A Lean Design Management Process Based on Planning the Level of Detail in BIM-Based Design

18

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Abstract

Few construction companies apply the available lean tools and processes in an integrated manner when managing design. Additionally, various lean design management -tools and -processes have each their own strengths and optimal phases in project when to apply them. Earlier approaches in lean design management have not explicitly included level of detail of BIM-models in connection with planning methods in an appropriate manner. For example, the Last Planner System (LPS) is a planning and control system that uses collaborative social methods to get task dependencies and commitments from project stakeholders, but it does not provide any guidance what those tasks should be in a BIM-based process. On the other hand, location-based methods such as Location-based Management System and takt planning have provided guidance for scheduling production by using (LPS). Thus, by combining information from various sources we were able to define a location-based design management process using the concept of level of detail that can be integrated with LPS. The level of detail definition must start from the end-user of the information in each stage of the construction project. The model was co-created and validated in focus group meetings with design and construction companies. In future research we will run case-studies to test the model in real-life settings.

Keywords

Level of detail • Lean design management • BIM • Last planner system

18.1 Introduction

Lean design management (LDM) has contributed in achieving remarkable results related to adding customer value, reducing project cost and increasing collaboration among project parties (e.g. [1–3]. Various LDM-tools and -processes each have their own strengths and optimal phases in project when to apply them [4]. However, few construction companies apply the available lean tools and processes in an integrated manner and much greater benefits could be gained by combining the tools and processes to exploit the synergies between the various tools [5]. In this paper we look at LDM process from construction project perspective assuming early involvement in BIM-based design. The authors of this paper are aware of LDM's technical and social aspects, however, this paper focuses on technical side of both LDM and information flow.

The goal of this study is to propose a process for design management by applying optimal lean tools and processes for managing BIM-based design. The process aims to eliminate production delays caused by missing or incorrect design, as well as minimizing the rework required from the design team caused by excessive level of detail too early in the process [6]. The project's production strategy determines the milestones which are the basis for scheduling Level of Detail (LOD) of

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information. Each LOD is based on information requirements for various end uses of design: permit process, procurement, prefabrication or installation. The planning of LOD needs to be pull-based process pulling from a location-based production schedule.

18.2 Background

18.2.1 Lean Design Management

Lean construction and lean thinking in design management have been studied for several decades [3, 7]. Lean design management is a collection of lean methods, tools and social processes that can be used to facilitate design [5]. Lean principles promote a structured means to improve the entire system. Lean in design management reduces waste and improves value and information flow [8].

The information in design management process adds value when it is transparent and flowing [8]. A superb tool for improving information flow and transparency is the Dialogue Matrix (DM). DM promotes common understanding and facilitates dialogue especially in meetings between project party. The matrix identifies preconditions for design tasks and supports the pull logic. DM is structured to record questions from team members to other team members. Answers to those questions are systematically tracked in the matrix [9].

Another system to manage design as well as production is the Last Planner System (LPS). LPS is a well-known, collaborative, commitment-based, mainly social process, that integrates (1) *should*—setting milestones and strategy as well as specifying handoffs and identifying operational conflicts, (2) *can*—making work ready and re-planning when needed, (3) *will*—making promises in weekly work planning, and (4) *did*—measuring success with PPC (plan percent complete) and acting on reasons for task failure [10]. The four levels of LPS scheduling are also called, master schedule, reversed phase schedule, look-ahead schedule and weekly schedule.

LPS uses the collaborative social methods in reverse phase scheduling (also called pull planning) to get task dependencies and commitments from project stakeholders [11], but it does not provide any guidance what those tasks should be in a BIM-based process. On the other hand location-based methods such as Location-based Management System (LBMS) (e.g. [12]) and takt planning (e.g. [13, 14]) have provided more structure for scheduling production by using LPS. In takt planning, takt refers to the regularity or intervals of tasks performed. Hopp and Spearman [15] defined Takt as the unit of time within which a product must be produced to match the rate at which that particular product is needed. In other words, balancing the supply rate to match the demand rate. Originally Takt time was developed for manufacturing, but since it has been applied in construction production, the results have been promising (e.g. [16]).

18.2.2 Level of Detail in BIM-Based Design

BIMForum, the US chapter of buildingSMART international, has promoted reference standards of LOD (Level of Development) for the construction industry to yield. Earlier approaches in LDM have not explicitly included LOD of BIM-models in connection with planning methods. LOD is a process where building information models and the complexity of their components progress from the lowest level of conceptual representation to the highest level of detail based on component's use, for example for fabrication or installation needs [5, 17, 18]. However, determining an appropriate LOD for each element is only part of the solution, and so far it has been considered in isolation with limited connection to design schedules. The total time spent in modeling increases vastly when going from LOD to another [18]. If changes occur, those hours spent developing the model in too much detail ahead of the actual demand would be considered waste.

Another system to manage detailed design is a method called Location-based Design Management (LBDM). In LBDM detailed design is done in production determined clusters and is managed by location. LPS is used to manage design hand-offs. LPS pull scheduling is implemented so that milestones are formed by every location and a location-based production schedule is driving the design so that modelling and document production is using the same locations as construction and they are sequenced in the order of construction [5]. However, the method did not consider explicitly the level of detail of information. We argue that the combination of these two technical approaches could be a powerful way to enhance design management in a BIM-based project.

18.3 Method

The method is design science research where we attack a real world problem [19], which was identified as the poor connection between production and design schedules. The process was developed by combining earlier research and best practices related to BIM scheduling processes. The developed solution artifact is a lean design management process, which was validated in a focus group meeting. Focus group discussion is a sound method of collecting group of professionals with similar experience from the same field as well as unravel their shared views and understandings of the subject at hand [20]. The focus group participants were invited from 13 Finnish design and construction companies. Each member of the focus group held a managerial position. The feedback and the general consensus of the focus group related to design management process helped the authors to validate and refine the technical and social parts of the process.

To get oriented in current status of design management in Finland, the research team conducted eight semi-structured interviews for construction professionals from several Finnish construction companies. Each of the interviews was recorded and the average length of interviews was 50 min. Before every interview, the interviewees were briefed on the purpose of the study.

18.4 Current Design Management Processes and Challenges in Finland

The interviews revealed the following details about design management practices in Finnish construction industry: (1) LPS is extensively used in construction companies, (2) LOD specifications are known at the end of project, but forecasting when those specifications are needed in middle of project is hard. (3) Designers are frustrated at the current process where constructors demand too detailed design too early in the project. (4) Constructors are aware that they demand too much information too early in the project. (5) Designers question constructors early design demands. (6) Design demands are generally divided into work packages for procurement reasons but there is no common understanding among project stakeholders of what information is required for each procurement package.

18.5 LDM Overall Process

Technical system of the proposed LDM overall process is based on Last Planner's four phase scheduling. Different techniques and tools are used on different levels and they link to production schedule differently. The developed process is a combination of LOD, LPS, BIM, LBMS, LBDM and Takt scheduling. The novelty of the LDM Overall process is in scheduling LOD of building information models using location-based methods and then using LOD to implement LPS. Table 18.1 presents the main components and sources of the LDM Overall process.

Master design schedule. At this level, the design schedule is integrated with its equivalent counterpart—master schedule of production. Master design schedule is based on controlling the LOD of information and BIM models as well as linking the design schedule to production demands. Building permit, procurement, pre-fabrication and installation are associated with individual information demands. Those information demands need to be defined at the beginning of the project. Some of the systems and information demands can be location-based, in which case their demand-times are defined by locations.

Table 18.1 LDM overall process and its main components

Scheduling phase/component	Description	Original source
Master design schedule	Linking the production schedule to information needs and milestones based on project teams decisions and production strategy	LPS + LOD (BIM) + LBMS/TAKT + LBDM
Phase design schedule	Collaborative pull plan meetings	LPS + LOD (BIM)
Look-ahead schedule	Combination of look-ahead scheduling and DM	LPS + DM
Weekly schedule	Weekly meetings for the project team	LPS
Measuring success	PPC	LPS

The LOD requirement is presented in numbers as a function of time. The adjusted examples are stemming from the BIMForums LOD Specifications [21]. LOD 350 contains information demanded by installation and that information must be ready before the first task, related to that particular system, starts. LOD 325 contains information demanded by pre-fabrication and that is scheduled with a delay from LOD 350. LOD 325 is a coordinated and clash-free model. LOD 300 is a model where model-elements are flawless and their position accurately defined. In LOD 290 all the necessary model elements and their accurate geometry is in the model, but the elements are not yet positioned as accurately as required for LOD 300. LOD 200 contains preliminary designs. Each LOD and the documentation related for that particular LOD is attached to the master design schedule. The idea is to schedule the demand for information and coordinating that demand to construction process.

In order to tie this idea to a location-based schedule (such as takt or LBMS schedule), the following issues should be defined: (1) what information is demanded and when, (2) what information can be developed by locations, and (3) what information is developed by systems. Here, the information is mainly referring to BIM-based information, however information may also be presented in other forms than BIM. To each transition, from one LOD to another, a responsible organization is needed. An example would be an interface between a trade partner and a designer.

Figure 18.1 presents an example of linking design tasks to production tasks that are location-based in a takt or LBMS schedule. The example here is a design and manufacturing of pre-cast concrete elements and installing them from floors 2 to 6. The information needs are different in each phase. For example installer requires more detailed design in installation phase than pre-cast company for making a bid in procurement phase. Before yellow area (LOD 290) is pre-planning. Procurement-level information (LOD300) is developed during the yellow area. Both of these areas are designed system-based (the LOD milestone happens at the same time for each milestone). Design for prefabrication (LOD 350, blue area), can continue location-based and the design can become a part of takt train at this point. By the time installation starts in the first red square the design must contain all necessary information for installation (LOD 400). Each LOD milestone is used as a phase scheduling milestone, and the lower part of the schedule can contain design tasks that are not location-based but have dependencies with the location-based design tasks—red arrow lines indicate examples of dependencies between other tasks.

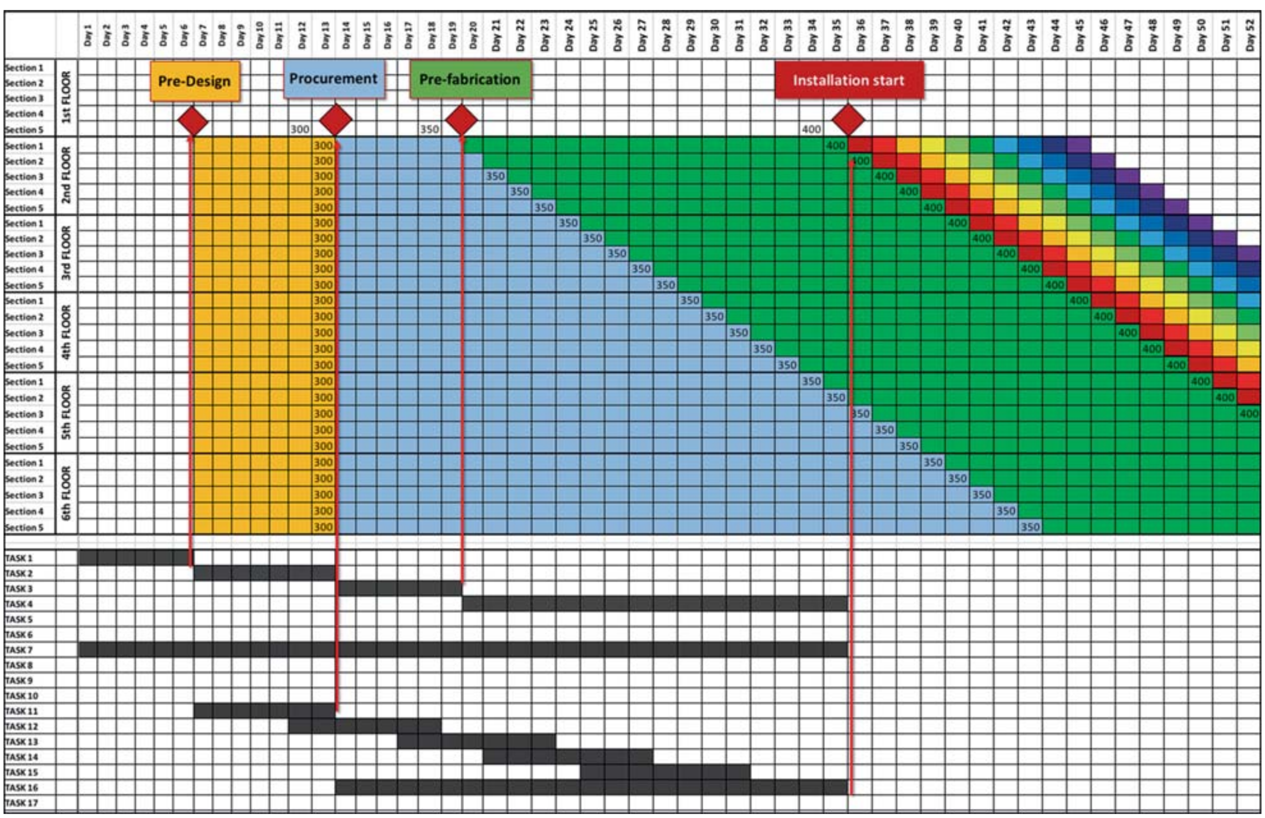

Fig. 18.1 Linking the design LOD's with the production takt time. Vertical axis presents locations and horizontal axis presents time

Phase design schedule. The basis of phase design schedule is performed as a standard LPS reversed phase schedule. LOD-demands from master design schedule act as milestones. These milestones are either one system or several interconnected systems, such as structural frame work, interior finishes and HVAC coordinating. Reversed phase schedule is performed by starting to pull from finished product. Project team consist of general contractor, trade partners and the designers.

First, the project team needs confirmation about mutual agreement of the final result of the phase (e.g. [22]). The final result embodies of what information demands are needed at the end of the phase. Second, start from the end and move towards the beginning. When placing a post-it note, the person requests information from the other project party. The focus is to progress based on information demands rather than listing each party's design tasks. The objective of this procedure is to delete unnecessary tasks. The results from these unnecessary tasks are not demanded by anyone.

A complementing tool to resolve task dependencies, would be Design Structure Matrix (DSM). DSM is a tool where tasks are defined, their relation and information need from other tasks, and from that information an optimal task sequence is indicated in the matrix [23, 24]. Although DSM and LPS have overlapping properties, and the fact that DSM is more technical tool and lacking the social aspects of LPS, the use of both tools would add to information flow inside the project.

Project team needs to resolve if each location where takt time work starts counts as a milestone. This resolution depends on the decision made on the master design schedule level—what parts of the design is performed location-based. Similar to production, the phase schedules of each similar milestone are likely to be very similar, so pull scheduling could focus in detail on just one milestone and then the team can determine any differences between locations that would necessitate variations from the template phase schedule.

Look-ahead design schedule. The basis of this phase conducts standard LPS look-ahead scheduling. The overall process adds more structured way of tackling emerging obstacles by combining the use of DM into this phase. All the questions, asked from other project party, are then documented using DM. Answers to those questions will turn into tasks for the answering party. Generally questions are equivalent to obstacles in LPS's backlogs.

Validation. Authors of this paper presented the LDM Overall process in the focus group meeting for validation. The focus group shared couple of concerns. The first concern was how the Overall process would operate with different project contract types where level of detail requirements for different phases are very different (e.g. fixed price requires almost completed design at procurement). The solution would be to have a project-based specification of LOD requirements at each step. The second concern was how to choose those design tasks that should be scheduled location-based and how to choose those design tasks that should be dealt based on a system. This is an open research question which can be addressed in future research. In general, all the focus group participants were ready to accept the concepts and liked the schedules simplicity and the visual performance. The model conceptually answers the requirements. However, implementing a full design schedule is required in future research in order to understand its usability in practice.

18.6 Conclusion

Good best practices were found from case-projects, interviews and earlier research, but each one only solved a part of the problem. By combining information from various sources we were able to define a location-based design management process using the concept of LOD that can be integrated with location-based methods and LPS. The LOD definition must start from the end-user of the information in each stage of the construction project. For example, to start procurement we do not need final positions of each building information model element, but we need a way to estimate the quantity of work and risks to come up with the price estimate. For pre-fabrication we need fully coordinated building information model to ensure that the pre-fabricated parts fit without field rework. For installation the BIM-based design must include all the necessary details required by the workers. Design for pre-fabrication and installation can be location-based and can be pulled by production schedule.

The overall design schedule is partially activity-based and partially location-based. The LPS is used to elaborate the design schedule and get to the level of commitment of individual designers and verify starting data requirements and required decisions for each design task. In this way the process involves several stakeholders: the owner, architect, engineers, and the general contractor as well as trade contractors. The model for LDM Overall process was co-created and validated in focus group meeting with engineering and construction companies. In future research we will run case-studies to test the model in real-life settings.

Related to the design management challenges revealed from the interviews of Finnish construction professionals, the LDM Overall process argues to invalidate them. Since LPS is already extensively used in Finland it would be fruitful to intensify design management to collaboratively manage the timing and the level of details and designs in a project. If every project party would commit to their task, there would be no need for constructor to demand too detailed design too early in project. The LDM Overall process steers the project stakeholders to thoroughly, and in a structured way, discuss upfront about the information need and its interdependency with building information models related to each procurement package, thus increasing common understanding among the project team. The Overall method also has a potential for removing waste in current BIM modelling process by scheduling accurate LOD of building information models based on pull from production demands. When committing to the scheduled LOD-based milestones, project team has the potential to decrease the need for modelers to advance their models into too detailed level based on assumptions thus facing the risk of possible remodeling when changes occur.

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