DESIGN PROCESS ORGANISATION AT INDUSTRIAL HOUSE BUILDERS: A CASE STUDY OF TWO TIMBER HOUSING COMPANIES IN SWEDEN

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In industrial construction companies the design process tends to be the bottleneck for further streamlining of the entire manufacturing process. The demands posed on this particular design process are diverse; should feed the production process with data, should satisfy the client with documentation and should document the project for experience feedback. Further complications arise from the internal notion of being a manufacturing company opposed to the external view of the company being a traditional building firm. In this work, the design process at two industrial builders was studied in-depth. The two companies have chosen opposing strategies for their design departments; one have specialised functions where all projects pass and the other have more general designers who work in parallel with similar tasks. With the support from lean production theory, the consequences of these two strategies on succeeding with design of industrial built houses are analysed. The results show that increased specialisation is beneficial in daily work, but can pose a sensitive design process if key competences suddenly vanish.

Keywords: corporate strategy, design process, housing, industrialisation, prefabrication.

INTRODUCTION

Industrialised housing is a growing market segment on the Swedish construction market with a market share of approximately 15 % (Höök 2008). The degree of prefabrication differs; single wall elements can be prefabricated as well as entire volume modules complete with interior claddings and equipment. When larger portions of the building process are harnessed by the same company, possibilities for streamlining the process arise. Later years have seen an increasing interest in lean construction (Koskela 1992). Industrialised housing was described by Lessing (2006) as having 8 characteristics; experience feedback, process control, developed technical systems, off-site manufacture, long-term relations, integrated logistics, customer focus and use of ICT tools. For industrialised house builders, the internal processes are best described by lean production, while the external processes belong to the lean construction framework (Höök 2008). In this study, two volume element producers are focused. They internalise the design, manufacturing and assembly processes normally carried out by different companies in an ordinary building process. Therefore a customer focus has to be placed on clients, subsequent activities as well as end customers. A common problem for the two companies is that the design process is the bottleneck for increasing volume in production. The aim of this paper is to analyse

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the design process at two industrialised house builders in Sweden through a lean production perspective.

METHODOLOGY

The decisive starting-point for the data collection were our research questions, “How is the design process organised?” and “How well do the respective organisations correspond to lean production principles? The unit of analysis was defined as the design process at two (specific) companies within industrialised housing in Sweden. Despite comparable settings on the market for both companies, the choice of strategy for organising the design process differs.

When choosing research design, case study research (CSR) was considered a suitable alternative, since the questions are “how” questions, we have little control over the events and focus a contemporary phenomenon in a real-life context (Yin 2003). In studies of how two companies in timber housing execute their daily work there are very little control over events for the investigators. The focus of this study is on a contemporary phenomenon within a real-life context. This is a multiple case study (of two companies) with a single unit of analysis (the design process) (Yin 2003).

Data has been collected using three different methods; interviews, archival analysis and participating observations at meetings. The interviews were all semi-structured in-depth interviews with 15 persons in total, 8 at Company A and 7 at Company B. (Functions of the respondents can be found in figs 1 and 2). Focus of the interviews was placed on the current way of working in the design process. The archival analysis was mainly focused on documentation regarding time scheduling for design projects. All in all, we participated in six meetings at Company A and seven meetings at Company B. Through the study, additional data has continuously been collected through an ongoing interview process. Identification of the need for additional data was made in a comparison between the two cases, but also when theoretical knowledge increases. At both companies there were designated contact persons for correspondence. Data from different sources were triangulated to increase the validity in the case. This was a well needed method since the models for organising the design process and associated activities were not directly observable at any of the two studied companies.

The material was then analysed through a Lean perspective, based on table 1. During this analysis, we realised that all diversities and similarities were consequences of choices made by the companies. Therefore it was essential for the study to find a theory capable of explaining differences in strategies. Mintzberg and Waters (1985) theory about deliberate and emergent strategies appeared to be usable.

Case study companies

Company A is a timber volume element builder specialised in products ranging from simple small booths, to office buildings, schools and multi-family dwellings. Houses built by Company A are mainly of four stories. Main customers are one large contractor in most of the multi-dwelling projects. The customisation degree is high due to several different factories. Company A has 300 employees allocated at four production facilities and an annual turnover of 42 MEuro.

Company B is also a timber volume element builder with specialisation in student lodgings, hotels, multi-family dwellings and senior dwellings. Houses built by Company B are mainly of four stories. Main customers are co-operative building societies, real-estate trustees and student associations. The

customisation/standardisation degree is high within projects. Company B has 135 employees located at one production site and an annual turnover of 42 MEuro.

LEAN THINKING

The aim for perfection is the foundation of lean production. Central to the success of the lean production approach is the involvement of personnel, who are encouraged to see mistakes as possible points of improvement. The basic idea is simple – reduce unnecessary operations (waste) with uncomplicated methods to promote increased flow targeted at creating customer value. The notion that work organisation is directly coupled to the manufacturing strategy might be most pronounced in lean production (Womack and Jones 2003). Lean production is one of the manufacturing principles that have been transferred to the construction industry i.e. lean construction (Koskela 1992).

In Lean production the concept of value is central together with concept of waste. Everything not adding value is considered to be waste. Womack and Jones (2003) states that the aim is increased value in every process step. Value is defined as the price customers are willing to pay for a product (Womack and Jones 2003). Value can also be research and development generating value for strategically important choices in a long-term perspective (Höök 2008). Organisationally and strategically, value stream is central for the management in Lean Thinking. Resources, such as information, people, systems and work strategies, are necessary in a holistic perspective to achieve a better value stream in the design process (Rother and Shook 2003). Pull is the mechanism to deliver exactly what the customers need, at the time it is required (Womack and Jones 2003). Björnfot (2006) summarises the approach of Lean Thinking in eleven principles for flow in construction, which are related to increasing the transparency and output flexibility with values from the process. Planning and management are important in the process for flow with a reduction of non-value activities, variability, cycle times and unnecessary steps.

Lean Design is summarised by Jørgensen (2006) for publications about design in construction through the late nineties until 2006. The design management is focused in the publications, where theories about conversion, flow and value from Lean Construction are presented and Lean theories are based on the five criteria of Lean Thinking i. e. Brookfields characteristics of management for Lean Design (Jørgensen 2006). See table 1.

For the prefabrication of timber housing it is important to see how different approaches to Lean can be applied. Design for industrial timber housing can not be fully described, neither using Lean Production nor Lean Construction (Höök 2008). Koskela (1992) emphasises the importance of the “connecting parts” in the construction process, where people and information links create transformation, which is the major difference compared to Lean production theory (Höök 2008). Both customers and actors in the design process must be analysed in view of the construction context. Within industrial manufacturing of houses the reuse of information in the design process is low and the actual design work is made with site construction methods. The project related approach in Lean Construction can be necessary for design activities related to value generation.

Table 1. Model for evaluation, based on the five lean principles.

Conceptualisation in construction (Björnfot 2006)	**Characteristics for lean design (Brookfield 2004)**	**Evaluation criteria for obtaining a lean design process**
1. Value Define the customer Define what is value for customer Define what is value to the delivery team Define how value is specified by products	Identify value from the customer's point of view	1.1 Are customers defined? 1.2 Is customer value defined? 1.3 Is value for the design team defined? 1.4 How is value transparent in information and drawings?
2. Value stream Define all recourses for production Define all activities required for production Standardise current practice. Define and locate key component suppliers.	Understanding the value streams by witch value is delivered for the whole design process.	2.1 Are all resources for the design process defined? 2.2 Are all activities in the design process defined? 2.3 Are the processes standardised? 2.4 Are key information suppliers defined?
3. Flow Identify non-value adding activities (waste). Remove or reduce the influence of waste as it is observed. Identify key performance indicators. Measure performance.	Achieving synchronous flow within work processes as waste is removed.	3.1 Are non-value adding activities (waste) identified? 3.2 Is the influence of waste removed or reduced? 3.3 Are key performance indicators identified? 3.4 Is performance measured?
4. Pull Keep the production system flexible to customer requirements. Keep the production system adaptable to future customer requirements. Exercise a conscious effort at shortening lead and cycle times. Perform work at the last responsible moment.	Achieving pull so that no information is delivered until it is needed.	4.1 Are design systems flexible to customer requirements? 4.2 Is the design system adaptable to future customer requirements? 4.3 Are efforts in shortening lead and cycle times exercised? 4.4 Is work performed in the last responsible moment?
5. Perfection Keep the production system transparent for all involved stakeholders. Capture and implement experience from completed projects. Exercise a conscious effort at improving value for customers. Exercise a conscious effort at improving the execution of work.	Perfection - recognising that improvement needs to be constantly pursued.	5.1 Are design systems and routines transparent to all stakeholders? 5.2 Is experience from completed projects captured and implemented? 5.3 Are efforts made to improve value for customers? 5.4 Are efforts made at improving the execution of work?

Lean Construction theory as well as Lean Design, mainly focuses on traditional onsite construction with customer value at a project level (Lessing 2006). Strategical choices in the organisation of the design process at two industrial timber housing companies are compared against the criterions in Lean Production and Lean Thinking, Table 1.

Björnfot (2006) states, that Lean philosophy can be applied to construction when a mixture of the five principles, represented in column 1, table 1, is at hand. In column 2, the characteristics for Lean Design according to Brookfield (2004) are presented. In column 3, the Lean criteria for evaluating design processes are presented, based on the theory characteristics in columns 1 and 2.

DIVERSITIES IN STRATEGIES

Strategy has been conceived in terms of what leaders of organisations 'plan' to do in the future. As long as there has been an interest in strategies within organisations, there has also been curiosity about the relationship between what is planned and what is actually done. Labelling these two phenomena in terms of strategy, Mintzberg and Waters (1985) make a distinction between deliberate strategies – realised as intended,

and emergent strategies –patterns or consistencies realised despite, or in the absence of, intentions. Deliberate and emergent strategies are by Mintzberg and Waters (1985) described as poles of a continuum along where all real-world strategies could be expected to fall.

Mintzberg and Waters (1985) propose eight types of strategies: 1. Planned strategy: Leaders formulate their intensions as precisely as possible and then strive for implementation i.e. translation into collective action. 2. Entrepreneurial strategy: One person in control of an organisation and imposes his or her vision of direction on it. Since vision only provides a general sense of direction, there are room for adaptation of other visions within the organisation. 3. Ideological strategy: When members of an organisation share a vision and pursue it strongly it becomes an ideological strategy. 4. Umbrella strategy: When leaders only have partial control over actors in an organisation, they implement a vision but have to convince others to pursue it. 5. Process strategy: Leaders exercise influence on strategy indirectly, for example by controlling the staffing of the organisation, and thereby determining who gets to influence strategy. 6. Unconnected strategy: If a part of an organisation is loosely coupled to the rest, it might be able to realise its own pattern in its stream of action and therefore its own strategy. 7. Consensus strategy: No need for central direction or control is required since different actors naturally converge on the same theme so it becomes pervasive in the organisation. 8. Imposed strategy: The organisation is forced into a pattern in its stream of actions of the environment, regardless of the presence of central control.

CASE STUDY

Company A has a total of eleven employees in the design department, divided into the functionalities of Design Process Manager, Purchase, Structural designers (six persons), Electrical drafting and HVAC drafting (two persons), see figure 1. A role called early planning has been established to enhance the readiness level of the input from the sales department to the design team. Sub-contractors are utilised for static calculations, foundation drafting and ventilation drafting.

Company B has a total of seven employees in the design department, divided into the functionalities of Design Process Manager, Project Manager, Design Manager, Purchase, Coordinator for sub-contractors, Building design and Structural design, see figure. 2. Sub-contractors are utilised for HVAC, foundation and ventilation drafting.

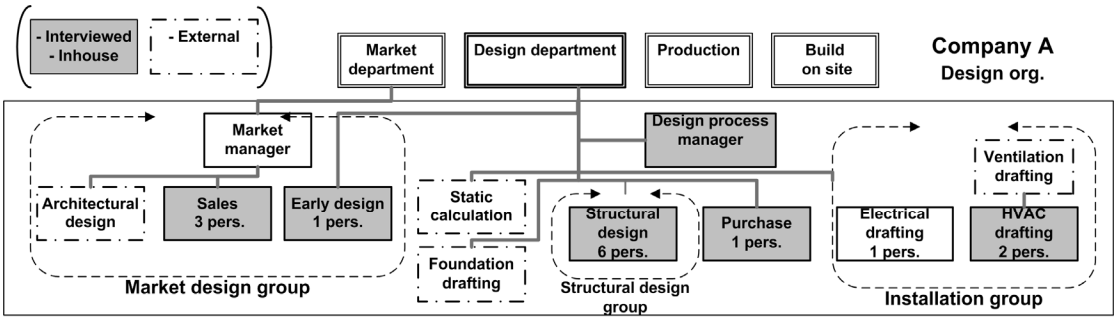

Figure 1: Company A organisation chart

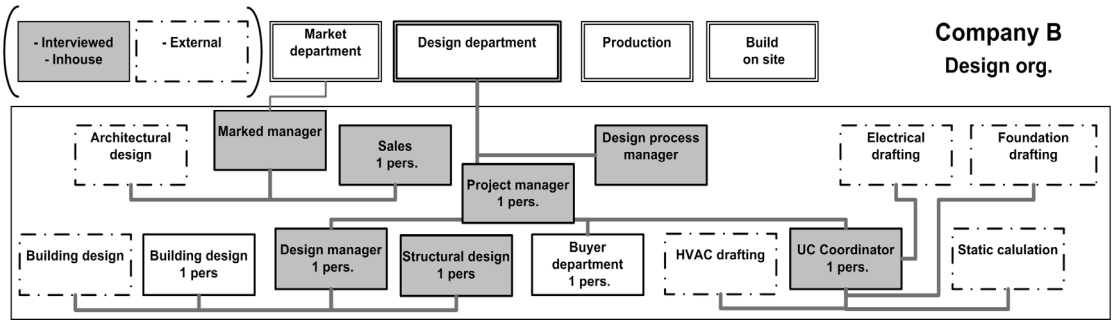

Figure 2: Company B organisation chart

Company A works project-based with normally just one project simultaneously, but occasionally two projects have been processed in parallel, see figure 3. At Company A, planning of projects is based on time in total for the entire group. The Design Process Manager distributes tasks and assignments to the members of the team, which they work with throughout the project.

Company B has a clear process-based approach with a capacity of up to six projects in parallel, see figure 3. Due to parallel project, Company B plans every included part of the design process in detail. Every team member can be described as a specialist within a certain area i.e. 2D CAD-drawing, design managing, volume construction.

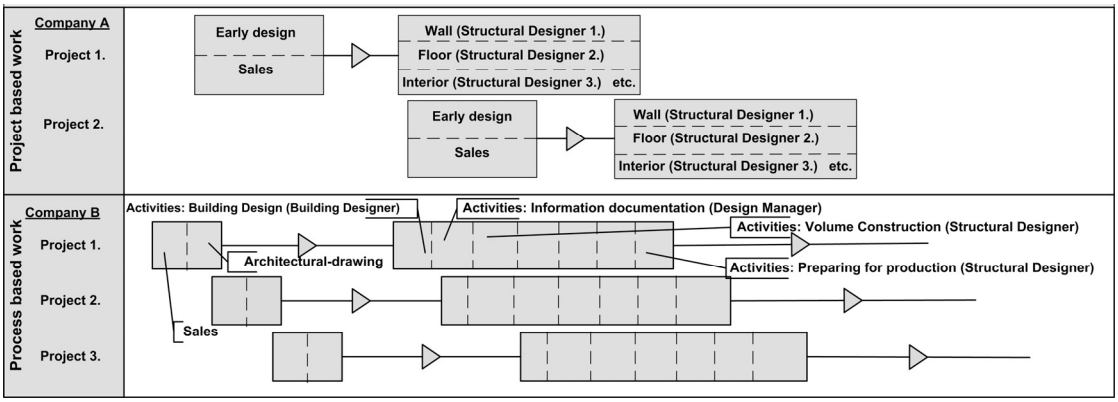

Figure 3. Design process illustrated in project and process based work.

Planned time for the design process has in both companies a mean value of 20 weeks from the start-up meeting to the production start. Both companies strive to reduce the design process time by 50 %. Company A is planning to reinvest the reduced time in standardisation of the building system, whereas Company B has an intention to focus on enhancing quality throughout the entire process. Activities are carried out sequentially as in traditional site construction for both companies, with documents being the most central information carrier instead of information systems. Company A uses one 3D-CAD software in which all design and drafting are performed, while Company B uses several software and is therefore obliged to produce up to four different model files.

For visualisation of the design process, both companies use visual planning. Company A uses live documents on a file server with ongoing projects' status, while Company B uses a whiteboard where the current status of thirty-two activities/documents is indicated by different colours.

Company A has recently decided to apply lean principles to the entire company, starting with enhancing the design process and plan to work their way throughout the production flow. Company B has focused on improving the production capacity by

investing in automation of the wall production line and has no comprehensive strategy for improving the design process. Lean principles are only used in minor sections in the design process at Company B.

ANALYSIS

Analysis of the design process at the two companies was done based on the lean perspective criteria in column 3, table 1. The analysis gives an indication on how well the design processes correspond to lean principles. Numbers in brackets indicate the corresponding criterion in table 1.

Value: Company A has their focus on the product in an object-oriented organisation. Value for the customer is the possibility of having better quality and controlled technical solutions due to an individual owner for each task in the design process. Customer value is a pronounced focus at Company B where the strategy is to take market shares in a new market area. The process-oriented organisation creates value for the customer, through flexibility in handling parallel projects in the design process (1.1, 1.2). Weekly meetings and sharing of visual information creates value for the design team itself. Waste is identified in the communication with sub-contractors e.g. time delays for checking drawings, information about project specific conditions and drafting revisions (1.3, 1.4)

Value stream: The value stream can be defined in resources and activities for conversion in Lean Design, where Company A uses fewer interfaces in the process but more interfaces in the product e.g. between wall and openings, wall blocks and inner roof. Company B has to deal with many interfaces in the process, to promote the value stream, such as software file formats, individual task status and individual work standards, but remains a comprehensive view on the whole product. Standardisation in the design process is done on a deeper level for Company A with standardisation for tasks (2.1, 2.2, 2.3). Company B has maintained its process focus and has not put effort in the work of standardising sub-tasks.

Flow: The flow of information and drawings in the design process is low within both companies. Company A uses 3D-CAD with central models for projects but with limited connections to production compared to Company B. Up to four different CAD models can be produced for each project at Company B, which decreases the flow. The range of software is the result of the implementation of automated machinery in the production. Nail robots use control files created by the CAD-system (DDS), which increases the flow. Paper drawings are used at both companies (3.1). The use of sub-contractors in the design process sometimes causes time delays for information sharing. In-house resources can be seen as supporting flow (3.1, 3.2, 3.3, 3.4).

Pull: Production time is shorter than time for design, which fulfil the pull criteria in-house at both companies. However, overall rate in design is too slow, 20 weeks in average compared to 4 weeks of production in the factory. Company A has streamlined their design work to obtain a production with higher delivery accuracy. Company B on the other hand, has started with streamlining their production and is now taking measures to convert design to flow better (4.3, 4.4).

Perfection: By the use of visual planning both companies have transparency in their design process status. Templates, checklists and quality routines for following up projects are present, but not common in the design process (5.1, 5.2). However, the common goal for the design team is not perfection of the entire process, since sub-

optimisation is common. Standardisation of certain sub-tasks is not the same as optimising the entire design process.

The analysis of the organisation in the two cases shows that the focus on different key factors for the entire manufacturing process affects the appearance of the activities and tasks in the design process. Company A's approach of implementing early design and allocating personal component responsibility (e.g. walls and floors), creates an apparent project focus which generates value in the product, both for internal (production) and external customers. Company B's strategy is reliant on customer requirements where the flexibility in the process-oriented organisation provides value for the customers. Having parallel design processes allows clients to influence the selection of components like alarm systems, kitchen appliances, etc. further into the design process. Decisions have to be structured with several object-specific deadlines through the process to use the advantage of flexibility.

Company A is part of a larger corporation where strategically important decisions and directives are emanated from central leadership. Therefore the concept of planned strategy, according to Mintzberg and Waters (1985), appears to be the best comparable alternative. According to Liker (2004) there is an evident need for leaders to live the philosophy of Lean and spread it to employee (top-down implementation). Company A has recently decided to adopt lean principles on the company.

Company B is a family business with a strong leader and facilitating Mintzberg and Waters (1985) terminology, the concept of entrepreneurial strategy seems to apply the best.

Since the leader's vision is personal, it can also be changed completely. This allows the organisation to quickly respond to changes in the environment, thus can be considered to enable implementation of new strategies. Company B has not adopted lean principles at a company level, but there are actors in the organisation influenced of Lean Thinking. Based on the evaluation of strategy types, neither of the companies appears to have strategies especially facilitating or obstructing implementation of a lean concept.

Standardisation is a principal strategy to create efficiency in the design process and the authors perceive different conditions at the studied cases. Company A have clearly defined their organisation with distinct assignments and responsibilities. Implementing the function of early design has given Company A the ability to ensure that potential projects are compatible with the building system as well as enhancing the quality of data entering the design process.

Company B has an organisation with explicit responsibilities, but activities are not divided into assignments for specific persons. The process-oriented approach creates expertise in performing the work task, but may not contribute to improvement of the product since focus is placed merely on one activity. Working with several different ICT tools, results in a non favourable situation regarding managing versions of files and documents. Based on these findings the authors believe that standardisation of the building system might be more straightforward to execute at Company A.

Using lean production principles to improve the design process in industrialised housing is considered to be insufficient due to the complex situation of being manufacturers in a constructional context. Neither concepts nor theories founded in manufacturing settings or traditional site construction are completely valid for these

particular circumstances. Lean production is by Crowley (1998) described as "unsuitable to small-scale production of non-standardise or customised products".

Jørgensen (2006) states that defining value for end customer in construction is complicated since end customer for a building can be several different individuals distributed over extensive periods of time. Furthermore, it cannot be taken for granted that an increased productivity necessarily serve the interests of the end customer (Green 1999). Neither can flow be considered to be as essential in everyday work as in theory, since the design process is not sequential as production generally is.

In order to differentiate which activities being repetitive (and beneficial for standardisation, i.e. cross sections, fire documentation and room description) from project-unique activities ("handled individually", i.e. balcony solutions, elevator and stairwell) the design process must be fractionised and analysed.

Former research in this field has primarily discussed the influence of lean production on regular site construction (Green 1999; Naim 2003). Since Koskela (1992) introduced Lean Construction, focus has shifted towards investigation of its applicability (also on site construction). Therefore it has been of extra interest to perform this case study with lean production perspective in the industrialised housing context.

This study states that lean production alone, is not a sufficient tool when improving the design process in industrialised housing. Future work needs to combine lean production and lean construction to support industrialised housing.

CONCLUSIONS

Industrial housing companies have to acquire control over the process to benefit fully from owning the entire system and therefore being able to improve it. Using only lean production principles for improving the design process is not sufficient.

It is therefore needed for the industrialised timber housing companies to:

- Thoroughly investigate all included tasks within the design process in order to differentiate repetitive and project-unique activities. By doing this, tasks suitable for standardisation can be identified.
- Standardise procedures for repetitive work in order to better utilise resources as well as ensuring that knowledge of the product and the building system is captured within the system itself, not only in persons working in it.
- Make use of well-suited ICT support to automate interfaces. Industrialised housebuilders have reoccurring interfaces every time the design process is repeated. However, they may not necessarily have a repetitive design in itself.

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