and mitigating the effects of fires on the building. Accomplishing this required producing design principles and premises for the other designers. Moreover, the work required providing assessments of design solutions and materials regarding their fire protection performance. From this it follows that the fire protection engineer needed timely information for setting the premises and then updated information of the design development during the project. The following quote illustrates this: "In a construction project, there is a rapid progress. Suddenly a wall is changed and something is removed […] then there is a chance we worked on the wrong edition of a drawing" (Engineering consultant #3). Moreover, in late project stages the fire engineer controls whether the set requirements were followed.

User state: "I am kind of old-school, right? I grew up drawing with ink, and white lab coats and all that was my youth. But I believe that digitalization, BIM, and all that is without any doubt the future" (Engineering consultant #3). While the fire protection engineer acknowledges the value of BIM, her preferred way of working is based on traditional two-dimensional technologies. Moreover, she worked for a small consultancy not extensively using BIM. When asked whether she had prior experience from running fire and smoke spread simulations in BIM she responded: "No, not really. But I understand that this can really be useful. What should I say, in another project I have seen how model based simulations can be done and how to use models actively. However, we understood that in this project the model was not well enough developed. Getting BIM and simulation was difficult in this project." (Engineering consultant #3).

Set of possible solutions: There were two different information technology options available:

- Designing based on AutoCAD delivering specifications using 2D drawings, written documents, or orally.
- Designing based on BIM and communicating requirements by using for instance Revit Fire and acoustics in Naviate from CAD-Q.

Selection of solution: A fire plan was made in 2D by the use of AutoCAD. In addition, pen and pencil were used. Requirements and solutions were communicated using 2D drawings in documents, e-mails and orally. More advanced smoke and fire simulations were run by a colleague, a ventilation engineer. "As far as the fire consultancy was concerned, there was no demand for BIM to be a part of the delivery, [moreover] I never received a BIM model and did not ask for it." From the quote above it follows that the fire protection engineer decided on using 2D CAD, moreover she did not even consider using BIM: "It is clear that […] as BIM is concerned, it was not even present in my mind" (Engineering consultant #3). The following quote illustrates that due to the choice not to employ BIM the fire protection engineer remained excluded from many project meetings: "I could bring a drawing [to the project meetings] and we sat down and wrote on the drawing, putting it on the table. But I never took part in digital meetings, no, no" (Engineering consultant #3). It can be argued that the fire protection engineer, by sticking to using 2D CAD as opposed to changing to modelling the building in BIM, followed the path of least resistance.

4.3. Vignette from practice: Acoustics design

User need: The acoustical design work was performed by an electrical engineer specialized in audio technology. 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. The architect needed to share architectural design visualizations to provide the canvas on which acoustical calculations could be performed. For performing his work in the best possible way acoustician needed a: "a ray tracing program [which] works very good to compute the acoustics in a room" (Engineering consultant #4).

User state: The acoustician was pressured for time, leaving little opportunity for learning and working with new technology, as the following quote illustrates: "We are… we have too much to do! To work with research and find new ways to do stuff, it's not always that easy…" (Engineering consultant #4). Nonetheless, the acoustician used a

simulation program developed for venue acoustics named EASE™. "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 use it mainly to get the areas right" (Engineering consultant #4). The acoustician pointed out that there was a different, more advanced way for conducting acoustical design. He mentioned a software called ODEON®, which had been developed for running room acoustics based on 3D models.

Set of possible solutions:

- Designing based on AutoCAD delivering specifications using 2D drawings, written documents, and orally. Conduct initial acoustic analysis based on EASE™ and do the acoustic calculations manually
- Get hold of an architectural IFC-file, send it to SketchUp and then import it to advanced room acoustic software like ODEON® or other similar programs.

Selection of solution: The acoustician received an architectural 3D CAD dwg-file. This file was then imported into EASE® to find the areas of materials used. The calculations were done manually. The acoustician explained his choice of design technology using the following words: "Yeah, acoustics have never really been at the forefront when it comes to using new technology. We kind of have an old-school approach to it" (Engineering consultant #4). From this quote follows that the traditional way of working based on 2D technologies and hand calculations continues to be the preferred way of working in acoustics design. Nonetheless the acoustician stated that he has undertaken some attempts to increase his firms BIM capability: "I had to work with the program I had. I have nagged about getting Odeon for years." (Engineering consultant #4). Thus, by not changing the established 2D-based way of working and by deciding against the adaption of a BIM-ready system the acousticians chose the way of least resistance.

5. Discussion

Lazy User Theory served well as an analytical tool for explaining user choice of information technology in the context of a construction project. The results show that in situations where more than one technology is available to a user there is a tendency to follow the path of least resistance. All three vignettes illustrate that a core consideration in IT selection was to keep efforts in terms of resources used low. This is echoed by user states such as perceived time pressure, traditional mindsets, and economic restrictions, all being identified as influential in IT selection. This resembles earlier research reporting that considerations about local resources drive IT-based work in construction projects [5]. Moreover, local considerations by individuals and organizations appear crucial in deciding which technology is deployed in a project. This has similarly been emphasized by Love and colleagues who argue that "…each discipline has become dedicated to the optimization of its own function, with little regard to, or understanding of, the construction process" [p.381, 25]. In addition, the data shows that the business value of using BIM is not yet apparent for all organizations. This finding does not come as a surprise and is reflected by the ongoing discourse in research trying to establish the business value of BIM [13].

So, how can the organizational and individual skepticism and reluctance towards using BIM be overcome? A starting point could be to further include design team members working in the periphery of the innovation network in collaborative BIM work [26, 27]. Our findings resemble earlier work in that they show how especially small companies working in early or late project phases struggle with working based on BIM [26]. A challenge for construction management is shaping a project culture where collaboration is prioritized over local thinking. Moreover, it has been argued that clients would need to clearly formulate a set of requirements and contracts for project level BIM work [4]. To achieve a 'breakthrough' BIM systems usage would need to be regarded as the path of least resistance. This would require making them easier to use and reducing the effort required for learning to work based on BIM. We are limited in our ability to generalize from the single case study presented in this article, and further work would need to inquire into IT selection processes in other projects. Nonetheless, given that multiple authors find cases of project teams struggling with working jointly based on BIM our article is important. First, it contributes to an understanding that local organizational considerations drive project

designers' selection of information technology solutions. Second, it illustrates how local decision making driven by resource considerations may affect digital work and overall functionality of BIM systems at project level. Last, the present work increases project management's awareness of how local decisions about IT use 'make or break' BIM in the entire project.

6. Conclusion

This paper has presented a case study of a construction project in which the design team worked based on digital modelling technologies. By doing so it was possible to explore what the influential considerations for designers were when selecting design solutions, and how these affected digital work in the design team. It has been found that information technology solutions were selected based on the perceived level of effort associated with their usage. Designers' IT decision making was driven by considerations about time, cost, and prior experience at local organizational level. Decentralized decision making prioritizing organizational level issues over project level issues appears to affect the overall functionality of BIM. It can be concluded that centralizing IT decision making with a powerful actor at project level, such as the client, could help to overcome these issues. This article is important since it uses a 'fresh' theoretical approach, namely Lazy User Theory. Moreover, this article contributes to understanding which considerations are influential for designers when selecting information technology solutions.

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