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Planning the building design process according to Level of Development

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Abstract

Question: Q1: What characterizes planning of the building design process in different industries today? Q2: How do the challenges of planning in the building design process stand out from other industries? Q3: How can planning in the building design process be improved?

Purpose: The purpose of this paper is to compare the design process in three different industries: 1) Architecture, Engineering, and Construction (AEC), 2) Offshore Construction (OC), and 3) Ship Building (SB), and from that learn how the AEC-industry can improve building design management.

Research Method: A comparative case study using one case from each industry (AEC, OC and SB) with interviews and a case-specific document study were conducted. In total, thirty-two semi-structured in-depth interviews were used to collect the analysed data from the three cases. Finally, a focus group interview with ten participants was carried out to test and develop a conceptual model.

Findings: This paper presents an analysis of the differences between design processes in the three industries and proposes a conceptual model for how building design management can be planned according to the Level of Development (LOD).

Limitations: The study is limited to single case studies in companies in three different industries.

Implications: The use of the proposed conceptual model with the LOD could improve planning of the building design process.

Value for authors: This paper gives project practitioners an insight into how the LOD can be used to structure the planning process and improve the design process.

Keywords: Level of Development, Collaborative planning, Design maturity, Building design management.

Paper type: Full paper

Introduction

The Architecture, Engineering and Construction (AEC) industry is facing challenges regarding productivity and increased complexity, which need to be addressed in the design

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phase to create value for the client (El. Reifi and Emmitt 2013) and to combat productivity issues (Love and Li 2000). When projects become more complex, they typically require more detailed drawings. Van Berlo and Natrop (2015) question if the information presented by the drawings constitute the information needed on the construction site, claiming that most drawings are not specific enough for specialized tasks. In Norway, Building Information Models (BIM) and Information and Communication Technology (ICT) tools have been investigated as measures for improving communication throughout the whole life-cycle of a building, from early design to operations and termination (Harstad et al. 2015, Murvold et al. 2016, Vestermo et al. 2016). With BIM, much more information can be available than on traditional paper drawings; therefore, increased use of BIM in projects poses new challenges in the planning of the design process. With the use of the drawings, it is easy to set statuses and plan for delivery of a certain drawing. The objects in BIM can have different statuses, causing challenges for planning the design process (Hooper 2015). Different approaches have been tested to address these challenges. Among the most promising is the Level of Development (LOD) (AIA 2013); however, experiences from the AEC-industry have shown that the introduction of LOD has not been as straightforward as hoped (Borrmann et al. 2014).

Other industries have implemented BIM more convincingly than the AEC-industry; consequently, there seems to be a potential for learning. Of particular interest are the Shipbuilding (SB) and Offshore Construction (OC) industries (Knotten et al. 2016). The OC and SB industries are typically characterised by a high level of complexity (Aslesen and Bertelsen 2008, Lia et al. 2014, Gaspar et al. 2012), a complexity that has reached the AEC-industry over the lasts decades (Forbes and Ahmed 2011). These similarities make a comparison of these three industries interesting, and to identify the potential for learning, the following research questions are addressed:

1. What characterizes planning of the design process in the different industries?
2. How do the challenges with planning in the building design process stand out from the other industries?
3. How can planning in the building design process be improved?

The first of these questions will be addressed in the theoretical framework section of this paper, whilst the two latter will be addressed in the findings and discussion sections.

Methodology

The research started with a literature review following the procedure described by Blumberg et al. (2011).

The comparative case study presented in this article is based on three cases. A case study is, according to Flyvbjerg (2006), an appropriate method for gaining context-dependent knowledge about complex issues. Ragin and Becker (1992), among others, highlighted the case study's ability to provide knowledge despite a small number of cases. Statistical generalization is not possible, but an analytical generalization is, which might lead to expanding the theory (Yin 2014). The three cases were found in three different industries: at an AEC contractor, an offshore contractor, and a shipbuilder. The cases were chosen from participants of a research project (Knotten et al. 2014) and are situated in the Nordic countries. However, both the OC and SB compete in a global market, while the AEC-contractor competes in the domestic market. The companies have implemented lean processes in their work, and the investigated cases use design-built contracts. Interviews, observations, and a document study were used for data collection. In these case studies, 23 semi-structured, in-depth individual interviews were carried out according to the procedures outlined by Brinkmann and Kvale (2015). The interviewees were design managers, project managers, designers, and site managers. In addition to the case-specific interviews, eight non-case specific unstructured in-depth interviews with senior level participants from OC and SB were carried out.

The semi-structured, in-depth interviews were carried out using a common interview guide. They were recorded, transcribed, and analysed based on the constant comparative method (Knotten et al. 2017), meeting the rigour of qualitative research as highlighted by Gioia et al. (2012).

The observations were made by a peripheral researcher with a focused observation approach based on the recommendations of Adler and Adler (1994), Gold (1958), and Postholm and Jacobsen (2011). The pre-defined focus of the observations was the behaviour of the design manager and the team participants in meetings.

The document study concentrated on schedules, contracts, organization charts and other project documents, carried out to find background information that could supplement the overall picture obtained during the interviews.

Yin (2014) suggests member checking as a way to strengthen the results of case studies, which were discussed with representatives from the three industries in workshops. The conceptual model of the workflow presented in the discussion section was presented and developed in a workshop with 10 design managers from the AEC-contractor experienced in the use of Last Planner.

Theoretical Background

The theoretical background consists of two parts. The first part describes the different types of dependencies occurring in the design process and how the process could be managed to handle these dependencies, which is recognized as valid for all the three industries. The last part sums up a previous study on how the reciprocal and sequential processes develop in the different industries.

Different types of dependencies in the design process

According to Knotten et al. (2015), there are four different interdependencies occurring in the design process, pooled-, sequential-, reciprocal-, and intensive-interdependencies. Kalsaas and Sacks (2011) maintain the importance of understanding the dependencies in the design process to handle them. Figure 1 shows the team task complexity and characteristics that can occur in a design process.

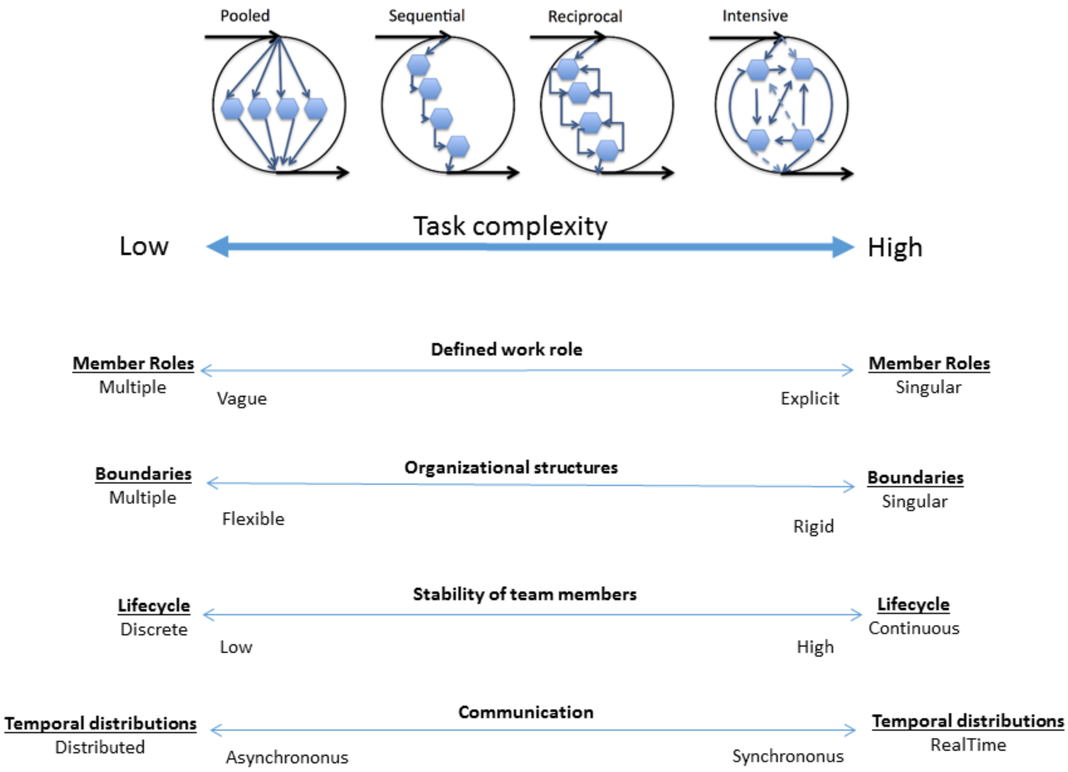

Figure 1: Team task complexity and characteristics based on Bell and Kozlowski (2002) and Knotten et al. (2015).

As shown in Figure 1, different team tasks encounter different types of dependencies. This requires different definitions of work roles, organisation structures, stability of team members, and communication. Intensive dependencies between design tasks require more teamwork, with a high degree of synchronous communication. Pooled dependencies between design tasks are the opposite and require asynchronous communication. Tasks with high complexity need explicitly defined roles and responsibilities, where the organization is transparent and the team members work continuously together in the project. The challenge is – according to Knotten, Svalestuen, Hansen, et al. (2015) – that the different types of interdependencies can happen at the same. In a design process, there will be several activities of which some can be pooled, while others might be either sequential, reciprocal or intensive. A tool like Design Structure Matrix (DSM) can be helpful to identify the different interdependencies in a design process (Browning 2001); however, according to Rosas (2013), a stand-alone DSM is not adequate to define the optimal design sequence. A tool like the Last Planner® System (LPS®) needs to be implemented in addition to DSM to control the planning process. Tuholski and Tommelein (2008)

A specific challenge for the AEC industry is the fragmented nature of the industry. The building process relies on different actors from different companies to complete the project. Consequently, there are challenges with teamwork and communication on the projects (Kerosuo 2015). The performance of a building design team is dependent on the team members' ability to work together as a team and their skills and knowledge (Emmitt and Ruikar 2013). Svalestuen et al. (2015) found 12 elements that were important to effectively build design teams. Out of those twelve, trust between team members and commitment to the project were the most important, and other elements can help enhance these essentials (e.g., a team-building exercise at the beginning of the project is important to be able to gain trust and commitment between project participants). One way of ensuring an effective team in the building design process is to use a method called Collaborative Planning in Design (CPD) (Knotten and Svalestuen 2016, Fundli and Drevland 2014). CPD's scheduling system is an adaptation of the Last Planner System to the design process (Bølviken et al. 2010) and is based around four elements: 1) the start-up process, 2) the scheduling system, 3) the constraint analysis, and 4) the meeting structure. The start-up process is where the team members get to know the project and each other. The goal is to ensure that all participants commit to the project and work towards completing the same goal. Together with the meeting structure and the constraint analysis, the system endorses teamwork and team development. A key tool in CPD is the dialogue matrix, consisting of design activities as well as new tasks needed to complete the work. The design team uses CPD in each meeting to tell each other what they commit to, what they need from others, and when they need it to accomplish their work on time (Knotten and Svalestuen 2016). Fundli and Drevland (2014) found that using a method like CPD led to better communication within the design team and a better understanding of and commitment to the project.

Transparent information flow is vital for an efficient project team, as it fosters trust between participants (Svalestuen et al. 2015) and reduces sub-optimisation (Knotten, Svalestuen, Lædre et al. 2015). Level of Development (LOD) is discussed as a possible tool to improve communication between actors (Hooper 2015). With a shared BIM-model capable of showing 4D and 5D information, the quality of communication between designers and construction practitioners increases (Svalestuen et al. 2017).

LOD is used to describe how developed a BIM is. The idea is that a LOD status is attributed to objects in conjunction with standardized, reusable checklists; therefore, a certain quality of information at a given point is guaranteed (Hooper 2015). The American Institute of Architects (AIA) has developed a LOD definition, describing how BIM elements evolve through the project, which ranges from the lowest, LOD 100, to the highest, LOD 500. Abou-Ibrahim and Hamzeh (2016) developed a framework for LOD that relates the LOD value of a model element to its actual design context. The framework divides the definition into three variables: 1) Graphical Detail Level, 2) Information Richness, and 3) Confidence Index, the sum of all three variables will define what LOD the different elements have. Although the concept of LOD was pioneered in 2004 by Vico Software, there are few cases where LOD is successfully implemented. One of the reasons for this is the lack of practical understanding of what LOD can be used for (Hooper 2015). Furthermore, the required minimum level of detail will change from project to project, as building projects vary in size and complexity. The pre-set values of LOD from AIA might be too detailed for some projects and too vague for others (Borrmann et al. 2014).

Comparison of industries

The AEC-, OC- and SB-industries have different approaches to handling reciprocal and sequential interdependencies in the design process. As shown in Figure 2, all industries have a creative reciprocal design process in the early design phase (pre-contract). The companies worked with design-build (DB)/Engineering-procurement-construction (EPC) contracts and were able to participate in a pre-contract layout phase before signing the contract. One difference between the approaches is that the reciprocal process is longer in the AEC-industry than in the SB- and OC-industries.

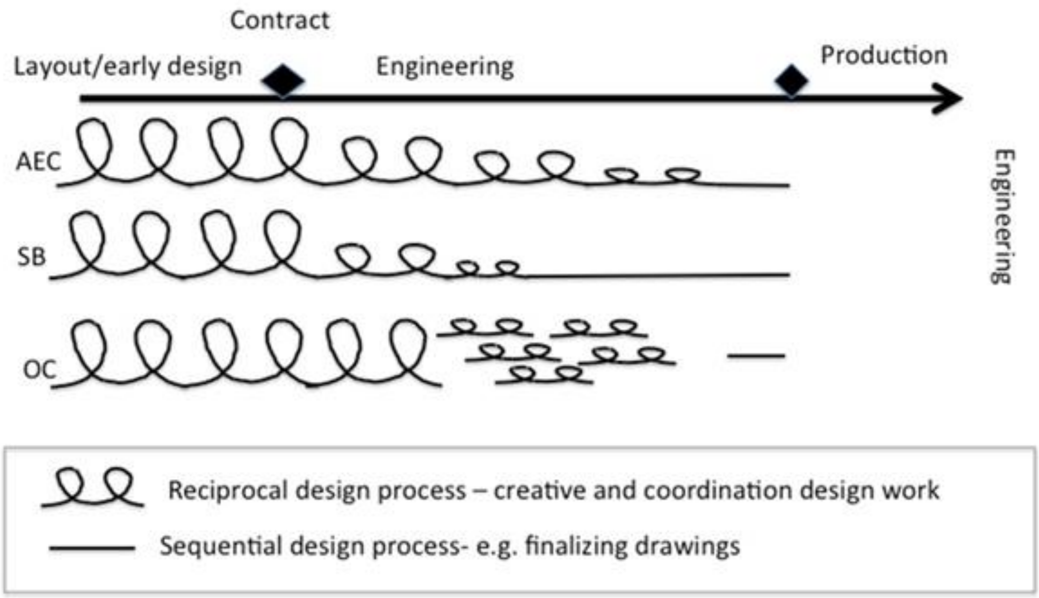

Figure 2: Illustration of reciprocal and sequential design processes in the different industries (Knotten et al. 2016).

According to a study by Knotten et al. (2016), the SB-industry has a stage-gate model with clear decision points that allows them to end the creative reciprocal design process before the AEC-industry can. In the OC-industry, the company had implemented a new agile method for the engineering process. By pushing the production of drawings to the last responsible moment and controlling the design process with BIM maturity levels, they allow the creative reciprocal design process to continue longer for each area of design. The OC planning method was described as a stage-gate model where the maturity of objects, together with production and procurement, dictates the plan. The research of Knotten et al. (2016) concluded that the AEC-industry could learn from the way the OC-industry planned the design process and how they used BIM. Mejlænder-Larsen (2017) described the use of Project Execution Models (PEM) in offshore engineering as something to which the AEC can adapt. PEM is a highly structured and systematic description of the process. SB is complex, and Killaars et al. (2015) emphasised the importance of a holistic view of the final vessel, as it is not only dependent on the function of the components but also their holistic interaction. This is also valid for OC and influences the planning and design.

Findings and discussion

This section contains the main findings and discusses how the AEC-industry can improve the planning of the design process. First, it gives a presentation of how the different industries in the three cases planned their design phase, followed by a discussion of how the AEC-industry can improve the planning of the design process in future projects.

Main characteristics of planning in the different industries

This study follows up the study of Knotten et al. (2016) and investigates the planning in these industries further. The OC- and AEC-projects investigated were in the early phases of detailed design, while the SB-project was in the concept development phase. The typical approach of the OC- and SB-industries is to look at the function, the overall systems to support, and the detailed layout (area). The typical approach of the AEC-industry is to look at the function of the building, how the detailed layout supports it, and then look at the overall systems. The holistic view is not as dominant in the AEC-industry as in the other industries.

The planning process in the three industries has a similar approach in that they all have a production that sets the framework for the design plan. Usually, the design plan is based on assumptions of what is needed (immaterial products like drawings, etc.) and when it is needed. The design process is inherently a creative reciprocal one, and its planning differs from industry to industry.

The AEC-industry

The AEC project was a design-build project with the contractor managing the design process. The architect and structural consultants were procured by the contractor, while the rest of the main designers were procured by subcontractors.

The main design plan was created collaboratively and guided the design activities, but little attention was paid to the plan throughout the project, and it was never revised. The dialogue matrix from CPD was used as a tool to map activities that needed to be completed in the next period.

The design team was exclusively set up for the project. The client had already procured the architect when procuring the contractor, and the subcontractors were procured based on lowest price. The subcontractors provided their own designers, and as a result, the team was not put together by the design manager. Despite this, the design team functioned well.

The main communication and coordination between the design team members took place in the project's Integrated Concurrent Engineering (ICE) sessions, which occurred one day a week. During the rest of the week, the design team was dispersed.

The OC-industry

The OC-industry also used Lean planning techniques to make the master schedule. The project participants paid attention to the schedule and important milestones, and the work was aligned with the schedule. BIM was used for design and whether progress was according to schedule or not was registered with colour coding in the BIM. An OC-company sub-contractor was responsible for a DES (drilling equipment set), while the main contractor was responsible for the remaining project (DSM, MFS).

The design team on the OC-project primarily consisted of the company's employees. At the time of the study, there was a recession in the industry, making it possible for the design manager to handpick team members based on competence and previous experience from a collaborative environment.

The whole project was co-located in the same building, including the client, users, constructors, and designers. The closeness accommodated informal communication, something that was obvious when visiting the office.

The SB-industry

The design process in the SB-industry changed from pre-contract to post-contract. The pre-contract design process was challenging with a high degree of innovation and a constant change in specifications from the client. Planning of this process was, therefore, considered useless among the team members. During post-contract design (engineering design) the project had a well-functioning plan for the process, linking production and drawings together.

Despite lack of planning and a highly unpredictable workload, the project delivered design and innovative solutions because of the members of the design team. Even though they belonged to different ship segments, the designers and design leads worked in an almost autonomous way, handling complex tasks and dependencies together. The actors were aware of each other's needs, shared inventive solutions across segments, and offered previously developed design solutions to each other.

Although the line of communication was informal, the formal procedure was to run all design issues through the Naval Architect, who had the role equal to the design manager in the AEC-project.

Main challenges with planning of the design process

The most prominent challenge for the SB-industry in the layout design phase is the general belief among team members that the phase is "un-plannable". The constant change in the specification from clients and the constant drive for innovation make planning seem useless. Another challenge is that the projects are dependent on the Naval Architect, as all the formal communication was routed through this key actor, creating an information hub around the Naval Architect with the possibility of information overload. The routing of the formal communication increased information loss, which could have caused design flaws. However, the autonomous informal communication solved these challenges. Additionally, the formal communication procedures set up by the client could not adapt to the rapid informal communication, which created challenges and frustration among the designers. The DM said his main task was "chasing" decisions for his team so they could move on.

The AEC-project had difficulties with following the schedule and adjusting it when needed. They had a collaborative planning session where they created the design schedule, but they did not use or update it. While the initial schedule looked like a good plan for the project, it was quite clear that the different disciplines had difficulties communicating what they needed from each other to complete their work. Another challenge for the AEC project was the fragmented team and the fact that the contractor was not involved in the early design phase. The fragmentation did cause some issues, threatening the trust between the different disciplines. This was made clear when the design manager did not want to share his model with the contractor because it was not finished, and he was afraid that the contractor would use it as if it was ready for construction.

Table 1 summarizes the challenges with the planning of the design process in the different industries.

Table 1: The main challenges with planning in the design process

	AEC	OC	SB
Contract models	▪ Design-Build were the contractor manage the design process	▪ Engineering-procurement-construction	▪ Engineering-procurement-construction
Communication	▪ Different disciplines have difficulty communicating actual information needs between each other	▪ Long lead time on formal communication channels	▪ Focused on Naval Architect, caused slow decision making
Team	▪ Fragmented teams ▪ Lack of trust between different disciplines	▪ Decisions across the different teams (DES, DSM, MSF)	▪ Culture with a high degree of specialisation ▪ Autonomous culture
Planning	▪ Follow the schedule and reschedule when needed ▪ Decisions	▪ "Chasing" decisions ▪ Lagged planning between the parts (DSM, DES, MSF)	▪ General belief that the project is too complex for planning

As shown in

Table 1, the main challenges with planning in the building design process are related to difficulties communicating information needs, fragmented teams, and problems with following the schedule. The different disciplines in a building design team seem reluctant to plan their work and prefer to handle tasks ad hoc.

Initiatives to improve planning in building design management

There are three elements that the authors think could benefit from the planning of the building design process in AEC-projects.

First, the importance of the schedule during the design process needs to be increased. The OC-project had a tighter follow-up on the schedule and managed to utilise resources better than the AEC-project. Second, the BIM should be used collaboratively as a communication and development tool. BIM increases the understanding between disciplines and displays solutions for decisions. Third, LOD should be used in the planning of the design process. By setting the maturity of an object at a given date, it is easier to know if the designers are on plan and what valid information can be extracted from the BIM at that time.

In addition, the findings showed that both the SB- and OC-project participants were more autonomous with clearly defined roles than those in the AEC-project, which Bell and Kozlowski (2002) highlight as important to successfully dealing with complex tasks.

The authors of the current study propose that the AEC industry use CPD and adapt the LOD-definition in every project. The LOD system proposed by Abou-Ibrahim and Hamzeh (2016) is a good measure to ensure a structured design process; however, the system is complex and might not fit all projects. As stated by Borrmann et al. (2014), a pre-set definition of LOD might not work for each project because each project is different in some way. The standard system is too rigid to fit all projects; consequently, LOD values must be defined for each project. The team should then agree on the different LOD values, developing a plan showing the development of the BIM. After, they can utilize the "start-up meeting" in CPD, where each team member gets to know each other and the project collaboratively before the planning the design phase. This is in line with how the OC-project focused their design plan on maturity levels on the model. Where they colour-coded the different areas of the model according to their maturity, the AEC-industry could do the same with LOD values. With a colour-coded system, the authors want to eliminate misinterpretation of the BIM by design team members, and the colour makes it easy to see how mature each element is in the model. Figure 3 shows a conceptual model of the design workflow in a LOD-decision plan.

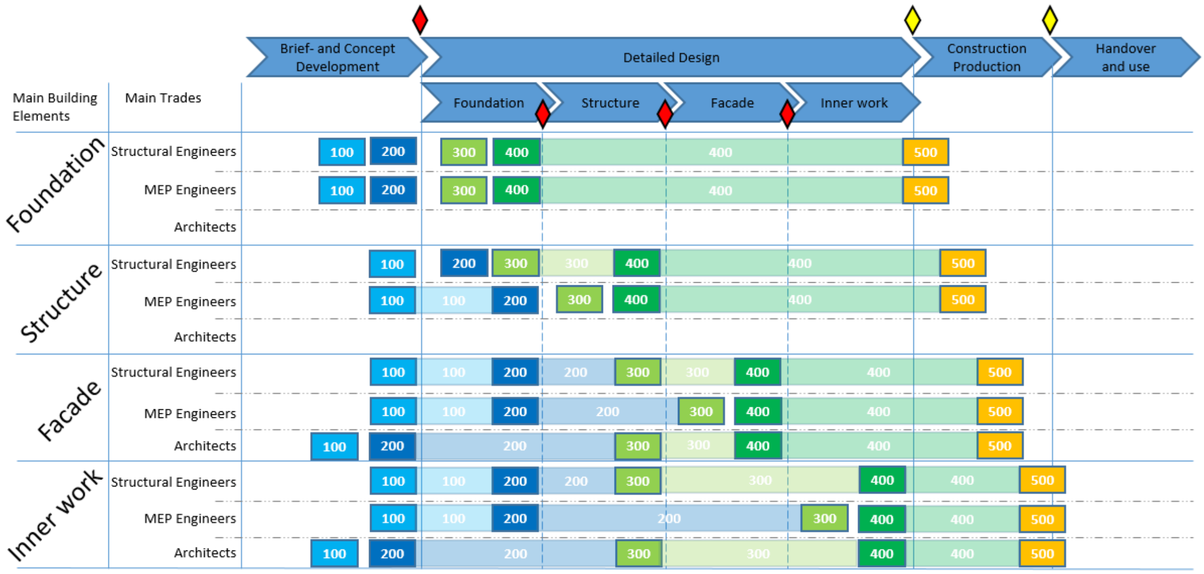

Figure 3: Conceptual model of workflow in a LOD-decision plan

In Figure 3, the workflow is represented by LOD values, where LOD 100 represents a draft and LOD 500 represents the final "as-built" element in the model. On the y-axis, the process is divided into the most common main building elements and the trades in a building process. The x-axis consists of stages in the building process, where detailed design is divided into a different phase for each trade. The order of the trades follows the natural way of constructing a building, which is to start with the foundation then the structure, façade, and finally the inner work. The diamonds after each phase mark important decision gates. The LOD values in the figure show the progress of the workflow for each building element and trade. If construction of one of the main building elements starts before the design process is finished, the LOD-decision plan should show deadlines for delivery of the final production blueprints.

The conceptual model in Figure 3 is supposed to be used for planning decisions and workflow of the design. The precondition for the LOD-decision plan is that each delivery in the plan is a commitment of work to be done or a binding decision to be made.

In the investigated AEC-project, which was without a LOD-decision plan, the structural- and MEP Engineers could have first designed the structure to LOD 400 and then the underlying foundation to LOD 400. If the engineers then come up with a good idea for the foundation that requires changes in structure, the decision makers would have two main options. First, they could reject the good idea or second, they could implement the good idea for the foundation, re-design the structure, and pay the cost difference. Without a LOD-decision plan, although it may be possible to do both large and small iterations on the building elements till construction production starts, it could be costly and cause a lot of re-work

In a project with a LOD-decision plan, the structural- and MEP (Mechanical, Electrical and Plumbing) engineers need to know that foundations are on LOD 400 (checked and ready for production, without room for iterations) before they can progress with designing structure (with room for iterations) to LOD 400. The LOD-decision plan helps the engineers to do the iterations in the right sequence. Large iterations can be taken early, but when reaching higher and higher LODs, the possible iterations become smaller and smaller. A LOD level marks the last responsible moment for decisions, and large iterations should, therefore, not be taken on elements that have reached a high level. Similarly, the foundation must have reached a higher LOD than the structure, etc. The LOD-decision plan still allows for positive iterations on elements that have low enough LOD values and it will make the design process more structured.

The LOD-decision plan is a conceptual model meant as an illustration of how LOD could be used to plan the design workflow and important decisions in a project. Using a LOD-decision plan opens new ways of illustrating the schedule and dependencies amongst disciplines. In the focused group interview with ten design managers, the authors showed how the LOD values with colour-codes illustrate the workflow by using 4D. Figure 4 shows a picture from the 4D representation of a small building in a fast-track project. The blue colour represents the progress of the physical construction work, while the orange colour represents the current LOD values of the elements in the model. The actual construction progress is, therefore, linked to the design progress. All participants in the focused group interview saw potential in this way of presenting the schedule, as it could rectify the difficulties designers sometimes have with communicating what they need from other trades to progress with their work.

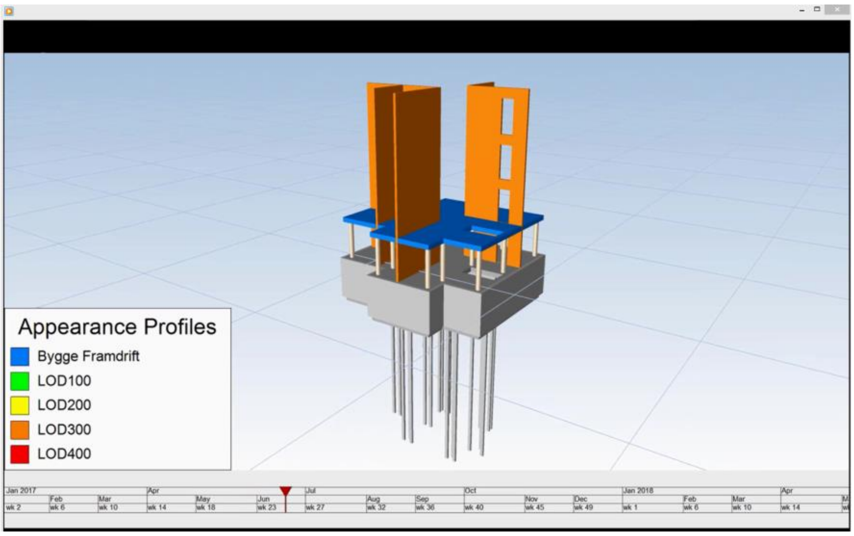

Figure 4: A movie capture of a 4D presentation of LOD and BIM workflow on a project.

Conclusions

This article set out to learn more about how building design management can learn from other comparable industries. Based on previous literature and case-studies, the article compares the management of the design process in three different industries and investigates specific challenges regarding the planning of the building design process. Although the LOD model stems from discussions with designers and design managers working on Nordic construction projects, the authors suggest that it could be generalized to other countries as well. Three research questions were posed based on case studies of the AEC, OC, and SB industry.

The first research question required describing what characterizes the planning processes in the different industries today. Our research shows that there are some differences in the planning processes; however, all industries face the same challenges with interdependencies in the design process, as illustrated in figure 1. As depicted in figure 2, the industries handle these challenges differently. The OC chose a more parallel design development strategy. The process was structured and had a strong focus on the plan and re-plan. Each area of design was colour-coded according to its maturity level to better communicate the progress in the BIM-model.

The second research question is to answer how the challenges in the building design process stand out from the other industries. The AEC industry, compared to the OC and SB industries, have more fragmented teams. Both the OC and SB have in-house design capabilities with good working experience, contributing to more autonomous work progress. Further, the OC has more focus on planning and re-planning throughout the whole design process.

Finally, the third research question was how to improve planning in the building design process. Based on the research, this article proposes a conceptual model of workflow in a LOD-decision plan. LOD is not a new concept in the AEC industry, but implementation on construction projects has not been as straightforward as desired. OC has had greater success with the implementation of a similar concept with shown maturity levels, so a comparison of what they had done to benefit the building design management was presented. Furthermore, based on the principles of Lean Planning, this conceptual model proposes to define the LOD not only based on pre-set definitions (e.g. AIA) but through a collaborative agreement in the project through CPD. The model is believed to increase the design teams' understanding and commitment both to the use of BIM in the project and to the planning of the design process.

Altogether, this article addresses a problem of planning in building design: to make comprehensive design information handoffs. Visualizing and communicating to align better the plan with the design team is important. A natural next step is to try the conceptual model and use CPD with LOD in a project.

Supplementary material

The main author of this paper has made a movie (figure 4) available on YouTube. The movie shows how LOD can be manifested into BIM and how 4D planning can be used to coordinate design and construction plan in a visual form: https://youtu.be/VFTli-bwy5w

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