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Investment Decisions on Automation of Manufacturing in the Wood Products Industry: A Case Study

Roaa Salim[1]*, Agostino Manduchi[2], Anders Johansson[3]

Abstract

The wood products industry is facing increasing challenges from global competition, and automation of manufacturing can greatly help companies in the industry to handle such challenges. Investments in automation of manufacturing are more likely to succeed if they are the expression of informed and systematic decisions. This paper aims to increase the knowledge on the process leading to investment decisions on automation of manufacturing in the wood products industry, as well as on the aspects considered in such processes. A real-time case study was conducted at a large Swedish wood manufacturing company to gain in-depth understanding of decisions related to automation investments. The findings demonstrate that mainly representatives from manufacturing and marketing functions were involved throughout the investment project's length. This could be a contributing factor to the narrow view on automation of manufacturing when decisions are made, where focus is placed on financial and technological aspects. The findings further show a limited knowledge regarding automation of manufacturing, which resulted in a tendency to heavily rely on the technical supplier's recommendations. This paper identifies the weak points related to decisions on automation of manufacturing in the wood products industry and provides insights on how to support the decision process.

Keywords: development projects, manufacturing technology, decision-making, wood products industry, empirical research

1. Introduction

Companies are investing in automation to enhance manufacturing performance in terms of cost, quality and delivery, in an effort to stay competitive in the global market (Machuca et al. 2011). Automation is a wide term that covers the use of several technologies in different areas supporting manufacturing system, such as computer-aided manufacturing (CAM), robotics, flexible manufacturing systems (FMS), and computerized numerical control machines (CNC). Automation is also connected to the initiative "Industry 4.0", which supports cost effective, agile and competitive manufacturing through digital technologies, such as the internet of things, cloud computing, simulations, and big data (Gilchrist 2016). Hence, automation of manufacturing can enable companies to make more efficient use of both cognitive and physical human labor (Groover 2007, Sheridan 2002).

While investment in automation allows some manufacturing companies to realize substantial benefits, other companies have not been as successful, indicating that these investments remain a promising but potentially risky venture (Almannai et al. 2008). Studies show that investments in automation of manufacturing are more prone to succeed if they are the expression of informed and systematic decisions anchored in manufacturing strategy (Ortega et al. 2012, Machuca et al. 2011). The initiatives that aim to use automation to simply reduce

1 Department of industrial Product Development, Production and Design, School of Engineering, Jönköping University, Jönköping, Sweden

2 Economics, Jönköping International Business School, Jönköping University, Jönköping, Sweden

3 Global Industrial Development, Scania CV AB, Södertälje, Sweden and Department of Engineering Science, University West, Trollhättan, Sweden

* *Corresponding author.* Email: roaa.salim@ju.se

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manufacturing costs rarely achieve the expected outcome (Winroth et al. 2007). By contrast, Sinclair and Cohen (1992) find a positive correlation between the adoption of incremental manufacturing innovations and performance among manufacturers in the wood building-products industry. In comparison with the incremental innovations, radical innovations such as automation thus appear to represent a more serious challenge for firms in the industry.

Decisions on automation of manufacturing in investment projects are mainly based on financial measures, such as net present value (NPV), return on investment (ROI), and return on assets (ROA) (Farooq & O'Brien 2009). Important aspects related to a company's broad strategy can therefore be disregarded (Machua et al. 2011, Jiménez et al. 2011). A well-structured decision process requires the decision-maker (henceforth "DM") to systematically consider the aspects of the project that have a strategic relevance, namely the aspects related to the company's broad goals and plan of action. The DM should thus evaluate the consequences of the project for the whole organization and guarantee the availability of the resources necessary for an in-depth analysis of the project (Cohen and Graham 2001). Studies that document and analyze actual investment projects and identify gaps between the projects' outcomes and the stakeholders' prior expectations and goals can play a critical role in the design of better decision schemes.

In this paper, we explore investment decisions on manufacturing automation in the wood products industry, defined as the industry that refines wood as it passes through sawmills and transforms it into products such as furniture, joinery, and home-building materials (Sandberg et al. 2014). Automation plays an important role in connection with the competitiveness of the European industry. In 2015, the European wood products industry was estimated to include more than 290,000 companies and 1 million employees, with an annual turnover of 129 billion euros (CEI-BOIS 2018). Yet, wood products manufacturers are facing several challenges due to increased global competition, resulting both from the use of alternative materials and from the growing market shares of manufacturers located in low-wage economies (NRA Sweden 2012). Productivity improvements aimed at preserving the economic viability of the industry are regarded as a high priority by the companies operating in the industry (Sandberg et al. 2014). Automation of manufacturing is generally emphasized as a key step in the pursuit of such improvements (NRA Sweden 2012, Nord & Widmark 2010).

The aim of the paper is to increase the knowledge on the process leading to investment decisions on automation of manufacturing in the wood products industry, as well as on the aspects considered in such a process. The comparison between our findings and the theoretical literature allows us to identify opportunities to improve the decision process, which can be exploited by the firms operating in the industry.

2. Literature Review

2.1 The Industry Context

Wood products manufacturing work is characterized by manual tasks consisting of repetitive motions and heavy lifting in an environment with noise and dust. Some operators are also exposed to chemicals, for example, due to the handling of glue and paint (Michael & Wiedenbeck 2004). The tough work conditions could be improved to some extent through an increased level of automation in manufacturing.

In comparison to other industries, such as the metal industry, the wood products industry has lower levels of automation. According to Karltun (2007), a reason for this is the heterogeneous character of the raw material used in the industry. There are several aspects regarding the raw material that can affect the manufacturing process, such as the origin and type of tree, the biological effects of wood (knots and other natural defects), and the moisture content (Eliasson 2014). Sorting and grading processes are relatively difficult to automate, since automation would entail tight acceptance tolerances and could therefore increase the rejection rate for raw materials, resulting in higher manufacturing costs. Additionally, the cutting forces and processing speed of automation technologies are significantly lower in the wood products industry than in the metal industry due to the nature of the raw materials used (Eliasson 2014, Karltun 2007).

Another factor that challenges the implementation of automation in the wood products industry is its culture. The wood products industry is generally viewed as a traditional industry with a culture closely linked to a negative attitude toward automation and an unwillingness to change, which contribute to hindering the implementation of automation in manufacturing (Makkonen 2018).

Moreover, automation of manufacturing in the wood products industry is also hampered by the rapid turnover and low education level of the labor force, which often lacks valuable certificates and operation licenses (Karltun 2007, Sowlati & Vahid 2006). Training and education are therefore emphasized as essential to support the implementation of new automation technologies (Wiedenbeck & Parsons 2010, Pirraglia et al. 2009). However, competence development should not be limited to the shop floor level. Grace et al. (2018) point out that skilled labor is considered as vital in the wood products industry; however, business management skill is often overlooked, although it has a vital role in company success.

2.2 Decision Theory

Investment decisions generally require the DM to collect and process several types of information (Russo et al. 2002). Using the information gathered to make decisions entails a significant challenge and a substantial investment of resources. If the ranking of the alternative options available differs across the possible scenarios, finalizing the decision may require the decision maker to assess the relative likelihood of the different possible scenarios. Tools such as decision trees and influence diagrams can help the DM in this process (French et al. 2009).

The ranking of the alternatives may also change, depending on the criterion used to evaluate them. In cases of this type, the DM must focus on his or her own preferences and aspirations and identify the criteria to which priority should be given. Similarly, different stakeholders may have different preferences relative to the alternative options available, due either to different perceptions of the problem or to a misalignment of the respective interests. A cornerstone result on collective decisions is that no single rule can always lead to a decision satisfying some basic "desiderata" for a reasonable decision, taking into account the will of multiple parties (Arrow 1963, Arrow 1951). Even in cases in which a consensus can in principle be reached, aggregating the stakeholders' preferences may be a difficult task. Tools such as the *Analytic Hierarchy Process* (Brunelli 2015), based on pairwise comparisons focused on specific aspects of the alternative options considered, can be used to facilitate preference aggregation.

Several models have been developed to provide analytically useful accounts of the decision processes followed by firms. These models can be classified into different categories, based on multiple criteria; classifications based on a given criterion may also be more or less refined. A first classification distinguishes between *descriptive* and *normative models*, respectively understood as models whose goal is to summarize and express the existing decision processes, for analytical purposes, and models that provide guidelines on how decisions should be made (Badiru 2014, Lehto et al. 2012, French et al. 2009, Davis et al. 2005). Some authors also consider a *prescriptive* approach to decision theory, whose goal is to develop models based on normative theories without losing sight of the prevalence of ill-defined problems and of the actual cognitive characteristics of DMs (Davis et al. 2005).

A related distinction is that between *rational*, *behavioral* and *naturalistic decision models* (Lehto et al. 2012). Traditionally, normative decision models consider highly stylized representations of the DM and the decision problem, in which sharp conclusions with immediate normative implications can be drawn (Gilboa 2010). By contrast, behavioral and natural decision models attempt to take into systematic account the cognitive limitations of human DMs (Gigerenzer et al. 1999, Tversky & Kahneman 1974, Simon 1955). Gigerenzer et al. (1999, p. vii) highlight the empirical relevance of *fast and frugal heuristics*, namely "inference mechanisms that can be simple and smart". Examples of heuristics are "educated guesses, rules of thumb, trial and error, and stereotyping and profiling" (Hamilton 2016, p. 18). A few especially common heuristics are reported in Table 1, based on Tversky and Kahneman (1974).

Inaccurate extensions of heuristics from settings in which they were developed and tested to new settings can lead to systematic biases, which may in turn cause systematic errors (Gigerenzer et al. 1999, Nisbett & Ross 1980, Tversky & Kahneman 1974), both in the case of single individuals and in the case of committees and organizations (Garicano & Posner 2005, Surowiecki 2004). Analyses carried out by teams may be subject to "herding" or "groupthink," whereby the reliability and/or the precision of pieces of information available to single team members are under appreciated, and valuable information is therefore lost (Banerjee 1992, Welch 1992).

Our main reference model in this paper is the *Integrative Model of (Human) Decision Making* (henceforth "IMDM" – (Lehto et al. 2012), which builds on Welford's model of information processing (Welford 1976) and provides a systematic illustration of the different steps of the decision process. This model, illustrated in Figure 1, views the identification of the general features of

Table 1. Some commonly observed heuristics.

Name	Description	Example
Adjustment and Anchoring	Conjectures on the unknown value of a variable – not necessarily numerical - are formulated by adjusting values obtained from cues or prior experience.	Guesses about the value of a variable made by experimental subjects can reflect in a systematic way the different, random cues to which the subjects are exposed.
Availability	The probability of an event in a specific, familiar type of situation is extended to situations that the DM regards as “similar”.	Occurrences of heart attacks among acquaintances may be used to assess the risk of a heart attack faced by a person in a given demographic group.
Representativeness	The probability of some event is assessed by referring to some broader category or stereotype, of which the situation faced is viewed as an example.	A person’s character and interests may be used as the basis for inferences about his/her occupation, based on stereotypes.

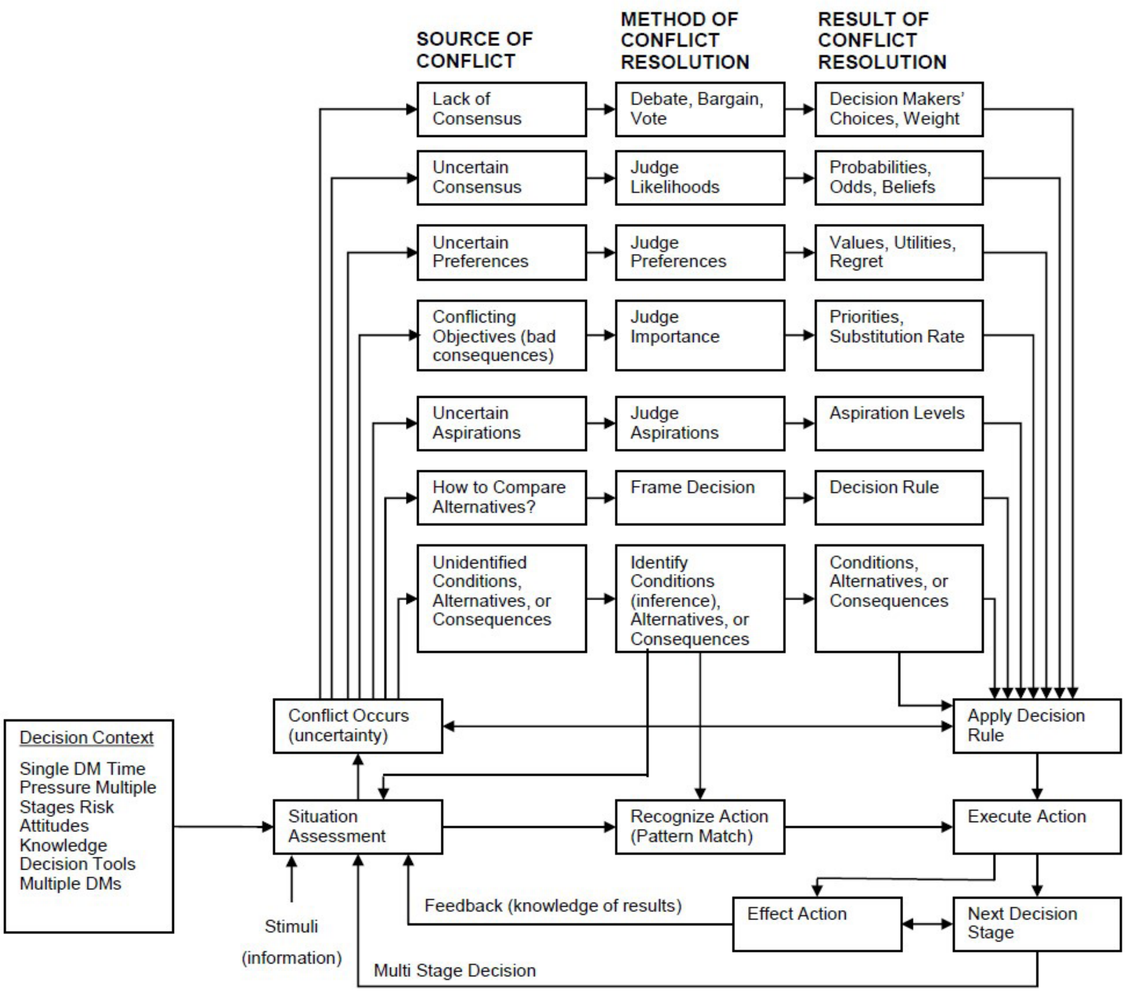

Figure 1. A diagrammatic representation of the Integrative Model of Decision Making. Source: Lehto et al. 2012.

the investment decision, from the point of view of the subjects involved, the time available to make it, and the perception and the relevance of the risks involved, as the first step of the process. The different aspects of the decision are then screened; if any areas of uncertainty and potential clashes between different priorities are identified, the DM can collect further information and/or resort to procedures that may allow him or her to reconcile the views held by different subjects. If necessary, the process can be repeated, possibly taking into account the results of a first implementation of the outcome of the decision.

The broad and comprehensive nature of the IMDM facilitates the identification of the weak points of the decision process followed by the case company. We then refer to more specific and focused models—such as the models of heuristics in decision-making (Gigerenzer et al. 1999, Tversky and Kahneman 1974) and the models on the choice between in-house and outsourced activities (Besanko et al. 2015, Williamson 1985)—for an in-depth discussion, aiming to provide operational recommendations.

3. Research Methods

3.1 Case Selection and Description

To examine investment decisions on automation of manufacturing in the wood products industry, an investment project was selected and analyzed. Two selection criteria were applied: (1) The project must be related to automation investments that support the manufacturing system. (2) The project must be performed in the wood products industry. The selected investment project was conducted at a large Swedish wood manufacturing company. The company manufactures primarily sawn timber, which is used in the construction industry.

The selected investment project was part of a larger initiative that aimed to create a new business segment at the case company, expanding the company's range of products. The new business segment would offer the construction industry products designed to add processing value to sawn timber. First, a certain product was chosen to be manufactured as the initial element of a product portfolio for the new business segment. To manufacture this product, the case company needed to invest in a manufacturing plant, including equipment. The initial project was later divided into two subprojects: Plant 1 and Plant 2. Plant 1 was designed to serve as a pilot plant, providing deeper knowledge about both the raw material, finished product, and manufacturing process. Afterwards, the project would continue with an investment in a full-scale manufacturing plant, Plant 2. The research underlying this paper examined the subproject that dealt with Plant 1, which was developed during the time period in which the study underlying this paper was conducted. The automation acquisition process for Plant 1 was initiated in September 2017 and was completed in December 2018.

3.2 Data Collection

The data presented in this paper was collected through a real-time case study. This type of study provides in-depth information on the project examined and how it evolves over time (Karlsson 2009). The data was collected between October 2017 and December 2018. Participating in meetings concerned with the investment project served as the main tool for data collection. Such meetings included a meeting with a technical supplier, as well as several project group and steering group meetings. The meetings ranged in duration from 1 to 3 hours. To collect data, notes were taken that included how decisions on automation of manufacturing were made, who made the decisions, and the aspects that were considered when these decisions were made.

Semi-structured interviews with open-ended questions were used as an additional tool to collect data. Semi-structured interviews allow the investigations to be based on, but not limited to, predefined questions (Yin 2014). This enables the flexibility to gain understanding on a complex topic such as decision-making. The interviews started with questions about the investment project's purpose and the people involved in it. The interview continued with questions regarding decisions in the investment project. The interview was then narrowed down to questions related to automation decisions, with a focus on the challenges of such decisions, the aspects that influence them, and how they are supported. In total, 11 face-to-face interviews were conducted with a duration between 31 minutes and 68 minutes. The interviews were conducted with steering group and project group members. The same interview guide was used for all respondents. Each interview was recorded and transcribed for analysis. The interviews brought forward the perception of the people involved in automation decisions in the investment project. Further, the interviews helped to validate the data captured through participating in meetings related to the investment project. Table 2 summarizes the type and

Table 2. Data collection.

Types of meetings	Number of meetings	Total length of meetings
Steering group meeting	9	20h 15 min
Project group meeting	5	12h
Technical supplier meeting	1	2h 30 min
Interview respondents	**Number of interviews**	**Total length of interview**
Steering group members	6	4h 48 min
Project manager	1	1h 06 min
Marketing and sales	2	2h 14 min
Purchasing	1	50 min
Production	1	55 min

number of meetings that were observed and their length, as well as the interview respondents that participated, the number of interviews conducted, and their length.

In addition to the participation in meetings and conducting interviews, information was collected through project documentation to validate the data collected. The documents provided data regarding project descriptions and motivation, project group meeting protocols, project activity time plans, supplier quotations, and protocols from steering group meetings. The documents provided a basis for improving the understanding of the context of the investment project. Taking part in email conversations related to the project was useful to get further insights into the phenomenon under study.

The close collaboration between the investigator and case company made it possible to collect valuable data. To avoid bias that could arise in such situations, data was verified through several data collection tools. Some participants in the study reviewed the findings to identify any possible errors and misunderstandings. Moreover, the findings were reviewed by academic peers.

3.3 Data Analysis

The data was analyzed following the three phases outlined by Miles et al. (2014): (1) data reduction, (2) data display, and (3) conclusions drawing and verification. In the first phase, data reduction, the transcripts and notes from the interviews as well as the notes from the meetings and documents were reviewed. The data was then condensed to information related to automation decisions, with an emphasis on the process leading to investment decisions on automation and the aspects considered in this process. In the second phase, data display, the data was organized in a matrix, which made it easier to draw conclusions. The third phase was based on the patterns identified in the collected data, as well as relating the empirical findings to the literature.

4. Findings and Analysis

4.1 Project Organization

The project organization involved a steering group and a project group. The steering group consisted of a project sponsor and representatives from the manufacturing and marketing functions at the case company. Its role was to set the broad guidelines for the project and follow up on the project's development. The steering group also had the power to modify its previous resolutions and to discontinue the project, had its potential revealed itself to be below expectations.

The core project group consisted of a project manager, two marketing representatives, and a wood technology expert. The role of the project group was to analyze the alternative options considered, to report the results of the analysis to the steering group, and to finalize the project. The project group was responsible for the activities specifically related to automation, such as contacting the technical suppliers and recommending complete manufacturing technology solutions to the steering group. From the standpoint of the IMDM, it thus appears that the decision was incorrectly framed, as the strategic relevance of automation was not taken into full consideration (Lehto et al. 2012, Russo et al. 2002).

A small project organization can make it possible to use a flatter hierarchy and thereby enable fast communication and fast decision-making (Hall 2008). However, the disadvantage is that some key competences might be missing. In this project, the manufacturing and marketing functions were involved for the entire length of the project. Representatives from purchasing, human resources, and finance supported the project in later phases, when needed.

Cohen and Graham (2001) suggest that the project team should include, *for the entire length of the project*, members from engineering and any functions directly connected with the design, use, and maintenance of the project outcome; marketing, technical support, quality assurance, and finance; and customer and other end-user groups. Not including different perspectives limits the view on the aspects considered when investment decisions are being made, particularly in connection with the analysis of the decisions related to the company's overall strategy. Heterogeneous groups are also more likely to challenge conventional lines of thought and can limit the risk of information losses due to group-think (Russo et al. 2002).

4.2 Reliance on Technical Suppliers

The DMs within the company were only partly aware of the details and the complexities of the different alternatives available, especially in connection with the broader and more far-reaching aspects of automation. This situation appears to be partly driven by the wood product industry's limited investment in the development of human and technological resources.

The manager of the investment project contacted a small number of technical suppliers and asked each supplier to offer complete solutions and prices. The case company showed a tendency to rely on the technical suppliers. The limited involvement in the design of the manufacturing automation appears to reflect the traditional culture of the companies operating in the area, which is focused on the efficient manufacturing of relatively large batches, under routines that have been relatively stable over time. The full reliance on designs provided by the technical suppliers is at odds with the procedures typically used by companies whose core activity entails frequent innovative investments. Such companies tend to be proactive and to directly engage in the analysis of the technical specifications to which the machinery and equipment should be built. The technical suppliers must then only make decisions related to relatively minor details and set the price. With a large number of technical suppliers potentially involved, competition on price can limit the cost of a solution of this type (Besanko et al. 2015, Williamson 1985).

Each one of these strategies presents its typical advantages and disadvantages. Putting the technical suppliers effectively in charge of the design of the manufacturing would allow them to rely on standardized solutions and would therefore not require them to bear the costs associated with the development of substantially new designs. These costs would include the costs related to the certification of the manufacturing. The procedures for the certification of standardized solutions are in fact typically carried out by the technical suppliers, who can realize economies of scale. By contrast, customized solutions limit the extent to which scale economies are possible and may impose an additional administrative burden on the manufacturer, especially if different sub-suppliers are in charge for different pieces of the automation technology (Besanko et al. 2015, Williamson 1985).

The low cost of solutions based on the technical suppliers' standard designs can however have a counterpart in the limited opportunities to adapt the solutions to the company's specific needs. Also, the solutions proposed by the technical suppliers may not allow the company to take advantage of specific opportunities faced. One of the project members did point out that a "copy-paste" solution would limit the company's benefits from automation, as the technical suppliers would probably offer similar solutions to the company's competitors. By contrast, asking the technical suppliers to offer customized solutions to a higher extent in order to increase competitive manufacturing advantages would require the company to invest human resources with the skills necessary to perform such tasks. A summary of the advantages of the latter type of procedures is provided in Table 3; a related table, focused on the standard ``make or buy" decision, can be found in Besanko et al. (2015).

The overall stance adopted by the company in connection with the design of the project and the interactions with the technical suppliers generally appears to be a further expression of the framing problem that we already pointed out in 4.1 above (Lehto et al. 2012, Russo et al. 2002).

4.3 Project Objectives and Project Format

The preliminary objective of the investment project for Plant 1 was to serve as a pilot, aimed to increase the knowledge regarding the raw material, finished product, and manufacturing process before the company continued with an investment in full-scale manufacturing (Plant 2). This objective was set by the steering group before appointing the project manager and project

Table 3. Advantages and disadvantages of reliance on technical suppliers.

Advantages • Economies of scale can make the solution proposed by specialized suppliers less expensive than in-house solutions. • Market competition can force specialized suppliers to achieve higher levels of efficiency than those achievable with in-house production, and thereby enhance the cost advantage of outsourced solutions. These advantages may also involve the cost related to the certification of the equipment.
Disadvantages • General purpose-solutions can be ill-suited to the specific needs of a company and may thus not allow the company to take advantage of any specific opportunities faced. • Sharing information may be leaked when an activity is performed by an independent market firm. • If drastically different solutions are available in the market, the seller of each solution can have an effective monopoly position in connection with the development and maintenance of the equipment. The supplier could exploit this position to renegotiate any previous contractual agreement, i.e., to "hold-up" the company.

group members. From the point of view of the IMDM, the company was faced with a problem that we could label as one of conflicting objectives. One objective was the development of refined and fully suitable equipment and procedures, which could have benefitted from the experience gained from the pilot plant. The other objective was a short completion time for the project, which would have been shorter if the main project had been started immediately.

With the benefit of hindsight, it is possible to say that the wrong decision was made regarding time. Accelerating the development of the main project turned out to be so important that the company chose to proceed with it even before the pilot plant was fully developed and while its mechanics were being explored. The reason for rushing the process was that a competitor was starting up a manufacturing plant to produce the same product in Sweden. Thus, the case company was reactive rather than proactive in their decision-making.

The choice of a pilot plant was motivated by the benefit that the company could have received in terms of the development of the skills of the labor force already in place. Although this was a laudable intent, the outcome of the project raises the question of whether finding alternative ways to train and educate the employees or hiring new employees would have been a better solution.

4.4 Aspects Considered in Automation Decisions

The discussions regarding automation were mainly carried out between the project manager, the wood technology expert, and the technical suppliers. These discussions involved the type of technological solutions needed, the number of operators required and, later, the compliance of the suppliers' offers with Swedish work environment regulations. Another aspect that was taken into consideration was the manufacturing layout, which was predetermined. The steering group had decided that Plant 1 would be located in an existing building, already owned by the case company, to reduce the costs of the project. Moreover, the steering group had decided upon the capacity to be manufactured, which was an additional aspect that was considered. Above that, the technical suppliers were offered information regarding the product specifications. Further, the technical suppliers were informed that for Plant 1, the level of automation was not expected to be high. The reason for this was to decrease the investment costs and increase operator knowledge about the process and product through learning by doing.

The outcome of the discussion with the technical suppliers was reported to the steering group. However, the steering group trusted the project group regarding other aspects of automation and tended to focus on the financial aspects solely.

Another aspect that was considered by the project group was the number of sub-suppliers to work with. Working with multiple technical suppliers was considered a challenge, since it could create problems regarding the compatibility of the equipment, as well as challenges with manufacturing certifications, which had to essentially be taken care of by the company. This would require the need for additional resources, time, and specific competences. By contrast, involving multiple technical suppliers could offer customization to a greater extent. Table 4 provides a summary of the aspects influencing investment decisions on automation of manufacturing in the examined investment project.

The node of the IMDM-decision graph to which these problems can be linked is the one related to the comparison of alternatives (Lehto et al. 2012). The findings demonstrate that the investment decisions on automation of manufacturing were mainly based on financial and technological aspects. Automation decisions should not be based only on that, however, since such deci-

Table 4. Aspects influencing decisions on automation of manufacturing.

- Number of operators required
- Swedish work environment regulations
- Manufacturing layout
- Manufacturing capacity
- Product specifications
- Levels of automation
- Investment costs
- Previous experience and knowledge of the technical suppliers
- Time to delivery
- Number of sub-suppliers involved

sions can influence several organisational decision areas in manufacturing (Winroth et al. 2007). For instance, Gouvea da Costa and Pinheiro de Lima (2008) state that "the adoption of material requirements planning (MRP) affects the 'production planning and control', and equally demands specific abilities (human resources) and an organisational and management processes revision (organisation)". Thus, automation decisions can be linked to various decision areas in manufacturing. To utilize the competitive advantages of automation, these decision areas need to be considered and compatible (Gouvea da Costa & Pinheiro de Lima 2008).

One type of benefits from automation that appears to have been neglected, also in connection with the use of the feedbacks from Plant 1, is related to additional flexibility and the possibility to plan small batches. This would increase the opportunities for value creation through offering more customized products. Customized wood products are a growing market segment, and the fraction of the producers who can offer products with a high degree of customization could be as small as 10%, according to the case company's estimates.

5. Recommendations

The findings presented in this paper do suggest a number of priorities that companies in the wood products industry should consider when structuring their investment decisions. One major factor behind our findings is the critical importance of human resources for the companies in the wood products industry, with specific regard to their investment process and investment decisions. Highly qualified human resources and appropriate hiring and training routines are generally necessary to enable the firms to provide adequate inputs to the suppliers of the designs and the technical equipment, and to assume a proactive role in the implementation of their strategic plans (Hollenstein 2004).

Our findings are thus in line with those of Stendahl and Roos (2008), who show that product innovation and development activities of the firms in the wood industry are frequently hampered by inadequate staffing and by the low educational level of white-collar workers. Our analysis can thus support their recommendation to promote increased educational levels, albeit our focus is on automation investments rather than product innovation and development. In the case at hand, greater in-house automation expertise could be helpful to deal with future investment in automation. Lack of specialized competences is indeed a problem that has been recognized in previous studies on automation technologies, such as those presented by Hameed et al. (2012) and Hollenstein (2004).

From a broader point of view, the availability of qualified personnel is a critical requirement for the adoption of automation technologies in many developed economies. Europe is currently not at par with the U.S. and the more developed Asian countries in this respect, on average (Gruber 2017). The problems experienced by the wood products industry therefore appear to be an expression of a broader problem, whose solution requires specific educational policies.

On a related note, companies should recognize that the strategic relevance of automation justifies a comprehensive approach to its implementation. An important element of this approach is a proactive stance in the design of the manufacturing automation, which takes into consideration the general benefits of the projects, as opposed to cost reductions and other benefits of a more immediate relevance. An example from our case company is given by the increased opportunities to produce small batches and to thereby gain access to a profitable market segment.

One issue that companies would in any case be bound to face is the weight of the established routines and heuristics in their decisional processes. Recognizing the presence and the relevance of such factors is however a necessary step to make in order to improve the structure of the processes. Essentially, improvements can be implemented by broadening the range of competences of the members of the decision group and by creating opportunities for the members to identify critical assumptions—either explicit or hidden—and to question and challenge them (Russo et al. 2002).

A further point that deserves special attention is the large bargaining power that the suppliers who develop highly company-specific solutions, in strict cooperation with the company, could enjoy (Williamson 1985). These problems could be mitigated by the size of the company and by the opportunities that the suppliers could face in connection with future projects, which could induce a reputational concern on the suppliers' part.

6. Conclusions

The aim of this paper has been to gain knowledge on the process leading to investment decisions on automation of manufacturing in the wood products industry and the aspects considered in this process. An investment project related to automation of manufacturing was followed up closely at a large Swedish wood manufacturing company. Participation in project meetings and email conversations regarding the project, along with having access to project documents and conducting interviews with project- and steering-group members allowed us to gain in-depth knowledge on the topic of interest.

The findings of this paper show that when the competence on automation of manufacturing in a company is limited, it results in uncertain preferences. The DMs tend to heavily rely on the technical suppliers, rather than developing their internal competence portfolio. Putting the technical suppliers effectively in charge leads to a limited involvement of the DMs in developing specifications regarding automation, and a limited awareness of the opportunities offered by automation. The limited involvement in the development of the automation specifications and the narrow view on automation reduces the potential gain of business wide competitive advantages. The DMs focus on the immediate cost reductions made possible by the automation investment, and not much attention is paid to other potential benefits. Moreover, when companies put the technical suppliers effectively in charge, they are often offered standardized solutions, referred to as "copy-paste" solutions. These offers are generally also available to the competitors, and the competitive advantages of automation would therefore be relatively small.

These findings are in line with the tendency of human DMs—both individuals and teams—to follow established mental patterns and use familiar heuristics, even in cases in which their use is unwarranted and untested (Gigerenzer et al. 1999, Tversky & Kahneman 1974). In particular, the emphasis on financial measures and the limited involvement in the design of the manufacturing automation appear to reflect the traditional culture of the companies operating in the area, focused on the efficient manufacturing of relatively large batches, under routines that have been relatively stable over time.

7. Limitations and Future Research

The study underlying this paper is based on a real-time case study, which was carried out to gain rich and in-depth data on investment decisions on automation of manufacturing in the wood products industry. As for all case studies, further studies would be required to verify whether the patterns identified and the conclusions drawn can be regarded as typical for the wood products industry, as opposed to reflecting the specific features of the case studies and/or the authors' biases.

Understanding investment decisions on automation of manufacturing is significant to support the decision-makers in such important strategic decisions in an organization. While this paper focused specifically on the wood products industry, future research could cast light on patterns that emerge across different industries.

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