Drivers and challenges for automation of manufacturing: a multiple case study in the Swedish wood products industry

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Abstract

The aim of this paper is to explore the drivers and challenges for automation of manufacturing in the wood products industry. A multiple case study was conducted where the drivers and challenges were examined from operative and managerial point of views. Findings indicate that improved profitability and competitiveness were some of the main drivers, while lack of strategies and insufficient technical awareness and expertise were emphasized as challenges. The identification of the drivers and challenges for automation can provide insights to be used as basis for investment decisions.

Keywords: Wood industry, Technology, Decision-making

Introduction

The wood products industry is important for Sweden's prosperity (Sandberg, et al., 2014) and generates the greatest income for the forest owners (Swedish forest industries federation, 2016). The domestic refinement of wood provides better profit margins and employment opportunities. The wood products industry further refines the raw material and adds manufacturing value to sawn timber. Despite this, two-thirds of the timber volume annually produced at sawmills is directly exported without any further refinement (Sandberg, et al., 2014). To avoid the gradual decline of the industry's contribution to the country's revenues and employment opportunities, the Swedish wood products industry needs to increase the proportion of the raw material that is refined. New and efficient manufacturing technologies are essential to support this development (NRA Sweden, 2012; Nord & Widmark, 2010). To support the industry through automated manufacturing systems, the implementation of automation in manufacturing needs to be supported by conscious and well-defined strategies. The initiatives that aim to use automation to simply reduce manufacturing costs rarely achieve the expected outcome. This is since automation decisions will become the core strategic decision area in manufacturing, not considering various aspects of manufacturing before the decision to automate is made (Winroth, et al., 2007). Currently, little is known about the underlying reasoning for decisions on automation of manufacturing in this industry. Few studies (Eliasson, 2014; Karltun, 2007; NRA Sweden, 2012) provide insights on single factors that either drivers or challenges the industry from automating in manufacturing. A more holistic understanding of this issue is lacking. Increased knowledge on the drivers and

challenges for automation in the wood products industry is needed. The knowledge on the drivers helps to create the understanding for the need of improvements through automation in the wood products industry. At the same time a better understanding of the challenges provides insights on potential problems that needs to be considered when decisions on automation of manufacturing are being made. This increases chances for successful implementation of automation in manufacturing. This paper aims to address this research gap by exploring the drivers and challenges for automation. The following research questions are addressed in this paper:

RQ1: What are the drivers for automation of manufacturing in the wood products industry?

RQ2: What are the challenges for automation of manufacturing in the wood products industry?

This paper is organized as follow: First, a theoretical background is provided, consisting of a definition of automation in manufacturing context and a brief description of the drivers and challenges for automation, identified by literature. Second, the research method is presented with emphasis on case company selection and description, data collection, and data analysis. Thereafter, the main findings are presented. Lastly, discussion is provided, and conclusions are drawn.

Theoretical background

This theoretical background provides a definition of automation in manufacturing context. Further insights are provided on the drivers and challenges for automation of manufacturing in the wood products industry identified in the literature.

Automation of manufacturing

Automation in manufacturing context replaces, to some extent, cognitive and physical human labor (Groover, 2007; Sheridan, 2002). Since automated manufacturing systems are perceived to be efficient, automation is often viewed as a tool that can potentially enhance manufacturing competitiveness (Säfsten, 2007). Automation is used as a broad term to describe a variety of technologies supporting the manufacturing function. It includes several technologies, for different aids and applications, such as computer-aided design (CAD), computer-aided manufacturing (CAM), robotics, flexible manufacturing systems (FMS), computerized numerical control machines (CNC), automated material handling systems, decision support systems, enterprise resource planning systems (ERP) and other types of automation technologies that can contribute to an optimized manufacturing flow. This paper includes all forms of automation applications that are related to, or support, the manufacturing function.

Drivers for automation identified in literature

Automation of manufacturing is identified as essential for the Swedish wood products industry to remain profitable (NRA Sweden, 2012; Nord & Widmark, 2010). Automation is viewed as a tool that can potentially increase manufacturing competitiveness by decreased costs, increased productivity, and increased quality consistency (Eliasson, 2014). Automation technologies such as automatic visual inspection is becoming vital to improve productivity and quality aspects in manufacturing. It enables more stringent, accurate, and effective quality controls. Further, the wood products industry is shown to have long manufacturing lead-time. The long and variable lead times indicate that there may be opportunities to increase efficiencies through new and efficient automation technologies (DeLong , et al., 2007). Another driver for automation emphasized in the

literature is to avoid the wide presence of handicraft that results in tough work environment conditions, such as heavy lifting and repetitive motions (Karltun, 2007).

Challenges for automation identified in literature

Previous research stresses several challenges for automation of manufacturing in the wood products industry. First, the slow technology development progress in the wood products industry has been emphasized as a reason for the decline in technical efficiency and manufacturing productivity. It is emphasized that the wood products industry need to adapt to automation technology in manufacturing more rapidly, and gain knowledge to utilize the manufacturing technology more efficiently. Besides the insufficient knowledge regarding automation technologies from an industrial point of view, insufficient operator skills and competence is identified as additional challenges (Sowlati & Vahid, 2006; Bumgardner, et al., 2005; DeLong , et al., 2007). The operators often have low level of education, and are missing certificates and operation licenses (Karltun, 2007). The low level of education has limited innovation and automation technology adaptation in manufacturing (DeLong , et al., 2007). Therefore, training and education when introducing new automation technologies are stated as essential since they have a positive impact on the manufacturing productivity. Overall, the wood products industry is described to need further investment in both human resource as well as automation (Teischinger , 2010).

Another challenge facing the wood products industry is the raw material. The raw material consumed is unique. Wood is a heterogeneous material, which means that its appearance and properties depend on several different biological factors. This affects the manufacturing process. Researchers argue that due to the anisotropic and variant character of wood, the wood products industry has lower degree of automation than comparable industries (Eliasson, 2014). Karltun (2007) compares the wood products industry to the metal industry and identifies the variation in raw material characteristics as a problematic factor regarding the implementation of automation. For example, sorting and grading processes are more difficult to automate. The implementation of automation requires tighter acceptance tolerances regarding the specifications of incoming raw material, which is associated with higher rejection rates. Despite automated visual inspection has become vital in the industry, it is not always optimal due to the limitation of automation technology flexibility (Eliasson, 2014).

Research method

A comprehensive overview of the drivers and challenges for automation of manufacturing in the wood products industry has not yet been provided in literature. Therefore, an explorative and qualitative approach was suitable to address this issue (Karlsson, 2009). Case study method is appropriate for exploratory studies on contemporary events. This study consists of a multiple case study since it is considered more compelling and robust (Yin, 2014). The unit of analysis is the manufacturing system.

Case company selection and description

The case companies that participated in the case study are referred to as Company A, Company B, Company C, and Company D (Table 1). These case companies were selected based on two selection criteria. First, the case company must be operating within the wood products industry. Second, the case company must have a manufacturing unit in Sweden. The case companies differed in terms of size and business areas they operated within. This enabled a more comprehensive view of the drivers and challenges for automation of manufacturing experienced within the Swedish wood products industry.

Table 1 – Participating case companies

Case company	Business area	Product	Number of employees
Company A	Interior products	Panels, floor, mouldings	640
Company B	Windows and doors	Windows, doors	714
Company C	Foil-wrapping	Furniture	127
Company D	Construction	Schools, offices, accommodations	164

Data collection

The data used in this paper is partly collected from a previous collaborative study. In this paper the focus is on the drivers and challenges for automation of manufacturing in the wood products industry, from a managerial and operational point views. The data is collected separately in each case company through in-depth and face-to-face interviews, using a semi-structured interview guide (Yin, 2014). To understand the manufacturing system thorough, a holistic approach was required to consider the different aspects included. For this reason, a systems perspective was applied (Bellgran & Säfsten, 2010). A common denominator for what a system need to consist of to perform specific activities is a collection of human, machines, and methods to organize those activities performed (CIRP, 1990). In manufacturing context, the human often refers to the operative staff. The machines often refer to tools, equipment, machines, information system, and technical expertise. The method or organization can be defined by goals, strategies and culture (Dunnette & Hough, 1992). Outside the system boundaries, an external business environment is present (Davis, et al., 2014). This environment refers to the external relationships, such as the relationships with suppliers, customer, and competitors. The semi-structured interview guide in this study was based on exploring the drivers and challenges for automation related to the different aspects of the manufacturing system. The case companies could identify drivers and challenges linked to additional aspects, not included in the interview guide. In total, 26 interviews with company representatives with experience that ranged from shop floor to managerial level were conducted (Table 2). The managerial level provided the perspective of the decision-makers, while the operational level provided complementary insights on whether people at different levels within a company shared same experiences regarding the issue.

Table 2 – In-depth interviews with company representatives

Case company	Number of interviews	Roll of interviewees
Company A	13	4 operators, production team leader, quality inspector, production planner, and 6 senior managers
Company B	6	3 operators, 2 production team leaders, and senior manager

Company C	5	2 operators, production team leader, 2 senior managers
Company D	2	2 senior managers

Data analysis

The evidence collected in this case study is based on interviews and contains qualitative data. The data was analyzed in three phases defined by Miles and Huberman (2014): (1) data reduction, (2) data display, and (3) conclusion drawing. In the first phase, data reduction, the data from the interviews were transcribed, and later coded and structured in categories related to the different aspects of a manufacturing system. Through iterative coding cycles, specific themes in each category are identified. In the second phase, data display, the organized data were displayed in a table. In the third phase, conclusion drawing, the data was interpreted, and conclusions were drawn regarding the specific research questions.

Findings

From the in-depth interviews with companies' representatives the identified drivers for automation of manufacturing in the Swedish wood products industry are displayed in Table 3, and the challenges for automation are displayed in Table 4. The tables also demonstrate whether the drivers or challenges are identified at operational or managerial level. The findings show that all the case companies had six drivers and six challenges for automation in common.

Drivers for automation

The drivers identified by all the case companies were: (1) Improve ergonomics, (2) Improve quality consistency, (3) Improve competitiveness, (4) Improve productivity, (5) Improve profitability, and (6) Decrease manufacturing costs. The first driver for automation of manufacturing was to enhance the ergonomic conditions at the operational level. The wood products industry was described to consist of monotonous tasks and heavy lifting. Therefore, automation was viewed as a potential solution. The second driver was to increase quality consistency. Visual quality assurance was described as common in the wood products industry. Consequently, the operators have different interpretations of quality, which leads to variation. This variation could be minimized with automation. The third driver was the perceived competitive advantage of automation. Automation was emphasized as necessary to keep and increase manufacturing competitiveness. The fourth driver was productivity increase. The last driver for automation was related to the other drivers, which is the economical aspect of automation. If automation would increase the competitive advantages, then company profitability would increase. Other drivers for automation was linked to decreased costs of manufacturing and with specific emphasis on decrease labor costs. The labor costs in Sweden was emphasized as relatively high to compete in a price stressed market. Therefore, there is a need to consider this cost in relation to competitors' labor costs in other countries.

Besides these five drivers that were shared among all the participating case companies, there were additional repetitive drivers in some of the cases: (7) Meet increased customer demand, and (8) Improve labor safety. Increased customer demand was observed by several case companies. This was identified as a driver for automating in manufacturing. Further, increasing labor safety by implementing automation in manufacturing was identified as an additional driver.

Table 3 – Drivers for automation identified by the case companies

	Company A	Company B	Company C	Company D
Operational level	- Ergonomics - Quality consistency -Competitiveness	- Ergonomics - Quality consistency - Productivity - Meet customer demand - Profitability - Stress reduction	- Ergonomics - Quality consistency - Productivity - Meet customer demand	-
Managerial level	-Competitiveness - Productivity - Profitability - Ergonomics - Manufacturing costs - Labor safety - Material utilization	-Competitiveness - Productivity - Profitability - Quality consistency - Meet customer demand - Manufacturing costs	-Competitiveness - Productivity - Profitability - Quality consistency - Ergonomics - Meet customer demand - Manufacturing costs - Operator flexibility - Market expansion - Capacity	-Competitiveness - Productivity - Profitability - Quality consistency - Ergonomics - Meet customer demand - Manufacturing costs - Labor safety

Challenges for automation

The challenges identified by all the case companies were: (1) Insufficient technical awareness and expertise, (2) Traditional industry, (3) Investment costs, (4) Lack of strategies, (5) Short-term goals, and (6) Flexibility limitation. One challenge that all the case companies identified was insufficient technical awareness and expertise. It referred to lack of updated knowledge and awareness of newer automation technologies of manufacturing. This was viewed as a hinder for implementation of efficient technical applications in manufacturing. The second challenge, traditional industry, referred to referred to the culture of the industry that was described to have an established and strong perception of how things should be done. This was emphasized as the basis for negative attitude to change. The attitude to change was emphasized among the operators and in terms of management mentality. The operators had a fear of losing employment due to automation but also a skeptical attitude due to possible change of job description. At the management level, the mentality was described as "old fashioned". The third challenge referred to the relatively high costs related to automation investments. The fourth challenge was concerned with lack of strategical and structured approaches when investing and implementing automation in manufacturing. The case companies described automation investments to often be based on "gut feel" and previous experience rather than strategies. The last challenge was closely linked to the previous one. The case companies described their focus to be placed on short-term goals and profits, which hindered them from focusing on the long-term perspective and company vision and strategies. Limitation of product mix flexibility was identified as another challenge since automation was perceived to limit the flexibility needed to produce customized and low volume products, which were described as common products at the case companies. The

technical limitation also included flexibility in terms of handling the variation in the incoming material.

Besides these five challenges that were identified by all the participating case companies, there were other repetitive challenges that were shared among multiple cases. These challenges were: (7) Raw material variation, and (8) Insufficient operator skills and competence. The raw material consumed was identified as a challenge due to relatively high variations in the input material. Lastly, insufficient operators' skills and competence were described to challenge the implementation of new automation technologies in manufacturing.

Table 4 – Challenges for automation identified by the case companies

	Company A	Company B	Company C	Company D
Operational	- Operator skills and competence - Technical awareness and expertise - Flexibility - Traditional industry - Raw material	- Operator skills and competence - Flexibility - Traditional industry	- Traditional industry - Flexibility - Investment costs	-
Managerial	- Lack of strategies - Short-term goals - Investment costs - Technical awareness and expertise - Traditional industry - Operator skills and competence - Technical supplier development - Customer demand - Raw material	- Lack of strategies - Short-term goals - Investment costs - Technical awareness and expertise - Traditional industry - Flexibility - Raw material - Product development	- Lack of strategies - Short-term goals - Investment costs - Technical awareness and expertise - Traditional industry	- Lack of strategies - Short-term goals - Investment costs - Technical awareness and expertise - Traditional industry - Flexibility

Discussion and conclusions

The purpose of this paper has been to discuss the drivers and challenges for automation of manufacturing in the wood products industry. The findings from the multiple case study demonstrate that several drivers and challenges for automation were shared across multiple cases. In the case studies some drivers and challenges discussed previously in literature are confirmed, while it also exposes additional drivers and challenges in this context.

Six drivers for automation of manufacturing were identified in all case companies: (1) Improve ergonomics, (2) Improve quality consistency, (3) Improve competitiveness, (4) Improve productivity, (5) Improve profitability, and (6) Decrease manufacturing costs. Additionally, two drivers were identified in more than one of the cases: (7) Meet increased customer demand, and (8) Improve labour safety. The view of the drivers for automation was similar at the operational and managerial level. However, the managerial level

emphasized more on the economic terms competitiveness, profitability, and manufacturing costs. The six commonly shared drivers identified by the case companies have also been identified by previous literature (Eliasson, 2014; NRA Sweden, 2012; Nord & Widmark, 2010; Karltun, 2007). A driver specific to the case studies was the increased customer demand. Increased demands from the customers was viewed as a driving aspect to improve manufacturing efficiencies through automation. Another new driver for the case studies was labour safety. Previous literature had identified ergonomics as a driver in terms of avoiding heavy lifting (Karltun, 2007). Labour safety was used as a broader term than ergonomics alone. Some case specific drivers were also identified. Company A identified higher utilization of the raw material as a driver for automation. This is caused by the fact that the case company was dependent on solid wood for their products, putting a great emphasis on material utilization. Automation was viewed as a more consistent way to handle the material variation despite its flexibility limitations. Company B identified stress reduction as an additional driver. Company C identified market expansion, increase of manufacturing capacity, and operator flexibility as drivers for automation. Company C identified the most number of driver for automation. This can be due to that the case company was less sensitive to the raw material variation and had more experience with automation in manufacturing.

Regarding the challenges for automation, the following challenges were identified at all case companies: (1) Insufficient technical awareness and expertise, (2) Traditional industry, (3) Investment costs, (4) Lack of strategies, and (5) Short-term goals, and (6) Flexibility limitation. Additionally, two drivers were identified in more than one of the case companies: (7) Raw material variation, and (8) Insufficient operator skills and competence. Further, at company B, one case specific challenge was identified: Product development. Overall, the point of views between the operational and managerial level slightly varied in terms of the challenges for automation. The operational level focused on shop floor related issues while the managerial level focused on strategic and economic issues.

This paper provides a ground for the understanding of the contextual influences that impacts the current state of manufacturing operations in the wood products industry. For researchers, this paper contributes to the identification of the drivers and challenges for automation of manufacturing in the wood products industry. For practitioners the findings can be used as guidelines to support the industry through automated manufacturing systems by understanding the drivers and challenges for automation.

Although several business areas within the wood products industry were examined to broaden the view on the topic, the number of cases is limited. Further empirical studies need to be undertaken for more reliable view of the drivers and challenges for automation. Further limitation of this paper is the geographical focus of Swedish manufacturing firms. Future research can be conducted in other countries to examine differences.

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