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Abstract

Wood product industries are a cornerstone of the Swedish industry and contribute vastly to the total Swedish export value. Wood as material itself has a promising perspective of becoming one of the most valuable resources. Sweden in particular has a long tradition and the knowledge of how to cultivate forests. In comparison to the highly automated forest industries, production systems of Swedish wood products industries are mostly characterized by a low degree of automation, tough manual labour and a relative low competency of the workforce. Facing fiercer competition on a global market, Swedish wood product industries are starting to lose touch with wood working industries in other industrialized European countries. Based upon established literature, this paper systematizes the status of automation practices in wood processing industries. The outcome of this study also outlines the expected effects and the future perspectives of digitalization and robotic automation for wood processing industries in high-cost environments. The study concludes that the typical production systems of wood product industries are not ready to implement the necessary standards to enter Industry 4.0. Not only are the technical prerequisites not fulfilled, but also a lack of appropriate production organization, logistics and economic basis is affecting negatively.

Keywords: Automation, Industry 4.0, industrial revolution, production system, wood processing, wood product industry

1. Introduction

Swedish forest and wood processing industries are one of the successful pillars of the Swedish industry, creating over 10.3% of the total value added by the manufacturing industry in Sweden in 2012 [1]. In 2013, nearly 30 000 people were directly employed at companies processing forest products or producing wood products. In addition, Sweden has about 18% of the market share worldwide in sawn timber production and timber products export [2]. This can be considered quite strong because of the small area available for forest usage in comparison to e.g. the USA, Canada or Russia. During the last couple of years, sawn timber and wood products account for around 10-12% of the total Swedish exports [2]. On first sight, this does not seem much. However, taking into account the added value and a very small import volume of those forest products, the net export value of forest products is about 50 to 75% of the total Swedish exports. Some experts even claim that it was the Swedish forest based industry which saved the economic growth in Sweden during the financial crisis in 2008-09 [3].

Despite climate change, progressing industrialization and deforestation of around 125 million cubic meters per year, Swedish forests were growing with around 50% in 2014 [1]. Because of their great possibilities of adding value to the export market, their access to a valuable, renewable resource and supporting sustainable development, timber and wood processing industries are playing a major role in Sweden’s (industrial) future. [4]

Sandberg, et al. [2] distinguish between the forest industry, consisting of forestry, energy, pulp and paper, as well as sawmills, and the wood products industry. This sector consists, among others, of the following branches: furniture, industrial housing, joinery, cabinetry and packaging. According to Sandberg, et al. [2] the added value of furniture and joinery products in relation to sawn timber is 20-30 times higher and therefore it is very important to have a strong industry in this sector.

Whereas the forest industry, especially the timber and pulp and paper industry, is highly automated and know-how intensive [1, 5], wood product industries lack behind in usage of machinery and automation equipment [6]. Wood product industries are often characterized by a low degree of automation and tough (heavy and noisy) manual labour. Because of the combination of hard manual work and relatively low usage of machinery, the risk for accidents, injuries or work related injuries is significantly higher than in other industries [7]. Moreover, Swedish wood product industries have high manufacturing costs [8] and lack behind in productivity [2]. But not only low productivity and high labour costs are considered to be problems for wood products industries in Sweden. A report from Träregion Småländ [9] reveals that forest and wood product companies will suffer from lack of competency in the next couple of years. Recruitment of skilled workforce will be especially hard in production because less young people attend relevant education on the high school level and are less attracted to that line of work [9].

An often chosen and approved strategy for facing high cost environments and low productivity is to raise the degree of
automation by the implementation of automated equipment in manufacturing processes [10]. Swedish companies, and this is especially valid for wood products companies, are not able to compete with cheap labour costs, but with fast and flexible production processes accomplished by innovative automation and production systems. Implementation of automation equipment will raise the products quality and make manufacturing processes more efficient. This is more important than ever before when considering the transformation many other industries, such as automotive or chemical process industry, are undergoing as a result of Industry 4.0 [11].

Kromann, et al. [12] address the usage of industrial robots and the productivity change caused by automation. This is done by comparing the degree of automation and productivity rate of several industrialized countries and different industry sectors. Their findings conclude that Sweden in comparison to the highest automated country in the wood and furniture industry, Denmark, lacks behind. By implementing the same degree of automation as Denmark has, Swedish wood and furniture industries could increase its productivity rate with over 17%.

2. Purpose

The purpose of this paper is to systematize the history and status of automation practices in wood product industries based upon established literature, research initiatives and reports of fairs. The objective is to introduce to the reader the current status of automation and manufacturing practices in wood product industries. It describes the industrial development in accordance with the four stages of industrial revolution according to Industry 4.0, beginning with the first industrial revolution to the now advancing fourth revolution. A baseline is constituted in order to establish a timeline of production practices, machinery and other equipment throughout the industrial stages. Wood product industries are traditionally slow in development and adaption to new machinery, flexible automation and computerization. Therefore, the developed timeline is compared to the industrial development of other industries.

3. Methodology

This study has applied two different approaches. An unsystemized search method was used for the historical overview covering the first and second industrial revolutions. A systemized approach was used for the third and fourth revolutions. The chosen approach is not a literature review in its classical meaning [13] and limited in its content. It is merely a methodology specifically designed to solve the given objective.

For the historical overview of the wood technology industry a broad search in library databases and the Internet was conducted using the key words such as “wood industry” and “wood product industry” combined with “history”.

For the overview of the third industrial revolution and the current status of automation practices in wood product industries, a literature review of relevant scientific literature as well as European research programs focusing on forest and wood products is conducted.

### Table 1: Results of the literature search

<table>
<thead>
<tr>
<th>Journal</th>
<th>Keyword</th>
<th># of relevant articles</th>
<th># of selected articles</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Journal of Wood and Wood Products (previous title: Holz als Roh- und Werkstoff)</td>
<td>Automation</td>
<td>9</td>
<td>3</td>
<td>[38, 39, 45]</td>
</tr>
<tr>
<td></td>
<td>CNC</td>
<td>11</td>
<td>11</td>
<td>[40, 41, 42, 43, 44, 46, 47, 49, 51, 52, 57]</td>
</tr>
<tr>
<td></td>
<td>Flexible manufacturing</td>
<td>6</td>
<td>5</td>
<td>[49, 50, 52, 53, 56]</td>
</tr>
<tr>
<td></td>
<td>Robot</td>
<td>2</td>
<td>1</td>
<td>[55]</td>
</tr>
<tr>
<td>Wood Science and Technology</td>
<td>Automation</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
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<td></td>
<td>CNC</td>
<td>0</td>
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<td>Flexible manufacturing</td>
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<td>Robot</td>
<td>0</td>
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<tr>
<td>Wood Material Science and Engineering</td>
<td>Automation</td>
<td>3</td>
<td>0</td>
<td>-</td>
</tr>
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<td></td>
<td>CNC</td>
<td>1</td>
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<td></td>
<td>Flexible manufacturing</td>
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<td></td>
<td>Robot</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>International Wood Products Journal (previous title: Journal of the Institute of Wood Science)</td>
<td>Automation</td>
<td>1</td>
<td>0</td>
<td>-</td>
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<td></td>
<td>CNC</td>
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<td></td>
<td>Robot</td>
<td>0</td>
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<td>-</td>
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<tr>
<td>Journal of Japan Wood Research Society</td>
<td>Automation</td>
<td>0</td>
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<td></td>
<td>CNC</td>
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<td>Robot</td>
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<td>CNC</td>
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<td>Flexible manufacturing</td>
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<td></td>
<td>Robot</td>
<td>3</td>
<td>1</td>
<td>[60]</td>
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</table>
The literature search is limited to six scientific journals in the field of wood science and technology. They have been selected according to Teischinger [14] who states the journals being active or related to wood science and technology research. Key words used were “automation”, “computerized numerical control” (CNC), “flexible manufacturing” and “robot”, thus reflecting aspects of industrial automation. The results of the literature search are found in table 1. A total of 525 articles were found of which 40 (34 unique) were deemed as relevant when reviewing keywords, title and abstract. Finally, 21 (19 unique) were selected for this paper after thorough reading.

In addition to the scientific database search a search for the latest machinery and technology for wood product industry has been conducted. This is been done by reviewing the periodicals of the biggest fair for the wood working sector, the Ligna [15]. The periodicals or summaries of the Ligna appear, since the founding of the Ligna in 1975, every second year.

4. The development of industrial automation

4.1. Industrial revolutions

When referring to the fourth industrial revolution, it has first to be set into context with the three industrial revolutions prior to the one currently occurring. Those three revolutions have during the last 250 years to a great extent changed society, economy and industry as well as status of industry as it is known to us today [16]. A common understanding is that the first industrial revolution starts around 1750 with the introduction of mechanical production powered by water and steam. The first mechanical loom in 1784 allowed continuous and steady production changing the way goods were manufactured.

The second industrial revolution is dated at the beginning of the 20\textsuperscript{th} century. With the first assembly line in 1870 the time of mass production powered by electricity began. Electricity allowed companies to choose their plant location independently from a water source prior necessary for power production of machines and conveyor belts.

The third revolution starting in 1970 refers to the digital automation of production by means of electronics, information technology (IT) and industrial robots. Already in 1969, the first industrial robot was installed in Sweden [17]. The further development and integration of those systems led to computer-integrated manufacturing (CIM) systems, now often referred to as so called cyber-physical systems (CPS), which mark the start of the fourth industrial revolution.

The term “Industrie 4.0”, commonly known as Industry 4.0, was coined in 2011 on the Hannover Fair in Germany [18]. However, rather than looking with a historical view on Industry 4.0, academia and industry predict with certain anticipation the changes which should happen in the next couple of years. Figure 1 depicts with the yellow arrow the future. Flexibility in production requires flexibility and adaptability also in the support processes such as maintenance and logistics [24]. Smart products can therefore also predict their own need for maintenance [25].

4.2. Industry 4.0

Industry 4.0 describes a future industry as result of the fourth industrial revolution. Connected machines, smart products and systems, and Internet-based solutions are the main characteristics that create intelligent production units consisting of integrated computer based or digital components that monitor and control the physical devices [20]. These self-organised CPS communicate through an internet-based network forming the “Internet of Things” (IoT) [21]. The technological advances allow flexibility and automation in production and support new manufacturing philosophies such as lean production. Smart products, i.e. products equipped with memory capability, keep track of required resources and orchestrate the production process [22]. The automation will not lead to less human interaction or worker-less production facilities, but the competence requirements will change [22, 23]. In general, the skills requirements will increase and become more specialised in the future. Flexibility in production requires flexibility and adaptability also in the support processes such as maintenance and logistics [24]. Smart products can therefore also predict their own need for maintenance [25].

4.3. Industry 4.0 in Sweden

In Sweden, the fourth industrial revolution took form in a coordinated manner between the government, the industry and academia with the launching of a couple of initiatives founded by Sweden’s innovation agency VINNOVA, the Swedish Research Council Formas and the Swedish Energy Agency. The strategic innovation programme for the IoT [26] focuses on how Sweden can be leading in digitalisation and how to utilize technology management. Process Industrial IT and Automation [27] concentrates on process industries while the Produktion2030 [28] has a broader production approach. The agenda Produktion2030 focuses on six main fields of manufacturing, so called areas of strength; environmentally sustainable and resource-efficient production, flexible production, virtual production development and simulation, humans in the production system, product- and production based services and integrated product- and production development.

A study conducted by PwC in 2015 [29], interviewing 64 Swedish industrial companies, revealed that around 60 \% of the participants think that Industry 4.0 will play the most important role in staying competitive on the global market. In 2020, already more than 90\% of the participants believe that digitalisation is the most crucial factor for staying viable on a global market. Over 50\% of the participants describe that their horizontal and vertical supply chains are digitalized to a high or very high degree. However, in five years’ time, the participants are convinced that the degree of digitalisation has risen to nearly 90\% in order to guarantee a successful
implementation of CPS. In comparison to Germany, Swedish company leaders are persuaded that they lack behind in education of their employees in regards to data management and new production systems [29].

5. Development of automation in wood product industries

Wood as material has been processed for creating housing, furniture and everyday objects for thousands of years. Before the industrial revolutions the processing was a matter of craftsmanship. This section outlines the development of the wood product industry in Sweden and globally.

5.1. The first and second revolution

Until the mid-nineteenth century in Sweden, wood was mainly consumed in the mining industry. The industrial revolution and the urbanisation that occurred in Sweden in the late nineteenth century resulted in increasing demand on processed wood products in form of building material and furniture but also other types of wood products. At the same time, the Swedish export of boards, battens, and similar products increased. The peak for the sawmill industry was between 1850 and 1900 [30]. The water driven sawmills decreased during the period in favour for steam driven mills. The steam engine allowed for production all year long and for mobile sawmills located close to the raw material. Moreover, during the late nineteenth century the circular saw was introduced, leading to increased productivity [31]. The Swedish joinery and furniture production underwent several changes during the same period. In 1846 the guilds were dissolved, leading to increased industrial manufacturing and economies of scale. The craftsmanship was replaced with manufactured products of lower quality [32]. One example of machinery introduced in the furniture production during the early nineteenth century is the carving machine based on the Irving/Pratt method (a steam-powered cutting tool passing over the surface of a cast-iron template) [33]. The automation in the furniture industry was driven by the increased demand of furniture products due to urbanisation. The joinery industry mainly automated cutting processes such as sawing, planning and milling [34]. Similar development is seen for other wood processing industries as well, such as the American cooper industry. In 1837 the first machine was introduced for cutting and dressing staves (the toughest manual operations) and over the next 30 years the manual work was replaced with machinery [35].

Swedish sawmills were electrified in the late nineteenth century. Electricity was used for extending the working hours by providing light in the production and for powering cranes and other lifting equipment for logistics purposes. Electrification of the production was made gradually, mainly in conjunction with new construction and extension of the power grid [31]. The sawmill industry was fully electrified in the 1930s. Other technical innovations during the period included continuous feeding of and automatic input of raw material. This resulted in a more automated and streamlined production process, reduced production costs and higher capacity, up to three times compared with the turn of the century. The Swedish furniture industry was concentrated to geographical areas rich of raw material and good transportation facilities, mainly in Southern Sweden. The production was characterised by a high level of craftsmanship and small businesses [36].

Post World War II (WWII) the need for wood products such as furniture was huge in large parts of the world. In 1946, the Swedish government appointed a commission for exploring the possibilities to rationalise production and distribution in the furniture industry, ensuring the needs of quality furniture to lowest possible price [34]. The impact was not big in the Swedish furniture industry at that point in time as the companies had the advantage in non-damaged machinery after the WWII. During the 50s and 60s further concentration and rationalisation was seen in the furniture industry, but the production was not developing in the same pace as other industries and was characterised by low level of product specialisation and technology utilisation. The situation was not unique for Sweden; reluctance to mechanize the furniture industry is also seen in Britain and America during the early twentieth century [37]. This in spite of increased market demands for furniture. One reason was the problem of creating individualised products while applying economies of scale; there were no suitable machine-based substitutes for e.g. manual marquetry work. IKEA went against the tide, proving that furniture could be produced with high quality at a low cost [34]. As IKEA grew stronger they largely affected the furniture industry.

5.2. The third revolution

Already at the beginning of the third revolution in the 1970s, several authors state the importance of automation and discuss the impact the introduction of electronic controlled machines could have on the furniture industry [38-40]. One of the focus points is about the combination of economic and technical aspects of the machinery [38]. In addition, the problem with finding competent personal is mentioned. Furniture companies needed to hire specialists who were able to handle the hydraulic and pneumatic systems of the new machines. New machinery at this time consisted mostly of automatic charging equipment for bonding and cutting as well as grinding machines [39]. In addition, the same was relevant for milling and drilling machines [40].

In the beginning of the 1980’s, new CNC machines with electronic controllers were introduced in the wood products industries [41-43]. Different CNC controlled machines, especially milling machines promised a much higher degree of automation than before [42]. Renner and Bell [43] state that there was a clear trend emerging to switch from manual machine tools to numerical controlled (NC) or even CNC-systems. In addition, a huge improvement of quality, easier machine handling and the possibility to manufacture complicated workpieces much faster was observed [42]. Laika [44] mentions as well the importance of providing precise NC-programs in order to be able to produce at low(er) costs. The development in the 1980s is supported by the machinery presented at the Ligna fairs [45-47]. Not only is the machine industry offering a large variety of different milling and drilling machines, conveyor belts and laser measuring systems, but also the first software tools were presented. The integration of production processes is put more into focus [47]. However, it is already described a trend to use more of the old equipment instead of investing into new one [46]. In addition, the first industrial robots were
presented [48]. They were exclusively used for finishing operations.

At the beginning of the 1990s, NC-machines had widely been replaced by CNC-machines because of their production advantage due to higher productivity, higher precision and quality, flexibility and better worker safety [49]. Shortly thereafter, [50, 51], CIM, computer-aided design (CAD) and computer-aided-manufacturing (CAM) [52] software and solutions such as AcadHOB were used in the wood product industry. CIM, CAD and CAM systems vastly improved the flexibility of the machines and productivity. However, investment costs for such machinery [53] and the lack of skilled workforce, i.e. workforce educated in the software usage of the new machinery and not only in wood working [50], diminished the successful widespread implementation of the equipment. Machine companies offered larger and more integrated machines with the capability to handle several different manufacturing steps and processes with one single machine [54]. New machinery for edge bending, veneer splicing and sanding became available.

Laika [55] mentioned already in 1990 the advantages of industrial robots for replacing monotonous and tough tasks even in wood product industries, e.g. painting of chairs, sorting of panels and machine tending. Even so the first robots where not exhibited on the Ligna before 2001. The industrial robots presented were intended for machine tending of wood applications were presented [48]. Their field of operation was limited to tasks in which human operators could not deliver the speed and precisely execution required in the production process. As reasons why industrial robots were not more prevalent during this period, Laika [55] states relatively high investment costs, low utilisation due to one shift work and the lack of adequate sensors. Furthermore, Bizjak [56] claims that wood product industries rather invest in conventional production systems, i.e. CNC machines, than flexible industrial robots due to their lower investment costs. According to Ratnasingam, et al. [57], wood machining processes are undervalued in terms of improvement for productivity, process effectiveness and efficiency.

5.3. The fourth revolution

Future challenges and improvement areas for wood technology, according to Teischinger [14], include wood supply, using timber in construction, material engineering, wood aesthetics, modification and fractioning of wood, wood refinery, and recycling. Teischinger [14] also recognises a couple of challenges regarding production processes, such as machining and processing which requires new process technologies and manufacturing concepts to be developed towards knowledge-intensive and mass-customization production. The forest-based sector technology platform has developed a strategic research and innovation agenda for 2020 [58]. The agenda addresses the research and innovation areas of Horizon 2020 and the main challenges for the wood industry sector within these areas. Information and Communication Technology (ICT) and advanced manufacturing and processing technologies are two out of seven areas connected to key enabling technologies, addressing challenges regarding the systematic use of mobile ICT solutions, embedded components, robotics and radio frequency identification, resource efficiency in manufacturing, and new business models and service concepts.

Teischinger [14] observed a series of current and future wood technology issues addressed by the European Cooperation in Science and Technology (COST) actions, spanning from wood properties for industrial use to management of recovered wood. COST actions in the wood technology area are numerous, but the main focus is on wood properties and other wood material issues while actions regarding industrial processes and automation are few in number. The same trend is seen in the wood related roadmaps and platforms. The Roadmap 2010 launched by CEI-Bois (the European Confederation of woodworking industries) identified four main future working areas: building with wood; living with wood; wood used in packaging and transport; wood in sustainable development [59]. Interestingly, none of the areas address automation or manufacturing innovation.

New manufacturing methods as developed by Krieg, et al. [60] show that completely new designs and shapes in housing construction can be manufactured with robotic production systems. Although, such housing types are mainly prototypes. With a focus on new architectonic structures they indicate possibilities for future fabrication.

At the Ligna in 2015, CIM systems for the furniture and joinery industry in the context of industry 4.0 stood in the centre of new development [61]. The focus was not directly on the machinery development, but on support systems allowing higher flexibility, economic efficiency as well as the concept of mass customization.

6. Analysis and Comparison

6.1. The first and second revolution

The first and second revolution with regards to the forest product based sector follow very much the technological trends usually associated with the concept of the mechanical development and mass production. This is especially true for sawn timber production. Wood product industry, especially furniture production started to integrate manually driven machines in production. However, during the 1920s, 30s and 40s the available machinery could not achieve the same quality as manual labour, e.g. the manufacturing of barrels for production [35].

In comparison to the technological development and extension of machinery of other industrial sectors (see fig 1.), it is not entirely evident that there was a timely displacement between those industries and the forest product sector. It can be assumed that even with less usage of technology in production, the wood industry did not face as serious economic consequences as today. This is mainly because of more local markets and less competitive behaviour. Competition in the forest based sector was still mostly national.

However, with the growth and the success of IKEA in Sweden, suppliers of it were both forced and enabled to adapt much faster to new technology and business concept than most of the rest of the industry [57]. This situation was quite unique after WWII until the early 1990s.

6.2. The third revolution

With the development and introduction of microprocessors, NC machines and later CNC machines, the wood product
industry did adapt quite fast. Machine manufactures developed a large variety of suitable machines specifically designed for the wood product sector. However, in the literature no development or research in regards to material planning systems or industrial robots could be found. This suggests, that the wood product industry started to lack behind other industries, mainly the automotive and engineering industry. Although a lot of old manually driven machines were replaced with CNC machines in the wood product industry, machine tending and machine control was still done by people. In the automotive industry a lot of those tasks were already taken over by industrial robots, especially more heavy tasks.

A trend to cheaper and more efficient machinery became visible in the early 1990s [53, 56]. A possible reason to this development is that wood product industry mainly handles smaller batch sizes and product volumes, making high investment costs for automation equipment less interesting. This situation was addressed with the introduction of CIM, CAD and CAM systems for wood product industries. This allowed wood product companies, mainly furniture and joinery companies, to manufacture more flexible [38, 51]. However, CIM, CAD and CAM systems together with manufacturing resource planning concepts were already widespread throughout the automotive, engineering and process industry [62]. Furthermore, no governmental financed research programs were aimed at developing new technology for the wood product industry. Thus, no additional support was given to companies or academia driving research forward.

The few industrial robots used in wood product industry can directly be related to suppliers of IKEA or other big furniture companies [57]. An interesting note is that all literature in regards to technological development of the wood product industries cited in this article (written between 1969 and 1994) is exclusively written in German raising the question if wood product industries in other parts of the world is even lacking behind more.

6.3. The fourth revolution

With the beginning of the fourth revolution, the lack of high-tech production systems such as CPS becomes more obvious. The literature search did not reveal any scientific articles related to technological development of the machinery for wood product industries. However, a couple of wood machining manufactures presented very advanced automated machines at the last Ligna in 2015 [61]. Even CPS could be observed at the fair. This trend will continue at the next Ligna in 2017 [15]. Research financed by different European initiatives and COST actions focus a lot on supply chain management and development of ICT as well as advanced and flexible manufacturing processes.

Thus, the research focus is not put directly on production equipment related systems, but on support functions. This seems to indicate that production system research for wood product industries is not perceived as a focus area for future research yet.

6.4. Development throughout the four revolutions

A clear distinction and evaluation of a time lag of the technology development in wood product industries, in comparison with general industry development, cannot be accomplished with exact certainty. However, a good estimation is possible.

The literature indicates that the first and second industrial revolution follow the general technology development and utilisation. However, when general industries started to implement industrial robots into their production in the 1970’s, it took at least 20 years longer for wood product industries to introduce robots [48, 55]. Fig. 2 illustrates the postponement (red arrows) between general industries (yellow arrow) and the wood product industry (green arrow). This development is not valid for all wood product industries: There are some furniture industries which are highly automated. This is mainly due to their large volumes and batch sizes, similar to general industries. For the fourth industrial revolution literature suggests an even larger time lag between general industries and wood product industries. Up to 30 years seems to be possible. It is possible that this development will continue to 2030 and the time gap will become even wider.

![Fig. 2 Possible time lag of industrial revolutions for general industries in comparison to wood product industries](image)

7. Conclusions

The study shows that wood product industries, not only in Sweden, but world-wide lack behind general industries in the utilisation of industrial robots, in supply chain management and economic possibilities. Although the paper failed to identify an exact time shift, it determines missing technology readiness and development. Not only the lack of flexible manufacturing systems, but also the large deficit in computer controlled production systems, e.g. CAD or CAM systems, integrated supply chains and the skilled workforce hinder wood many wood product companies to advance further. The step from manual craftsmanship to automatic production has not been accomplished, yet. Fölster [63] discusses that nearly over 50% of all work places in Sweden and 80% of all work places in Swedish wood product industries could disappear due to digitalization and automation. Up to this point wood product industries have worked against the trend, but is questionable if they can continue on this path. Chances are bigger that those kinds of companies will disappear in Sweden because of a vast global competition if suitable adaptions are not made.

Studies done by Kortüm, et al. [64] and Gronalt and Teischinger [65] claim that Industry 4.0 in context of Smart Factories or CPS for wood product industries is hardly possible at the moment. Some possibilities, such as RFID tagging of workpieces [64] are of course possible. It is rather the horizontal integration of supply chains which development will be further progressed instead of more advanced machinery [65].
This raises the question if the wood product industry should not focus blindly on new production systems, but rather study and learn from other industries how supply chain integration, Lean principles and new business models could be adapted. There is no need to hurry into Industry 4.0 for Swedish wood product companies due to the fact that the technological development in other industrialized countries has not advanced that much further. However, in order to compete with production in high-cost countries, it is necessary to implement new approaches and not continue with the technological stagnation as described in this study. In addition, wood product industries can observe how other industries work with Industry 4.0 and adapt to suitable concepts.

For many suppliers of wood product retailers or wholesalers with large quantities the technology advancement is instead encouraged. Such companies are often highly automated and can compete in regards to automation and digitalization even with the automotive industry. Those companies have to invest into Industry 4.0. There is an opportunity for wood product industries to decrease or close the time gap in relation to technology development and utilization until the year 2030. It is possible to learn from general industries, avoid mistakes they made and seize positive transformation.

For further research, and to understand which factors are crucial for successful implementation of automation equipment and progression into Industry 4.0, empirical studies at different wood product industries will be necessary. The development of specifically tailor-made automation equipment based on the industry’s unique settings is one way to go. It is also possible to find industry-wide standard solutions for processes that are most suitable for automation. The development of new business models can also lead to advancement. Finding the right balance for change could be the key for progression.

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References


