MANAGING TRANSFORMATION, FLOW AND VALUE GENERATION: A SOLID TIMBER FRAME HOUSING CASE

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A governmental evaluation of the Swedish construction industry indicates the possibility to reduce the production costs of housing through industrialisation, customer orientation and a more efficient construction process. A way to address this is through implementing the concept of lean thinking, which stresses the importance of improving and integrating design and production while eliminating waste. This paper analyses the design process of a recent Swedish solid timber frame housing project by using the concept of lean thinking. The aim is to suggest actions to improve the management of transformation, flow and value generation. For the timber construction process to become more effective (lean) and customer orientated, the timber frame supplier is suggested to increase the information flow and make the flow management more efficient. To establish a better control of the processes in timber housing in particular, the design process must be decomposed into small manageable pieces (time and cost specified) and evaluated within the project team. To increase value generation and make the construction process understood as a generation of value for the client, we think that active clients are the key.

Keywords: Lean construction, Design management, Solid timber frame housing, Project management, Information management

INTRODUCTION

An extensive governmental evaluation of the Swedish construction industry (Yngvesson 2000) indicates the possibility to reduce the production costs of housing construction through industrialisation, customer orientation and a more efficient construction process. A subsequent governmental evaluation shows the Swedish construction industry to have a low degree of competition, yielding small incentives for change (Ericsson 2002). For example, only a few companies are active on the market for flat buildings. A strategy to increase competition in Swedish housing construction, developed on behalf of the government, suggests an increased use of timber (Von Platen 2004). Because timber is a new frame material for flat buildings, it is hoped that this will act as a driver for the necessary change. One possible way to improve construction of customised housing is by combining and applying lean and agile production principles (Naim and Barlow 2003). Lean production has its roots in the Japanese car industry.

Small Swedish construction firms handle a large part of the "actual" production, while the large construction companies focus more on dealing with systems, purchasing products, coordinating and the handling of the financial risk (Ericsson 2002), i.e. the

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large construction companies expect and demand that suppliers develop and deliver system based solutions.

This paper analyses the design process of a recent and unique Swedish six storey high-rise project. The project is considered unique because the frame system is new to the market and the frame supplier is both a supplier and a design specialist. The aim is to use lean construction theory to evaluate a research and development high-rise timber frame project and to suggest actions to improve the management of transformation, flow and value generation within such projects.

CONSTRUCTION AS A PROJECT BASED ACTIVITY

The construction industry is project-oriented. Although every building, road or bridge construction project involves a similar set of process stages, each project is regarded as unique (Wegelius-Lehtonen 2001) because each site is different, and hence each design is different. Also, the team carrying out the project is usually assembled just for this project (Wegelius-Lehtonen 2001). The Swedish construction industry has a limited number of actors who can manage being involved in large projects (Yngvesson 2000). This means that the construction network is static over the long-term as the number of possible actors to invite into a specific project is limited, though in the project specific, short-term the network is dynamic as the actors in the network change during the project (Hellgren and Stjernberg 1995). This also happens when new actors are introduced to the construction market, i.e. solid timber suppliers and designers.

The industry has long and entrenched traditions to temporarily handle the nature of project teams. Although each project is different, it is approached very conservatively in process terms (Cigén 2003, Fredriksson 2003). In fact, there is no process view in a typical construction project, since the project is seen as independent project stages with different actors who have no common goal (Howell 1999,Wegelius-Lehtonen 2001, Bertelsen and Koskela 2004). This division of work in the project network means that organizations are dependent on each other and have to cooperate, while no formal authority that alone can impose the necessary amount of coordination exists (Hellgren and Stjernberg 1995).

From a production point of view, a general definition of the nature of construction considering the surroundings is given by (Bertelsen and Koskela 2004)): "*Construction is complex production of a one-of-a-kind product undertaken mainly at the delivery point by cooperation within a multi-skilled ad-hoc team.*" This definition states that construction is a type of production, conceptualised by (Koskela 2000) as transformation, flow and value generation, Figure 6. Managing these three concepts is one of the central ideas in lean construction theory.

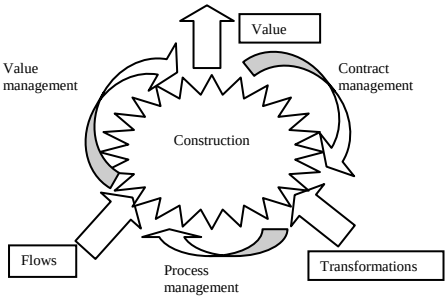


Figure 6: ***Management in construction after*** **(Bertelsen and Koskela 2002).**

LEAN CONSTRUCTION

The primary goals of the lean construction concept are increased product quality and reduced costs (Yusuf and Adeleye 2002). To attain these goals, lean construction stresses the importance of improving two main conversion processes (design and production), while eliminating waste (Crowley 1998). According to Koskela (2000), this is best done by paying attention to not only the traditional transformational view of construction, but also to the management of flow and value generation, Table 4.

Table 4: The TFV theory of production after Koskela 2000

	Transformation view	Flow view	Value generation view
Conceptualization of production	As a transformation of inputs into outputs	As a flow of material, composed of transformation, inspection, moving and waiting	As a process where value for the customer is created through fulfilment of his requirements
Main principle	Getting production realized efficiently	Elimination of waste (non-value-adding activities)	Elimination of value loss (achieved value in relation to best possible value)
Associated principles	Decompose the production task Minimize the costs of all decomposed tasks	Compress lead time, reduce variability, simplify, increase transparency and flexibility	Ensure that: 1) all requirements get captured, 2) the flow down of customer requirements, 3) requirements for all deliverables are taken into account,4) the cap ability of the production system, and 5) measure the value
Methods and practices (examples)	Work breakdown structure, MRP, Organizational Responsibility Chart	Continuous flow, pull production control, continuous improvement	Methods for requirement capture, Quality Function Deployment
Practical contribution	Taking care of what has to be done	Taking care that what is unnecessary is done as little as possible	Taking care that customer requirements are met in the best possible manner

Managing transformation is the task most familiar to project managers. Its primary goal is to take care of what has to be done, namely by managing contracts and establishing quality and safety requirements and procedures. Managing construction transformations is necessary because of the large contract values involved; however, this simplistic kind of project management is not enough in the complex and dynamic system the project usually represents (Bertelsen and Koskela 2004). Traditional contract management creates and maintains the relations between the values, as defined in the drawings and specifications and the operations to be performed by the contract parties.

Managing flow in construction introduces new management activities, e.g. supply chain management or setting up the logistics for materials and information (Love, Li and Mandal 1999, Bertelsen and Koskela 2004).These activities strive to increase and structure the information between the different actors and stages of the

construction process. They coordinate the production flow as well as the flow of information, materials and equipment through which the product gets its final form (Bertelsen and Koskela 2002).

Managing value generation is probably the most difficult concept to approach in the "lean" way of managing construction projects. Value generation is achieved by ensuring that the activities conducted within the transformation and flow processes add value to the customer. A close relation between the client and design professionals during the early design phases should generate an understanding of how the client's value parameters can be fulfilled (Bertelsen and Koskela 2004).

The key features of these management concepts are summarised in Table 5.

Table 5: Three part theory of management in construction, after (Bertelsen and Koskela 2002)

	Contract management	**Process management**	**Value management**
Objective	To manage the individual and customized contractual arrangement.	A predictable production flow with a high efficiency. Establishing cooperation between actors.	Ensuring that the construction process generates the value wanted by the client.
Success factors	Timely hand-over, low costs and a zero punch list.	To avoid making errors and to eliminate the sources of errors.	Customer satisfaction
Nature	Hard and formal. Conducted indoors	Soft, putting cooperation, respect and compromise at the front. Takes place on site.	Soft, service oriented, towards the client and hard towards the production system.
Tools	The contract, requests of various kinds, work orders, organizational charts and master schedules, quality assurance system, etc.	The Last Planner system with the PPC (Ballard and Howell 1998), productivity indicators, kick off and time out meetings, etc.	QFD, questionnaires and evaluations with clients and stakeholders.

One-of-a-kind production makes it necessary to integrate the design and production processes (Bertelsen and Koskela 2004). Inadequate, incomplete and outdated information will not only lead to delays and extra costs during the design stage, but also during the production of a construction project (Hong-Minh, Barker and Naim 2001). One solution to all these problems is to improve communication between and within the participating companies (Hong-Minh, Barker and Naim 2001), though this substantially adds to the project complexity.

The increased complexity is clearly dependent on the large number of intermediaries who mainly serve as consultants to translate the needs of clients into a design for construction. This is in contrast to other industries where buyers find it easy to specify their needs and check that they are met by the products offered to them (Bröchner 1990).

METHOD

The case presented in this paper is part of a larger case study conducted between December 2003 and May 2005. The empirical material was collected through participation in design and site meetings and by studying project documentation, interviews and repeated personal meetings with the actors. We have also studied the material from other researchers and conclusions concerning the case.

TIMBER FRAME HOUSING CASE

The studied case focuses on the construction process of a design-build contract for five – six story timber frame houses. The client, Mitthem AB, is the largest landlord in the area. During the last five years they have increased their output rate so that no more flats are available for hire. This increasing demand for flats was the initiating factor for Mitthem's involvement in the project. The local city plan prescribed a timber frame for buildings at the project site, while the landlord declared that this project was an opportunity to develop and promote the high-rise timber houses that have made the project a pilot. This attracted financial support from the government, county administrative board, municipality and players within the forestry, construction and wood working industries. In the project, Mitthem's acoustic demands exceeded the functional demands of the Building Regulations, placing even more focus on the acoustic issues than usual in timber houses. Because this type of pre-fabricated timber structure is new to the market, very few solutions tested in full scale for issues such as acoustics and fire exist.

Design of the first three houses started with a meeting in December 2003 and continued until the start of the production phase in May 2004, during which time some parts were even done in parallel. Each house in the first stage contains 20 small flats with two rooms and a kitchen. The house's foundation is concrete slabs supported by concrete piles. The frame system consists of pre-fabricated walls and slabs of load bearing, solid wood. The facades are made of glulam panels, tongue and groove, spruce panels. The roofs are fabricated on site and lifted into place in four parts.

Mitthem is an important client to the contractor, NCC construction Sweden AB, and because the construction market in the region is relatively small, this means that it was strategically important for the contractor to be awarded this contract. According to claimed and official statements, NCC is by principle material neutral. However, they have a historical and "organisational" built-in knowledge of concrete technology.

The only knowledge possessed by the contractor and suppliers at the beginning of the project regarding solid timber construction, e.g. glued cross laminated timber boards, was from participating in an earlier R & D project where no solid timber houses were actually built.

The structural designer of the solid timber supplier, Martinsons Trä AB, says that solid timber is a new material for him as he is more familiar with long-span glulam design than with solid timber housing frames. Accordingly, without the proper knowledge and past experience the structural designer as perceived and entered into this project as if it was a development project. The frame supplier participated in the project because they wanted to develop systems for timber frame construction, while increasing their own knowledge about the housing process.

The contractor, however, purchased the timber frame for this project as a traditional frame for houses, e.g. they expected ready-made solutions for construction. Since the supplier did not have any pre-experienced or pre-developed-ready-to-use systems for solid timber house structures, it was hard for the contractor to control the design phase. This meant that the designer did as usual, i.e. he designed a concrete frame house that was, accordingly, not optimised for wood.

The installation designers also entered the project thinking that it was a traditional housing project. The project has required more details to be resolved during the design process than the installation designers thought and planned for in their tenders; it is

believed that the frame producer does not understand that "*the design process demands coordination between participants*".

The design engineer and the architect stated that there have been "*a lot of surprises from tender to project*" and that the largest problem was the lack of experience of the suppliers in working with housing projects. The supplier does not "*know what questions to ask and what to presuppose*" and they have had problems to "*understand the house as a system*", according to the design engineer.

According to the architects' engineer, the largest difference between this and other projects was the high degree of prefabrication. When the project started, the engineer said that a high degree of prefabrication would demand more design work as prefabrication limits the possibility to adjust the design on site. Coordinating the installations and prefabricated elements became a more important condition for a good end product. He thought that the difference when going from traditional construction to a higher degree of prefabrication was the abundance of different actors, and that the production and assembly related issues of the architect were more significant in this kind of project.

From a contractual point of view the biggest concern was the various technical issues to pay attention to in this project compared to traditional projects as the contractor does not know what problems to expect with the new frame system, e.g. the behaviour of the frame material, the frame system and the frame producer are largely uncertain. Although considered normal, another issue was the warranty time being set to five years instead of two. This strategy by the client was presumably used to reduce their uncertainty about the performance of the house as a system.

According to NCC's project manager, the project has a great innovative value because of the large attention from the media and other groups (such as universities and the wood working industry) and because it was an untested frame system from a technical point of view. The project is risky both economically and for the reputation of the actors since it relies on this new technology.

ANALYSIS

To increase product quality and reduce costs, lean construction stresses the importance of improving design and production, while eliminating waste. One suggestion is to pay attention to the traditional contract view as well as to the aspect of managing flow and managing the generation of value, Figure 7.

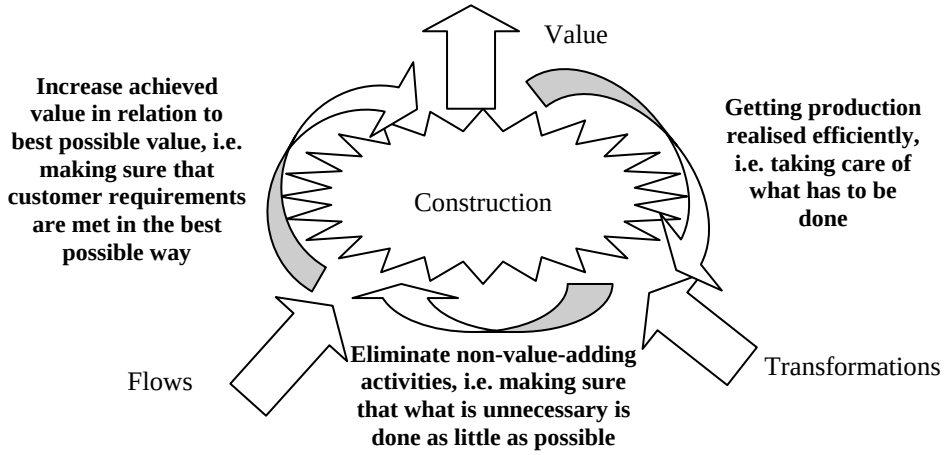


Figure 7: The tree parts of management in construction

Managing transformation is done by decomposing the production tasks and minimising the time and cost of parts, Table 4. Timely hand-over and low costs are the main success factors, see Table 5.

In this project the management of transformation has been more complex than normal, due to the frame producer being newly introduced to the construction market and to the construction principles of the "new" frame material. The contractor felt uncertain about the behaviour of the frame system, the frame material and the frame producer. The client expressed his uncertainty about the project's performance through the choice of design-build as contractual form, thereby moving the financial and social/public risk to the contractor. The client also demanded a longer warranty time than usual. Another issue of transformation considered more difficult than in a standard project is the lack of ready-to-use solutions. Since few solutions were tested for full-scale use in both the design and production stages, predicting the tasks that need to be done, the time it takes to perform them and the cost of getting them done has been difficult.

The contractor decided on a long design phase (5 months) before production started after realising the complexity of the project. Still, the misunderstanding regarding the development state of the timber frame system, made the time barely long enough for the frame designers. The production time, which was supposed to be short because of the pre-fabrication, was also a bit longer than expected, though it was ready just in time for the tenants to move in. It was realised that the frame producer did not know how the construction process works in terms of what they were expected to do and how they were expected to communicate with the other actors.

The objective of flow management is to create a predictable and highly efficient production flow by minimising waste and establishing cooperation between the actors. The main success factor is to minimise the number of errors and eliminate the sources of errors, Table 5.

In this project the flow has been handled closely, more iteratively than in a traditional construction project, i.e. some level of cooperation between the actors has been present. Communication intensity between the actors had been higher and more important due to the designers' uncertainty about the characteristics of the frame system. The problem has been the somewhat weak management of the information flow. The information has been very fragmented and individual, resulting in misunderstandings and extra work, considered a major flaw since managing flow is all about minimising waste (Crowley 1998). No coordinating function was present, even though the contractor clearly stated that this was the project manager's (employed by the contractor) task. This is because the project is too complex with too much information for one person to coordinate. If this is true, one might ask why they did not employ more people. It is suggested that the contractor ensure a transparent and efficient flow of information from the different designers to someone, designated at the beginning of the project, who coordinates and ensures that the correct information is available for all actors, i.e. increase transparency. Database solutions might be used, though the Swedish construction industry is very conservative regarding the use of computer tools (Berggren, Cigén and Fredriksson 2001).

In almost every construction project the project team is of a temporary nature, though this is not normally a problem within the Swedish construction industry. In this project the project team and its lack of previous experience of working together have been a

problem. The frame supplier is a new actor and the frame material is an “unknown” to the rest of the team, meaning that there was a disturbance in the information flow as the project team lacked the knowledge for the design of the building and the frame supplier did not have the experience to know what information the others needed. Love et al. (1999) identified the necessity in this situation that materials and information logistics should be set up to improve the flow management.

The client has participated in this project from the start and an awareness of the client’s value parameters has been high. This awareness is special as the client has usually been strong in this project; we believe that strong clients who know what they want are the key to managing value generation in construction (Bröchner 1990). Value generation in construction means ensuring that all customer requirements get captured in the design process and realised in production, Table 4, while an indicator of success is a satisfied customer, Table 5.

The clients’ representatives have participated in every design meeting as well as in every site meeting, and have been very clear during the whole process about what they want and how they want it done. One reason for the clients’ strong position is the municipality’s power as one of the regions only large, potential clients for residential housing projects. The problem with this is that the contractor has felt forced to agree to changes in the facility management system, electric system, etc., during the design process, thereby increasing the number of recalculation and redesign rounds and increasing waste, and contradicting what is trying to be achieved in the management of the flow.

CONCLUSIONS

A strategy to increase competition in Swedish housing construction, developed on behalf of the government, suggests an increased use of timber in housing construction. Our suggestion to make the timber construction process more effective and customer orientated. To promote this change, (timber) frame suppliers carefully increase the information flow and make the flow management more efficient.

Timber frame suppliers should take actions to increase the accuracy in the information flow by ensuring that there is efficient and correct information about the frame system available for other actors.

To improve the management of transformation and flow, a standardised way of exchanging information and a developed and (in manuals/handbooks) described system for logistics, design and construction are essential. To accomplish this, the actors in the construction process need a thorough understanding of the construction process as a system, something lacking today. One way to do this is to engage a project manager who coordinates the information needs from the supplier and other design team members and ensures that the right information is handed over in a timely manner, see

Figure 8.

All actors in the specific construction process need a thorough and common understanding of the construction process as a system. This could be obtained by engaging a project manager who coordinates the information flow between the actors.

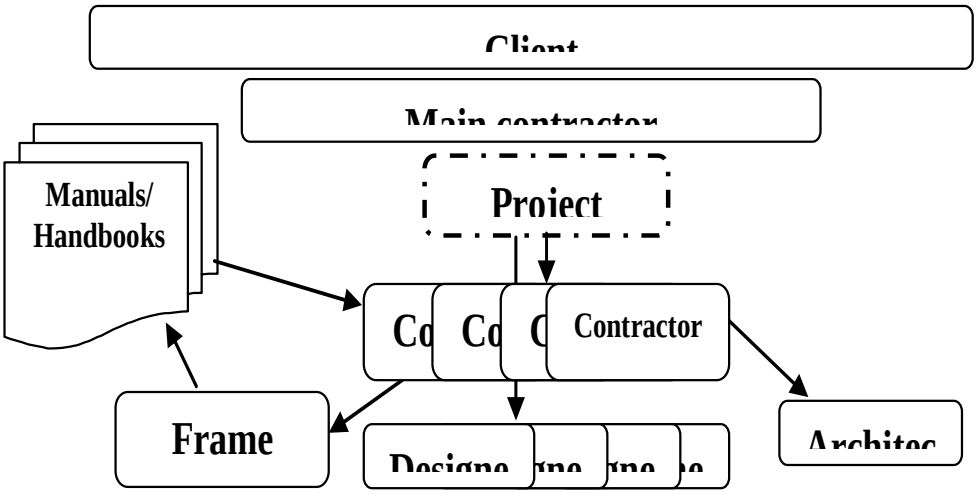
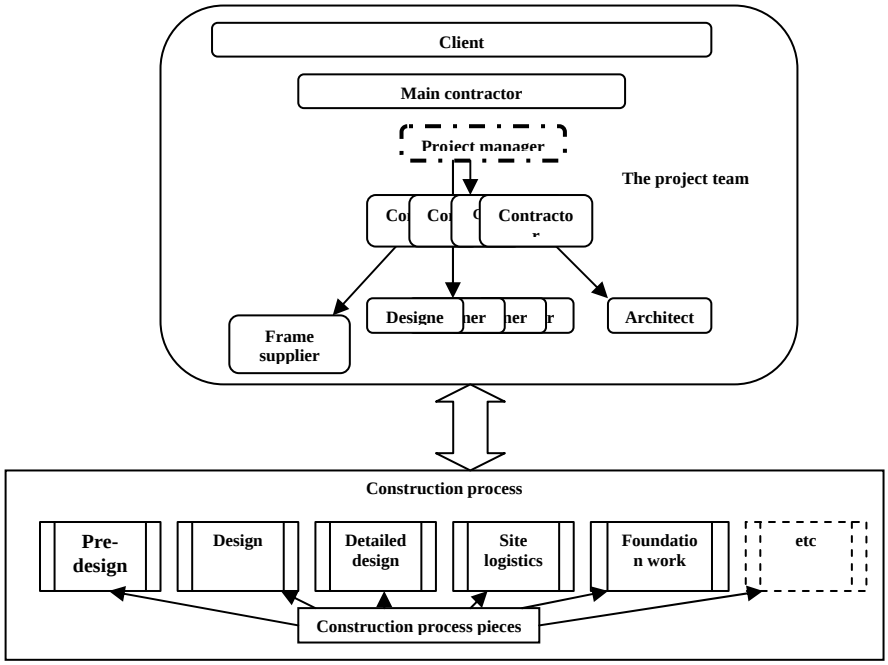


Figure 8: The project manager as a coordinator of information.

The recommendation concerning managing transformation in a pilot project is to start the project by thoroughly decomposing the design process into small manageable pieces that are time and cost specified and evaluated together with the main actors, and then recomposing and evaluating as a whole again, see Figure 9. This is true both for the contractors and the new (timber) frame supplier who need to establish an understanding of the processes involved in housing construction.

In a pilot project with new materials and new actors, it is important to, together with the project team, decompose the construction process into small, manageable pieces, which are evaluated with respect to time and cost, and the put together into one piece and re-evaluated. To increase value generation and make the construction process understood as generating value for the client, we think that strong clients who know what they want and have the means to put pressure on the contractors to get it, is the key. *Strong clients, who know what they want and have the means to* put pressure on *the contractors* to get it, *is the key to increase the importance of value generation.*

Figure 9: The project teams de- and re-composition of the construction process.



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