Information Flow Optimisation: Enabling Standardisation towards Modular Building Methods of Wood-Building Solutions

Fredrik Lindblad, Bengt Magnusson, Alan Luu, and John Ragnarsson

***Abstract*—Currently, there is a considerable lack of residential buildings in Sweden. Hence, companies that are active in the housing industry producing wood-building solutions have been affected by high demand for their products. The industry tries to be more effective, and one means of achieving this goal is to automate the production, similar to the automotive industry. However, improvements in the information flow have not come as far as developments in the production. Therefore, it is necessary to streamline the entire process and reduce the amount of manual work using rationalisation and automation to enhance competitiveness. This is not only applicable to the actual manufacturing process but also in a large degree to the design process, i.e. the transition from the basic to the detail design stage. The purpose of this research is to compare the information flow for various building projects before production, identifying development possibilities by using an improved information process.**

Information has been collected into a status report using interviews, surveys and from data in the Enterprise Resource Planning (ERP) system.

Two areas were identified out of the status report: standard projects and special projects. The special projects constitute 90 % of the project departments actual workload, whereas standard projects do not exceed the projected lead times creating less problem than special projects. Therefore, the long-term development strategy for the industry should be to improve the level of project standardisation, developing an advanced modular system based on improved information flow minimising the need for special projects.

***Index Terms*—Information flow, product variation, wood buildings, standardisation, modular building methods, BIM.**

I. Introduction

Currently, there is a great demand for new residential buildings to be built in Sweden [1]-[3] and the consequence of an insufficient amount compared to the current demand could result in social problems [4]. Further, the Swedish Government [5] connect decreased mobility of the population with difficulty to find accommodation, which affects company development based on difficulties in recruiting staff due to problems find accommodation [6]. 64 000 homes were being built during 2016 [7], but according to SCB (Statistics Sweden) [8], approximately 88 000 homes need to be completed annually between 2015 and 2020 to fulfil the demand. Statistics indicate that the industry producing wooden multi-family buildings does not use their resources in the best possible way, which resulted in increased production costs per square meter of 91 % between 2001 and 2014 [4]. According to Boverket (National Board of Housing, Building and Planning) [3], lowering production costs results in reduced residential prices for final customers, which enables a higher degree of movement within Sweden. According to Karlsson [9] and Atterhög [10], an increased amount of companies producing housing units leads to higher competition, which causes prices to fall and companies to improve the quality and their resources utilisation to maintain competitiveness. Therefore, companies have to review their production methodology and improve the internal operational efficiency to stay competitive by lowering production costs [11].

An approach to achieving reduced production costs is to change the production processes by applying Lean production methodologies [12]. However, difficulties may arise when improvements in administrative activities such as design and pre-production are achieved through Lean, as these activities and processes are more difficult to visualise than operational processes [13]. Instead, Lean needs to be perceived as an overall system that permeates the entire organisation and business culture [14]. For this to succeed, skilled planning of the entire process is required, up until the building is erected [15]. This process is rarely identified in the administrative processes of the building process but can just as easily reveal if waste exists [16]. However, identifying the various steps associated with the administration components is a challenge according to Rother and Shook [17]. Therefore, improved information flow reduces lead time and allows more time for potential problems or additional time to improve processes [13]. Thus, enhanced productivity is obtained by standardisation and rationalisation of the design process utilising Building Information Modelling (BIM). This gives a large number of advantages, not least a limitation regarding the loss of information between the different stages in the production process. Also, possibilities to present information in different ways, not only visual models and traditional drawings but also as data providing information about procurement and automation in the manufacturing process. A major improvement by improving standardisation and employing BIM technology is that design alternatives can be cost-estimated with a high degree of reliability quite early in the process, which is a necessity for efficient customer management.

A. Purpose and Goal

The purpose is to identify the information flow within a

Manuscript received Junn 30, 2018; revised August 2, 2018.

Fredrik Lindblad is with Linnaeus University – Faculty of Technology, Institution of Mechanical Engineering, Växjö, Sweden (e-mail: fredrik.lindblad@lnu.se).

company producing wooden buildings, comparing the differences between standard projects and special projects. This provides the possibility to identify improvement possibilities enhancing company development, customer focus and contribute to a higher degree of product modularisation through BIM utilisation.

II. Conceptual Framework

The internal and external factors affecting a company are constantly changing, and it is important to identify and take advantage of the positive changes leading to strengthened competitiveness. This is a strategic challenge where the success of the company is based on the active development of different types of business models over different strategic horizons [18]. However, the primary focus is to create value for the company, e.g. generate profitability and deliver customer value [19], [20]. Osterwalder & Pigneur [20] has created a business model based on nine key focus areas, which is used throughout the organisation's processes and systems; *The Customers, Value Proposition, Channels, Customer Relationships, Revenue Streams, Key Resources, Key Activities, Key Partnerships* and *Cost Structure.*

A. Improved Flexibility Using Modularisation

Private and public customers expect that constructions are carried out at the budgeted costs, high quality and the possibility for product customisation. Therefore, new manufacturing methods to achieve flexibility within the production are required. Hence, development of improved industrial production techniques is necessary to provide possibilities for product customisation at a larger scale [21]. A product or system is made up of many different components, and the product can be assembled by a certain number of standard components, i.e. modules, which makes it possible for late customisation [22]. The large-scale customisation can be made possible by introducing modularisation in mass production, e.g. as the heavy truck manufacturer Scania has developed their production model. The concept of modularisation implies that costs can be greatly reduced in the development phase of a new design, which is based on the premise that modular systems can easily be replaced or reused without the need for the entire design to be re-developed. Therefore, development of new constructions becomes a flexible process due to the product adaptation taking place at a modular [23].

Components of a production system can be divided into subgroups or subcategories, thereby provide possibilities to handle product complexity [24]. However, it is important when dividing these complex systems to find natural break points and not separate associated production components or processes [23]. Hence, modularisation is considered as a general method managing complex systems and processes, such as for the building construction. However, for modularisation to be successful, the components of a system must be able to interact, which can be done by standardising information, interfaces and architecture [24].

B. Process Mapping for Enhanced Information Flow

According to discussions by Söderqvist [12], processes consist of a flow of materials, products, information, individuals, etc. that exits within a company as work is executed. Conducting an activity-based process mapping exercise using the following steps can be of great value for accuracy; *Define and demarcate the process, Intended use of the flowchart, Identify activities, Sort activities, Describe process, Finalise the flowchart,* and *Document the result*. The flow of information can also be followed by identifying the organisational activities within different departments, thereby providing the possibility to develop the process flowchart to a more comprehensive matrix flowchart [12]. Further, simplicity is desired when designing the information flow, both regarding finished products and materials. The primary purpose is to find a simple way to transfer the information requirements between the various processes steps in the production flow [25]. The flow of information should be designed making it is easy for everyone involved to interpret the information and minimise the request for information [26]. Insufficient and incomplete information flow creates the need for increased security and higher costs in the value chain, while accurate information flow provides the opportunity for improved production and lower inventory levels [22].

C. Lean production Enables Modularisation by Standardisation

One of the goals of Lean is to identify and eliminate all activities in the company that are not contributing to value creation for the end customer. Lean is more than just tools and methods; it's a comprehensive system of principles that must be communicated throughout the organisation, i.e. from administration department to the operational production unit [14]. Management is therefore constantly committed to investing in its employees, contributing to a culture that continuously improves its processes [14], [15].

Instead of companies focusing on short-term financial targets, focuses should be on creating long-term value [16]. Liker [14], discuss long-term thinking as one of the key pillars of Lean activities that can be categorised into four main groups; long-term philosophy, focusing on right process producing the right result, the value for the organisation to develop people and solving root problem to create a continuous learning organisation [14]. Part of the Lean concept is to minimise waste, i.e. resources consuming activities not creating value for the customer. However, wastes can be converted to improved customer value by using Lean, i.e. the goal is to achieve more value with fewer resources [16].

Another focus area is the possibility to equalise the production volume, production mix and administration process to reduce the workload. This is conducted by producing orders evenly over a certain time frame, enabling an optimum production volume and product mix to minimise or eliminate daily irregularities [14], [27]. This is linked to demand-driven manufacturing based on producing the correct product, in the right quantity and at the right time based on customer satisfaction [11]. However, considerations must be taken based on the logistic perspective where product design has to be based on standardised units and modules, facilitating customer specific production [28]. Standards and standardisation are seen as the default performance for a process or service that executes according to the predefined standard [29]. Standardisation creates stability in the process

that enables constant improvements [14]. Standardisation provides different benefits, such as *Stability of the Process, Clear Start and Stop Mode for Processes, Learning for Organisation, Review and Problem Solving and Employee Participation* [27].

III. General Research Process

The study is conducted at a specific Swedish company that produces wooden houses, as well as with their external partners in the development and production process. Initially, this study focuses on creating an understanding of the information flow, thereby providing information about the company's current situation in order to identify problems. Fifteen projects were included in the study, providing the possibility for a broader representative sample within the company. Furthermore, efforts have been made to achieve objective results that reinforce the improvement proposals. The used methods have been direct interviews and telephone interviews.

Data collection was conducted through interviews and questionnaires where answers were provided in writing [30]. Questions were asked to selected key individuals, which are believed to be a good representation of the company [31]. The result has been compiled in various ways depending on the questions, e.g. through statistical analysis or content analysis [30]. Further, additional secondary data has been collected from the ERP system providing a base for comparison with previously gathered information in the interviews and questionnaires. Strategically placed people at the company was involved in the project selection phase, minimising bias and data corruption. After that, contacts were established with employees within the selected companies that had specialised skills associated with the selected projects.

Moreover, triangulation was applied to enhance the findings of the study [32]. By using multiple respondents allowed for source triangulation and investigator triangulation was used since the findings from this study was discussed among the research group and certain respondents for possible adjustments based on their interpretation of the result derived from the interviews [33]. Furthermore, the study has addressed validity and reliability by conduction pre-interviews with selected industry specialists and having a defined selection process of key stakeholder to be included in the study [34]. Thereby, capturing their perspective and experience to validate the questions and result regarding the effect of information flow optimisation. By using systematic analysis of the result and by ongoing discussions between involved researchers and industry stakeholders provided improved validity and reliability of the study [35].

IV. Data and Project Information

The project department was selected to be included in the study. Their primary role is to make structural calculations, adjusting the production data, facilitating that the specific project can be manufactured within their normal production. The normal process is for the project department to receive a draft of the drawings and digital models from the customer or the company's internal design department, thereafter hand over to the production. This study focusses on the information flow within this chain of events. The comparison is conducted between the information flow of standard- and special projects, where the standard projects are seen as a reference point for this study.

A. Standard Projects

The company has developed a standard range of wall elements, corner details and specialised solutions around windows and doors. Standard products are products and solutions available in the company database ready for use without any additional structural calculations or adjustments. The various components in the standard range are already finalised for production and assembly, and the necessary structural calculations have been made following the project plan. Only smaller adjustments based on specific customer requirements are conducted at this stage. Construction time and additional calculation are made considerably shorter by choosing the standard range i.e. lead times from customer request to production start are shorter.

The activities and lead-time included in the process for a standard project can be seen in Table I and Fig. 1.

TABLE I: Lead Times for Standard Projects

Standard projects				
	Start	Finish	Budgeted time (h)	Actual time (h)
Project documentation, design	2017-01-13	2017-01-19	3	0
Structural calculation	2017-01-20	2017-02-02	2	0
Calculation of roof truss elements	2017-02-03	2017-02-09	2	1
Building permit	2017-02-10	2017-02-23	10	10,3
Building documents	2017-02-24	2017-03-20	27	20
Releasing drawings to production	2017-03-21	2017-03-21	0	0
Sum			44	34,3

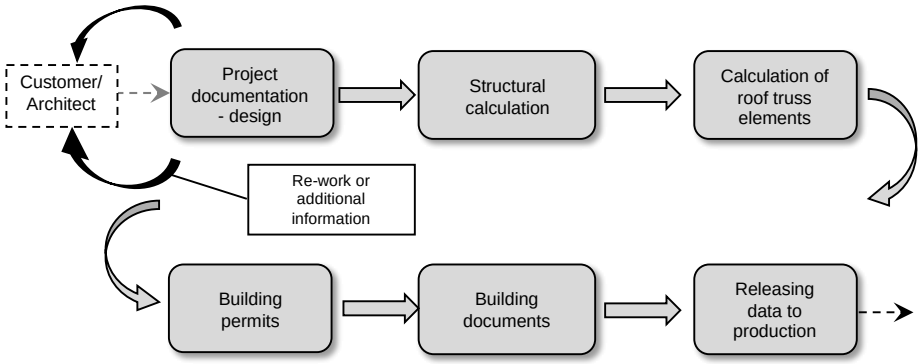

Fig. 1. Process map standard projects.

Table I display a summary of the information from seven standard projects. Scheduled time is considered the same as budgeted time. The difference between the scheduled time and the reported time indicates if the process was completed on time. Based on data from the standard projects display 22 % reduction of time spent in comparison to the budget and several of the pre-planned steps were excluded based on their use of standardised processes.

Fig. 1 presents a visualisation of the process for standard projects from customer request to project release into production.

It is possible to see the advantages of standard projects for the development of modular systems since the current lead times for standard projects (Table I) shows the benefits of standardisation as this creates a stable process with time efficiencies. With a stable process, information is delivered on time to the subsequent process step, creating a good flow of information throughout the company. Furthermore, a stable process creates the possibility of continuous improvements including quality, lead time, cost and productivity, which is based on a standardised approach. This provides possibilities to focus on activities that add customer value, minimising sub-optimisation and improving profitability. Standard projects can meet the planned lead times, as made visual by the activity list in Table I. This is mainly due to the project departments being able to perform their work using previously developed standard solutions and modules.

B. Special Projects

Special projects are defined as projects when customers or architects do not select among the standard range of products provided by the company, resulting in adjustments in the data and of the structural calculations. This may occur when the customer designs one of a kind buildings or other features not complying with the standard dimensions. As a consequence, the project department has to spend considerable time making new calculations e.g. load capacity and stability, which leads to longer lead times from customer request to production start.

The activities and lead-time included in the processes associated with a special project can be seen in Table 2 and Fig. 2.

Table II below is a summary of the information provided regarding eight special projects within the company. The difference between the scheduled time and the actual reported time indicates if the process was completed according to the predefined schedule. Data from the specialised projects display 40 % increase of time spent compared to the budgeted time. Several of the administration processes included had no times allocated towards them, either budgeted or actual. This is derived from these activities are included and executed in previous process steps, which is based on insufficient understanding of the processes resulting in higher costs and inaccuracy.

TABLE II: LEAD TIMES FOR STANDARD PROJECTS

Special projects				
	Start	Finish	Budgeted time (h)	Actual time (h)
External consultant, initial order	2016-11-14	2016-12-06	75	0
External consultant, revised order	2016-11-24	2016-11-30	10	0
Calculation of roof truss elements	2016-12-15	2016-12-21	5	1,8
Building permit	2016-12-22	2017-01-05	10	39,6
Building documents	2017-01-09	2017-01-31	150	309,3
Releasing drawings to production	2017-02-01	2017-02-01	0	0
Time for review/design	2017-02-08	2017-02-08	0	0
Sum			250	350,7

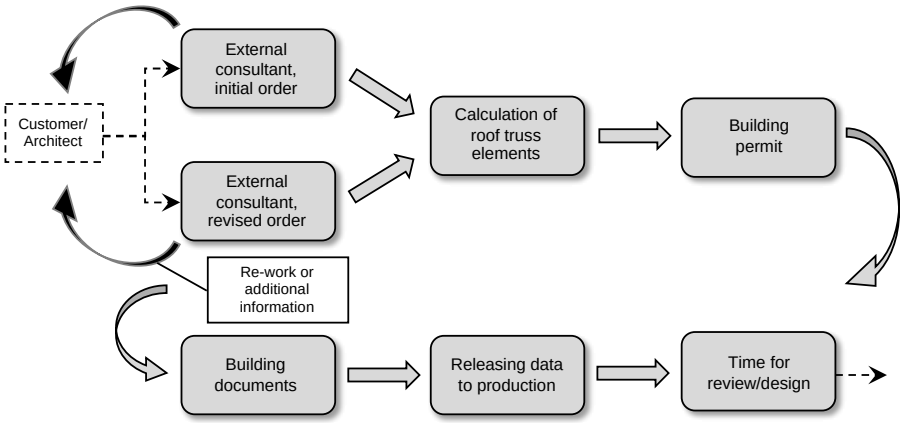

Fig. 2. Process map special projects.

Fig. 2 presents a visualisation of the process for specialised projects from customer request to project release into production.

According to the project department, approximately 90 % of all the handled customer documentations are categorised as special projects. Special projects are normally derived from the project department's requirement to adjust the design based on specialised requests from the architect or customer. Therefore, any possibilities to achieve economies of scale based on previous projects cannot be accomplished since each project require a unique and specialised solution. Thus, the increased product variation based on the required specialised solutions lead to difficulties fulfilling the projected goals regarding quality, cost, lead time, security, environment and productivity, compared to standard projects.

Based on the activity list in Table II, the actual lead time greatly exceeds the planned lead time for special projects. This primary applies to activities related to construction and consultancy documents. The main reason for the construction documents exceeding the planned time can be linked to lack of communication, lack of standardised methods and errors in the documentation provided by the architects and project managers. This contributes to process waste based on the information flow not being properly developed. One reason for the consultancy documents exceeding their planned time is based on requirements from the municipalities planning departments in regards to safety, environment and review of architectural drawings, considering it being a specialised project. This may cause the designer or architect to make certain changes before the project start, which results in additional work, waste and additional costs that rarely is absorbed by the customer.

V. Analysis and Discussions

The purpose with Lean is to create value for the customer by eliminating waste in the company and continuously work towards the most efficient processes. Currently, the project department confirms that the information lead times are not according to the budget times. This causes problems where they cannot perform planned jobs based on insufficient documentation from architects not being provided in time. This indicates waste and must be eliminated in order to create a continuous and efficient process flow, which according to Womack & Jones [16] and Liker [14] is considered as contributing factors to an insufficient production process and contributes to the financial and operational loss. Substantial delays affect the information quality due to time constraints for the project department, resulting in possible inabilities to perform according to the expected quality levels. It is important that information is accurate, detailed and available in the agreed time frame, thereby delivering the project in accordance with customer expectations.

Special projects amount to approximately 90 % of all projects within the company, primarily based on increased demand by architects and customers to customised their building projects. However, the project department's ambition is for special projects to be reduced since they create problems and additional work due to limited standardisation. Standard projects can be supported by established standard solutions, which is based on a modular approach that poses a problem for special projects due to its complexity according to Paulsson, Nilsson & Tryggestad [22] and restricts the possibilities to create efficiencies by establishing sub-groups according to the study by Langlois [24]. Information flow is highly dependent on efficient communication and standardised methods. Considering there is a large proportion of projects that consist of custom-made designs where specific demands need to be incorporated further emphasise the benefit of standardisation. A comparison with standard projects shows that special projects rarely adhere to the planned lead times, which leads to additional costs and deteriorating profitability. This is discussed by Womack & Jones [16] and Dennis [27] as one of the eight categories of waste, where efficient information flow contributes to good resource utilisation and a stable production process.

Standardisation contributes to stability by simplifying processes minimising the problems of special projects and create a stable basis for continuous improvement. The collected data display that the project department lack a standardised approach, which contributes to process stability, cost and lead time goals are fulfilled. This is discussed by Rother [29], mentioned the importance of standards for an efficient process, furthermore Likert [14] stress the value of standardisation enabling continuous improvements. Therefore, it is essential to introduce standardised working methods and the project department have to develop the most effective work methods and introduce them as standards for the process. In the end, standardised processes should not be an obstacle hindering creativity, rather be seen as the best and

most effective way to perform the specific task.

Standard projects displayed a reduction of time with approximately 20 % compared to budgeted expectations and the comparable number for special projects is an increase with 40 %. However, more importantly, is the difference in time consumption between special projects and standard projects, where special projects require approximately ten times more time than standard projects. This difference can be seen as a symptom that only will accelerate in the production phase due to limited knowledge of the special projects. Thus, the required time to complete a special project in production will increase beyond the difference displayed in the information flow between special- and standard- projects. Therefore, focus on standardisation already at the information level will provide the foundation to develop a modular production approach for the company [25].

A. Development of Standardisation Leading to Increased Modularisation

Problems with special projects arise due to its complexity, whereas standard projects and standardisation provide better conditions for implementation of modular systems [24]. It is believed that the lead time for special projects can be reduced compared to the levels for standard projects through a higher degree of modularisation. Modularisation and automated industrial production within the wood-building industry can to some degree be compared with the automotive industry or IKEA. The company develops a variety of modules, variants of walls, etc. that are compatible with each other and form a system. Jiao & Tseng [21], further discuss this concept and the importance of improved production technologies to enable large-scale customisation by modular development. From the manufacturers' perspective, modular systems should be seen as standard components assembled in a sequence suitable for construction of the building. Whereas the customer's perspective should be that the final design is a unique building tailored to their demands [22].

Creating an understanding of the customer demands provides possibilities to develop custom designs by segmenting their requests, enabling market-driven standardisation using fewer resources as discussed by Womack & Jones [16]. By getting the customer to understand the benefits of using standard solutions, many customers are likely to make more use of standard solutions. Company expectations are that 80 % of all customers could order standard projects, 10 % special projects and the remaining 10 % as a combination of both solutions. Thereby, companies will be given better opportunities to plan their production, utilising their resources better. This is based on a structured method towards customer segmentation driving standard- or special- projects, rather than the ad hoc situation as is today. Thus, this further enhances the benefit of utilising modular building systems based on a broader standardised concept, which is discussed by Clark & Baldwin [23] identifying possibilities for flexible solutions based on standards and generating enhanced competitiveness.

Hence, companies can offer solutions that generate a cost-effective method to mass-produce buildings based on standardised modules, and not based on specialised solutions driven by customer's demands. The customer would be limited to a selection of standardised modules. These can be combined to create a customised home based on standard solutions, which is reviewed by Paulsson, Nilsson & Tryggestad [22], looking at the benefits of standard components being assembled into specific modules that enables late customisation and high customer value. This resembles IKEA's methodology where a customer buying an IKEA kitchen can choose between already existing modules that combined form a unique kitchen. The customer cannot make any exceptions from the available standard modules when designing the kitchen, i.e. in the building industry customers can choose from different wall modules and thereby design their own building, which is further discussed in the study by Langlois [24] emphasising the importance for standard components in a modular system to interact and not deviate from the standard solutions to be successful and support the complexity of producing wood-buildings. These modules can be used interchangeably by different designs. This means that the total number of components and the total cost can be reduced as the modules only need to be developed at an initial stage, minimise the information requirements to provide short delivery times. Hence, provide possibilities for an efficient production process based on modularisation as discussed in the studies by Olhager [11], Jonsson [28] and Jiao & Tseng [21].

B. Market Development Possibilities Using Standardised Information Flow

Buildings with wooden load bearing structural systems have a low market share compared to solutions based on concrete. However, it is increasing with the introduction of environmental requirements and greater interest in the environment and climate-friendly houses. Hence, an increase to ramp up production by improved production methods, based on efficient use of information in the project-planning phase is a requirement for the customer. The company that succeeds in scaling up the production and fulfilling the market demand can achieve an advantage, as discussed in the study by David & David [18]. To succeed, the trend of modularisation and increased automation in manufacturing has been introduced in the building industry, which enables the mass production of different product mixes cost-effectively with short lead times. Today, there are shortcomings regarding standardised working methods, cooperation and lack of communication between architect and production department. A strategy to eliminate these problems and enable modular systems would be to integrate vertically in the value chain. This would enable a stable process where lead times from design to production would decrease based on standardised project information using data in accordance with BIM to digitalise the product design and production process enabling standardisation of information and modularisation. Market possibilities for the industry to develop, based on a standardised information flow leading to modularisation is visualises by Fig. 3 illustrating how customer value is created and delivered. This is emphasised by Dahle, Holm & Dagestad [19] and Osterwalder & Pigneur [20], highlighting the importance for companies to develop a business model focused on value creation to the customer.

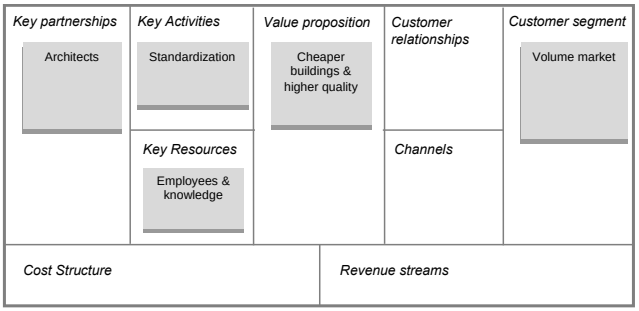

Fig. 3. Business model.

In summary, optimising the company's information process by a higher degree of standardisation provides better utilisation of resources and stronger competitiveness. Many believe that efficiency is being made within the operational production process, whereas optimising the information flow is considered difficult or impossible to achieve. The result shows that there is a lack of stability within the information flow of the project department, resulting in additional work due to errors or corrections. Therefore, long-term plans are required to improve the level of standardisation within the industry, resulting in better use of company resources and products with higher quality. The automotive industry has developed further regarding modularisation of their production than the building industry, which could provide a blueprint for the building industry. Opportunities linked to modular systems could be introduced and developed in all companies that prefabricate and build houses in the factory. This would indicate that buildings will be produced at a faster phase and cheaper than using traditional methods. Companies working with their strategic business model developing towards modularisation by increased standardisation have the possibility to gain market shares by mass production and simultaneously create a unique customisation, according to customer's demands.

REFERENCES

[1] SCB [Statistics Sweden]. (2017). Sveriges folkmängd från 1749 fram till idag, (Sweden's population from 1749 until today). [Online]. Available: http://www.sverigeisiffror.scb.se/hitta-statistik/sverige-i-siffror/manniskorna-i-sverige/befolkningsutveckling/

[2] Boverket [National Board of Housing, Building and Planning]. (2016). Behov av bostadsbyggande - Teori och metod samt en analys av behovet av bostäder till 2025. *Requirement for Residential Construction -Theory and Method as well as An Analysis of the Requirement for Homes to 2025.* [Online]. Available: http://www.boverket.se/globalassets/publikationer/dokument/2016/reviderad-prognos-over-behovet-av-nya-bostader-till-2025.pdf

[3] Boverket [National Board of Housing, Building and Planning]. (2011). Vad bestämmer bostadsinvesteringarna. *What Determines the Housing Investment*. [Online]. Available: http://www.boverket.se/globalassets/publikationer/dokument/2011/vad-bestammer-bostadsinvesteringarna.pdf

[4] F. Lindblad, T. Schauerte, and M. Flinkman, "Changes in industry structure and concentration? Welfare loss due to perfect competition in the Swedish industry for wooden single-family houses," in *Proc. of the Forest Products Society International Convention, Portland, USA*, 2016.

[5] Regeringen [The Swedish Government]. (2015). Bostadsmarknaden och den ekonomiska utvecklingen. *Housing Market and its Economic Development*. [Online]. Available: http://www.regeringen.se/contentassets/bdf96e86d579425581134dae37c1b3d2/lu-bilaga-3-hela-till-webben.pdf

[6] SCB [Statistics Sweden]. (2015). Bostadsbyggandet ökar kraftigt. *The Housing Construction is Increasing Rapidly*. [Online]. Available: http://www.scb.se/sv_/Hitta-statistik/Artiklar/Bostadsbyggandet-okar-kraftigt/

[7] Boverket [National Board of Housing, Building and Planning]. (2016). Boverkets indikatorer november 2016. *Housing Indicators.* [online]. Available: http://www.boverket.se/globalassets/publikationer/dokument/2016/boverkets-indikatorer-november-2016.pdf

[8] SCB [Statistics Sweden]. (2017). SCB-Indikatorer: Sveriges ekonomi ökade takten. *SCB Economic Indicators: Sweden's Increased Pace*. [Online]. Available: http://www.scb.se/contentassets/37b41d21b97e4585851ccaf8caec9ae6/aa0101_2017m02_ti_a06ti1702.pdf

[9] M. Karlsson. (2005). Avreglering, konkurrensutsättning och ekonomisk effektivitet - offentligt eller privat? En översikt av svensk empirisk forskning (Deregulation, competition and economic efficiency-public or private? *An Overview of Swedish Empirical Research.* [Online]. Available: http://www.konkurrensverket.se/globalassets/forskning/projekt/avreglering-konkurrensutsattning-och-ekonomisk-effektivitet.pdf

[10] M. Atterhög. (2006). *Increased Competition in the Swedish Housing Market and its Effect on Rents and Quality of Housing Services for Households.* [Online]. Available: http://www-tandfonline-com.proxy.lnu.se/doi/full/10.1080/14036090510034545?scroll=top&needAccess=true

[11] J. Olhager, "Produktionsekonomi: Principer och metoder för utformning, styrning och utveckling av industriell production," *Production Management: Principles and Practices for the Design, Management and Development of Industrial Production*, 2013.

[12] L. Sörqvist, "Lean: Processutveckling med fokus på kundvärde och effektiva flöden," *Lean: Process Development with Focus on Customer Value and Effective Value Flow*, 2013.

[13] G. Lane, *Made-to-order Lean: Excelling in A High Mix, Low-Volume Environment*, New York: Productivity Press, 2007.

[14] J. K. Liker, *The Toyota Way: Lean för Världsklass, (The Toyota Way to Lean Leadership)*, Malmö: Liber AB, 2009.

[15] M. Forslund, *Organisering Och Ledning, (Organisation and management).* 2nd ed. Malmö: Liber AB, 2013.

[16] J. P. Womack and D. T. Jones, *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, Sydney: Simon & Schuster, 2003.

[17] M. Rother and J. Shook, *Learning to See: Value Stream Mapping to Add Value and Eliminate MUDA*, 1st ed. The Lean Enterprise Institute, Inc, 2004.

[18] F. R. David and F. R. David, *Strategic Management: Concepts and Cases, Global Edition*, 5th ed. England: Pearson Education Limited, 2015.

[19] Y. Dahle, H. Holm, and S. Dagestad, *Lönsam Tillväxt: Affärsidé, Affärsmodell och Affärsplan, (Profitable Growth: Business Idea, Business Model and Business Plan)*, 1st ed. Malmö: Liber AB, 2012.

[20] A. Osterwalder and Y. Pigneur, "Business model generation: En handbok för visionärer, banbrytare och utmanare (business model generation: A guidebook for visionaries, pioneers and contenders)," *Lund: Studentlitteratur AB*, 2013.

[21] J. Jiao and M. M. Tseng, "A methodology of developing product family architecture for mass customisation," *Journal of Intelligent Manufacturing*, vol. 10, no. 1, pp. 3-20, 1999.

[22] U. Paulsson, C. H. Nilsson, and K. Tryggestad, *Flödesekonomi: Supply Chain Management*, Lund: Studentlitteratur, 2000.

[23] K. B. Clark and C. Y. Baldwin, *Design Rules: The Power of Modularity*, Cambridge: MIT Press, 1999.

[24] R. N. Langlois, "Modularity in technology and organisation," *Journal of Economic Behaviour & Organisation*, vol. 49, pp. 19-37, 2002.

[25] B. Bergman and B. Klefsjö, *Kvalitet: Från Behov till Användning, (Quality: from the Requirement to Use)*, 2nd ed. Lund: Studentlitteratur AB, 2012.

[26] P. Petersson, B. Olsson, T. Lundström, O. Johansson, and M. Broman, *Lean: Gör Avvikelser till Framgång, (Lean: Allow Deviations to Succeed).* 2nd ed. Bromma: Part Development, 2009.

[27] P. Dennis, *Lean Production Simplified: A Plain-Language Guide to the World's Most Powerful Production System*, 3rd ed. New York: Productivity Press, 2016.

[28] P. Jonsson, *Logistics and Supply Chain Management*. United Kingdom: Mcgraw-Hill Education, 2008.

[29] M. Rother, *Toyota Kata: Lärande Ledarskap, Varje Dag, (Toyota Kata: Managing People for Improvement, Adaptiveness and Superior Results)*, Stockholm: Liber AB, 2013.

[30] J. A. Kylén, *Att få Svar: Intervju, Enkät, Observation, (To Get Answers: Interviews, Surveys and Observations)*, Stockholm: Bonnier Utbildning AB, 2004.

[31] A. Meeuwisse, H. Swärd, R. Eliasson-Lappalainen, and K. Jacobsson, *Forskningsmetodik: för Socialvetare, (Research Methodology for Social Scientists),* Stockholm: Bokförlaget Natur och Kultur, 2008.
[32] A. Bryman and E. Bell, *Business Research Methods,* 3rd ed. New York: Oxford University Press, 2011.
[33] M. Barratt, T. Y. Choi, and M. Li, "Qualitative case studies in operations management: Trends, research outcomes, and future research implications," *Journal of Operations Management*, vol. 29, no. 4, pp. 329-42, 2011.
[34] M. A. McKendall and J. A. Wagner, "Motives, opportunity, choice and corporate illegality," *Organizational Science*, vol. 8, no. 5, pp. 1-24, 1997.
[35] J. L. Whitten, L. D. Bentley, and K. C. Dittman, *Fundamentals of System Analysis and Design Methods,* 6th ed. McGraw-Hill Irwin, Boston, USA, 2004.

Fredrik Lindblad currently works as a researcher at Linnaeus University in Sweden, with focus on a specific building project. His focus is on the market and strategic components influencing the building process, which enables an increase of wooden multi-family houses. This requires a multi-disciplinary research approach considering the scope includes procurement, strategy development, logistics, construction management, building technology, etc. Fredrik has an industry background within the supply chain field, including roles with the Swedish Department of Commerce, and on global level with Danzas, DHL and as the Global Head of Supply Chain at Aramex. In addition, he holds several board level commitments and consultancy engagements on an international level.