Summary of research result from the "City development project Torparängen"

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Växjö, 2019, Fredrik Lindblad

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1 INTRODUCTION

1.1 Växjö Municipalities renewed wood-building focus

Växjö focused in modern wood construction and building high structures in wood at an early stage. This have generated a national and international focus with many delegations visiting to review best practices that support sustainability within construction developments, which initially has been focused around the earlier projects, Välle Broar and Limnologen. It is agreed in the declaration of intent between the municipalities in Växjö and Skellefteå that focus should be in clarifying respective wood construction strategy and to raise the Governments awareness to provide suitable working conditions for a long-term strategy towards wood construction on a national level.

With the new urban development project Torparängen in Växjö provides new opportunities for a wood-building arena to once again take on the role as Sweden's leading municipality related to wood construction. Torparängen can provide the basis for increased cooperation related to research, business and education. Hence, the university and the municipality can jointly work together and create a greater interest in the industry for wood constructions, which can provide an increase of more sustainable housing being produced in an economically cost-efficient way.

The aim in Växjö municipality's wood building strategy is to increase the proportion of wood-based construction in new developments, which is among others defined as 50 % of new developments by 2025 (Boverket, 2018) should be based on a wood-based construction solution. Implementing this strategy requires a combined approach that create both economic- and technical possibilities for sustained development. Specifically, how can the goals be fulfilled through actions in, e.g. land allocations and tendering processes, combined with the defined challenges in the municipality's strategy documents

related to life cycle costs, construction costs, maintenance costs, and sound and vibration.

1.2 Wood-building project in Växjö with special focus on Project Torparängen

In recent years, a number of high residential buildings have been built using a wooden frame. Several of these buildings are advanced constructions and are products of best practices and innovative solutions. Commonly, the technical challenges are, e.g. sound transmission, vibration, stabilization, moisture and statics, etc. But equally important are the controlling mechanisms if the buildings can be built or not, i.e. But so important is what controls if they can be built or not, i.e. construction cost, the long-term financial and operational implications of building using a wood frame. This can include areas such as process management, logistics, industrial construction, production management and procurement.

Project Torparängen includes a major research study, which is seen as the continuation of the increased wood construction focus in Växjö and how the Växjö-model can be transferred and generate a boost for a national wide wood-building drive. The benefit with the project is that the research have followed a specific development located in Växjö, Figure 1, which provided access to the decision making process from start to finish not common in other research projects.

Figure 1: The location of the development project Torparängen in Växjö.

The purpose of the research project was to document a number of processes associated to wood-building construction, but also the entire building process before they arrive, as well as study the unique properties that are important in wood buildings. This in order to increase the overall knowledge that can be used for enhanced quality in future wood-building projects and to increase the proportion of construction of wooden buildings in Sweden.

1.3 Project overview

The project proposal contains several parts, preliminary studies, procurement, production, technical conditions, operationalization and follow-up, Figure 2. All of these elements have been defined in 11 research projects. These projects have been held together and through coordinated project management to provide a birds-eye perspective throughout the project and not lose focus related the interconnectivity between the sub-projects.

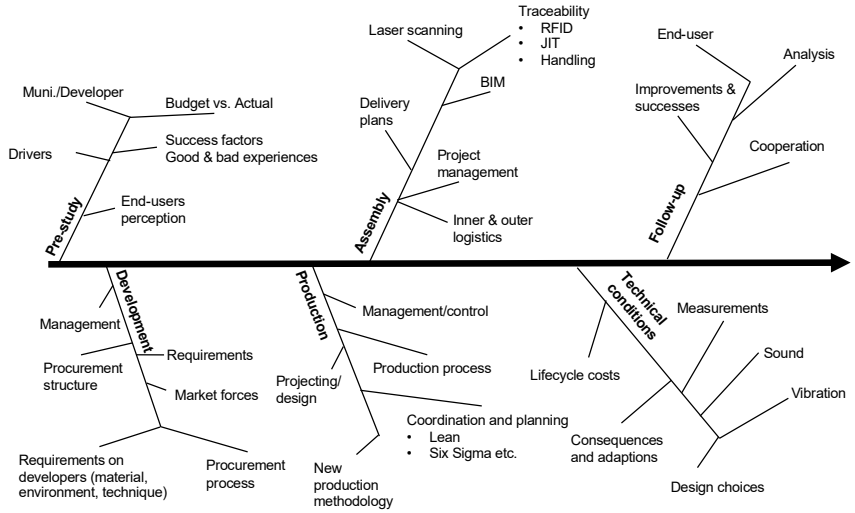

Figure 2: Research scope.

1.3.1 Research sub-projects

The research sub-projects where decided initially at the start of the project as being of importance for the development of the wood-building construction industry and incorporate an end-to-end perspective. This included financial

and market related factors, logistic processes and building technological areas of interest.

1. Market study, why is not wood used in any extent in construction today?
2. Procurement and tendering
3. Construction development
4. Production
5. Delivery and assembly, including lacer scanning
6. Wind induced vibrations
7. Acoustics and vibrations
8. Measurements of moisture and heat
9. Measurements of vertical relativity displacements
10. End-user analysis, expected and perceived customer value

1.4 Outline of the summary document

The document is built up using a structure based on an extended summary of all the research topics and the papers included in the thesis. The structure is visually presented in Table 2 below, which describes the six chapters included in the extended summary.

Chapter 1 focuses on the introduction, background that provide the scope for the research project.

Chapter 2 present the research that has been conducted in association to this project and how the research is related to the project scope presented in Figure 2.

Chapter 3 briefly describe the scope and findings of all the included research and a general summary of the conclusions derived from each research phase based on Figure 3.

Chapter 4 presents an aggregated summary and reflections about the conducted work and a recommendation about future possible research areas.

2 RESEARCH INCLUDED IN THE PROJECT SCOPE

Paper 1
Schauerte, T., Lindblad. F. and Johansson, J., Market structure and risk for wooden single-family house firms: Possibilities and Barriers to enter the multi-family house segment*, Proceeding at the World Conference on Timber Engineering*, 2014.

Paper 2
Schauerte, T. and Lindblad, F., Corporate economic distress in the wood construction industry: Current state and trend after the economic crisis, *Pro Ligno*, 11 (4): 389-396, 2015.

Paper 3
Schauerte, T. and Lindblad, F., Productivity trend in the off-site construction sector of wooden houses, *Pro Ligno*, 11 (4): 432-439, 2015.

Paper 4
Lindblad, F. and Schauerte, T., Operational and financial risks in the Swedish industry for wooden single-family houses. A trend analysis, *Proceeding at the 4th Forum Wood Building Nordic*, 2015.

Paper 5
Lindblad, F., Schauerte, T. and Flinkman, M., Changes in Industry Structure and Concentration? Welfare Loss due to Perfect Competition in the Swedish Industry for Wooden Single-Family Houses, *Proceeding at the Forest Products Society International Convention*, 2016.

Paper 6
Lindblad, F., Flinkman, M. and Schauerte, T., Assessing corporate economic distress: A study of the wood construction industry, *Pro Ligno*, 13 (4): 594-601, 2017.

Paper 7

Lindblad, F. and Schauerte, T., Identifying drivers facilitating product development within the industry for wooden multi-family houses, *Pro Ligno*, 13 (4): 602-609, 2017.

Paper 8

Lindblad, F., Schauerte, T., and Johansson, J. Identifying market mobility barriers for wooden single-family house producers to enter the multi-family segment, *Proceeding at the Forest Products Society International Convention*, 2018.

Paper 9

Lindblad, F. and Schauerte, T., Public procurement enabling the development of wooden multi-family building projects in Sweden, *Wood Material Science and Engineering,* 2018.

Paper 10

Lindblad, F., Barriers in the public procurement process, restricting long-term sustainable construction of wood buildings, *Scandinavian Journal of Public Administration, Special issue: Hard utility services*, 2018.

Paper 11

Lindblad, F., A case study of Växjö municipality's actions to increase the construction of wood multi-family buildings, *Proceeding at the 7th Forum Wood Building Nordic,* 2018.

Paper 12

Lindblad, F., Bolmsvik, Å., Pettersson, J. and Wiberg, S., Efficiencies in the on-site material handling process by using radio frequency identification in the wood building construction industry, *International Journal of Innovation, Management and Technology,* 2018.

Paper 13

Lindblad, F., Magnusson, B., Luu, A. and Ragnarsson, J., Information flow optimisation: enabling standardisation towards modular building methods of wood-building solutions, *International Journal of Innovation, Management and Technology*, 2018.

Paper 14

Lindblad, F., Lehman, K. and Aggerstam, E., A comparative study of the environmental impact from transportation of prefabricated building elements using wood or concrete, *International Journal of Engineering and Technology,* scheduled for March/April 2019.

Paper 15
Schauerte, T., Lindblad, F. and Flinkman, M., Critical success factors determining economic health of firms producing wooden single-family houses, *Arkitektur N*, 2018.

Paper 16
Johansson, J., Schauerte, T. and Lindblad, F., Balancing the production flow in prefabrication of wooden houses, *Forest Products Society annual convention - Forest Products: Key To A Sustainable Future,* 2018.

Paper 17
Lindblad, F., Market development barriers for Swedish wooden multi-family house industry, *International Journal of Structural and Civil Engineering Research,* (scheduled for April) 2019.

Paper 18
Beijbom, D. and Hög, F., Vad är bostadskvalitet? – En jämförelse mellan boendes och arkitekters uppfattning, *Kandidatuppsats – Byggteknik vid Linnéuniversitetet, Fakulteten för Teknik, 2018.*

Paper 19
Aggerstam, E. and Lehman, K., Materialvalets miljöpåverkan på transporten: En jämförelsestudie mellan transporter till flerfamiljshus i trä och betong, *Kandidatuppsats – Industriellekonomi vid Linnéuniversitetet, Fakulteten för Teknik, 2017.*

Paper 20
Fohlin, E. and Ekström, H., Increase efficiency of production flow and bottleneck, *Kandidatuppsats – Industriellekonomi vid Linnéuniversitetet, Fakulteten för Teknik, 2018.*

Paper 21
Ragnarsson, J. och Luu, A., Effektivisering av informationsflödet hos ett företag med produktvariation, *Kandidatuppsats – Industriellekonomi och Maskinteknik vid Linnéuniversitetet, Fakulteten för Teknik, 2017.*

Paper 22
Lundström, F., Utvärdering av miljön i området Torparängen med laserskanning, [Evaluation of the environment in the area Torparängen with laserscanning], *Kandidatuppsats – Byggteknik vid Linnéuniversitetet, Fakulteten för Teknik, 2016.*

Paper 23
Stefan Marusic, S., Ibrahim, B. G. and Alhamed, Y., Vad påverkar kommunerna i deras val av upphandlingsform?, [What effects municipalities in their choice of procurement?], *Kandidatuppsats – Byggteknik vid Linnéuniversitetet, Fakulteten för Teknik, 2016.*

Paper 24
Pettersson, J and Wiberg, S., Tidseffektivisering av materialleveranser på byggprojekt med radiofrekvensidentifikation, RFID, [Time efficiency of material deliveries on construction sites with radio frequency identification, RFID], *Kandidatuppsats – Byggteknik vid Linnéuniversitetet, Fakulteten för Teknik, 2015.*

Paper 25
Lindblad, F., Summary of the research result from "City development project Torparängen", *Linnaeus University Press, 2019.*

2.1 Research papers related to the general project structure

The identified research areas are separated in four project phases and are defined in Figure 3. These phases incorporate the 10 sub-projects that was outlined as the main research focus. The research have managed to produce 24 different studies within the scope of the different phases, Figure 4, where the 25th study represent this summary.

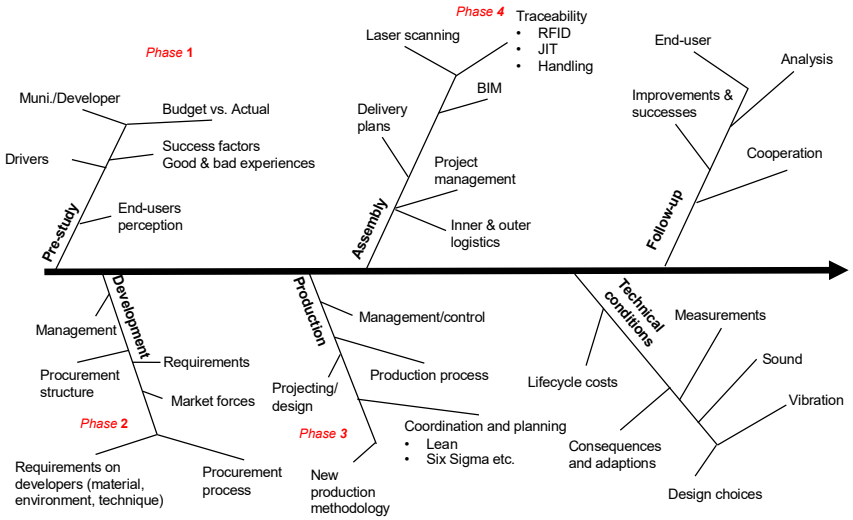

Figure 3: Main structure for the research projects.

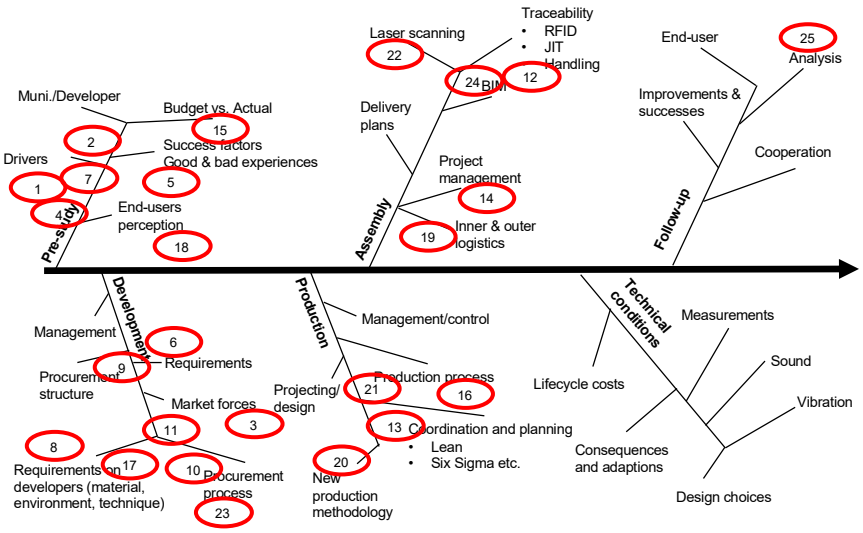

Figure 4: Mapping the research projects in the general structure.

3 RESEARCH FINDINGS

3.1 Phase 1 – Pre-study

3.1.1 Included research projects

Paper 1

Market structure and risk for wooden single-family house firms: Possibilities and Barriers to enter the multi-family house segment.

Housing shortage has become a serious issue in Sweden and too little firms are offering solutions for multi-family houses in wood. Possible firms to enter that segment are those currently producing wooden single-family houses. The aim of this paper is to explore the potential of these firms to enter that segment, which is linked to investments in production development, and investigated by mapping the industry structure for sellers, describing the financial situation of the firms and their risk position. Using the Herfindahl-Hirschman index, the Herfindahl-Hershaman number equivalent, Altman's Z' value and a risk position model for 51 investigated firms, the results show that the industry is perfect competitive with too many firms involved. Further, the majority of the firms have favourable financial prerequisites and risk positions to invest in production development, in order to produce prefabricated wooden multi-family houses as well.

Paper 2

Corporate economic distress in the wood construction industry: Current state and trend after the economic crisis

In order to obstruct housing shortage in Sweden, wood is considered as an alternative material for multi-family applications. Yet, more firms are needed to prefabricate wooden elements, volumes or modules in an industrialised way. These could be found amongst firms producing wooden single-family houses; however, they might suffer from economic distress, since their core market dropped by more than 60% in the aftermath of the economic crisis. This study investigates corporate economic distress from 2010 to 2013 of 52 Swedish firms producing wooden single-family houses. This, by applying Altman's Z'-score model, grouping firms into a risk, a grey or a safe zone. Results show that from 2010 to 2013, firms suffering from economic distress decreased from 11.1% to 3.8%. The two remaining firms in the risk zone most likely will face bankruptcy, if no radical action will be taken. Firms in the grey zone increased from 31.1% to 36.5%. The 19 firms in this zone are dependent on appropriate strategies to positively develop their business. Finally, firms in the safe zone increased from

57.8% to 59.7%. These firms are in good economic conditions and can be regarded as potential candidates for investing in a development towards multi-family applications. For the investigated time period, the average Z'-score improvement for the whole industry equals 38%, with a major upturn from 2012 to 2013.

Paper 4,

Operational and financial risks in the Swedish industry for wooden single-family houses. A trend analysis

Shifting concentration of population to urban areas has increased the shortage of available housing. The combination of housing shortage with a limited number of companies that provide solutions for multi-family houses in wood has become a serious concern in Sweden. Those companies that possibly could fill this void and enter this segment are at present time producing single-family houses. The development for these companies is connected to investments in long-term product development. The aim of this paper is to examine the possibility for these companies to develop and enter this segment. This is investigated by describing the risk position and financial situation for the companies with-in this industry, over time. It is conducted by utilizing a risk position model for 46 selected companies, comparing the development trend over a selected time period. This has exposed that many of the companies have demonstrated a positive financial situation and risk position over time, indicating a favourable position to invest in product development towards wooden multi-family houses in addition to their current products.

Paper 5,

Changes in Industry Structure and Concentration? Welfare Loss due to Perfect Competition in the Swedish Industry for Wooden Single-Family Houses

As studies based on data from 2012 show, the Swedish market for wooden single-family houses is highly competitive, with many firms offering relatively homogeneous products or services. In order to serve the demand on that market, only 38 % of the existing firms actually were needed. Thus, an uneven distribution of resource utilization let to welfare losses. Yet since 2012, the demand on the market increased by more than 35 %, which potentially had an effect on resource utilization. This study is aiming at describing the development of the structure and concentration in the Swedish industry for wooden single-family houses, for a ten-year period from 2005 to 2014. This could help to understand, if and how market demand affects structure, concentration rate and consequently welfare loss due to resource utilization. The required data were collected from the annual reports of the 51 relevant firms in

the industry. By means of the Herfindahl–Hirschman Index, Concentration Ratio and the Herfindahl–Hirschman Number Equivalent, industry structure and concentration rate were calculated. The results show how the industry structure and concentration rate developed from 2005 to 2015, the distribution of resource for welfare purposes and thus, how many firms there actually are needed to serve the market.

Paper 7

Identifying drivers facilitating product development within the industry for wooden multi-family houses

Sweden is forecasted to grow its population with 1.1 million people over the next eight-year period, increasing the demand on the construction phase of housing units throughout Sweden. However, at present, 240 of Sweden's 290 municipalities show an existing deficit of available housing units in their regions, resulting in inherent difficulties fulfilling this demand utilizing the current production structure. Therefore, further utilizing wood as a building material could contribute to minimize the gap, as well as fulfilling the EU's goals towards the Europe 2020 strategy and the EU forest strategies, focusing on development towards innovation, bio-economy, sustainable sourcing and use of raw materials. This study is aiming to identify drivers supporting the Swedish industry of wooden multi-family houses to enable market growth through competitive and sustainable strategies. The representatives within the building process identify drivers, how they perceive their effect on the companies' abilities to develop based on long-term and short-term strategic impact. Thus, the goal is to find ways in which wooden multi-family houses could compete as a building solution, compared to established solutions, thereby increasing the market share in Sweden. The methods used in this study is surveys distributed to representatives from municipalities, developers, contractors, architects and real estate companies. The result identifies three change drivers influencing the industry development for wooden multi-family houses in Sweden: technological-, knowledge- and environmental- drivers. These drivers have an effect on the companies' ability for successful new product development and for development of sustainable strategies towards market growth for wooden multi-family houses.

Paper 15

Critical success factors determining economic health of firms producing wooden single-family houses

Firms in the Swedish industry for wooden single-family houses operate on a highly competitive market. Products are relatively homogenous, easily substitutional and firms mainly compete by prices. Since 2005, the accumulated

market share for the five largest firms decreased from 53 % to 39 %, whilst the number of firms in the industry increased by almost 60 %. In addition to these internal issues on industry structure, construction firms are generally sensitive to external impacts, like the current changes in bank loan policy for the customer. Nonetheless, the number of produced single-family houses in Sweden increased by almost 130 % since 2012. Contributing to reducing the existing housing shortage in Sweden, wooden single-family house producers play an important role. However, earlier studies show that around 40 % of these firms are economically distressed, or in a situation, where they need to take appropriate strategic action to avoid economic distress in the near future. Yet, what actions are appropriate? This study is aiming at identifying current critical success factors determining economic health of Swedish firms producing wooden single-family houses. By means of these factors, conclusions about appropriate strategic actions might be drawn to avoid economic distress. Data from the 2015 annual reports of 50 relevant firms were collected and processed by means of the Altman's Z′-score model and regression analysis. The results show that two factors accumulate to 99 % explanatory power (adj. R2) of financial health: (1) the manufacturing capacity of the firms' assets and (2) the firms' equity ratio. These are the current critical success factors for economic health of Swedish firms producing single-family houses. (1) matches to-days' debate about automated prefabrication and (2) can be seen as the way of financing such assets. Thus, these issues should guide the strategic agenda of firms in the industry.

Paper 18

Vad är bostadskvalitet? – En jämförelse mellan boendes och arkitekters uppfattning [What is living quality? – A comparative study between residents and architects perception]

There is currently a housing shortage in Sweden that requires for more housing units to be built. It is therefore important to investigate what the residents consider to be building quality and what they prioritize when selecting accommodation. This is to see if it is consistent with what is being built and what architects consider to be quality and what they prioritize in their design solutions. There are more apartment buildings being built with wooden frames than ever before and it is therefore interesting to compare if there is a difference in how they experience quality of living in a multi-family house with wooden frames compared with concrete frames. A questionnaire has been sent out to selected multi-family houses in Växjö and Västerås, and interviews have been conducted with architects in order to gain a deeper understanding of the perceived quality of new building developments.

An analysis of the study showed that the location in the city was the most important parameter when choosing an apartment. Thereafter, light, apartment size and sound insulation were prioritized by the residents. Architects prioritized lighting, natural materials over the location in the city and good furnishing possibilities. The results of the survey can form the basis for further investigations into new construction projects, as well as support architects and builders in housing and urban planning.

Having the ability to build good housing units is an important part of society since it directly affects people's way of life and living standard. Therefore, it is important to understand housing quality to create a possibility to adjust the construction and design of housing units accordingly. The purpose of the study is to show what residents consider to be quality and if it is in line with the design of today. The study also reviews if there is any quality difference in accommodations using wood or concrete as a building material. The survey provided data from eight selected multi-family houses, which showed that the quality of living did not differ between the selected materials. On the other hand, there was a difference between the perception of residents and architects.

3.2 Phase 2 – Development

3.2.1 Included research projects

Paper 3

Productivity trend in the off-site construction sector of wooden houses

With rising production costs and an insufficient production development, firms in the Swedish industry for wooden single-family houses might face severe problems in productivity. This is gaining in importance, considering that this industry highly tends towards perfect competition, i.e. firms mainly have to compete by prices. This study investigates the productivity of Swedish firms producing wooden single-family houses off-site, by analysing the ratio between turnover and number of employees as factors affecting productivity. 48 firms were studied from 2010 to 2013 and the results show that the average firm productivity in the industry worsened by 6.56 %, with a slight improvement from 2012 to 2013. 23 firms increased and 25 firms decreased their productivity during the investigated time span, yet, from 2012 to 2013, 31 firms improved productivity. Almost half of the 23 firms with increased productivity achieved that betterment even though their turnover decreased and 12 firms improved productivity with declining turnover. Another 12 firms tried to compensate declining turnover with resigning employees, yet, could not keep their former productivity level.

Paper 6

Assessing corporate economic distress: A study of the wood construction industry

Wood buildings are considered as a viable option to support the effort minimizing the current housing shortage in Sweden. Companies trying to develop into this industry are needed to increase the use of prefabricated wooden elements, volumes or modules in an industrialized way. Suitable companies to make this development could be found amongst firms producing wooden single-family houses. These companies currently act on a highly competitive market with many companies offering relatively homogeneous products or services. Therefore, differentiation towards the wooden multi-family house industry could be considered as a long-term strategy, minimizing the economic distress and improving the survival of the company. The study is aiming at describing the development of economic distress and market concentration ratio in the Swedish industry for wooden single-family houses, for an eleven-year period from 2005 to 2015. The companies could be helped to understand, if and how the market concentration ratio and the economic distress are connected, linking company size to economic stability and efficient resource utilization. This will be conducted by applying Altman's Z'-score model, grouping firms into a risk, a grey or a safe zone, combined with calculating the industry structure by means of the concentration ratio model. The required data were collected from the annual reports of the 51 relevant firms in the industry.

Paper 8

Identifying market mobility barriers for wooden single-family house producers to enter the multi-family segment

In the past decades, the housing shortage in Sweden accumulated to a level that led to acute problems for many people combined with continuously rising housing prices. The market for single-family houses, where wood dominates with 85 – 90 % of market share, is highly competitive with many companies offering relatively similar products or services. To serve the demand on that market, only 38 % of the existing companies were needed. One way to tackle the existing housing shortage, and to develop new business opportunities, could be to get more companies from the single-family house industry to produce multi-family houses. Current competence in prefabricated house production could be utilised, yet, other areas could act as barriers for these companies. The aim of this study is to identify potential market mobility barriers for Swedish companies currently producing wooden single-family houses to develop towards the construction of multi-family houses. This will be conducted by initial interviews with decision makers in those companies,

combined with a survey-study covering companies within the industry. The results show that the main market mobility barriers are related to the strong market presence of traditional building materials, lack of knowledge by the market of wood as a suitable building material and the importance of governmental guidance and actions.

Paper 9

Public procurement enabling the development of wooden multi-family building projects in Sweden

Sweden is currently faced with a housing shortage, and the responsibility for detailed planning and the construction rate falls on the respective municipalities. Further, an ambition to develop sustainable building solutions based on wood is combined with the building requirements, which increases the complexity of the process. Thus, the public activities leading to an increased construction rate of multi-family wooden houses are of importance for all actors participating in this process. This is currently managed by the municipalities' through the public procurement act or the land allocation process, dependent on their development plan. The aim is to investigate how the land allocation activity can improve its project efficiency, and provide transparency and structure in the land allocation activity between developers and Swedish municipalities. The study is using the public procurement process as a model, due to the similarities between the two processes, and applying it on the activities in the land allocation process to provide a sufficient structure for the municipalities to follow. The result display discrepancies how the process is perceived and the level of competence displayed by the municipalities managing the process, which hinders the development of wooden multi-family houses in Sweden.

Paper 10

Barriers in the public procurement process, restricting long-term sustainable construction of wood buildings

The municipalities control the planning of new housing projects in Sweden, which is based on their general requirements and future strategic expectations. The activity is managed through the public procurement act or the land allocation process dependent on their development strategy. It involves the development of local strategies regarding design, geographical development, as well as the development of suitable procurement methods. Therefore, having the ambition to develop sustainability by increasing the use of wood building solutions imposes new challenges on the procurement process as performed by municipalities in Sweden. The aim of this study is to identify barriers in the public procurement process for new building developments

based on land allocation projects managed by Swedish municipalities, enabling an increase of wooden multi-family houses in Sweden. The study is based on direct participation at a municipality performing this activity, combined with interviews including municipalities and developers involved in the procurement process using land allocation. The result of the study shows discrepancies in how the municipalities and developers perceive the land allocation activities. Furthermore, national standards, equal evaluation methods and a defined procurement process have been identified as drivers towards an efficient activity, which currently act as a barrier to the development of wooden multi-family houses.

Paper 11

A case study of Växjö municipality's actions to increase the construction of wood multi-family buildings

In 2005, a national wood-building strategy was adopted with the aim that 30 % of all new buildings within 10-15 years should use a wood-frame and that the number of buildings out of wood increase by 30% within a five-year period (Ds 2004:1). Despite this, less than 10 % of the multi-family houses are currently being built in wood, and the building developments in Sweden continue to show an upward trend for using concrete in building solutions for multi-family houses (Sveriges Träbyggnadskansli 2017; Svensk Betong 2016). However, several municipalities in Sweden chose to develop against this prevailing trend, Växjö municipality being one of them. Hence, Växjö municipality have since the implementation of the national wood-building strategy focused on using wood in new building projects. Therefore, Växjö municipality already in 2015 reached the municipal objective where 25 % of the construction directly controlled by the municipality would be wood-based. There is currently a change under way within public governance, from 'government to governance', which usually represents a shift from central governance to interactive governance because of a shift from public sector control to the private sector control (Montin & Hedlund 2009). In practice, this means that much of the power and control of municipalities has been transferred to private or other social actors Vall (2007). The planning for the construction of buildings has changed historically. Today, this is largely based on market actors fulfilling the requirement, and municipalities are expected to develop controlling instruments in line with the goals mentioned in the environmental policy and housing policy (Boverket, 2016). The municipality is expected to meet the public interest in housing and contribute to achieving Sweden's environmental and climate objectives, while at the same time the government are attempting to influence municipalities through the planning and environmental legislation that regulates construction.

Paper 17

Market development barriers for Swedish wooden multi-family house industry

The Swedish industry for wooden multi-family houses have in comparison with houses in concrete had a relatively small market share. This contradicts EU's ambitions defined in the Europe 2020 strategy, focusing on development towards innovation, bio-economy and sustainability. These strategies highlight the importance of developing the wooden multi-family houses industry to fulfil the increased market demand combined with increased sustainability in the building industry. This study aims to identify barriers enabling market growth for the Swedish industry producing wooden multifamily houses. Current barriers within the industry are reviewed by identifying areas restricting the development, e.g. the building process and procurement cycle. Thus, the goal is to find ways in which wooden multi-family houses could improve competitiveness compared to established solutions and increase its market share. The study was conducted with representatives from municipalities, developers, contractors, architects and real estate companies providing insights on new strategic possibilities in the building process. The result identifies different barriers that exist in various stages of the value chain, from procurement to construction. Furthermore, it indicates that wooden multifamily houses could be a competitive solution by developing new strategies, mitigating the identified market barriers facilitating growth towards sustainable building solutions. These instructions give you basic guidelines for preparing camera-ready papers.

Paper 23

Vad påverkar kommunerna i deras val av upphandlingsform?, [What effects municipalities in their choice of procurement?]

According to Boverkets report "Behov av bostadsbyggande" it is estimated that an addition of more than 705,000 new homes are necessary by 2025. As a consequence of the housing shortage and the need to produce a cost-effective building system, Sveriges allmännyttiga bostadsföretag (SABO) invited construction companies to the competition "Kombohus". This led to an establishment of procurement contracts with several companies that offered several turnkey apartment buildings in different categories, sizes and price levels. With these homes a procured contract can be established by the municipal housing companies with an existing framework contract. Despite SABOs fixed prices which is described to be twenty-five percent below the market average, the agreement is not used to the extent that it could be by the Swedish municipal housing companies. Only 60 of the 290 municipal housing companies that are members of SABO uses or has used the existing framework agreement. This work aims to find out what affects the municipalities in their

choice of contract terms, and to find out if SABO provides the cheapest housing concept that the market obtains. The basis for the work is a survey, interviews and an observed case study that compares the construction process in a traditionally procured item with an item that is procured under a framework agreement with SABO. The interviews have been using a half-structured interview form. The work is based on primary data collected from the survey.

The results of the study highlight many factors that are affecting municipalities in their choice of contract terms, it includes zoning, building processes and the final cost. The main reason that is affecting the municipalities in their choice of procurement is the zoning. According to the results of our case study it can be concluded that the procurement process is faster with the framework agreement and that the framework agreement is cheaper. Based on the result the writers conclude that SABO and the construction companies should work to develop better products that are not limited by the local zoning. The attractiveness and the design of the product should also be improved. SABO and the construction companies should also develop more products which are suitable in various municipalities and demographics. In addition, construction companies and SABO should market themselves towards politicians to increase the knowledge about the agreement.

3.3 Phase 3 – Production

3.3.1 Included research

Paper 13

Information flow optimisation: enabling standardisation towards modular building methods of wood-building solutions

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.

Paper 16

Balancing the production flow in prefabrication of wooden houses

The industrialization of wooden house building processes from traditional on-site production to off-site prefabrication is challenging, concerning the possibility of effective handling of numerous product variants, where each house is more or less unique. To obtain high productivity in the production, a well-balanced flow with minimization of waste is of great importance. In Sweden, many off-site house producers are in the starting phases of introducing advanced automation technologies in their production processes and the need for a more detailed process control therefore increases. In previous studies, the installation of windows has been identified as a demanding step in the prefabrication process, since it often creates a bottleneck i.e. the most overloaded part of process and thus negatively affects the cycle-time and a balanced production flow. This study aims to understand, how the effectiveness of windows installations could be improved. By using a multiple case-study methodology, processes of several companies are compared and discussed. Further, suggestions for improvements are made for one case company. The results show that a replacement of the windows installation could (a) shorten the cycle-time of one wall by more than 10 %, (b) reduce the queueing time for the entire wall assembly process by more than 48 % and consequently (c) help to create a more balanced production flow.

Paper 20

Increase efficiency of production flow and bottleneck

The rapid technological development in the industrial sector has made it possible to create better living conditions in a constantly growing world population. In connection with this development, conditions for the industrial market have also changed. Customer expectations regarding quality, high reliability, fast delivery and low price are getting higher. Companies must therefore become more productive and streamline their processes in order to meet these increased demands. One fundamental criteria for achieving a production with high quality products, and short lead times is good production

planning and well-functioning manufacturing processes. From this standpoint, there is a clear need for a focus shift towards internal operations and processes and to get an increased understanding of these. The pursuit for continuous improvements to better meet the customer's increased expectations is crucial if the company want to continue to be competitive in the global market.

The purpose of the study was to increase understanding and develop proposals for how production flows can be more efficient. The study has been conducted at case company X, which is a company active in the wooden house industry which manufactures prefabricated modular wood houses. To enable an improvement in production, the current situation of the case company was assessed by a value-flow analysis, with lead times and cycle times being clocked. By mapping the current state, restrictions (bottlenecks) could be identified and studied. Subsequently, the design of a future mode for more efficient production could be made. Activities regarding as waste in form of unnecessary movement could be mapped through spaghetti diagrams. The study has resulted in various improvement proposals being designed to streamline a bottleneck. The proposals for improvement show a theoretical reduction in lead time by approximately 15%. Furthermore, a reduction of wastes in the form of unnecessary movement has also been achieved. Based on the open discussion, the conditions for, and the effects on implementation of improvement proposals have also been highlighted. Finally, the current working conditions of the business have been studied regarding how the automated machines affect ergonomics and efficiency in production.

Paper 21

Effektivisering av informationsflödet hos ett företag med produktvariation [Streamlining the information flow in a company with product variation]

In today's market there is a big lack of residences in the country than ever before. Enterprises that are active in residence manufacturing industry have been affected by a high demand of their products. Like any other industry the construction industry tries to be more effective within the business. The production starts to proceed like the industry in terms of methods and automation. Improvements in the information flow have not come as far as in the production. The purpose with this research is to identify the information flow through comparing standard project with special project and bring suggestions for improvements. To be able to answer the examination question, theory about Lean production has been used but also theory from a market strategic perspective to give further support to the research. Information has been collected through interviews, surveys and from the ERP system and has

been compiled to a status report. Three areas were identified out of the status report which were: problem area, standard project and special project. Special project stands for 90 % of the constructors work.

From the collected information issues were identified between architect and constructor. Foremost in lack of communication and cooperation between them. These create unnecessary work, delays and wait. Some sort of standardized work is not established among the constructors and all of them construct in their own way. This makes it hard to reveal problems but also hard for newly employees when there is no guidelines for work. Many of the constructors sees special project as problems. Because the architects fulfil their wishes about the design of the residence and then the constructors find it hard to calculate strength calculation and also adapt to manufacturing process. It creates tightness to hold the set lead-time and the client can also do changes in the design late in the process.

Standard project do not exceed the set lead-time and creates less problem than a special project. The constructors prefer to work with a standard project rather than special project. It should be established a standardized work way. A smooth cooperation between architects and constructors to secure the quality of the information, example by A-hus recruit their own architects instead of working with external architects. A-hus should develop a more advanced modular system. Work of improvements should be a long-term work that never ends.

3.4 Phase 4 – Assembly

3.4.1 Included research

Paper 12

Efficiencies in the on-site material handling process by using radio frequency identification in the wood building construction industry

In the past decades, the housing shortage in Sweden accumulated to a level that led to problems finding accommodation for many people, which created opportunities for the market producing multi-family houses. The market is dominated by concrete solutions whereas solutions using wood as a building material only comprise 9 % of the market. This market is highly competitive with many companies offering relatively similar products or services. One way to develop new business opportunities is to enhance other competence besides production technology that currently acts as a market development barrier. Hence, the material handling process at building sites is seen as a barrier that can contribute improving competitiveness. There are currently problems with

material handling at many building sites of wood-building solutions in Sweden, materials arrive at the wrong time, waste of storage space, unnecessary tracking of materials or wrong quantities arriving at the sites. The purpose of the study is to investigate if Radio Frequency Identification (RFID) is a technology that can be used to achieve an efficient material handling process and if the wood building industry in Sweden is willing to implement the technology. Thus, investigate if material handling using RFID can improve time effectiveness, minimise waste and monitor moisture levels in the material efficiently, creating improved competitiveness. The study shows that the use of RFID improves time efficiency and control the material handling, indicating that RFID has potential to improve this process. Further, the study identifies possibilities by using RFID technology to minimise damages and control moisture levels.

Paper 14

A comparative study of the environmental impact from transportation of prefabricated building elements using wood or concrete

During 2015 as many as 240 of Sweden's 290 municipalities estimated that there existed a housing shortage within their region. Therefore, many homes are required to be built in a relatively short period to fulfil the demand. Production is required to take into consideration sustainable building solutions to reduce climate impact. Hence, logistics must become more efficient to contribute to an environmental solution, and the use of transports should be examined reducing the effect of heavy vehicles to meet the climate objectives. The focus of this study is to identify differences between the transportation of materials for building projects based on wood or concrete. Different key performance indicators were derived from the collected data and presented in this study, which resulted in two formulas focusing on transport- and environmental impact. The KPI's indicates that the weight of the load does not have an important impact on the amount of emitted CO_2, but it is the number of transports associated with the projects that are the main problem regarding emissions and environmental impact. Hence, the number of transports and the amount of CO_2 emissions can be calculated by the support of the formulas derived from this study.

Paper 19

Materialvalets miljöpåverkan på transporten: En jämförelsestudie mellan transporter till flerfamiljshus i trä och betong [The environmental impact of transports: A study between transport to apartment buildings in wood and concrete]

Several municipalities in Sweden experience a housing shortage that requires an increase in construction phase combined with increased focus in sustainability throughout the building process. In this context, the use of heavy vehicles has to be reduced, logistics must be streamlined, and alternative means of transportations should be explored. By improving resource efficiency, emissions can be reduced and money saved.

The aim of the study was to identify possible differences between the transportation of the building materials wood and concrete. The aim of the collected data was to find a ratio that could be used in practice. The key performance indicator will then be put in a formula so that anyone can calculate how many transports they need, and the amount of CO_2 emissions a transportation of elements in wood and concrete emitt when constructing multi-family houses. In order to achieve the purpose and aim of the study, a literature study within the subject area was required in parallel with data collections and field visits.The study is a qualitative study and all data is based on three different cases. During the course of the study, different assumptions were required based on general relationships that could be identified in the data collection. To be able to present a result the assumptions were necessary to make the different materials and projects comparable. 5.1524 times more transportations are required to convey concrete planes to a multi-family house than planes made in wood to a multi-family house. This indicates that it is about five times costlier to transport concrete elements than wood elements from manufacturer to the construction site, but it also means that five times more CO_2 emissions are emitted. The result of transported squaremeters concrete to wood calculation, gave a ratio of 14.5221. This designates that there are other factors affecting the number of transportations than weight. The ratio calculation of environmental emissions resulted in 1.3884 and shows that a concrete element shipment emits 1,3884 times more CO_2 than a shipment with wood elements. This specifies that the loaded weight is not significant and that the root problem on environmental impact is the number of heavy-duty trucks.

With the first formula presented in this paper, the number of transportations required for a multi-family house can be identified. With the second formula presented, the amount of CO_2 emitted upon transportation of the elements into a multi-family house can be calculated.

Paper 22

Utvärdering av miljön i området Torparängen med laserskanning, [Evaluation of the environment in the area Torparängen using laser scanning]

Laser scanning is used to produce a 3D-model that can be used in different areas. The data provided can then be processed in computer software and multiple laser scans can be combined into one model. The method of laser scanning can be used to document cultural buildings, reconstructions, city models and calculate volumes. The area of Torparängen is located in Växjo, Teleborg, and is meant to allow new buildings. The purpose is to meet the need for new homes in a lakeside area where nature is given a large space. In this report a laser scanning of the building Furutå with surrounding area have been made in Torparängen. Finding out this information can be useful in the future for the area Torparängen, because several laser scans are also planned during the construction phase and later. The purpose of this report is to find out if laser scanning is a suitable method to use for external laser scanning of buildings and can replace more difficult methods that are widely used today. The execution of this study has been done by scanning the building with a terrestrial laser scanner. Several set-ups are made to ensure that the entire house is captured and to increase the level of detail. In addition, a georeferencing by measuring with GPS equipment have been made. Scan data will after this be processed in the computer program Leica Cyclone where the scans from the different setups have been set together and added into Swedish referencesystem SWEREF99. The study shows that laser scanning is often a good method to use and provide high accurracy of just a few millimeters. The documents can be produced either to make 2D-drawings, such as facades or to produce 3D models to visualize a building.

Paper 24

Tidseffektivisering av materialleveranser på byggprojekt med radiofrekvensidentifikation, RFID, [Time efficiency of material deliveries on construction sites with radio frequency identification, RFID]

The daily strive is to improve and make the material flow process more efficient on construction sites. There are problems with material deliveries and material management at many construction sites. Radio Frequency Identification, RFID, is a wireless technology used to identify objects. The purpose of the study is to investigate whether RFID is a technology that can be used to achieve a more efficient material management. Thus, investigate if tracking of material using RFID can improve and make the flow of materials more efficient in today's construction projects.

To achieve the aim of the study, in-depth interviews were performed at four building construction projects, where Skanska Sweden AB is an entrepreneur.

Many studies show a vast number of defects and problems associated with material management. The problems are, among others, that materials arrive at the wrong time, the specification is incorrect, orders are forgotten, defects of information about the orders status or arrivals, abundance or shortage of materials, waste of storage space, unnecessary time for searching and tracking materials or the wrong amount of material arriving to the workplace. RFID is a technology in which objects can be traced and identified. A tag consists of a microchip and antenna placed on the object. With the assistance of a receiver unit, the tag can be read wirelessly. RFID tags are set apart by two main groups: passive and active tags. The receiver unit that reads the tags wirelessly can be a handheld computer with an integrated RFID reader. RFID is daily used for a variety of areas, such as tracking of books in the library, tolls, inventory, ski lifts, anti-theft devices, entry to construction sites and identification of rolling materials on the railways.

The result of the work consists of mapping material flows and material management on each project. The receiving procedure of material deliveries has been proven to be a problem at the construction sites. The study shows a possible solution for improved control management using RFID technology. The information is automatically sent to Skanska and the transport company's systems. The investigation shows that the use of RFID probably improves the time efficiency of material deliveries. The construction industry is positive to the technology of simplification of material deliveries and shows a high level of desire to develop. The study indicates that RFID has great potential and opportunity to improve receipt verification of deliveries. However, more areas should be improved and made more efficient within the material flow process before RFID is introduced. First the construction sites should work with a more digitized just in time systems. Then the step to RFID would become more natural and should involve a time-streamlined flow of materials.

A better option for using RFID in projects that still lacks a digitized just in time systems is to use moisture control for improved material handling. Dealing with construction errors due to moisture could cause considerable amount of time. The humidity sensor causes no major changes in the material flow process and the step to the technology would not be as large. This technique can be a good start for several construction sites striving time efficiency.

4 SUMMARY OF PROJECT TORPARÄNGEN

4.1 Background of wood-building development within the Växjö municipality

Several buildings out of wood had been constructed in Växjö, even before the first wood construction strategy was adopted in Sweden. The same year, 1994, as the ban on building houses over two floors with wooden frames was abolished, Värendshus built a three-story house using wooden frames that became the first building built in accordance with the new building regulation (VKAB 2016). Shortly thereafter, in 1996, Sweden's first modern 5-story wood-frame building was built at Välludden, Växjö, as a demonstration building for the purpose of developing wood construction technology following changes to the regulations. Thereafter, a research project was initiated 'Multi-storey buildings with wooden frames and light flooring' (VKAB 2016). The municipality had already been working to strengthen the local business community and the university, prior to its timber building strategy. Hence, since the 90's, Linnaeus University has collaborated with business actors to develop the forestry industry through the Wood design and technology programs. Therefore, since the municipality adopted their wood construction strategy 2005, they have continuously worked to identify partners and contribute to the processes that promote wood construction.

Växjö municipality has since its goal of becoming a fossil fuel-free municipality actively been working to profile itself as a municipality focusing on environmental and climate and has the slogan 'Europe's Greenest City' (Växjö Kommun 2011). The municipality is part of the Association of Climate Municipalities, an association of municipalities, county councils and regions that actively work with local climate development aimed at reducing greenhouse gas emissions in Sweden. (Klimatkommunerna 2017). An important aspect in the municipality's environmental and climate ambition has become its focus on using wood as a construction material, where 50% of all municipal new construction projects will be wood-based by 2020 "(Växjö Kommun 2014). Växjö municipalities renewed wood construction strategy “Växjö - the modern wooden town” contains more links with the municipality's goal of reducing carbon dioxide emissions in accordance with the municipality's environmental program. Furthermore, in the renewed wood construction strategy focus for the strategic environmental work is mainly to reduce carbon dioxide emissions. Växjö environment and sustainability work is about seeing all the effort in the environmental area as part of one greater

whole. Wooden construction in Växjö, with its well documented climate benefits, is part of this whole (Växjö Kommun. 2018).

4.2 Environmental drivers and market conditions influencing the wood-building industry

Issues regarding sustainability within urban planning practices have increased in line with urbanisation and is now firmly on the political agenda in Sweden (SCB, [Statistics Sweden], 2015; Ministry of the Environment 2002:5). Further, the recent increase of sustainable development strategies enhances the importance of urban planning focusing on ecological sustainability (Carmona 2009). Also, The UN has included 17 global sustainable objectives emphasising the importance of sustainable building-solutions, using local materials that can be recycled locally (UN 2015, Process Objective 11c; UN-Habitat 2016, §71, §76). The EU's ambition is to reduce greenhouse gas emissions by 20 % by 2020 (Regeringskansliet, [Government Offices of Sweden], 2017) whereas the Swedish target is a reduction of 40 % compared to the 1990 emission levels (Boverket, [National Board of Housing, Building and Planning], 2016a). Buildings using a wood fame have nearly half of the climate impact to a comparable building using a concrete solution, which would have a positive effect on fulfilling the environmental target linked to the projected building demand during the coming decade (Norén & Jarnehammar, 2001; Gustavsson et al., 2006; Gustavsson & Sathre, 2006). The execution of new building development plans is the responsibility of the Swedish municipalities, based on their internal strategies combined with the Government's goals towards sustainability (Boverket, 2016b). Hence, the building development plan is intended to incorporate the environmental effect by combining new building strategies and technologies (FORMAS, 2012; NRA, 2012). Also, new initiatives with focus on climate change in our economies recommend the development of wood-based industries to improve sustainability (EU, 2011. COM 2020) and implementing technology and strategies to increase wood as an environmental and sustainable building material (EU, 2012. COM 433).

The current demand for housing in Sweden is derived from a period of reduced construction resulting in a supply/demand imbalance, where it's estimated 700 000 housing units are required to be built until 2025 (Boverket, 2018), which during the current construction rate will not be fulfilled (Boverket 2014a; TMF 2016). Therefore, it becomes important to enhance the production potential of wooden multi-family houses, which also contributes to green economies by developing sustainable building solutions. Traditionally, multi-family houses have used concrete as building materials, and solutions based on wood only

contribute to a small part of the market, restricting the environmental effects (TMF, 2018), Table 1.

Table 1: Market development, * concrete, steel and others are grouped together since separate statistics are not available for 2017 (TMF, 2018).

Year	Number of apartments	out of wood	concrete	steel	other	% wood
2007	16,310	1,190	15,675	356	89	7.3%
2008	9,019	983	7,928	0	108	10.9%
2009	6,961	859	6,005	27	70	12.3%
2010	12,127	1,047	11,018	62	0	8.6%
2011	13,398	882	12,258	129	129	6.6%
2012	12,520	1,267	11,035	143	75	10.1%
2013	16,951	1,711	14,917	293	30	10.1%
2014	19,216	1,691	17,019	506	0	8.8%
2015	26,727	2,322	23,916	489	0	8.7%
2016	33,121	3,599	29,206	316	30	10.9%
2017	37,467	3,797		33,353*		10.1%

Despite the imbalance where concrete solutions have dominated the industry producing multi-family houses during a long period (Andersson & Larsson, 2014), the situation is opposite for the industry producing single-family houses (TMF, 2016; SCB, 2016). This provides opportunities for companies producing wooden single-family houses to utilise resources more efficiently, and diversify into the multi-family wood building industry. This would create new market opportunities by leveraging their production technology on a new market with high production demand (Schauerte et al., 2014; Nord & Widmark, 2010).

The challenges of using wood as a building material are not only linked to technical limitations. Equally important are the market factors, which to some extent are limiting the development potential for both producers of single-family wooden houses to enter the multi-family house market, and those already producing wooden multi-family houses. However, product and production development could be necessary to enter the new market segment successfully and increase their profitability (Besanko et al., 2013; Bottazzi et al., 2008). Hence, by utilising their knowledge of industrialised building methods can increase the production capacity (Grant 2010). Also, companies producing wood building solutions within the industry for multi-family houses have not fully taken advantage of the possibilities related to best in class industrialised building techniques and leverage this entry barrier (Stehn &

Brege, 2007; Schauerte et al., 2014). This can be advantageous considering the market segment is mainly developing towards industrialisation through the off-site construction of pre-fabricated building elements or modules and assembled on-site (Pan & Goodier, 2011). This has several benefits in regards to the production environment, logistics, quality and cost, which is not equally favourable for on-site construction (Stehn & Brege, 2007; Mahapatra & Gustafsson, 2008). The demand for available housing units in Sweden creates an opportunity for producers of wood building solutions to develop strategies fulfilling this demand improving their competitiveness within the market for multi-family houses (Nord and Widmark, 2010).

4.3 Market factors influencing development

The development potential of wood building solutions is based on the expectations that wood has the potential to outperform the production rate of other types of building materials by 2020, becoming a viable solution for the current demand faced by the Swedish municipalities (Schauerte et al., 2014; Engström & Hedgren, 2012). The focus on enhancing standards and technological capabilities, linked to the environmental advantages of using wood, has increased the utilisation of wood in building construction (Nord, 2013). This affects the production costs, reducing rents for consumers, and increase its competitiveness towards traditional building materials and improve the development of wooden multi-family houses (Svensson, 2015; Schauerte et al., 2014).

The construction of wood buildings, in relation to traditional building material such as concrete, face a similar market situation, yet require alternative strategies to mitigate internal and external market challenges, to be successful. Producers of wood-building solutions have an advantage since they already understand the market, combined with their off-site production technology, which will enable wooden single- and multi-family houses producers to outperform competitors using concrete (Schauerte et al. 2014; Lindblad et al. 2016). Therefore, companies producing wooden multi-family houses need to adjust and leverage their organisation towards the new market barriers to create a competitive advantage using, e.g. improved technological advances towards those companies already established within the market (Karakaya & Parayitam, 2013), thus create a fit between entry barriers and market strategies to increase their chance of successful market entry (Pehrsson, 2009). Additionally, political decisions and actions through legislation, duties, and taxation can support the companies' development into a new industry or market (Björheden, 2006; Tudor et al., 2006). However, this should not solely be supported by political decisions. Equally important are company activities to leverage internal synergies, i.e. financial planning, project development

teams, strategic development, combined with governmental actions (Chiu & Yong, 2004; Roberts, 2004).

Having the ability to integrate these activities into the development strategies provides better possibilities towards the industry barriers and a stronger competitive position (Sigalas, 2015; Cool & Schendel, 1988). Also, companies aligning their market strategies with the external market context, e.g. procurement situation, legislation and market maturity, have a greater possibility to minimise the effect from market entry activities (Venkatraman, 1989; Venkatraman & Prescott, 1990). The market barriers facing the producers of wooden multi-family houses are not static over time, rather something that evolves dependent on the internal and external market conditions, i.e. financial status, political situation, interest rates or legislation favouring (OECD Policy Brief, 2007).

4.4 Pre-conditions for building development

In 2005, a national wood-building strategy was adopted with the aim that 30 % of all new buildings within 10-15 years should use a wood-frame and that the number of buildings out of wood increase by 30% within a five-year period (Ds 2004:1). Despite this, less than 10 % of the multi-family houses are currently being built in wood, and the building developments in Sweden continue to show an upward trend for using concrete in building solutions for multi-family houses (Sveriges Träbyggnadskansli 2017; Svensk Betong 2016). However, several municipalities in Sweden chose to develop against this prevailing trend, Växjö municipality being one of them. Hence, Växjö municipality have since the implementation of the national wood-building strategy focused on using wood in new building projects. Therefore, Växjö municipality already in 2015 reached the municipal objective where 25 % of the construction directly controlled by the municipality would be wood-based.

There is currently a change under way within public governance, from 'government to governance', which usually represents a shift from central governance to interactive governance because of a shift from public sector control to the private sector control (Montin & Hedlund 2009). In practice, this means that much of the power and control of municipalities has been transferred to private or other social actors (Vall, 2007). The planning for the construction of buildings has changed historically. Today, this is largely based on market actors fulfilling the requirement, and municipalities are expected to develop controlling instruments in line with the goals mentioned in the environmental policy and housing policy (Boverket, 2016c). The municipality is expected to meet the public interest in housing and contribute to achieving Sweden's environmental and climate objectives, while at the same time the

government are attempting to influence municipalities through the planning and environmental legislation that regulates construction.

4.5 Policies and control mechanisms used by municipalities

According to Boverket, (2014b), "Buildings and facilities should be located and designed in an environmentally sound way and so that good long-term management of land, water and other resources is promoted". Boverket have the primary responsibility for the national environmental quality objective "God bebyggd miljö" through the development of different policies (Grip 2013). The national strategy "More wood in construction" was adopted in 2005, where climate and environmental issues were highlighted in reference to the Kyoto Protocol by reducing the impact of the construction industry by increased use of wood as a building material (Ds 2004: 1).

Municipality often requires that land development agreement is established as a condition for detailed planning prior to the exploitation of land (Moberg 2015). There are several possibilities and limitations to pose specific municipal requirements in the guidelines regarding land development agreement with reference to wood. The legislation permits municipalities to pose specific requirements and guidelines for land allocation agreements based on the municipality's internal targets and policy documents (Swedish law 2014:899). However, the Planning and Building Act pose restrictions regarding the municipality’s possibilities to pose specific technical requirements for land development projects. This complexity is also analysed by Sveriges Kommuner och Landsting [Swedish Association of Local Authorities and Regions] (SKL), reviewing land allocation and confirming the municipalities position using civil law to pose specific requirements when selling their land for building projects (SKL 2014).

4.5.1 Administrative controlling instruments

In order to identify the administrative instruments controlling the possibilities or limitations for the municipalities' prerequisites for the development of wood construction a number of regulations have to be reviewed; The Swedish Environmental Code (MB) (SFS 1998:808), The Planning and Building Act (PBL) (SFS 2010:900), the Boverket’s Building Regulations (BBR) (BFS 2011:6) and The Public Procurement Act (LOU) (SFS 2016:1145).

- Physical planning: SFS 2010:900 is a designated controlling instrument for the regulating of land, water and construction planning.

- Comprehensive plan: Presents the basic features of the intended use for land and water areas as well as the future development of buildings. The plan is not legally binding - but it is mandatory to have a comprehensive plan (Boverket 2017).
- Planning program: The municipality can in a planning program set goals and starting points for any planning work in a specific program" (Boverket 2014).
- Detailed development plan: Mainly governed by SFS 2010:900, Chapter 4. Regulation with detailed development plan and area regulation.
- Plan description: The plan description are required combined with the detailed development plan to describe how the detailed development plan is to be understood and implemented. SFS 2010:900 defines what should be included in the plan.
- Planning provisions: The detailed development plan is legally regulated by planning provisions such as usage provisions, property regulations and administrative provisions and is controlled by SFS 2010:900 (Adolfsson & Boberg 2013).
- Environmental impact assessment: Environmental impact assessments must be included in the environmental plans describing the environmental impact of planned land development required by SFS 1998:808.
- The prohibition against specific technical requirements by the municipality: The regulations in the Planning and Building Act regarding municipalities' ability to set their requirements for specific technical requirements in planning were amended in 2014 (SKL 2014).
- Public procurement: SFS 2016:1145 applies to procurement made by a public entity.
- Land allocation and Land development agreements: The Swedish Government decided on a new law (SFS 2014:899 Act on Guidelines for Municipality Land Allocations, that are of major importance for the municipalities in terms of land development agreements, land allocation and the pre-conditions for setting their requirements for construction.

4.6 Operational development

The industry producing multi-family wooden houses have had an upturn with higher demand due to an increased market requirement for accommodation and a new awareness of sustainability in the construction industry. Hence, like any other industry the construction industry tries to be more effective in order to increase production and improve productivity, generating higher

profitability. One way of achieving this goal is to automate the production, similar to the traditional industrialised concepts in, e.g. automotive and electronic industries, which have already been implemented in certain areas of the industry to a varied extent.

However, improvements in the information flow have not come as far as the developments of production methodology and it is necessary to streamline the entire process and reduce the amount of manual and duplicated work using standardisation, thereby avoid sub-optimisation and improve productivity. This is not only applicable to the industrialization of the manufacturing process but also in a large degree to the design process.

Furthermore, the requirements to increase efficiencies within the industry are not only focused on improvements in the information flow leading into the production process. Equally, the industrialization of the building processes to leverage the benefits of wood-building solutions by transitioning from traditional on-site production to off-site prefabrication, is challenging and requires additional information and planning processes. Also, a well-balanced material flow is of great importance to obtain high productivity in the production process, which require a certain degree of technological development throughout the value chain. These actions are deemed as important considering many house producers are in the starting phases of introducing advanced automation technologies in their off-site production processes and require detailed process control to take advantage of the strength of wood-building solutions and increase their market share.

The conditions for the industrial market have also changed combined with this development and customer expectations regarding quality, high reliability, fast delivery and low price are getting higher, forcing companies to become more productive and update their processes in order to meet these new demands. In this context, a well-functioning manufacturing processes with high quality products and good production planning are required to fulfil these goals, which further emphasises a shift in focus towards internal operations and processes to better meet the customer's increased expectations.

There are several areas to focus on in regards to the assembly phase of the building process, which are related to process improvement, efficiencies and increased environmental focus. Initially the logistics process must become more efficient, starting with the inbound flow to the construction site. The use of transports, dependent on building solution influence the environmental impact, and an increased understanding provides greater possibilities to contribute to an environmental sustainable solution. Hence, the use of heavy vehicles transports should be examined further to meet the climate objectives.

There are currently several factors influencing the impact on the amount of emitted CO_2, most important have been the volume/weight factors related to the distribution of concrete of wood-building solutions. This is however only important in a like-for-like comparison where the driving distance from production site to construction site is similar, which in these cases favour wood as a construction material. In reality, the market strength of concrete building solution provides a more comprehensive production infrastructure with shorter driving distances that can outperform the environmental advantage identified for wood-building solutions.

The effect of an efficient inbound logistics process on the construction phase is only fully efficient if the material handling process is structured and planned efficiently at the construction site. One factor to leverage the effect of an efficient material handling process is to have a clear picture of the construction site, which can be conducted using laser scanning. This procedure is used to produce a 3D-model that can be applied in different areas besides an efficient construction site, e.g. to document cultural buildings, reconstructions city models and calculate volumes. This information can be useful for the planning during the construction phase and later stages of the building process establishing a suitable site infrastructure, which can be established by georeferencing certain areas for storage based on material type in relation to the construction cycle.

There are problems identified with material deliveries and material management at many construction sites, making the material handling process at building sites a barrier that can contribute to improved efficiency. The activities related to making the material flow process more efficient on construction sites are associated to suitable storage sites, materials arrive at the wrong time, waste of storage space, unnecessary tracking of materials or wrong quantities arriving at the sites. This is a process that can be supported and improved by technology such as Radio Frequency Identification, RFID, which is a wireless technology used to identify objects and can be linked into BIM or on-site construction plans if required. Material handling using RFID can improve time effectiveness, minimise waste and monitor moisture levels in the material efficiently, creating improved sustainability within the building process.

5 CONCLUDING STATEMENTS

5.1 Market evolvement

The gradually changing behaviour of the population, towards urbanization, led to an increased shortage of available housing. This development has resulted in not enough companies are providing solutions for multi-family houses in wood. Potential companies that could fill this increasing demand are those in the single-family house industry. Yet, these companies might face considerable problems with productivity, predominately derived from increasing production costs and inadequate production development.

Developing these companies are associated with long-term investments, which is investigated by evaluating the industry structure for sellers, highlighting the financial and market situation within their industry. These factors are growing in importance due to the current market concentration, where more companies are required to focus on product development driven by the demand to prefabricate wooden elements, volumes or modules in an industrialized way.

Results show that the industry tends towards perfect competition with too many companies involved, i.e. companies mainly have to compete by prices. These companies have promising positions to invest in product development towards wooden multi-family houses, in addition to their current products. The results show that the investigated companies have good possibilities gaining a competitive advantage by diversifying into the growing wooden multi-family house industry. Further, producers of wooden multi-family houses have a relatively small market share in comparison to traditional building materials. The limited capability to fulfil the increased building demand also restricts the possibilities for development towards innovation, bio-economy and sustainability.

The municipalities in Sweden are responsible for planning of building development in their region based on their projected requirements and strategies. This is to some extent combined with a desire to develop sustainable building solutions based on wood, which increases the complexity in the public process. Currently, public building developments are achieved through the public procurement act or the land allocation activity, dependent on their development strategy. This normally involves the development of local strategies regarding, e.g. design, material choice and geographical development. By identifying drivers and barriers found in the industry and market, enables improved market entry activities related to public building initiatives using wood-based solutions. In this context, the industry experience

barriers associated with the municipalities' actions and knowledge level related to wood as a building solutions, combined with the strength of concrete as a building material is an issue since the municipalities tend to opt for familiar solutions. These factors contribute to uncertainty and sub-optimisation for the developers proposing a wood-based building solution and where increased sustainability in the building process cannot be achieved at the desired level.

5.2 Public actions

Växjö Municipality has during some time made a strategic decision to be profiled as a green city with a focus on sustainability, which has contributed to an increased focus on wood construction. Therefore, any new building developments under the municipality's control are required to test and present the new building developments based using a wood-building solution. Hence, the governance of the public process affects the development towards wood-based building solutions by communicating an ambition to focus on sustainability and provide a faster pace in regards to new developments using wood. The municipalities have several options to initiate building developments based on the projected demand, e.g. using public procurement of new developments or the land allocation activity. Växjö Municipality has to a large degree opted for the land allocation activity since it provides more flexibility to pose specific demands regarding the building specification, which is not possible using public procurement that is limited by the public procurement act. The reason for these differences related to the selected models are based on land allocation activity is a sale of land with specific buyer requirements imposed on the developers by the municipality.

Several areas have been identified as barriers, which provide guidance on how the Swedish municipalities can adjust their current process and enable a more efficient result:

- increased knowledge regarding the procurement process
- changed approach towards land allocation activities based on new buyer/seller perspective
- evaluating functional specification
- increased knowledge regarding wood building solutions

The practical implications of this study are based on how the land allocation activity is used by municipalities. Municipalities see themselves as a seller of land, which is not a procurement activity that is associated with requirements in regard to public regulations. They embrace the opportunity to pose requirements on those companies invited to make a bid for the land and influence the project according to their strategic ambition. However, this is not

a view shared by the developers who have to provide a detailed proposal of their intended solution, which also is an activity more associated with a sales process, where they have to convince the seller of their solution. This can be derived from an unclear buyer/seller relationship that provides uncertainty in their internal expectations. Therefore, the process would benefit if the buyer/seller relationship is clarified as a modified procurement situation by the municipalities, which would improve how the participants perceive their roles and facilitate a transition for the municipalities to develop a standardised method. Reviewing the interaction between municipalities and developers from a public procurement situation requires an understanding of the specific conditions and legislative constraints to efficiently reorganise the process (McCue & Prier, 2008; Johnston & Seidenstat, 2007). As a result, if municipalities adjust the requirements of the land allocation activity based on the perception of their counterparts, the developers who see themselves as sellers, therefore, municipalities must take the role as a buyer of a product or service. This change in scope will clarify the process and minimize information asymmetry reducing project costs and improving project fulfilment (McCue & Prier, 2008; Wiseman, Cuevas-Rodriguez & Gomez-Mejia, 2012; Aguilera & Jackson, 2010). Furthermore, the perception of the participant's roles in the land allocation activity also influences how and what kind of information is provided by the municipalities, which currently is lacking, and limit the effectiveness of the process (Nyman, Nilsson & Rapp, 2005).

Clarifying the roles and responsibilities offers opportunities to create a stringent process and provide a platform for development that requires a new approach considering the uncertainty of how the involved parties perceive the land allocation activity. This provides an unstructured and subjective approach towards the prerequisite of being awarded a building project. With the municipalities using a limited evaluation process, displaying a knowledge gap regarding their internal activities in relation to the land allocation activity, providing inadequate information, not presenting clear requirements of their expectations and having no process to follow up the project deliverables on completion, the situation is far from ideal.

The municipalities are recommended to treat the land allocation activity similar to a normal procurement process to provide more control and transparency throughout the project life cycle. Only if the municipalities start adjusting their perception towards a procurement situation, instead of a sales situation defined in the land allocation process, will the possibility to evaluate the various process steps successfully be incorporated (Arrowsmith, 2010; Weele, 2010; Atkins & Sapat, 2012). Hence, it becomes more important to design a new process that is adjusted to the land allocation activity, using

clearly defined process steps of pre-acquisition, acquisition and post-acquisition. This will provide internal guidance for the municipality as well as increased transparency regarding the project requirements for the developers – evaluation criteria, extending municipalities' focus beyond the point of sale and project fulfilment rate as well as accountability for discrepancies with the initial proposal (Arrowsmith, 2010; Dimitri, 2013).

These issues, combined with the general independence of the 290 municipalities in Sweden, provide a complex situation with sub optimization for the developers. This could be rectified if a national standard is developed regarding how the land allocation activities are performed and to what extent the municipalities are involved to influence the project progression after the sale of land has been finalised. It would also be beneficial if the evaluation criteria could include quantifiable information such as project budget and cost per square meter, in addition to design and sustainability. In addition, both municipalities and developers have identified a knowledge gap regarding the possibilities of using wood in building projects, which can limit the development of wood buildings in favour of traditional building materials, such as concrete. The decision-makers within municipalities are more likely to continue opting for solutions based on concrete if they have a long tradition of evaluating building projects based on this solution. Therefore, municipalities have to make certain this gap is closed, either by internal development or by an external partnership to enhance the competence level, thus providing an environment where different building solutions can compete on equal terms (Addo-Duah et al., 2014).

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