

COLLABORATIVE DESIGN MANAGEMENT

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ABSTRACT

So far, Lean Construction has exerted a far greater influence on the production aspect of construction than on its design. However, Koskela and Ballard – the authors of what are to date the two most influential contributions to come from Lean Construction – both regard their respective input as no less relevant to one of these aspects than to the other.

The theory hypothesis of this paper is that *Lean Construction and the Last Planner System™ principles are equally relevant to design and production in construction.*

The study is based on the design process in design-build contracts, where design is partly carried out in parallel with construction, and the completion date is fixed. Literature studies of the design process indicate that the hypothesis is partly true. However, the findings of this paper indicate that the design process has certain characteristics that makes it fundamentally different from the production process.

This paper argues that the design process should be defined as consisting of three phases, involving three different management strategies. The decision making process is identified as an integral part of the design process. A relationship between design and production plans, and six preconditions for the constraints analysis in design processes, are proposed.

KEY WORDS

Design management in construction, Preconditions for design, Decision making.

INTRODUCTION

The two most influential contributions to have come from Lean Construction are the Transformation-Flow-Value (TFV) theory of production (Koskela 2000) and the Last Planner System™ (Ballard 2000). Both Koskela and Ballard see their contributions as relevant to construction design and construction production alike. Nine years after these seminal works were written, Ballard returns to the same question (in Ballard, Hammond and Nickerson 2009), and reaches the same conclusion: “*The Last Planner principles, functions and methods (...) appear to apply to the work of design*”, but he adds that “*future research is needed on a number of issues and questions*”. Despite this assertion of the scope of the relevance of the principles, Lean Construction has had far more influence on production than on design.

The hypothesis of this paper is that *Lean Construction and the Last Planner System™ principles are equally relevant to design and production in construction.*

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In order to study the application of Lean Construction and The Last Planner System™ to design, one must understand in what ways the design and production processes in construction are similar; in what ways they differ; and how they are connected. The approach to this task adopted here will be to examine selected works of relevant literature to find out how the design process in construction can best be characterized. This includes the study of design phases; of the relationship between the planning processes of design and construction; and of which preconditions for design tasks may be appropriate for the constraints analysis in the lookahead planning of design.

WHAT IS DESIGN MANAGEMENT?

In English ‘design’ is both a verb (‘to design’, that is, an activity or a process) and a noun (‘the design’, that is, the outcome of the design process). In its most basic sense, design management is about managing the design process (Best 2006). Design management is about how to manage, not about how to design (Gray and Hughes 2001).

Construction projects can be carried out in a wide range of contractual and organizational models. This paper approaches the topic from a general contractor’s point of view. The interest is focused on the management of design in the construction phase of design-build contracts, that is, management of the design process which is to a large degree carried out in parallel with construction. The completion date is usually fixed.

Design in construction is a complex process and the constructed building is a complex product. Due to the internationalization of design, the increase in wealth and the dramatic increase in specialist knowledge, complexity is growing (Gray and Hughes 2001). In large projects several of the specialists (architects, structural engineers, etc.) need to conduct their own internal coordination and management. These activities are not referred to as ‘design management’, however. In this paper ‘design management’ means the common management and leadership⁴ of the design process and the relation of this process to production in design-build contracts.

WHAT KIND OF PROCESS IS THE DESIGN PROCESS?

In Thompson (1967) the agenda is to analyse organizations as such. Thompson examines the interdependencies of parts of organizations, and divides them into three groups:

1. *Pooled interdependence*. This is a situation in which each part renders a discrete contribution to the whole and each is supported by the whole.
2. *Sequential interdependence*. In this case the interdependence takes a serial form: X must act properly before Y can act, etc. A sequential interdependence is therefore always also pooled (but not the other way around).
3. *Reciprocal interdependence*. This is a situation in which the outputs of each part of an organization become inputs for the other parts.

Activities within the organization have to be coordinated, and Thompson finds that there are three types of coordination:

⁴ The distinction between management and leadership in construction projects is discussed in Andersen, Bølviken, Dammerud and Skinnarland (2008).

1. *Coordination by standardization.* This involves the establishment of routines or rules. We can expect to find coordination by standardization in organizations with pooled interdependencies.
2. *Coordination by plan.* This involves the establishment of schedules. We can expect to find coordination by plan in organizations with sequential interdependencies.
3. *Coordination by mutual adjustment.* This involves the transmission of new information during the process of action. We can expect to find coordination by mutual adjustment in organizations with reciprocal interdependencies.

Reinertsen (1997) sees design as the generation of information, in contrast to manufacturing which generates products. From this he derives some fundamental differences between design and manufacturing:

- Design is nonrepetitive, a one-time process.
- The cost of making changes throughout the design process increases exponentially.
- Requirements often change during the design process.
- The design process has much variability, and variability is the source of the value creation of design.
- Design is an inherently expandable task (a better solution is always possible).

Ballard (2000) sees design as the production of requirements for the physical production ('making'). Considering the nature of the design process, Ballard observes the following:

- The design process is not merely about determining the design criteria and then applying those criteria in the production of the design. Design is, rather, a process of negotiation and adjustment (oscillation or conversation) between criteria and alternatives, a progressive determination of both ends and means.
- In the design process everything is connected to everything. What is being designed is one whole, so parts have the logic of the part to the whole, potentially conflicting properties, etc.
- Design is a learning process.
- The design process cannot be determined in advance; overly 'rationalistic' models of problem solving processes are therefore inappropriate.

Koskela (2000) first examines the differences between physical production and design from the operations management's point of view, and then proceeds to examine design through his TFV concept. From the operations management's point of view he finds the following:

- There is much more iteration in design than in production.
- There is much more uncertainty in design than in production.
- Design is a non-repetitive activity, whereas production is often repetitive.
- In the design phase, the customer requirements are translated into a design solution. In the production phase, this design solution is realized. Thus the functional performance is determined in the design phase.

From the transformation⁵ point of view he observes the following:

- Design is seen as a sequential process based on a work breakdown structure (hierarchical decomposition).
- Design is seen as a process through which needs and requirements are converted into descriptions of the product by means of decisions and problem solving.
- Design management is focused on coordination of the whole and enhancing of the efficiency of individual tasks.

From the flow point of view, Koskela finds the following:

- Design is seen as a flow of information, in which a piece of information may be in one of the following four stages: transformation, waiting, moving, or inspection
- The design process is seen as one of three basic flows in construction projects. The other two are the material process and the work process (Koskela 1992).
- Changes in requirements are seen as disruptive.
- Iterations may be needed.
- Improvement is seen as eliminating waste and shortening design time.

From the value point of view, he observes the following:

- Design is seen as value generation by a supplier to a customer through fulfillment of customer needs and requirements.
- The needs and requirements are captured and converted into a product or service delivered to the customer.
- Due to conflicting needs and requirements, tradeoffs have to be optimized.

The design process is a project and can be described through the use of different phase or stage models, for example the following (Best 2006):

1. *Design strategy*, where design projects and initiatives are conceived.
2. *The design process*, where design projects and agendas are developed.
3. *Design implementation*, where design projects and outcomes are delivered.

Cooper and Press (1995) divide the design process into an internal creative process and an external productive process. Gray and Hughes (2001) also make a similar distinction.

THE LAST PLANNER SYSTEM™

From a Scandinavian perspective, the two most significant contributions of the Last Planner System™ have been the introduction of:

- The phase scheduling process using post-it notes
- Constraints analysis as part of the lookahead process

The collaborative approach to the phase scheduling has produced common understanding and commitment. The constraints analysis is based on the seven

⁵ In Ballard and Koskela (1998) the term ‘conversion’ is used.

preconditions for successfully undertaking construction tasks as described by Koskela (1999) and visually illustrated by Bertelsen (2003):

1. Construction design (renamed 'Information' by Bertelsen)
2. Components and materials
3. Workers
4. Equipment
5. Space
6. Connecting works
7. External conditions

Being both theoretically based and intuitively understandable, the seven preconditions have been viewed in Scandinavia as an integral part of the Last Planner SystemTM.

The Last Planner SystemTM has a plan hierarchy of four levels, where the weekly work plans constitute the lowest and most detailed level. The organizational units in the week-to-week planning are the crafts and crews. Veidekke's (2008) modification of the Last Planner SystemTM indicates a need for a fifth plan level: the crew plan, where tasks are assigned to individuals.⁶

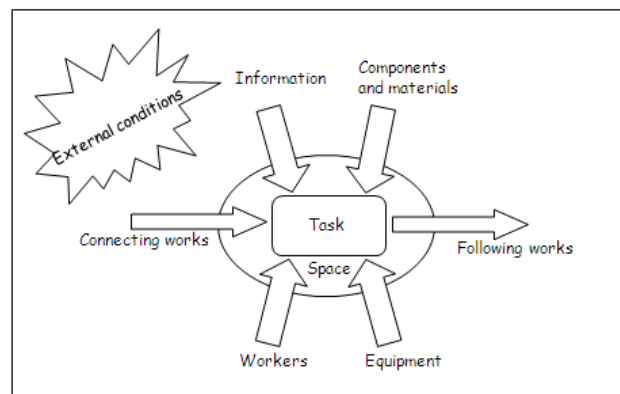


Figure 1: The seven preconditions for construction tasks as illustrated by Bertelsen (2003)

WHAT KIND OF PROCESS IS THE DESIGN PROCESS? – DISCUSSION

The most interesting findings from the literature review are that the design process has much variability, and that variability is the source of the value creation of design (Reinertsen 1997). This observation challenges the distinction between waste and value, a distinction which may only be made with difficulty or not at all in relation to design processes.⁷ Waste reduction and reduction of variability are traditionally seen as basic *lean* strategies. This paradox may be one of the reasons for the limited application of Lean Construction and The Last Planner SystemTM to design processes.

Reinertsen (1997) also identifies a very interesting feature of design: it is an inherently expandable task, as a better solution is always possible. From the value point of view, Koskela (2000) describes the need for optimising trade-offs, due to conflicting needs and requirements. Ballard (2000) supports this view by describing design as a process of negotiation and adjustment. To end an inherently expandable

⁶ Ballard, Hammond and Nickerson (2009) also comment on a fifth level of plans.

⁷ Josephson and Saukkoriipi (2005) make the same observation based on empirical studies

task, make a trade-off, or to end or make progress in negotiations, *decisions have to be made*. Whereas the completion of manufacturing processes requires physical action, design tasks and processes are completed *by means of decisions*. The decision making process may therefore be identified as an integral part of the design process.

Koskela (2000) is also relevant, as he describes design as the translation of customer requirements into a design solution. Seen in relation to Reinertsen (1997), Koskela (2000), and Best (2006), this suggests that design needs both a creative phase with much variability (translation), and a more streamlined phase in order to materialize the solution into product documentation (information). Inspired by the presented literature, the argument is made in this paper that the design process should be defined as consisting of three different phases:

1. *The design creation process*, where the design is invented.
2. *The design production process*, where the decided design is documented in writing, drawings and models, and communicated to the production organization.
3. *The decision making process*, where it is decided what to construct or on what to base further design.

These three phases can be seen as the phases of a sequential process where designers first work out one or more designs, and then, after deciding what to construct, work out the construction drawings and specifications. On the other hand, there can also be iterations between the three phases. For example, the decision-making process may end in a conclusion that none of the present designs are to be accepted, and the production of construction drawings and specifications may demonstrate that the chosen design will not work as intended.

Decision making is a phase connecting the creation phase with the production phase of design. On the other hand, decision making is also an integral part of each of the two other phases. Both the progress and the completion of the design process depend on the making of decisions. Each of the three phases of the design process can be characterized according to a dominant logic. With reference to Thompson (1967), these dominant logics can be used to identify the main management strategies of design management:

1. *The design creation process* is basically characterized by reciprocal interdependences, and the main management strategy should therefore be dialog and mutual adjustment. Because the design creation process also has sequential elements, this strategy should be supplemented with collaborative planning elements.
2. *The design production process* is basically characterized by sequential interdependences, and the main management strategy should therefore be collaborative planning. Because the design production process also has reciprocal elements, this strategy should be supplemented with elements of dialog and mutual adjustment.
3. Because *decision making* is both a separate phase connecting the two others and an integral part of each of these, it can be characterized by both sequential and reciprocal interdependences. Decision making will therefore have to be managed through collaborative planning as well as dialog and mutual adjustment.

The Last Planner System™ and other basic *lean* strategies are relevant for phase 2, but for phases 1 and 3 other main management strategies are needed. This indicates that this paper's hypothesis is partly true.

COLLABORATIVE DESIGN MANAGEMENT

Collaborative Design Management is a design planning and management system which applies Lean Construction and The Last Planner System™ principles to design in the construction phase of design-build contracts. Being a conceptual response to this contractual model, Collaborative Design Management focuses primarily on the design production and decision-making processes, and only secondarily on the design creation process. Among the important goals of this concept of design management are compliance with contractual demands regarding cost, time and quality; buildability; adequate quality; and on time delivery of design documentation.

The Last Planner System™ levels of planning are not adequate for the design process. As decision making is identified as an integral part of the design process, the decision-making plan must be included in the plan system. Veidekke (2008) also indicates that a new plan level is needed: the crew plan, which assigns tasks to individuals. The dialog matrix is not a plan as such, but a tool that has proved its ability to facilitate dialog and mutual adjustment. Thus, Collaborative Design Management defines the following plan levels; *Master Schedule, Phase Schedule, Decision Plan, Lookahead Schedule, Two Weeks' Work Plans, Crew Plan and Dialog Matrix*.

Master Schedule: Because the scope of this paper is design processes in design-build contracts, the Master Schedule for design is identical to the Master Schedule for construction.

Phase Schedule: This is a schedule for design, worked out through a “post-it process”, similar to the process of working out the phase schedule for construction.

Decision Plan: Planning and management of decision making are identified as integral parts of design management.

Lookahead Schedule: As explained above, Scandinavian construction companies have adopted the seven preconditions for construction as fundamental in the constraints analysis for construction tasks.

The question for Collaborative Design Management is therefore: *Which are the preconditions for design carried out in parallel with construction?* The theoretical approach was described above.

Six preconditions are derived in this paper as crucial for constraints analysis in design processes:

1. **Connecting design task** – equal to precondition #6 for construction tasks
2. **Expectations and demands** – design is the translation of customer requirements into a design solution
3. **Dialog** – the process need dialog and mutual adjustment
4. **Decisions** – identified as an integral part of the design process
5. **Manning** – equal to precondition #3 for construction tasks
6. **Methods and tools** – equal to precondition #4 for construction tasks

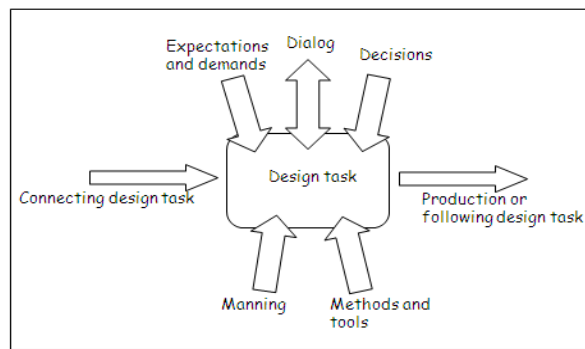


Figure 2: The six preconditions for design tasks

Two Weeks' Work Plans: This is the most detailed plan to be managed by the design manager. It lists the tasks the different designers promise to complete in the coming two weeks.

Crew Plan: In big projects, this is the internal plan of the different design companies, where they assign tasks to individuals. Because this is an internal plan for the different design companies, it is not one to be managed by the design manager.

Dialog matrix: Dialog is identified as one of the preconditions for design tasks. One common dialog matrix is proposed as a technique to structure parts of this dialog. The matrix consists of questions and answers to and from the parties in the design process. One of the main advantages associated with the dialog matrix is that it establishes a pull logic in the dialog: it is the party needing information or dialog that is obliged to take the initiative.

Since this paper studies design processes in design-build contracts with fixed completion dates, it follows that the planning of production should come first, thus setting the preconditions for the planning of design. If the planning of design indicates that the related plan of production should or must be changed due to an unforeseen design interdependence, both phase plans must be adjusted through mutual adaptation between production and design.

The internal relationship between the different design plans is similar to that of the production plans. The decision plan and the dialog matrix are common plans related to all planning levels.

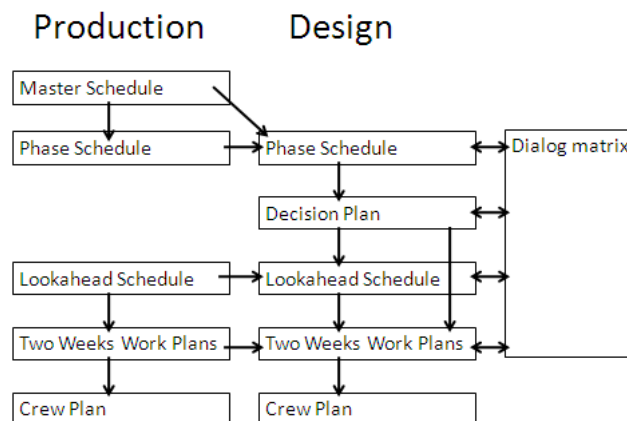


Figure 3: The relationship between plans

CONCLUSION

The objective of this paper is to examine the hypothesis that *Lean Construction and the Last Planner System™ principles are equally relevant to design and production in construction*. The hypothesis is found to be partly true. The findings of this paper indicate that the design process has certain characteristics that makes it fundamentally different from the construction process. Based on these identified differences, this paper proposes that the design process should be defined as consisting of three phases, each of which requires different management strategies:

1. *The design creation process* – main management strategy: dialog and mutual adjustment, supplemented with collaborative planning elements
2. *The design production process* – main management strategy: collaborative planning, supplemented with elements of dialog and mutual adjustment
3. *The decision making process* – main management strategy: both collaborative planning and dialog and mutual adjustment

Decision making is a phase that acts as a connection between the two other phases, but it is also an integral part of both. The design process is contingent on decisions, both for progress and for its completion. The Last Planner System™ and other basic *lean* strategies are relevant for phase 2, but phases 1 and 3 need other main management strategies.

Collaborative Design Management is a conceptual response to the design process in design-build contracts (focuses primarily on phases 2 and 3). The main characteristics of the concept are as follows:

- The three design processes with different main management strategies.
- Integrated relationships between production-, design- and decision plans.
- Six preconditions are used for the constraints analysis in design processes: *Connecting design task, expectations and demands, dialog, decisions, manning, methods and tools.*

The hypothesis may be tested empirically. Feedback is welcomed both in terms of theoretical arguments and practical experience. The consequences of identifying the decision process as an integral part of design management have not been studied. Hopefully, this will be further examined in the future.

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