Developing Client-Supplier Alignment in Swedish Wood Supply

From Efficiency Engineering to Managing Performance

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Abstract

Historically, several different approaches have been used to foster alignment in Swedish forest operations. These approaches span from complete reliance on competitive forces in service markets, to Tayloristic management of employed workers. Which was the preferred approach has varied over time. Today, outsourcing of forest operations prevail, which combined with, relative to historical levels, few supervisors and low level of research and development efforts means that competition in the market is the primary driver of change. However, poor competition in local service markets, and increasingly complex supply chains indicate that this driver may not be sufficiently strong to on its own promote the development of more effective operations.

This thesis investigates the concept of 'harvesting operations performance', and aims to identify ways to improve the forest industry's supply chain by developing alignment between forest companies and harvesting contractors.

Study I investigated how routinely collected follow-up data from forest machines can be used to model harvester and forwarder productivity in various conditions, and concluded that analyses of such data can help managers identify the most efficient machines for various conditions. In study II, a set of attributes of the harvesting service were identified, indicating that harvesting is a more complex service than commonly is acknowledged. Customer perceptions of contractor performance in the identified attributes were quantified, indicating substantial variation in contractor performance. Study III developed and tested a process intended to help customers of harvesting services to actively foster alignment of their employed contractors' performance with their needs. The results from study IV, which empirically investigated benefits of alignment, suggests that if the employment of such a performance management process is successful and manages to improve alignment, increased contractor profitability and stable contractor relationships are likely to follow.

A transition from market mechanisms as the primary drivers of development in Swedish harvesting operations towards more active performance management, as suggested in this thesis, will likely lead to a more positive development of operations in the future than has been the case in the recent past.

Keywords: harvesting operations, performance management, forest engineering, customer-perceived value, supplier satisfaction, supply chain management, historical review

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Dedication

To my family.

History doesn't repeat itself but it does rhyme.
Unknown

Contents

List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Mattias Eriksson & Ola Lindroos (2014). Productivity of harvesters and forwarders in CTL operations in northern Sweden based on large follow-up datasets. *International Journal of Forest Engineering* 25(3), 179-200.

II Mattias Eriksson & Ola Lindroos (2011). Customer-perceived value in forest harvesting operations. *Proceedings of the 34th Council on Forest Engineering*, June 12-15, 2011, Quebec City.

III Mattias Eriksson, Luc LeBel & Ola Lindroos (2015). Management of outsourced forest harvesting operations for better customer-contractor alignment. *Forest Policy and Economics* 53, 45–55.

IV Mattias Eriksson, Luc LeBel & Ola Lindroos. The effect of customer–contractor alignment in forest harvesting services on contractor profitability and the risk for relationship breakdown (submitted manuscript).

Papers I-III are reproduced with the permission of the publishers.

The contribution of Mattias Eriksson to the papers included in this thesis was as follows:

I Conceiving the original idea, designing most of the study, all of the data collection and analyses, and some of the writing.

II Conceiving the original idea, designing the study and developing the methods used, all data collection and analyses, and writing the majority of the manuscript.

III Conceiving the original idea, designing the study, making all of the literature study, conceptual development, and analyses, and writing the majority of the manuscript.

IV Conceiving the original idea, designing the study and developing the methods used, all data collection and analyses, and writing the majority of the manuscript.

Abbreviations

Table 1.

Abbreviation	Explanation
BSc	Bachelor of Science
MSA	Mellan- och Sydsvenska skogsbrukets arbetsstudier
MSc	Master of Science
SAC	Sveriges Arbetares Centralorganisation
SDA	Föreningen skogsarbetens arbetsstudieavdelning
SLU	Sveriges lantbruksuniversitet
SCA	Svenska Cellulosa Aktiebolaget
VSA	Värmlands skogsarbetsstudier

1 Introduction

Ten years ago, for the first time since the crisis in the late 1970s, forest work productivity began to decrease (figure 1) with a resulting increase in logging costs (Brunberg, 2012). With raw material cost and cost efficiency being considered as the most important drivers of competitiveness, this change was perceived to represent a major threat to the Swedish forest industry (Nellbeck, 2015; Rennel, 2010).

Different factors were suggested that could have adversely affected productivity, including: increased environmental considerations; increased biofuel operations; and stalled technical development. None of these factors explains the decline. The environmental considerations in forestry had been more or less the same since the 1990's which makes it unlikely that they would cause a sudden effect in the mid 2000's. The downturn also occurred in pure logging operations (fig 1) which makes its connection to biofuel harvesting unlikely. And finally, if technical development had stopped, the machinery in use would still be the same, which could hypothetically explain productivity not increasing, but could not explain productivity decreasing. Consequently, the decrease in productivity seems to indicate a systemic failure to perform for organizations involved in Swedish forest operations rather than being caused by some single factor.

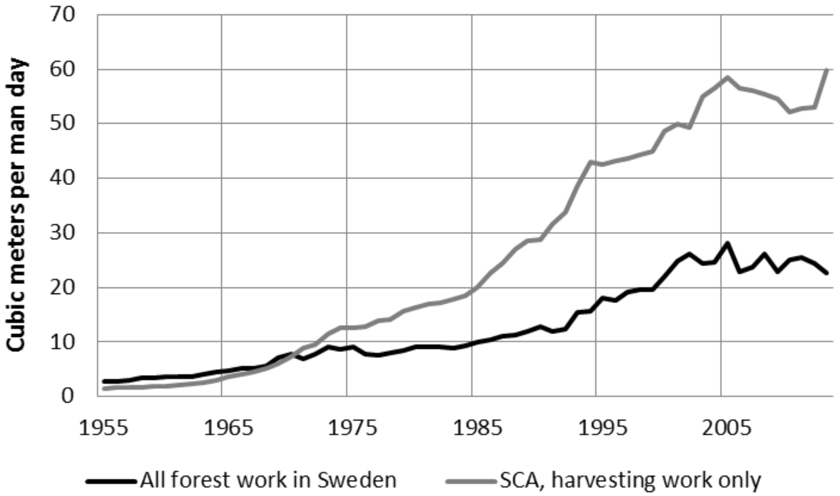

Figure 1. Productivity over time in Swedish harvesting operations (source: Skogforsk; SCA).

Note: All forest work in Sweden includes all forestry related activities except transport, such as harvesting, forwarding, silviculture, planning, supervision, etc., whereas the harvesting work productivity curve only comprises workers involved in SCA's harvesting and forwarding operations.

One analysis of the downturn, from a systemic perspective, suggested that the informal collaboration between forest technology researchers, machine manufacturers, and forest companies, often referred to as the "triangle of development", had lost its vitality. This informal collaboration had accelerated technical innovation and development of forest machinery in the decades following the 1950s, but at some time since had lost its power. Supposedly, this was the result of the downsizing of research on forest technology, but also due to the reduction in the number of technical staff at the forest companies that followed the outsourcing of harvesting operations (Thor, 2012).

Such a historical perspective on drivers of system performance may offer explanations to what happened to productivity in forest operations, and hopefully provide some guidance for the future. In this thesis I outline the development that led to the current situation and, based on historical events, recent research, and my own studies, provide some suggestions for the future. The next section briefly describes the context (1.1), and is followed by a section stating the aim of the thesis (1.2).

1.1 Context of the thesis

This thesis was conducted as a project within the Forest Industrial Research School on Technology at the Faculty of Forest Sciences at the Swedish University for Agricultural Sciences. The project was partially funded by the forest industry company SCA, my employer for the last 10 years. The purpose of the project was to analyze the performance of forest operations from an industrial perspective in order to identify options to improve of the industry's supply system efficiency. To focus the research, it has been limited to studies of large scale cut-to-length harvesting operations in Northern Sweden. Nonetheless, many of the results presented in this thesis and its appendices are likely to be applicable to other contexts.

If cost efficiency is the determining success factor for the forest industry (Nellbeck, 2015; Rennel, 2010), it follows that forest operations need to align with this goal to help to secure the industry's competitiveness. The interest in the harvesting productivity per man day as indicated by, for instance, figure 1 needs to be understood from this perspective. This was especially valid when most work was done manually and labor was the dominant production factor in forest operations.

However, the focus on time-based performance measures has long been criticized, for instance by Farrel (1957):

> Indeed, for a long time it was considered adequate to measure the average productivity of labour, and use this as a measure of efficiency. This is a patently unsatisfactory measure, as it ignores all inputs save labour, but it was so widely used by economic statisticians that it is now enjoying an extensive popular vogue, which may indeed have unfortunate effects on economic policy.
>
> M. J. Farrel, 1957.

In mechanized harvesting operations, other important inputs in production would include, for instance, capital, fuel, and parts (Dodson et al., 2015). Apart from overlooking production factors other than labor, productivity per man day also overlooks differences in the output from operations. For instance, a cubic meter of wood bucked exactly according to the requirements of a certain saw mill's customers is of course much more valuable to the mill than a cubic meter bucked according to some random pattern. Further, a delivery of wood on time is more valuable than one that is delayed and causes stoppage at the mill. Judging from these examples, forest operations performance is multi-dimensional and definitely more complex than can be expected from the commonly applied productivity per man day measure. Furthermore, alignment between forest operations performance and mill requirements along more dimensions than just cost efficiency offer potential benefits.

Taking the complexity into account, Beamon (1999) suggests that performance should ideally be measured for a supply chain as a whole by using performance measures of resource consumption, output generation, and flexibility. It is difficult to argue against Beamon’s (1999) holistic approach for supply chains that are controlled by a single organization. In practice, however, supply chains often comprise multiple companies or organizational entities which may pursue their own goals rather than strive to optimize the supply chain as a whole. For instance, a typical wood supply chain of today may include a mill that depends on the deliveries from a supply company, which in turn depends on the services of a number of trucking and harvesting contractors to do the actual work. Relationships in such a supply chain, where one actor delegates work to another, are often referred to as agency relationships. In agency relationships a) conflicting goals between the principal (e.g. the supply company) and the agent (e.g. the harvesting contractor), and b) the principal’s imperfect control over the agent, may cause problems when the agent is pursuing its own goals rather than working in the principal’s best interest (Eisenhardt, 1989). In supply chains where such agency relations are present, managers may pursue disparate goals which make performance measures that overarch the whole supply chain too abstract to be of relevance. Instead, a focus on alignment of the actors involved to minimize any negative effects of the agency relations and improve their collaboration may hypothetically be a more realistic approach to improve supply chain performance.

However, application of the notion of ‘alignment’ has varied within the scientific community, with different researchers applying different perspectives. In the most limited sense, alignment in supply chain relationships has been considered as the absence of agency problems. From this perspective, configuration of incentives structures plays a key role in promoting alignment and ensuring supplier performance in alignment with downstream needs (Lee, 2004). Firms should, according to this perspective, strive to develop relations with partners who have coinciding, or at least synergistic, interests to avoid being subject to opportunistic behavior by its partners (Ketchen & Hult, 2007). An alternative perspective is put forward by van Hoek & Mitchell (2006), who focus on a firm’s internal alignment and found that misunderstandings and disagreements within a firm may be hampering overall supply chain effectiveness by leading to suboptimal management decisions. Chorn (1991) adds a firm’s ‘fit’ with the surrounding environment to this internal alignment, and argues that superior firm performance is associated with high degrees of alignment between the four elements: competitive situation, strategy, organization culture, and leadership style. A firm's fit with the environment as described by Chorn (1991) somewhat resembles the perspective of many researchers interested in strategic alliances between clients and suppliers, which evolved into a research field of its own in the 1990's (see Elmuti & Kathawala, 2001, for a review). Complementary firm resources and cultural and operational compatibility facilitates efforts to make such long term business relationships work well and contribute positively to the performance of involved parties (Sarkar et al., 2001). Use of the word 'resources' in this context follows the definition by Wernerfelt (1984), and includes any tangible or intangible asset tied to a firm, such as: knowledge, machinery, brands, or effective processes. Firms possessing complementary or supplementary resources are considered to have good resource fit, and may enter a state of resource alignment if they engage in an alliance where these resources are utilized (Das & Teng, 2000; 2003).

In this thesis, the term 'alignment' primarily refers to the alignment between forest companies and their harvesting contractors as defined by Das & Teng (2000; 2003), unless otherwise is indicated by the context. These authors suggested good resource fit and high utilization of key resources as determinants of alliance performance. The search for determinants of 'alliance performance' is common for much research on close business relations between customers and suppliers, but the concept of performance has been given different meaning in published studies (e.g. Sarkar et al., 2001; Das & Teng, 2003; Draulans et al., 2003; Yang et al., 2008). In this thesis, the perspective has mainly been that of a forest company acting as channel leader of a wood supply system (c.f. Kotler, 1967), which is a common occurrence in many parts of the world. Consequently, harvesting operations performance in general, and harvesting contractor performance in particular, has primarily been assessed according to how well the needs of such forest companies are met. These needs are assumed to include requirements on the actual outcome from the operations, but also on the contribution of key resources for the forest company to benefit from. When the term 'performance' is used below, it generally refers to the outcome of operations from the forest company's perspective. However, it is used also in other meanings which should be clear to the reader by the context. To indicate a state where the outcome of operations is in line with the contracting company's needs *and* where key resources are contributed by the contractor as needed by the contracting company, the term 'performance alignment' is used. Consequently, high performance alignment indicates a state where customer and contractor experiences good resource fit, key resources are utilized in the alliance, and outcome of operations are in line with the customer's needs.

In the forest industry, cost efficient wood supply has been a success factor for a very long time, and will probably continue to be one for the foreseeable future (Nellbeck, 2015; Rennel, 2010). This encourages a strong focus on productivity and cost efficiency in forest operations extending into the future. However, several other factors are important in the industry's wood supply (e.g. Audy et al., 2012), and this necessitates a multi-dimensional approach when trying to improve operations. Further, efforts that aim to improve supply chains including agency relationships, which wood supply chains typically do, need to be adapted to the problems that may occur in such relationships.

1.2 Aim of the thesis

This thesis investigates the concept of 'harvesting operations performance', and aims to identify ways to improve the forest industry's supply chain by developing alignment between forest companies and harvesting contractors.

2 Historical background of the forest industry

Forest industry has a long history in Sweden. Through time, the efforts of countless managers, workers, rangers, and researchers have contributed to creating the industry we see today. This development has been an iterative process where various conditions have directed development efforts in different directions (with varied success). Many of these efforts may now be outdated, but we can identify feasible ways to improve current forest operations by analyzing how various approaches have worked historically.

The aim of this section is to present a selective review primarily of the history of Swedish forest operations, with the intention to present a general picture with focus on issues and events that I consider to be most of interest for current and future development. The review is presented chronologically and is divided into sections in the form of ‘eras’ of Swedish forest operations. These eras are inspired by Bengt Ager’s recent work (2012), and also closely resemble the ‘paradigms’ suggested by Heinimann (2007).

2.1 Competitive expansion -1937

The earliest roots of Swedish large scale forest operations may be found in wood supply operations connected to mines, dating back at least to the medieval period. The oldest known and for centuries also the largest operation was the Falu copper mine, which consumed approximately 500 000 m^3 of wood and charcoal annually during its peak production in the 1600s (Sundberg, 1991). A dedicated large scale forest products industry did not appear in Sweden until the 1800s.

2.1.1 Emerging forest industry

When industrialization started in England and subsequently in other European countries, a need for wood products was triggered that could not be met by far by domestic production. This need was recognized as a promising business opportunity in the mid-19th century by owners of Swedish iron works and other financially strong actors. Frenetic activity started to exploit this opportunity and the sawmilling industry was soon booming with hundreds of mills opening all over the forested parts of the country (Pettersson, 2015b). The need for manpower soared both in the new mills and in the harvesting operations that had started up to supply the newly founded mills with wood. Workers and their families came from far away to build themselves a new future in the resulting boomtowns and thriving countryside around the harvesting districts, bringing with them experience and know-how (Pettersson, 2015b). Throughout the 1800s, hundreds of sawmills opened in Sweden, at first exclusively powered by water. Gradually, steam power was introduced, the mills grew larger, and production increased. Wood costs increased due to the increased demand, leading to large scale land purchases by industry companies to secure supply (Pettersson, 2011). At the end of the 1800s when the industrial technique of making paper from pulped wood was developed, mills were opened in their hundreds. The average size of pulp mills was small and the total wood consumption for pulping was small compared to the volumes consumed by sawmills (Palm, 2011a). In addition, charcoal was an important product in the early days of the forest industry (von Eckermann, 1925). Charcoal was produced on a large scale throughout the World Wars, but subsequently became obsolete as an industrial product (Nilsson, 2011).

The most efficient way to extract the vast inland forest resources was to use the many rivers and creeks, most of which were well suited to floating the timber to the industries (Kinnman, 1925). Normally, the mills were built on major rivers or by the sea for this very reason (Palm, 2011a). The network of main rivers used for wood transportation was organized and regulated fairly efficiently and was open to anybody who needed to float goods, thus lowering barriers of entry for industrialists who were prospecting for new industry sites (Lindberg, 1917; Pettersson, 2011). The river transport depended on the spring flood which enlarged the rivers and enabled floating of timber in also minor rivers and creeks. The operations' reliance on the spring flood, and on the snow for land transport using horses and sleds, meant that the operations followed a seasonal pattern for more than a hundred years. Harvesting season started in early winter and the wood was transported to landings beside rivers or on the ice of lakes. When spring came and the ice began to break up, the wood started its journey downstream. At this time, harvesting operations ceased and the harvesting workers were usually employed to help out in the river drive. This lasted for a few weeks or so until the flood ended, after which the majority of workers went back to other types of work (Kinnman, 1925; 1930). Consequently, more or less a full year of the industries' wood consumption was transported downstream to the mills during a short period each year, effectively decoupling the harvesting operations from the mills. The mills had to specify before the harvesting season what kind of wood was to be sourced in the winter's harvesting operations, but they could never really be sure what they would get until the wood appeared in the mill pond the following spring (Nellbeck, 2015).

During the first turbulent half of the 1900s, overall sawmill production stagnated, mainly because of shrinking exports, and the bulk of the volume was consolidated in larger more efficient mills. More advanced processing steps, such as planing and controlled drying, were included in production to increase revenues despite the stagnation of overall production (Pettersson, 2015a).

2.1.2 Organization

Usually, local farmers were recruited as horse drivers, and since logging was conducted in the winter, this complemented their work on the farms. In contrast, fellers were often not settled but moved to where work could be found. Piece rates combined with various penalties for poorly performed work were the primary means for managing costs and work quality (Ekman et al., 1922; Kinnman, 1930).

The fast increase in forest harvesting operations in the early 1800s required not only skilled workers with efficient tools and working methods, but also professional supervisors and managers to organize and oversee the operations. Schools were founded to educate students who could meet this demand, the first being the Royal Institute of Forestry in 1828 (which later became the Royal College of Forestry and subsequently the Swedish University for Agricultural Sciences) and this was soon was followed by a number of schools for rangers. The Royal Institute of Forestry provided a higher level academic education and awarded the degree of Jägmästare (equivalent to an MSc in today's terminology) to graduating students. The ranger schools ran shorter and more practically oriented courses for students who were aiming for lower supervisory positions (Bendz, 2011).

The different levels of education followed from the different hierarchical levels of the most common forestry organization at the time, where a forest operations district was usually managed by a Jägmästare and comprised a number of ranger districts. The rangers, in turn, usually had a few foremen, wood measurers, and other specialist workers to their help in supervising the manual labor force (Byström & Troedsson, 2010; Andersson, 1964). In this system, forest workers were directly employed by the forest companies, who relied on their employed rangers and foremen to provide supervision. One benefit of directly employing the workers was that forest companies could choose exactly which individual workers to hire and could direct their work as needed. Several ranger schools and other educational facilities were started to fill the need for educated professional harvesting managers and supervisors (Bendz, 2011).

However, the hierarchical way of organizing work only dominated the more populated regions of Sweden. In the less populated western interior of the country and to the north, long distances and limited availability of supervisors led to the development of a contrasting second system of organizing forest work. In this system, forest companies hired contractors who usually were local farmers acting as horse drivers in the winter. These contractors in turn hired and supervised personnel as required to fill the contracted volume. Administrative simplicity for forest companies and better coordination between horse drivers and fellers were distinct benefits of this second system. A result of this system was that only 16 foremen were required to supervise the work of 1000 forest workers in the mid-1920s, which can be compared to 38 foremen for the same number of sawmill workers. In both systems, piece rates were the completely dominant form of compensation, both for contractors and for workers (Ekman et al., 1922; Kinnman, 1925). Piece rates for contractors were sometimes the result of auctions between the lowest bidders, which could result in tough economic consequences for contractors who miscalculated their costs and productivity (Ager, 2012). However, the use of auctions also risked leaving the employer with inexperienced contractors, who would cause trouble and additional costs, and this limited the use of the method (Kinnman, 1925; 1930).

The two early systems of organizing harvesting work together with, for instance, different geography and population density probably led to quite different conditions for the competitive forces of the market to work. In the north and west, forest companies used contractors instead of employed forest workers, indicating that competitive forces should have had the strongest effect there. However, several factors acted in the opposite direction. A dispersed population and long distances reduced the dynamics of the market through the relatively limited availability of contractors and workers, and probably hindered the spread of new knowledge. Consequently, workers resorted to local traditions rather than attempting to take advantage of the benefits of state-of-the-art tools and working methods, of which they had little knowledge. The situation was quite the opposite in the southern part of Sweden, which in the late 1800s was overpopulated. This led hundreds of thousands of people to migrate to America during a relatively short time, but also to high competition in the labor market. This competition together with the piece rate system eliminated most of the potentially negative effects on competition resulting from the forest workers being direct employees. Further, the presence of professional and educated supervisors worked as a catalyst for the competitive market forces. Supervisors could transfer their knowledge to the workers and also pick up new innovations, practices or ideas and make sure that they were spread and utilized quickly among the workers. By the end of the 1930s, productivity differed considerably between different parts of the country, with the South being the most productive (Ager, 2012; Schön, 2000).

2.1.3 Technology

Long before industrial forest operations and some decades into the 1800's the axe was the dominant tool in wood harvesting, complemented by horses and sleds for transport. As harvesting increased due to the emergence of the sawmilling industry in the mid-19th century, novel hand tools were introduced such as the two-man cross-cut saw, the one-man cross-cut saw, the bow saw, barking spuds, various log lifting tongs and hooks, and so on. Similarly, more efficient sleds were developed and spread over the country (Ager, 2012), and horse breeding programs were launched to raise more efficient logging horses (Dyrendahl, 1988). At the beginning of the 20th century, these developments had led to the use of specialized tools, often with many variants. For instance, a catalog from the Gränsfors axe factory at the time included 11 different styles of delimbing axe heads, most also offered in several weights. Similarly, transport equipment also varied a lot over the country, and even though horses were the main draft animal, oxen and even reindeer were also used to some minor extent (Ekman et al., 1922). The Nordsvensk ('Northern Swedish') horse breed was introduced in the early 1900s by crossing earlier indigenous breeds, and it came to dominate logging operations since it was considered to be 'unparalleled as a logging horse, wise, agile, energetic, easily fed, and content' (Dyrendahl, 1988). The number of horses in Sweden peaked between the two World Wars, but declined rapidly thereafter due to the mechanization of agriculture and forest work (fig. 2).

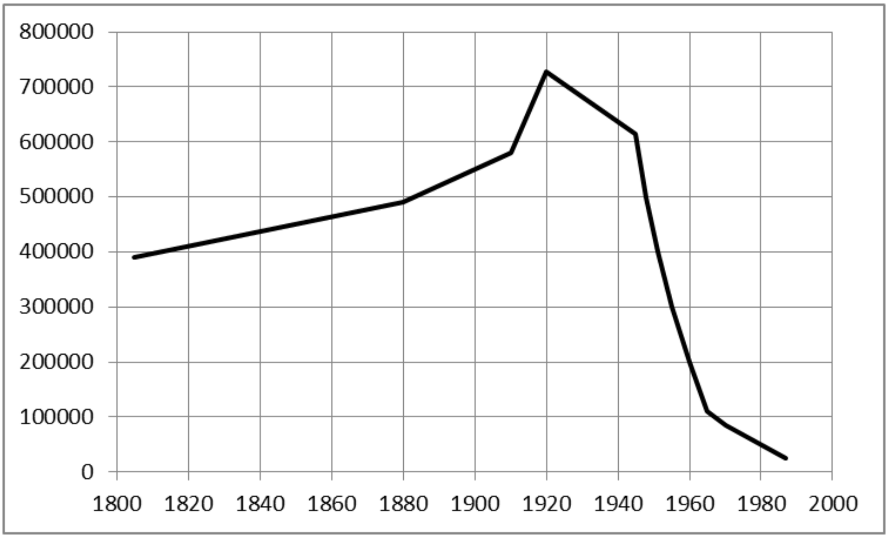

Figure 2. Approximate number of horses in Sweden according to Dyrendahl, 1988 (only working horses shown after 1970).

Technological development during these first centuries of large scale forest operations seems to have been slow and greatly reliant on local traditions and know-how. Tools and equipment came from a variety of sources. For example, the Gränsfors axe museum holds records of about 20 factories that produced axes in Sweden around the year 1900, not counting imported tools or the countless blacksmiths who made smaller or larger quantities of axes for the local market. The tools and equipment produced for harvesting operations were for the most part relatively cheap (i.e. hand tools and horse equipment), which meant that workers could, at a relatively low cost, switch to what they perceived to be the most efficient technology.

2.1.4 Competition driven rationalization

In this section, I argue that the process of introduction and adoption of new technology and working methods that predated the late 1930s, rather than being a result of spontaneous events, was guided by a major force: competition in a free market. Understanding of this force, resulting from numerous individuals in a market who strive to find the best business opportunities for them and exploit these opportunities efficiently is important when analyzing events later in history. In this thesis I refer to this driving force of rationalization as ‘competition driven rationalization’.

In the early days of the forest industry in the 1800s and early 1900s, conditions were nearly perfect for competition driven rationalization. As has been previously described, the period was characterized by a multitude of companies conducting harvesting operations (i.e. sawmills, mines, iron works, pulp and paper mills, and their respective supply organizations), and a fluid workforce that used different working methods and equipment from a variety of manufacturers. Hundreds of industry companies and landowners managed their own competing harvesting operations. Dozens of manufacturers, and probably hundreds of blacksmith shops, put tools on the market. A large proportion of the workforce was fluid and moved about the country to find the best work opportunities, and the workers were paid by a piece rate. In this environment, every actor involved in harvesting operations was subject to strong competition from peers which spurred development. Further, workers and forest owners had not yet begun to organize into unions and forest owners associations to any significant extent, and relatively few regulations were in place (Sjunnesson, 2011).

In such a fragmented market, the primary driver of development is competition between individuals who seeks to maximize their returns (Stigler, 1957). The competition forced mills, supply organizations, mills, and tool and equipment manufacturers constantly to use the most efficient equipment and working methods available.

Previous reviews of forest operations history have referred to this period as a period of trial and error (Heinimann, 2007) or spontaneous rationalization (Ager, 2012). However, as discussed, was this development really spontaneous? Sweden had been one of the poorest countries in Europe at the beginning of the 19th century. Labor and business were strongly regulated, and most land belonged to the Crown. However, in the 19th century liberals increased their influence in society and parliament, suggesting the liberalization of society to increase the wealth of the nation. A series of deregulations that together with free trade policies and the redistribution of land ownership from the Crown to individual farmers spurred economic growth throughout the 1800s (e.g. Schön, 2000).

The early pioneer economist Adam Smith (1776) argued that production would, if given enough freedom, self-organize based on the price mechanisms within the free market. This self-organizing attribute of free markets was referred to as the ‘invisible hand’ of the market, and still today is considered to contribute not only to organizing production, but also to providing a mechanism for continuous development. For competition to be efficient in a market, five conditions need to be met:

The rivals must act independently, not collusively.

The number of rivals must be sufficient to eliminate extraordinary gains.

The economic units must possess tolerable knowledge of the market opportunities.

There must be freedom to act on this knowledge

Sufficient time must elapse for resources to flow in the directions and quantities desired by their owners.

George J. Stigler, 1957

The market for harvesting work in the first decades of the Swedish industrial forest industry certainly exhibited these characteristics. Literature from the early 1900s describing good forest operations practices reflects the reliance on market mechanisms by giving insightful descriptions of the benefits and drawbacks of various contracting and employment forms, pricing and compensations, quality control, and the importance for harvesting managers to attract good workers by offering fair conditions (e.g. Ekman et al., 1922; Kinnman, 1930). An especially interesting quote is found in Gunno Kinnman’s book “Skogsteknologi” (“Forest technology”) from the year 1930, which describes how harvesting managers should relate to rationalization:

> Through time, efforts have continuously been made to improve working methods in order to increase production and reduce costs. Forest work too can and should be performed more rationally, which primarily implies that forest district management should interest itself in tools and make sure that suitable variants are for sale locally or keep new models available for testing.
>
> Gunno Kinnman, 1930 (translated from Swedish)

Notably, this recommendation recognizes the importance of good equipment, but places the decision about what tools to use on the workers and contractors. The role of management could be described as focused on facilitating competition in the market by making tools available and helping to spread knowledge about the business opportunities for the workers that were associated with use of both traditional and novel tools.

So, did this laissez faire attitude towards rationalization produce any results? Geete indicates in a 1927 article on the productivity of forest operations that harvesting productivity by that time had doubled when compared to historical levels, which gives an idea of the gains during the period. For sure, technical innovation played its part in improving productivity, but it too seems to have been unorganized and purely driven by the forces of the market, where better products soon achieved a larger market share until the competition caught up.

However, the dynamics of the market eventually changed.

2.2 Organized rationalization 1938-1954

Even though competition and free market characterized forest operations well into the 1900s, several trends in the forest sector gradually changed the characteristics of the market. One early consequence of the free market policies of the 1800s was a short-sighted focus on exploiting the forest resource as cheaply as possible, which meant minimum regeneration efforts and a deteriorating state of the Swedish forests. This exploitation was as early as in the 1850s identified as a threat to the country's forest industry, which led to a series of regulations of forest harvesting (Carlgren, 1925). However, these regulations failed to foster sustainable forest management, probably because of a reluctance to intrude too much in the land owners' rights to manage their own property (Enander, 2011). Eventually, sentiments changed and those who advocated the state of the forests as a national interest rather than a private concern managed to pass a silviculture act in 1905. In this act, regeneration and silviculture was made mandatory by law and local county forestry boards were founded to ensure compliance with the law, but also to educate forest owners in forest management. Further, forest companies were prohibited to acquire land from private forest owners in 1906, with the primary aim to preserve farming also in the more remote parts of the country. This halted a process in which Crown land had been disseminated to farmers who subsequently sold it to forest companies (Carlgren, 1925; Enander, 2011; Pettersson, 2015). Private landowners who had kept their land started to organize themselves into land owners' associations in response to the consolidating industry's increasing bargaining power. At the same time, workers began to unionize and employers to organize as a response, which probably had a great effect on the labor price mechanism (Sjunnesson, 2011).

In the late 1920s, the Swedish forest industry along with many other export-oriented industries went into a state of deep crisis. Protectionism in export markets raised import taxes, which basically cut sawmills off from many of their business opportunities in international markets. The crisis was especially serious since it coincided with fierce competition from construction material substitutes such as concrete and steel, and rising wood costs due to the steadily increasing depletion of forest resources at the time (Pettersson, 2015a; Carlgren et al., 1925). The consequences for the industry were consolidation of production within larger and more efficient mills and closure of unprofitable mill capacity, which led to a somewhat decreased production but increased unemployment and poverty (Pettersson, 2015a). Simultaneously, times were changing and the liberal and conservative sentiments characterizing the 1800s faced competition from new socialist ideals and increasingly powerful labor organizations. Eventually, this led to a major shift in the political arena: the social democratic party came to dominate the Swedish parliament for some 44 years starting in 1932. Important objectives for the social democrats in government were to raise wages, reduce work time, and simultaneously fight unemployment, which demanded measures that the industry feared would include nationalizations or other forms of far-reaching governmental control. Finally, both sides agreed on a collaborative approach and decided that the most feasible option was to increase the industry's competitiveness, which if successful would create returns that then could then be divided between workers and shareholders (Henriksson, 1990).

2.2.1 Forest work science

From this environment of strong demand for increased competitiveness and rationalization, the pioneer Bo Flodman was recruited to Föreningen Skogsarbeten (the Forest Employers' Association) in 1937 and sent to Germany. His mission there was to investigate whether forest operations could be modernized by following the German example of introducing Taylor's concept of Scientific Management (1911) to Swedish forest operations. Scientific Management is a concept to guide managers in improving operational efficiency, primarily by addressing the productivity of workers. Standardization of work tasks, specialization of workers, and time and motion studies to establish best practices are some key attributes associated with Scientific Management. The introduction of these initiated a range of activities throughout Swedish forestry, such as work studies, training of work study officials, worker education and training, and the promotion of best practice among the workforce (Ager, 2012; Flodman, 1942). Several research organizations were founded in the following years, the first two being the Work Science department at the Forest Research Institute of Sweden and Föreningen Skogsarbetens Arbetsstudieavdelning (The Work Study Department of the Forest Employers' Association) in 1937-1938. The Forest Research Institute of Sweden was a government research institute with a diversified research agenda that later became part of what today is the Swedish University for Agricultural Sciences. The Work Study Department of the Forest Employers' Association, later known under the abbreviation SDA, mainly focused on applied issues related to the operations in northern Sweden, which soon led to the founding of two research organizations covering the rest of the country. The first of these was the Värmlands Skogsarbetsstudier, VSA (The Värmland Association for Forest Work Studies), founded in 1939 and soon followed by Mellan- och Sydsvenska skogsbrukets arbetsstudier, MSA (The Association for Forest Work Studies in Central and Southern Sweden), which was founded in 1944. In 1964, these regional work study organizations merged into what would later become Skogforsk (Bendz, 2011; Ager, 2012). In the same period, The Industrial Institute for Economic and Social Research, which was founded in 1939 by the Swedish employers' organization to advance the use of economic and social sciences in the Swedish industry, started its 'Norrlandsutredningen' (The Norrland enquiry). Its purpose was to find solutions to the problems facing the industry in the northern parts of Sweden, of which the forest industry comprised the major part. Besides the fashionable Tayloristic rationalization efforts, the enquiry sought to find solutions to the increasingly serious lack of wood that could be retrieved at an acceptable cost. Norrlandsutredningen was active between 1939 and 1948 and employed the services of various actors including the previously mentioned research organizations and experts from forest companies (Henriksson, 1990). To summarize these years around the Second World War, several significant research organizations were founded with the aim of gaining an understanding of how to rationalize Swedish forest operations using state of the art methods; this was the start of something of a golden age in Swedish forest operations research.

Early and significant results from these first examples of systematic rationalization research included identification of the best tools available, development of best practices for their maintenance, and dissemination of this knowledge to practitioners (Ager, 2012). Both Heinimann (2007) and Ager (2012) underline the use of Tayloristic techniques as defining the period. However, even though the development efforts during the period were, no doubt, much inspired by Taylor's Scientific Management, practitioners and researchers at the time seem to have adopted a more liberal version of Scientific Management which they interchangeably called Forest Work Science, Forest Work Study, or Science of Forest Labor. A conceptual difference between Scientific Management and its interpretation in the form of Forest Work Science is that, where the former relied on control of workers, the latter seems to have placed more focus on educating workers in best practices. Apart from this difference, the tools for rationalization mimicked those of Scientific Management (Flodman, 1942). The adaptation of Scientific Management when applied to forestry was needed because of the inherent difficulty in controlling forest operations due to their geographical dispersion, heterogeneous working environment, and possibly also because of scarcity of supervisors (Mattson-Mårn, 1953).

By the early 1950s, some 60 forest work science researchers were working in the regional research organizations. In addition, two professorial chairs had been established in 1949 at the Forest Research Institute of Sweden, of which one was fully funded by the Northern Sweden’s Forest Employers' Association to educate forestry students in forest work science (Mattson-Mårn, 1953). This gives an indication of the industry’s perceptions about the importance of the discipline. Ludvig Mattsson-Mårn (1953) described the research field as follows:

> The science of forest labour deals with all work in the forests with regard to production and harvest of the raw material wood. […] The labour science may be regarded as an applied productivity doctrine of economics. […] The most profound task of the labour science, in this case, is to find and disseminate the methods which in the quickest way further improvements. One of the main points in this approach is the use of a critical and constructive analysis. The method of carrying out this analysis must be developed and stabilized, i. e. an improvement technique as such must be developed.

To be able to take full advantage of the research findings, the old system with contracted horse owners who in turn subcontracted felling started to be phased out and the workers gradually became directly employed by the forest companies. This enabled the employers to dictate the tools, equipment, and methods to be used and how work was to be organized. However, the piece rate system was kept intact thus ensuring strong incentives for workers to perform to the best of their ability and embrace potential rationalizations of the work (Ager, 2012).

The organized rationalization efforts initiated in the late 1930s generated considerable gains in forest operations productivity in subsequent years, despite the absence of major technical breakthroughs. Exactly how much productivity actually increased is difficult to tell, primarily due to lack of reliable production data. Ager (2012) cites several sources that together indicate that the production per man day increased about 2-4% annually during the period starting with the organized rationalization and ending in the mid-1950s when large scale mechanization began.

2.2.2 Work organization and supervisor education

The two levels of education that were established to provide the forest industry with the managerial staff for its wood procurement organizations were kept intact with only minor gradual changes until 1997. During this period, 100-150 rangers (or forest technicians as they were called from 1969), and about 20 Jägmästare were educated each year. After *c.*1930, the number of educated Jägmästare increased gradually to about 50 per year. A third mid-level education, equal to a BSc, for the degree of Forest engineer has been awarded since 1945 with 20-40 students educated annually (Bendz, 2011). In addition to formal education, companies arranged their own foreman and ranger schools which, at least in some cases, were more or less equivalent to formal education (Orgård, 2006). Stig Hagner, who eventually became a Jägmästare, a silvicultural researcher, and chief forestry officer of the SCA forest company, started his academic forestry studies in the early 1950s and later recalled it as follows:

> We were already trained in practical forest work. We knew the working conditions in the forest through our own experience. This was important, since the aim of the school was to give us the necessary competence to head a forest operations district.
>
> S. Hagner (2005) – translated from Swedish

At that time, experience of practical forestry and also some preparatory vocational training was mandatory for all forestry education (Hagner, 2005). This experience together with the work science influenced academic education must have been an ideal background for positions in forest operations management. The strong focus on management in early forestry education is explained by the fact that supervision of harvesting operations was the main work task for foresters at all levels of the forest companies' organizations, with the only exception being top management (Andersson, 1964). Despite this, the requirements for practical experience and preparatory training before admission to higher forestry education were relaxed gradually over the following decades, as was the focus on work science in education.

2.3 Mechanization 1955-1974

During the post-war era, dramatic shifts occurred both in industry and forest operations. The most significant shift in the industry was that demand for both pulp and paper based products increased substantially, leading to numerous

large mills starting up with an accompanying increase in production (Palm, 2011b). This also allowed the use of large quantities of small diameter wood for industrial production, which for instance allowed commercial thinnings.
However, the main theme of this section is to describe the era of accelerated mechanization of forest operations that took place in Sweden from the mid-1950s. To facilitate a more complete understanding of the historical events, this section also includes a general history of mechanized forestry predating the period indicated in the section's heading.

2.3.1 Early mechanization

Mechanization of forest operations started in America with the adaptation of conventional steam-powered railroad technology to enable efficient long-range log transport on primitive, often wooden, railroads. Due to the difficulty in accessing harvesting sites with heavy equipment, mechanization of harvesting operations was delayed until 1883, when the first steam-powered cable skidder was invented. Subsequently, machine inventions enabled the mechanization of most parts of harvesting operations, such as the steam log hauler and steam-powered loader in 1885, and the (stationary) gasoline-powered endless chain saw in 1907 (Bryant, 1913).
Soon thereafter, the mechanization of Swedish forest operations commenced, when inventions from abroad were introduced. A domestic invention that is worth mentioning is the Sector portable chainsaw which was operated by 'a man and a boy', but never became a big success due to mechanical problems. Sector is first mentioned in the literature in 1916, possibly making it the very first portable chainsaw ever invented (Ekman et al., 1922; Kinnman, 1930). Mechanization was expected to accelerate due to rapid technical development during World War I and the following years (Ekman et al., 1922). However, this did not happen until some decades later. Gunno Kinnman, who was a lecturer and later professor in forest technology and wood science at the Swedish Royal College of Forestry between 1915 and 1953, gives some indications of why this was in his 1930 book 'Skogsteknik' ('Forest technology'). He described several types of felling and debarking machines, but concluded that since they normally required two men to operate and one man to undertake tasks that the machine could not handle (e.g. delimbing), too much time was wasted in moving the crew between trees. Further, he appreciated tractors for log transport over longer stretches, but claimed that since they need good haul roads to be efficient, much horse skidding was required to bring the logs to the tractor roads. The close and easy access to well-developed floating systems in most parts of the country meant that

conditions where tractor logging could be profitable were relatively scarce (Kinnman, 1930). Another condition that may have worked as an opposing force to mechanization was that logging horses had full employment most of the year by alternating between logging in the winter and farming duties in the summer, which probably kept the costs comparatively low. However, after the Second World War, mechanization of agriculture started to have a great impact on the availability of horses (fig. 2). In the 1950s, this forced many forest companies to start breeding and keeping their own horses, since horses used for farming in the summer were gradually replaced by tractors (Dyrendahl, 1988). This probably gave forest companies strong incentives to develop mechanized hauling, and this was soon realized.

2.3.2 Rapid technological development

Large scale motorization of forest work in Sweden started in the 1940s with the introduction of better and lighter chainsaws. One accelerator of the rapid technological development that followed may have been the employment of dedicated technical staff at the forest companies during the 1940s (e.g. Byström & Troedsson, 2010; Vannby, 2011).

In the 1950s, the state-of-the-art chainsaws were so light that they could be carried by one worker, eliminating their main drawback compared with manual saws. After the invention of the first successful debarking machine, the Cambio, the only manual tool necessary for felling and processing was the delimbing axe. Subsequently in the 1960s, chainsaws were fitted with more robust carburetors that enabled their use for delimbing work as well (Nordansjö, 2011).

The major breakthrough that led to mechanization of the hauling work was the development of purpose-built off-road forestry tractors, such as the BM Bamse introduced in 1957. This eliminated the need for horse skidding to tractor trails and, consequently, the end had come for the horse in forest operations. The introduction of wire cranes and subsequently hydraulic grapple loaders first facilitated and then eliminated the need for manual loading. The first wheeled forwarder in Sweden was VSA Brunett, which was inspired by earlier Canadian forwarders and the Garret Tree Farmer skidder, and was introduced in 1963. Wheeled forwarders have been the dominant machine concept for log hauling in cut-to-length systems since then. However, development has continued with today's machines being considerably more powerful and able to haul significantly larger loads with reduced ground pressure compared to the early forwarder models (Nordfjell et al., 2010; Nordansjö, 2011; Öhman, 2013). In the 1960s and 1970s some efforts were made to introduce whole-tree and whole-stem methods, but these were eventually considered uncompetitive compared to the conventional cut-to-length method. Mechanization of felling and processing followed suit, with the introduction of the processor version of VSA Brunett in 1966, the ÖSA felling machine in 1968, the ÖSA 670 feller buncher in 1973, and various kinds of two-grip and single-grip harvesters in the late 1970s and early 1980s. An example of how mechanization progressed in a Swedish forest company is presented in figure 3.

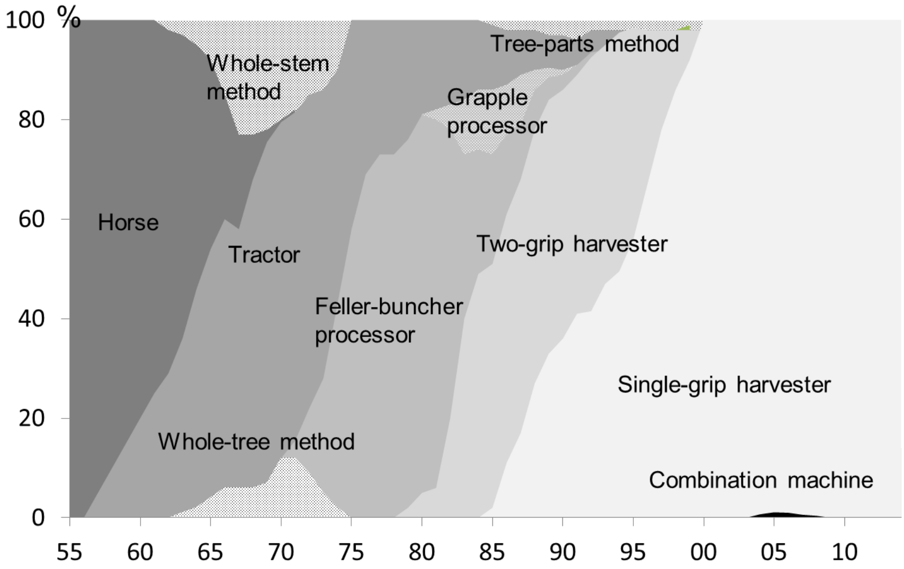

Figure 3. Historical use of different harvesting systems at the forest company SCA measured in percentage of annual harvested volume (source: SCA).

In the era of manual harvesting work, the limitations of human and animal body strength and stamina presented restrictions to the productivity levels that could be reached (Hansson, 1965). This provided strong incentives to motorize and mechanize operations. When motors and vehicles eventually replaced human and horse power, dramatic gains in productivity were achieved. The next step in mechanization was integration of work tasks into fewer machines and machine elements to minimize the required number of operations. This development too generated significant productivity gains with each new machine system, but seems to have stabilized with the single-grip harvester and forwarder. Trials of combination machines and harwarders have so far not proved successful. Surely, technical innovation will continue to be a powerful driver of productivity in the future, but the development seems more likely to occur gradually through small improvements within existing machine systems rather than by leaps as was the case in the past.

2.3.3 Mechanization of transport

In the early days of mechanization, several factors appeared and gradually increased in significance that, together with some inherent drawbacks, eventually put an end to the floating of logs for transport and radically changed the supply system of the forest industry. First, floating of wood inherently causes some wood losses, partly because some of it sinks, and partly because of damage to logs from, for instance, crashing into rocks or other logs when passing down rapids. To compensate for some of this damage, logs were cut 4-6" longer than required by the mill to enable sawing of boards and planks of desired lengths even from damaged logs, leading to poor utilization of the stems (Kinnman, 1930). This was not particularly relevant as long as no competing system was available for transporting the wood to the industry. However, as cars became increasingly popular, the road network expanded and its quality improved over time. (e.g. Carlgren, 1925; Segebaden, 1964). The trucks, which initially could only carry loads of a few tons (Kinnman, 1930), gradually increased their load capacity and power, and were eventually equipped with various types of loaders, making them very efficient for road transport of wood. Similarly, railroad systems were built that also facilitated long-distance transport at an affordable cost. These advancements in transport technology soon led to the suspension of floating operations in the rivers that were most expensive to use. Finally, society's need for electricity led to an extensive hydro power industry which required the damming of rivers, effectively blocking the river drive (Nordansjö, 2011).

The end of the floating system came gradually, with the last rivers being used as late as the early 1990s. However, floating was a marginal operation already by the 1970s. The system that replaced it relies primarily on timber trucks for short and medium distance transport, whereas railroads are used for longer distances (Nordansjö, 2011). In this system the decoupling of forest operations from mill operations in the form of the seasonal river drive is gone and all links in the supply chain are more or less direct to each other. However, forest operations are by nature difficult to control because of, for instance, heterogeneous raw material, geographically dispersed operations, and weather dependency, which encouraged the maintenance of large roundwood stocks that largely continued to decouple harvesting operations from the industry.

2.3.4 Research

During the heydays of motorization and mechanization of forest work, the various research institutions founded in the previous era continued their efforts to identify ways to improve manual work (e.g. Hansson, 1965). Furthermore, research institutions were typically heavily involved in promoting technical innovation and studies of the organization of work around the new tools and machinery (e.g. Ager, 1961; Axelsson, 1975). An example of an institution that, besides research, was also actively involved in technical development is VSA (Värmlands Skogsarbetsstudier, Värmland Forest Work Studies) who manufactured the first Brunett forwarders (Adelhult, 2014; Bendz, 2011). During this time, many excellent studies were published. Early examples resembled work studies from the manual era and include, for instance, studies on the relationship between walking speed and chainsaw weight (Lundgren et al., 1955), and rational operation of a Cambio debarking machine (Lundgren & Sundberg, 1958). Such studies probably guided and accelerated development by identifying the best concepts and potential for further development, and suggesting rational operating practices. Worker safety and welfare became an important topic for many researchers as the novel technology led to accidents and cases of work related illness (e.g. Axelsson, 1968). Analyses of harvesting efficiency became increasingly advanced as research progressed and made significant contributions to the development towards integrated forest machines conducting multiple work tasks (Heinimann, 2007). In addition, studies of different transport solutions from forest to mills became an important field of study as it became clear that the river driving soon would be outdated (e.g. Segebaden, 1964).

2.4 Organizational development 1975-1989

By the mid-1970s, the cut-to-length system dominated Swedish forest operations after some extensive trials of full-tree and tree-length systems (fig. 3). Forwarding work had been fully mechanized, whereas much felling work was still conducted motor-manually. The motor-manual work was physically challenging (e.g. Hansson, 1965) and paid by the piece, which together were considered to present an unattractive work environment by many workers. In 1975, the forest workers went on strike for monthly wages and better working conditions. One of the most radical unions, SAC, described their perceptions of forest work colorfully:

> You knew what you were fighting for. Broken backs, worn out joints, chest pains, bad stomach, those are some of the experiences you get from the piece rate hysteria in the forest.
>
> Anon. (1976) – translated from Swedish

The workers eventually managed to achieve many of their goals resulting in, for instance, introduction of occupational health programs. Further, the strike meant the end of the piece rate system which in most places was replaced by monthly wages with a performance bonus of 16-17% of the total pay (Ager. 2012). When monthly wages for workers were introduced, many of the workers' incentives to improve efficiency disappeared. As a consequence, productivity development in Swedish forest operations stalled for a decade (fig.1).

Two main approaches were applied by the forest sector to promote continued productivity increases. The first approach was to continue the mechanization of forest work to reduce the need for expensive manpower. In practice, this meant no big change but rather a continuation of the work in progress from the previous period (i.e. 1955-1974) characterized by close collaboration between researchers, machine manufacturers, and forest companies. This was quite successful, and with the invention of two-grip harvesters and eventually single-grip harvesters, the motor-manual fellers were no longer a necessary part of the harvesting system (Thor, 2012; fig. 3). However, some motor-manual fellers were kept in service by the companies primarily because of the need to provide winter occupation for silvicultural workers.

2.4.1 Sociotechnical organization of forest work

The second approach to improving operations after the strike in 1975 was to develop a new kind of organization of forest work to adjust for the poor conditions highlighted by the striking workers. Another possibly equally important reason for this approach was to compensate for the loss of motivation to perform that followed the introduction of monthly wages (Ager, 2012). The organizational ideology behind the changes in forest work was adopted from trends in the industry, where Tayloristic management and subsequent management ideologies had gradually been replaced by a "sociotechnical" ideology, focusing on work enrichment, group organization, and democratic work places. According to this perspective, work should be performed by self-regulating groups who, through their control over the work, are motivated to perform well. Further, the decentralized work management gives work groups the mandate to address problems or capitalize on opportunities immediately within the boundaries of their work, supposedly simultaneously leading to higher efficiency and work satisfaction (Cummings, 1978). Even though the need for developing self-motivating and self-regulating work teams in harvesting operations was identified early, implementation of such efforts was slow (e.g. Byström & Troedsson, 2010). It was suggested that more work tasks, such as planning, silviculture, and responsibility for bucking patterns and stock levels, be included in the work normally performed by harvesting teams. A one year long university education for forest workers was suggested to help them cope with such new responsibilities, but was never implemented (Hägglund & Lundell, 1994). Bengt Ager (2012) provides an excellent review of the process from the identification of sociotechnical principles as a possible solution to some of the forest sector's problems through its implementation in practical forestry to its decline from being a dominating ideology in the 1990s.

The focus on work life quality and self-regulating teams in the forest after the forest worker strike in 1975 certainly had many positive effects, such as occupational health services for workers and improved work satisfaction. However, its contribution to improving the industry's competitiveness seems more uncertain (apart from offering an attractive work environment for workers and increased attractiveness to new recruits). Some anecdotal evidence of the effects of implemented sociotechnical principles on performance have been reported in the form of case studies (see Ager, 2012). However, the small scale of these observations and the lack of control groups, for instance, give little support to the hypothesis that sociotechnical organization of work fosters harvesting performance any better than other organization forms. Nonetheless, self-governing and well-functioning teams in which all members have a stake in the team's collective success have, for almost 100 years, been identified as an ideal for the organization of geographically dispersed harvesting operations (Kinnman, 1925).

2.4.2 Research

As the machines used in forest work became increasingly more complex, failures of machine parts and other malfunctions became more common and started to cause expensive downtime (Mellgren, 1989). This opened up a new field of study for researchers interested in examining mechanized forest operations (e.g. Axelsson, 1975). However, some major foundations that had provided the major funding for research geared towards mechanization of

Swedish large scale forestry were dissolved in the mid-1970s, thus limiting future academic research and development efforts on associated subjects (Nordfjell, pers. comm.[1]). However, the lack of funding for research into traditional forest technology was somewhat compensated by increased funding for academic research regarding various work life related topics (Ager, 2012), such as working conditions for machine operators (Teljstedt, 1974), and machine-related ergonomic problems (Axelsson & Pontén, 1990).

2.5 Outsourcing and downsizing 1990-2004

In the 1990s, the single-grip harvester and forwarder combination replaced all other machine systems in Sweden and ended the era of motor-manual felling and processing in normal operations (Nordansjö, 2011; fig. 3). This system has been challenged by other shortwood machine systems, such as the direct-loading harwarder, the dual combination machine, and the remote controlled 'beast' with its shuttles (Lindroos, 2012; Ringdahl et al., 2012), but so far no other system has managed to compete effectively with the harvester-forwarder combination.

During mechanization, forest machines were typically either owned directly by the forest companies, or by their operators. All operators and workers were usually employed directly by the forest company, even those who owned the machinery (fig. 4). This system closely resembled that in the manual era, in which workers and horse drivers mostly were supposed to keep their own tools and animals regardless of whether they were independent contractors or company employees (e.g. Ekman et al., 1922).

In the 1980s, independent contractor firms were formed that owned whole machine groups (i.e. a harvester and a forwarder) and besides the owner of the firm, workers were employed to operate the machines (fig. 4). This facilitated coordination between the machines and reduced the need for supervision, but remained a marginal occurrence until the early 1990s. At that time, an economic crisis hit Sweden which forced companies to cut their costs to survive, and encouraged rapid outsourcing of most forest work (fig. 4). In a way, the outsourcing of forest work can be seen as an extension of the sociotechnical thinking from the previous era: the small contractor enterprises that formed following outsourcing share many characteristics with self-regulating teams as defined in sociotechnical terms. However, how much the contractor enterprises really functioned as self-regulating teams may have varied. The forest company SCA launched a contractor certification program in the late 1990s aimed at developing contractors' management and helping them

1. Nordfjell, Tomas. Professor, Department of Forest Biomaterials and Technology, SLU.

develop into independent, self-improving partners of the company. The vision was that certified teams would deliver high quality work, be self-improving, and require minimal supervision. In a second step, it was considered an option that such contractors would take on additional work tasks and develop more advanced services which ultimately would also allow outsourcing of higher echelons of the company's forest operations organization. This resembles the vision of tomorrow's forest work presented by Hägglund & Lundell (1994), who from a sociotechnical perspective suggested that small independent work teams of employed workers should be responsible for managing and conducting most of a company's forest operations in a limited area. This suggests that the certification program can be seen as an attempt to forward the sociotechnical concept into the era of outsourced operations. However, the certification program was eventually dissolved, since no differences in performance or development could be detected between certified and non-certified harvesting crews (Bergman, pers. comm.[2]).

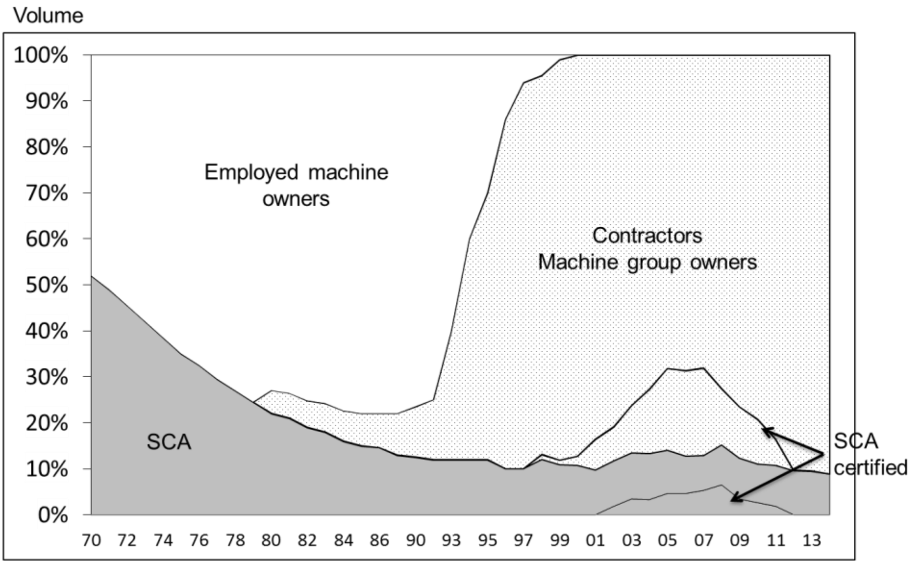

Figure 4. Ownership of machines working for the forest company SCA (Source: SCA).

The negative effects of monthly wages from an efficiency perspective seem to have been balanced by the subsequent large scale outsourcing of harvesting work, since contractors usually were paid on a piece rate basis.

2. Bergman, Magnus. Chief technical officer, SCA Skog AB

However, competition between contractors is limited by the steadily increasing productivity, which means that today’s workers are each achieving similar output to that of dozens of yesterday’s workers (fig. 1). Consequently, the harvesting needs in an area are often covered by a handful of contractors where there once were hundreds of manual workers. In addition, the workers nowadays operate expensive machines, of which there are only handful of manufacturers, and even fewer machine mechanics with an acceptable presence in the operating areas. Similarly, consolidation of the industry to fewer but larger mills has led to a limited number of clients for contractor services. An example of the effects of consolidation is the Sundsvall area in mid Sweden, which used to be, possibly, the most dynamic area of forest industry related enterprise, and where today there are only two major clients – SCA and Norrskog – who control the absolute majority of harvesting operations. Of these two actors, only SCA owns mills in the area in the form of one sawmill, one papermill, and one pulpmill.

Consolidation of industry and machine manufacturers together with reduced need for labor due to high productivity, and regulation of the labor market has gradually reduced competition in the market. In this business environment, a limited number of employers hire the services of a limited number of contractors, who in turn pay their workers monthly wages and buy machines from a limited number of manufacturers. Such an environment can be described as involving several interacting oligopolies rather than being a free market, and can be assumed to strictly limit the effect of the previously described competition driven rationalization mechanism. In section 2.1.4, I argued that this competitive rationalization induced by the competition in a free market was a major driver of efficiency in the 1800s and early 1900s. Albeit that this early period and the period after the outsourcing programs in the 1990s share some similar characteristics (i.e. fairly stable technology, work performed by independent contractors), it is unlikely that the forces of competition will have as large an effect today as they had then.

2.5.1 Forest company downsizing

Another significant development that has taken place throughout history is that the density of personnel in managerial and supervisory positions has fallen dramatically. Byström and Troedsson (2010) developed a measure for supervisor density – harvested volume in the company’s operations divided by the number of non-worker employees – based on Stora Enso archives in their unpublished work on the company’s history. Their data show that the density decreased at about the same pace that productivity per worker increased. The decrease in density was especially pronounced in the 1990s, during which the volume per employee increased from about 10 000 m^3 to 22 000 m^3 annually. Probably, the reduction in supervisors was an effect of outsourcing of forest work and the economic crisis that hit the forest industry and the rest of society in the early 1990s. At the same time, the daily productivity per worker increased from 12 m^3 to 25 m^3, which may have maintained a more or less constant workload on the supervisors and managers in the organization.

Further, a consequence of the increased pace of production is that where a harvesting site could last a whole season for a crew in the manual era, today it only lasts for a week or two – or even less. Consequently, the crews working for any supervisor are getting geographically more dispersed as their productivity increases, since an increasingly larger area is needed to provide the crews with sufficient volume. All in all, these changes by necessity mean that it is more difficult for today's supervisors to maintain a presence on the harvesting sites than it was for the rangers of yesterday, with much of the work only supervised via a computer screen.

The potential negative effects of a decrease in supervisor presence on the logging sites was probably balanced by the large scale outsourcing of harvesting work to independent contractors. Generally, these contractors are small business owners who usually operate one, but occasionally a few, harvesting crews each, and generally simultaneously act as machine operators themselves. Thus, the contractors are on site in person most days of the week, and have excellent opportunities to supervise the activities of their workers. This transfer of responsibilities from the company-employed supervisors to contractors may be convenient for the forest companies, but also means that the first echelon of supervisors of harvesting operations are in an agency relationship with the companies. In such relationships there is an inherent risk that differences in goals between the principal (i.e. the forest company) and the agent (i.e. the contractor) lead the agent to behave in ways that are not in the best interests of the principal (Eisenhardt, 1989).

In the same period that outsourcing occurred, many companies reduced their technically knowledgeable staff. This was probably done under the assumption that the outsourcing of forest work to contractors would lead to a situation where the contractors themselves would promote technical development, much like the competition driven rationalization of forest work of the early 1900s (2.1.4).

2.5.2 Research

Over the years, a significant center for research in forest operations had been established at the Swedish University of Agricultural Sciences' facilities in Garpenberg. Here, approximately 60 people, of whom five were full professors, were involved in research on topics such as forest operations, forest technology, and forest work science. Apart from being involved in research, this unit was responsible for many of the applied parts of the education of Jägmästare (MSc in forest sciences), of which the first year was located to Garpenberg at the time. However, the Garpenberg facilities were closed down in 1995 and replaced by a small department of forest technology in Umeå, comprising one full professor and four researchers. Needless to say, much competence was lost in the process and the operations and technology related research at the Swedish University of Agricultural Sciences has still not quite recovered. The main focus of the new forest technology department in Umeå has been research on technology for bioenergy recovery from forest operations, for which external funding has been available (Nordfjell, pers. comm.[3]).

However, the closure of the Garpenberg research unit was not the only reduction in forest technology research in the 1990s. In 1993, Skogsarbeten merged with Institutet för skogsförbättring to form Skogforsk, while cutting the funding for applied forest technology research in half (Fryk, 2013). Nonetheless, several interesting results regarding forest technology were published by Skogforsk researchers in the 1990s and early 2000s, including analyses of harvester-based wood scaling (Möller, 1998), harwarders (Bergkvist et al., 2003), stem-accumulating harvesting heads (Bergkvist, 2003), and adjustable forwarder load space (Brunberg, 2001).

In the late 1990s, more advanced analytical methods, such as optimization and simulation, had a breakthrough in the international forest operations research community (Heinimann, 2007). Accordingly, Swedish researchers too soon published results produced using the new methods (e.g. Arvidsson et al., 1999; Eliasson & Lageson, 1999).

2.5.3 Educational reforms

In 1997, the biggest change in forest education since it began in the 1800s occurred, when almost all ranger/forest technician education was suspended. This reduced the output of educated forest technicians trained for first echelon supervisory positions from about 100 to about 15 per year. Simultaneously, the education leading to the title of Jägmästare was transformed to a somewhat shorter, more modern, and theoretically oriented MSc education and the output was increased from about 50 to about 100 students per year. The first year of the Jägmästare program covered various applied subjects and used to be delivered in Garpenberg. These applied parts of the course were suspended in favor of more conventional academic education at the two educational facilities in Umeå and Uppsala. After the transformation, interest in applying to the new

3. Nordfjell, Tomas. Professor, Department of Forest Biomaterials and Technology, SLU.

MSc program dropped and for a few years not all of the available places were filled. After reinstating the title of Jägmästare and prolonging the education to five years, interest from students grew and all places on the program have been filled until recently. During this turmoil, the education of Skogsmästare (equivalent to forest engineers or a BSc in forest sciences) in Skinskatteberg remained intact with an annual output of about 40 students (Bendz, 2011; Nordfjell, pers. comm.[4]).

Consequently, the old educational system of three levels (forest technician, forest engineer, and Jägmästare), each resembling an echelon in the traditional organizational hierarchy of forest companies (e.g. Byström & Troedsson, 2010; Andersson, 1964), was suspended in favor of an untested system focused on higher academic education. Focus had clearly switched from producing future managers of forest operations to educating academics for a broader market. Possibly, this was a result of the downsizing that went on in the forest sector which limited the job market for traditionally educated forest technicians and Jägmästare.

2.6 Recent development 2005-2015

Since the downsizing activities following the 1990s crisis, the job market for forest operations supervisors and managers stabilized with few open positions in the forest companies for many years. However, when the baby boomers started to retire in the mid-2000s, a strong need for new employees emerged with many forest companies. This need was, to a large extent, filled by fresh recruits from the MSc in forest sciences program in Umeå, who had a quite different profile both regarding education and experience than the retiring baby boomers.

Simultaneously, productivity in harvesting operations as well as in forest operations in general started to fall (fig. 1). It seems likely that the decline in productivity, at least to some extent, was an effect of the change in competence among the foresters in combination with the reduced technical staff at the companies, even though a causal relationship is difficult to determine with certainty.

The development of technology for forest operations stabilized after the introduction of the single-grip harvester. However, even though the system has remained the same, there have been some significant improvements made to both harvesters and forwarders. In general, both machine types have become heavier, more powerful, and with better mechanical availability over time (Nordfjell, et al., 2010). In addition to this general development, various

4. Nordfjell, Tomas. Professor, Department of Forest Biomaterials and Technology, SLU.

innovative improvements to the harvester-forwarder system have been implemented, such as stem-accumulation in harvesters (Bergkvist, 2003) and adjustable load space in forwarders (Brunberg, 2001). Ergonomics too has been gradually improved, for instance by the introduction of rotating and self-leveling cabs (Gellerstedt, 1998). Furthermore, machines have become computerized which has led to a development which is still ongoing and difficult to determine where it will end (e.g. Guimier, 1999; Morales et al., 2014). Perhaps the most significant development is the bucking optimization in the harvester, which allows better utilization of the forest resource and enables a better fit between the produced logs and industry demand (e.g. Tikkanen et al., 2009).

2.6.1 The industry and its supply chains

Today, both the sawmilling and pulp and paper industries in Sweden are dominated by a handful of major companies accompanied by a number of independent mills. The Swedish forest industry has always depended on the export market to sell the bulk of its products. Nellbeck (2015) investigated what had led to success in the sawn products market in different periods, and concluded that cost efficiency had been the primary competitive advantage for sawmills through the last 150 years. From time to time, strategies for adding value to the product by either more advanced processing or customer-focused distribution led to advantages for individual companies, but these advantages did not last as competitors soon copied the novel concepts. Somewhat contrarily, Lähtinen & Toppinen (2008) found that cost efficiency explained most of the short term financial performance, whereas added value had an impact in the longer term. However, their study only covers a few years and so does not counter Nellbeck’s conclusion, which draws from a longer time span. Rennel (2010), after a career in research and management consulting within the forest products industry, draws a conclusion very similar to Nellbeck’s: the cost of fiber to the mills has been a determinant of firms’ competitiveness since the transition to wood fiber based pulping processes. Nevertheless, adding value to the products may be necessary for mills to sell their products at all if other mills’ value adding activities make customers expect higher quality products (Yang, 2005).

The increasingly close links between forest operations and forest industry must be considered against the background of the industry’s strive to add value to its offering to the customers, which often boils down to better and more advanced customer service (Nellbeck, 2015; Lähtinen & Toppinen, 2008; Rennel, 2010). The tight links between forest operations and the industry underline the fact that operations much more than before need to be aligned to each other in order to deliver a certain offering to the end customers cost efficiently.

2.6.2 Research and development

The decline in forest operations productivity starting in 2005 placed the then fairly recent radical reductions in research and development capacity regarding forest technology in a new light. However, much competence had been lost in the process which made it difficult to start over again. A broad consensus was reached that one of the first steps to revitalize the Swedish research environments in the field of forest technology would be to start a new research school. This school, FIRST, was launched in 2009 as a collaborative project between Swedish and Finnish forest companies (and other similar organizations involved in logging), academia, and machine manufacturers. This collaboration mimicked an old but very successful collaborative approach from the days of mechanization: the ‘development triangle’, albeit this time also including Finnish organizations. The vision for the FIRST research school is to improve the competitiveness of the Nordic forest sector by educating the next generation of forest technology researchers and leaders, and to develop a strong Nordic research and development system (Thor, pers. comm.[5]). Projects completed within the school so far cover topics relating to harvesting on soft ground (Edlund, 2012), mechanized tree planting (Ersson, 2014), stump harvesting (Berg, 2014), human factors in mechanized forestry (Häggström, 2015), and methods for forwarding analyses (Manner, 2015), each contributing unique insights. The project culminating in this thesis also started as part of the FIRST research school, and has been a collaborative project between SCA, the Swedish University for Agricultural Sciences, and the research consortium FORAC at Université Laval, Quebec.

Besides the FIRST research school, research on technology for recovering bioenergy from forest operations has continued to be in focus for forest technology researchers at the Swedish University for Agricultural Sciences (e.g. Athanassiadis et al., 2011; Bergström et al. 2010). Similarly, several projects focused on bioenergy have been launched at Skogforsk (e.g. Eliasson, et al., 2015), some of which span the whole supply chain from the forest to industry (e.g. Eriksson et al., 2014).

The advancement of analyses from single functions (e.g. harvesting, forwarding, or transport) to consideration of whole supply chains can be seen as a natural development of the research field of forest operations engineering

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5. Thor, Magnus. Head of wood supply research, Skogforsk.

and management (Heinimann, 2007). Accordingly, several studies on various aspects of wood supply chain management have been published in the last decade, both in Sweden and internationally. Examples include, for instance, practical cases (Carlsson & Rönnqvist, 2005), development of frameworks for describing and analyzing supply chains (Audy et al., 2012), and applications of operational research methods (D'Amours et al., 2008). However, few studies undertaken within the forest operations community have addressed the specific issues that are tied to agency relationships in the supply chains.

2.7 Drivers of development through history

The primary driver behind the doctoral project of which this thesis is the result was the reduction in Swedish forest work productivity beginning in the mid-2000s after an almost unbroken history of annual productivity increases (figure 1). This section summarizes the reasons behind this development that have been identified in the historical review above, and also some changes that have occurred in the forest sector over time and that may have significance for the future.

The causal structure explaining the details of the historical development of forest operations productivity is certainly too complex and multi-faceted to allow for a complete description in a brief review such as this. However, the review presented above has identified four main drivers that together seem to explain much of what has occurred, and that policy makers and managers consequently should consider when planning for the future:

- *Competition driven rationalization.* The conditions for the competitive forces of the free market were almost ideal in the early decades of the industry. However, increasing regulation and consolidation has gradually reduced the room for these competitive forces to work. Today, markets are generally characterized by relatively few buyers and sellers of services and products related to forest operations, especially locally, which probably has significantly diminished the effect of the competitive forces.
- *Organized rationalization.* The introduction of forest work science in the late 1930s sparked large scale organization of rationalization efforts in both practice and academia. These efforts to foster efficient work based on (at the time) state-of-the-art theory and knowledge were in full effect approximately from the 1950s. However, forest work science gradually lost its influence as first academia and then practitioners changed their focus to other activities. Forest work science was not replaced by some other doctrine for how efficiency of forest work should be fostered.

Consequently, the organized rationalization efforts of today seem to be more characterized by “learning by doing” than by state-of-the-art theory and knowledge.

- *Technical innovation.* Introduction of novel technological concepts and improvements in existing technology have occurred as long as man has used tools and will probably continue as long as man exists. In forest operations, the biggest effect on productivity seems to have occurred in the early mechanization era (table 1), where human and animal power were replaced by engine power. Since the introduction of the single-grip harvester, development seems to have stabilized with only gradual improvements within the existing system being made. In the future, automation could offer a possible leap in productivity, but so far this has not been realized.
- *Worker motivation.* In the first 150 years or so of large scale Swedish forest operations, most workers were incentivized by being paid on a piece rate. Monthly wages were introduced after the strike in 1975, which seemingly was the reason for slowed or even declining development of productivity in the following years. Self-managing teams and other socio-technical concepts were tested to improve the situation, but became more or less obsolete when most work was outsourced. The piece rate paid to most contractors for their services reinstated the monetary incentive to perform efficiently in forest work, at least for the contractors themselves. Nonetheless, the contractors’ abilities to motivate their employees and create functional teams are likely still to be of importance for their performance.

Apart from the aforementioned drivers of development, several events and processes of varying significance have occurred during history that in one way or another have affected forest operations. Some of these are of greater interest than others from the perspective of this thesis, since they have affected the deployment and effect of the drivers of development, or can be assumed to do so in the future:

- *Increasingly linked wood supply chains.* The decommissioning of the floating transport system and the transition to harvesting operations around the year tightened the link between the wood consuming industries and forest operations. Today, this link is tighter than ever as a result of increased demands on wood freshness and reduced roundwood stocks. The closer links mean that operational decisions made by an actor immediately affect other actors' operations and this underlines the need for coordination and alignment to ensure overall efficiency.

- *Industry's transition towards increased customer service.* Increased focus on providing better and more advanced services to end customers has made the mills increasingly dependent on the services from their wood supply organization. The increasingly linked wood supply chains of today must consequently be in alignment with the mills' requirements and their strategies within the market to maximize competitiveness.
- *Academization of supervisor training.* The termination of the education of forest technicians in 1997 reduced the output of potential forest operations supervisors with a practical background, schooled in applied subjects. Further, focus in higher education changed from training future managers of forest operations to training more theoretically schooled academics. This meant that the industry after 1997, with few exceptions, only had theoretically schooled candidates to choose from when recruiting its officers.
- *Reduced rationalization competence in practice and academia.* During the era of mechanization, the focus on work science and organized rationalization was strong in both practical forestry and in academia. Subsequently, this focus gradually diminished into a state where work science and organized rationalization today no longer have a significant presence either in practical forestry or in academia.

A schematic view of how forest operations and their conditions have developed through history is presented in table 1. The history is divided into six eras, separated by some defining events. The first period covers the era from the birth of Swedish forest industry to 1937, when Bo Flodman introduced Tayloristic ideas to Swedish forestry. The second era was characterized by organized rationalization efforts that followed and ended with the approximate start of large scale mechanization in 1955. The mechanization era lasted until 1975 (even though mechanization as such continued), when striking forest workers enforced the end of piece rates in favor of monthly wages, significantly changing the incentive structure for forest work. In the subsequent era, forestry focused on various organizational reforms to compensate for the lost piece rate incentives. Next, large scale outsourcing in the early 1990s defined the era that lasted until 2005, when productivity in harvesting operations started to decline.

Similar classifications of forest operations history have been presented by Ager (2012) and Heinimann (2007), and both are recommended to the interested reader for alternative perspectives.

Table 2. *Schematic overview of the main trends in the Swedish forest sector's development since industrialization.*

	-1937	**1937-1955**	**1955-1974**	**1975-1990**	**1990-2005**	**2005-2015**
Productivity	Indications of 1-2% annual increment in harvesting work (Geete, 1927)	Indications of 2-4% annual increment in harvesting work (Ager, 2012)	All forest work 6% annually (Skogforsk) Harvesting work 11% annually (SCA)	All forest work 2% annually (Skogforsk) Harvesting work 6% annually (SCA)	All forest work 5% annually (Skogforsk) Harvesting work 5% annually (SCA)	All forest work -1% annually (Skogforsk) No trend in harvesting work (SCA)
Main characteristic of period	**Dynamic competition**	Rationalization	**Mechanization**	Organization	Outsourcing and downsizing	Local oligopolies
Labor force	Contractors and employees, both paid on piece rates	Unionized employees paid on piece rates	Unionized employees paid on piece rates	**Unionized employees with monthly wages**	**Contractors with unionized employees**	Contractors with unionized employees
Supervisors' education	Mainly ranger school or similar	Mainly ranger school or similar	Ranger school or applied academic education	Ranger school or academic education	Ranger school or academic education	**Academic education**
Rationalization activity	Few examples	**Strong focus in both practice and academia**	Strong focus in both practice and academia	Strong focus in practice, less in academia	Some activities in practice and academia	Some activities in practice and academia
Industry	Fragmented Mainly sawmills	Consolidation Sawmills, some pulp and paper mills	Increasingly consolidated Sawmills, pulp and paper mills	Increasingly consolidated	Increasingly consolidated	Increasing value-added production Increasing customer focus
Supply chain	Decoupled by the floating transport system	Decoupled by the floating transport system	Decoupled by the floating transport system	Decoupled by large roundwood stocks	Increasingly linked	Tightly linked

Note: Main trend of each era indicated by bold text.

Today's Swedish forest sector is the direct result of the development outlined in the sections above, together with any other event that the review omitted or failed to identify. What the future holds is difficult to determine with certainty, but it seems likely that some of the trends observed in the past will continue for some time. Consolidation of industry production is a process that will probably continue, as indicated by the recently announced expansion of production capacity in SCA's Östrand pulp mill, for instance. How the industry's supply chains will develop is more uncertain, but if the trend towards greater customer service continues it will most likely increase the need for precise and agile wood supply (Audy et al., 2012), which more than before will require aligned actors in the supply chain and improved management and control of forest operations. However, the declining productivity of forest operations raises doubts about whether today's way of managing forest operations is efficient enough with respect to promoting performance. Consequently, there seems to be a need for a new kind of operations management adapted to today's contractor-based forestry.

Before the large scale outsourcing in the 1990s, most forest work was performed by direct employees of forest companies or other wood procurement organizations. Under such circumstances, application of forest operations engineering methods and practices in order to improve performance may have been fairly straightforward since changes in, for instance, operational practices or equipment could be promoted through chain of command if the forest engineer deemed it necessary. In contrast, operations where the actual work is outsourced to contractors may be significantly more difficult to manage. Here, a chain of command does not exist in the same way as with employees, since contractors are independent businesses and the relationships to them need to be regulated by contract rather than by command. Consequently, outsourced operations mean that application of forest engineering methods and practices eventually need to be approved by the contractors, and may additionally depend on their active contributions to ensure success. This can present a challenge for managers who wish to re-engineer their operations considering that their contractors' objectives may not necessarily be in alignment with the suggested course of action, and they may not necessarily possess or be prepared to contribute the resources needed to take that course.

Heinimann (2007) reviews the emergence and development of the field of forest operations engineering and management research, and shows that the field has gradually evolved to use five increasingly advanced scientific procedures: trial and error, observation, experiment, systems analysis, and network analysis. This review has much merit, and certainly outlines an important development that has provided managers and researchers with powerful tools to analyze and improve forest operations. However, the frequent reliance on contractors in forest operations and the inherent difficulties associated with managing outsourced operations suggests that the field would benefit from expanding to address issues stemming from characteristics of business relationships that affect the studied operation. A natural starting point would be to promote alignment between contractors and clients to minimize any agency related problems in operations and maximize the chances of successful implementation of managerial decisions.

In the next section, I describe how this PhD project has, in four different studies, produced a set of results that may help forest operations managers promote alignment with their contractors, and hopefully inspire other researchers to contribute more to the topic.

3 The studies

This section gives a brief overview of the studies included in this PhD project. The interested reader who wants more detailed information about the individual studies is advised to consult the attached articles and manuscripts which provide in-depth descriptions of each respective study. All empirical parts of the studies were conducted within the boundaries of the forest company SCA's operations. Consequently, the subsections below for each study are preceded by a short subsection presenting SCA to give the reader an understanding of the context of this research project.

3.1 The SCA case

SCA Skog is responsible for forestry management of SCA's extensive forest holdings and wood procurement for SCA's Swedish forest industry operations from the company's own forests and purchases from private forest owners. Annual harvest is approximately 7 million m^3 of roundwood under bark in total, originating from five forest districts in the northern half of Sweden. Harvesting operations are mainly performed by independent contractors, but a minor proportion is undertaken by the company's own harvesting crews. Contractors are generally employed with long term intent, but contracts are normally negotiated for one year at a time. Normally, contractors operate one crew each, but some contractors manage up to four crews and in some cases also manage additional business besides logging. The harvesting crews exclusively use cut-to-length systems, normally consisting of one harvester and one forwarder each working two shifts per day.

3.2 Study I

It can be argued that performance measurements are necessary (or at least a great help) for managers to control and improve operations that they are responsible for. In forest operations, productivity measurements have received much attention over the years due to its strong correlation to cost efficiency, but studies have often had a rather limited scope due to the cost of data collection. Commonly applied methods to analyze forest work productivity include work sampling (e.g. time and motion studies) and follow-up studies (historical output records). The main differences between methods may be characterized by the fact that the former usually gives detailed information about a limited experimental setting, whereas the latter gives more generalizable results but with less detail. This lower level of detail in follow-up studies is a consequence of the costs traditionally associated with collecting large quantities of detailed data. However, computerization of forest machines and digitalization of information has greatly facilitated such data collection and technology now allows increasingly detailed follow-up studies of forest work to be made at comparatively low costs (e.g. Manner, 2015). Many key issues in forest operations management such as, for instance, accurate predictions of wood flows, identification of the most efficient machinery, and benchmarking of crews and regions, depend on accurate predictions of productivity. Despite the fact that detailed follow-up data are ideal for developing models predicting productivity, few such studies have been published, and most of the published work has had a rather limited scope. Recognizing this gap, the objective of the first study was to develop models for predicting harvester and forwarder productivity in cut-to-length thinning and final felling operations.

The dataset used in the study was extracted from the from SCA's system for routine follow-up of harvesting and forwarding operations, and represents by far the largest dataset ever employed for modeling harvesting operations, comprising the work of more than 700 machines handling *c.*20 million m^3 in total. Independent variables used in the resulting models to predict machine productivity were mainly identified from the literature, even though some variables and interactions between variables were included based only on logical reasoning. Some variables needed to be transformed, primarily to fulfill the requirement of homoscedasticity in multiple linear regression analysis. However, some ad hoc transformations and interactions between variables were also tested to improve the fit between model and data. The variance inflation factor was monitored during the analysis to avoid problems due to possible multicolinearity. Finally, a bi-directional stepwise regression analysis was conducted to check whether the manual selection of independent variables could have compromised the resulting models in some way. Models of varying detail predicting productivity per productive machine hour based on these variables were subsequently developed for harvesters and forwarders used in thinnings and final fellings, respectively, using multiple linear regression analysis.

Results from the study conform fairly well to predictive productivity models developed in previous work considering the most commonly used variables, such as mean stem size and mean forwarding distance. However, one distinct feature of the more detailed models developed in this study is that they also include significant effects of a number of variables reflecting the configuration of the machines in use, such as machine size, harvester head size, multi-tree handling equipment, and adjustable load space. Information on such effects may be important to managers striving to optimize their harvesting fleet to the forests available for harvest. This indicates the potential of routinely collected machine follow-up data as a useful tool for analysis of various aspects of forest operations. In a more general context, automated collection of follow-up data represents a convenient way to secure valuable information that can be used to monitor and analyze several performance criteria besides harvesting and forwarding productivity. Consequently, an organization's ability to collect, analyze, and act upon relevant follow-up data may very well be a source of competitive advantage in the future.

3.3 Study II

Much of the literature in the field of forest engineering is focused on minimizing costs, usually by searching for various means to increase machine productivity, measured on the basis of volume produced divided by time expended. Study I falls in this category. However, managers of forest operations have more aspects than productivity to focus on. This is indicated by the proportion of forest engineering literature that considers other results of harvesting operations, such as length- and diameter distribution of logs (e.g. Uusitalo et al., 2004), log damage (e.g. Nuutinen et al., 2010), thinning quality (e.g. Camp, 2002), and ground damage (e.g. Eliasson, 2005). Supposedly, this multi-facetted nature of forest work is a challenge for managers of harvesting operations, especially when harvesting resources are outsourced to independent contractors. Consequently, it is necessary for a service client to value possible performance aspects and measure actual supplier performance in relevant aspects in order to have an idea of suppliers' alignment with the client's needs, and if there is a need to engage in corrective measures. The objective of study II was to develop a methodology for identifying and valuing attributes of harvesting services, and to measure contractor performance in these aspects.

After a broad search of suitable theoretical frameworks for the study, a candidate from the field of service marketing in the form of the concept customer-perceived value, as defined by Grönroos (1997), was selected.

Grönroos' four generic service attributes: core solution, additional services, price, and relationship costs, were used as a starting point in a process involving interviewees from a large Swedish forest company. The purpose was to develop a set of harvesting-specific service attributes, and a survey designed to measure contractor performance in the identified attributes. The identified harvesting-specific attributes were timber quality, thinning quality, environmental considerations, harvesting and forwarding productivity, harvester and forwarder capacity utilization, flexibility, management, cooperation, delivery performance, daily communications, and business relationship, which clearly indicate that customer requirements with respect to harvesting contractors go beyond high efficiency and low costs.

Using a survey, perceptions of how important each attribute was were recorded for five production managers each responsible for contracting large numbers of harvesting services annually, and contractor performance was quantified for each service attribute for each of the 74 contractors employed by these production managers in total. Follow-up data from the customer were used to measure performance for service attributes where available. However, this was missing for most attributes, thus encouraging us to develop a survey to measure the customer-perceived performance for these attributes on Likert scales. The survey was subsequently distributed to the production managers, who were asked to score their perceptions of the performance of each of their employed contractors. Finally, the data were compiled into a dataset in which each contractor had a performance score for each of the identified service attributes; this was used in subsequent analyses.

The production managers responding to the survey considered all suggested attributes to be important with the only exception being the "delivery performance", which two of the managers considered unimportant. The reason given for this was that the two managers claimed to have flexible enough operations to be independent of precise deliveries from single contractors. Contractor performance was, on average, rated fairly high, but varied considerably. Notably, harvester and forwarder productivity varied greatly between contractors, with the most productive contractor recording almost double productivity level compared to the least productive one (in comparable conditions). Large gaps between perceived contractor performance and perceived attribute importance were found for the attributes timber quality, thinning quality, management, and cooperation, which consequently are suggested as future focus areas for the case participants.

The study found that the harvesting service is of considerable complexity, and that performance among contractors varies substantially, which is likely also to be the case for many other customer-contractor cases over the world. The complexity of the harvesting service and variations in contractor performance suggest that management of subcontracted harvesting services is a fairly complex activity with many factors that need to be accounted for. This has not been addressed much in previous research and requires further investigation. The identification of contractors' management as a key attribute of the harvesting service is also an interesting finding, since it suggests that the respondents consider it important to contract resourceful partners. This is probably because of an assumption that more resourceful contractors will require less supervision and be able to develop their operations proactively.

3.4 Study III

Applying the methodology developed in study II to the case company revealed some systematic misalignments between the company and its contractors in certain attributes of the harvesting service, and also showed large differences in alignment for individual company-contractor relationships. This suggests that the company may be advised to take corrective actions to ensure that contractors perform according to the company's needs. Consequently, the objective for the third paper was to develop and test a framework that could guide managers in their work to improve the operations that were their responsibility by assessing and fostering alignment with their contractors.

A literature review was used to identify feasible approaches to improve alignment between contractors and their clients, and contractor characteristics that could affect the usefulness of each identified approach. Based on the literature review, a process was developed to help managers identify the best alignment strategy for a contractor relationship. Subsequently, the utility of this process was analyzed against the background of the contractor relationships scrutinized in study II. In this analysis, Pearson's correlation, one-way ANOVA, and k-means cluster analysis were used to identify some correlations between service attributes and differences between contractor groups in the dataset.

Four possible approaches to aligning performance of a contractor fleet were identified in the literature: active sourcing, incentives aligned with customer requirements, contractor development programs, and the use of power advantage. Further, the literature suggested several contractor-specific factors that may affect contractor performance, such as managerial capability, entrepreneurial orientation, ability to build successful alliances, and contractors' motivators and objectives. To help customers of harvesting services to identify the most efficient course of action to align contractor performance with customer needs, a process was developed to select the most suitable alignment approach for any given contractor. The process comprised five steps: 1) specify attributes of service needs, 2) specify importance of these attributes, 3) evaluate contractor performance in each attribute, 4) assess contractors' abilities to improve independently, and 5) choose an alignment strategy. It was suggested that the final choice of alignment strategy be based on a) a contractor's performance in the service attributes deemed most important by the customer, and b) the contractor's ability to align performance with customer needs independently.

Application of the suggested process for the case described in study II identified three groups of contractors differentiated by their overall alignment with customer requirements. Contractors' management and collaboration with the customer were found to correlate significantly to performance in most other service attributes, leading to the conclusion that contractors' managerial and collaborative abilities are likely to be important to achieve alignment with customer requirements. Even though this finding was for a limited case, both literature and common sense suggest that the importance of these contractor abilities for contractor performance may be successfully generalized to many other settings as well. As already described herein, the market for harvesting services is not particularly dynamic in many harvesting regions. This has the consequence that forest companies may benefit the most from trying to improve services of contractors they already have relationships with rather than relying on finding alternative contractors in the market. Results from this study indicate that companies who strive to improve alignment of their employed contractors would benefit from developing incentive programs in alignment with their needs. Further, if contractors fail to align independently despite proper incentives to do so, forest companies need to empower the contractors by helping them develop necessary managerial and collaborative capabilities. Even though such efforts would reduce the benefits of not having to get involved that are associated with outsourcing of operations, they would probably present good investments in the long run if contractors were enabled to respond more effectively to customer requirements and incentives. However, for this to be a viable option at all, forest companies need to possess the capability to develop their contractors effectively.

3.5 Study IV

Studies II and III suggested that harvesting services comprise multiple attributes valuable to the customer, and that customers of such services need to foster alignment of their contractor force actively in order to maximize their benefits. Supposedly, such alignment would benefit from stable relationships where both parties have an interest in aligning to each other's needs. However, reports of financial problems for many contractors and suggestions in the trade press that the cause of low profitability was a poor business environment indicate, if true, serious problems in the relationships between contractors and their customers. This motivated that study IV was aimed towards advancing our knowledge about how these relationships work.

Study IV was driven by the hypothesis that both the contractors' and the customer's perceived alignment to the other partner would lead to short and long term profitability for the contractors and a stable relationship. The same case and dataset as in study II were used but complemented by additional information. Financial information for the studied contractor enterprises was collected from public financial records both for the period covered in study II, and for an equally long period a few years later to produce a longitudinal dataset. A Likert scale survey was developed to measure contractor's retrospective perceptions of how well the customer's business environment aligned with their preferences at the time of study II. The contractors were asked to answer the survey as the first step in a telephone interview, which also included a couple of open ended questions and the chance for the respondents to add anything they deemed important. If a contractor was no longer employed by the customer, the reason for this was investigated. This resulted in a dataset containing information on both the customer's and the contractors' perceptions of their alignment, development of contractor profitability over time, and any changes in relationship status, giving the study a unique longitudinal perspective on how alignment affects business relationships. Subsequently, the developed measures of alignment were used as explanatory variables in analyses of contractor profitability and relationship stability. The hypotheses were analyzed quantitatively using a range of statistical methods: Pearson's correlation, one-way ANOVA, binary logistic regression analysis, and multiple linear regression analysis.

Results indicate that the two measures of alignment are, to a large extent, independent of each other. Overall customer-perceived value affected both contractor profitability and the risk of relationship breakdown. The strongest predictors of contractor profitability were the profitability in the previous period, and operational efficiency. However, no significant support was found for an effect between contractor-perceived alignment and contractor profitability or the risk of relationship breakdown. Notably, the customer-perceived value attribute of additional services, comprising items measuring the contractors' management, collaboration, flexibility, and delivery performance, had the strongest positive effect on the chance of maintaining a relationship. This effect indicates that the customer is striving to maintain the relationship with resourceful contractors, who the customer can expect to perform without having to apply the more costly options for contractor alignment suggested in study III.

All in all, this study suggests that customer–contractor alignment should be considered a key objective by contractors who wish to increase the likelihood of business success. More specifically, at least in this case, contractors could be advised to focus their efforts on developing managerial resources and operational efficiency. Alignment should also be fostered by forest companies who wish to improve their supply chain performance by achieving services in line with their needs, and a stable and dependable contractor force.

4 Discussion

The aim of the research presented in this thesis was to identify ways to improve the forest industry's supply chain performance by developing alignment between forest companies and harvesting contractors; this can encompass many different approaches to improving alignment. The title of the project, "Developing client-supplier alignment in Swedish wood supply – From efficiency engineering to managing performance", gives an indication that the scope of investigations has been broad rather than deep. The reason for this choice was that the topic of alignment in forest operations has received very limited interest from the research community over the years, despite its importance to overall performance (e.g. Lee, 2004). The perhaps most significant finding made in this project is that the currently common reliance on market competition to promote development is unlikely to fulfill demands for harvesting performance more in alignment with downstream needs. The solution to this problem suggested by this project is a shift towards more customer involvement in contractors' operations by the employment of a performance management process. These results are discussed more in detail in the sections below.

4.1 From efficiency engineering…

Historically, various forest engineering methods and practices have been applied to improve forest operations efficiency. Some examples are given in the review (2), ranging from simple time studies to advanced application of operations research methods. However, the examples presented represent only a proportion of all the efforts that have been made by people in the forest sector to develop ever more efficient tools, machinery, and work methods. During the era of mechanization, forest operations engineering was conducted within strong research environments in collaboration with forest companies and forest machine manufacturers, leading to effective development of both machinery and operational practices (Thor, 2012). The resulting novel machinery and more efficient ways of working allowed workers to produce more wood than ever before in a given amount of time (fig. 1).

Even though alignment may need to include additional aspects of a relationship, strong arguments can be found for the idea that cost efficiency was the primary attribute of alignment between forest operations and mill needs for a very long time. First, Nellbeck (2015) and Rennel (2010) both underline that low fiber cost and cost efficiency are strong determinants of mill competitiveness within the forest industry, which upstream from the mills translates into demands on efficiency in forest operations. Second, forest operations were effectively decoupled from downstream industrial processes by large roundwood stocks in the floating and, subsequently, railway transport systems (Nordansjö, 2011), leading to few demands on forest operations apart from delivering wood to rivers or railway terminals as cheaply as possible. Consequently, promoting cost efficiency in forest operations more or less equaled promoting alignment with mill requirements. This explains the popularity of forest operations engineering practices in Sweden from the advent of forest work science in the 1930s, through the mechanization era and to the declining position of the subject during the outsourcing of forest work in the 1990s.

Even though other aspects of alignment may have increased in importance recently, cost efficiency will probably continue to be among the prioritized goals of forest operations in the future. Consequently, engineering practices that have been used to develop forest operations efficiency in the past, such as those reviewed by Heinimann (2007), should also have an important role in the future. However, modern technology allows new engineering methods to be developed, and new applications of old methods. One promising technology is the use of sensors and communication equipment installed in forest machines to record and collect follow-up datasets on forest work automatically; these can then be used for a variety of purposes (e.g. Manner, 2015).

One example of collection of such a dataset is study I, which was based on data relating to the work of hundreds of machines collected with comparatively little effort thanks to modern technology. Using this stand-level dataset, several results were obtained that can be used directly to separate more efficient machine configurations from less efficient ones.

Information about machine performance is important for practitioners who are deciding on, for instance, which machine to acquire, or what kinds of work a certain machine should perform. However, even though study I indicated that specialized heavy machines are the most efficient alternative in final fellings, managers may be prevented from acting upon this information for various reasons. For instance, the need for flexibility in deliveries or uncertainties about which harvesting sites will be available may force a manager to employ harvesting crews who can shift between thinnings and final fellings at short notice (Erlandsson, 2013), which the largest machines simply are not suitable for. Thus, this study suggests that there are trade-offs between cost efficiency in harvesting operations and the ability of harvesting operations to contribute to supply chain agility. Consequently, managers of wood supply chains who are interested in maximizing harvesting efficiency may be advised to secure sufficient supply chain agility by developing flexibility-enablers other than multi-functional harvesting crews (Audy et al., 2012).

One such enabler could be routine collection of follow-up data on harvesting operations. If a continuous flow of such data is secured, it would allow a more detailed level of control, which in turn allows management to react quicker and more precisely when unexpected events occur. In study II, respondents placed quite different weights on the importance of harvesting contractors' delivery performance, purportedly because of different ways of controlling production. Possibly, the ability to utilize the continuous flow of information on production provided by the follow-up system described in study I for more agile production management may have been the critical factor that allowed some managers to relax requirements with respect to delivery performance. Probably, the implementation of such agile production management could also allow organizations with a need for a high degree of flexibility to utilize more of the benefits of specialized machinery outlined above.

Despite the benefits of analyzing follow-up data, more detailed studies or controlled experiments may be necessary in many cases to disentangle causal relationships in such data. An example of such a spin-off study was undertaken by Arlinger et al. (2014), who, using conventional time studies, confirmed the indications from study I that large harvesters are most cost efficient in the majority of final fellings. To reduce the need for such experiments, however, features may be included in machines that enable automatic collection of large scale but detailed follow-up data with a resolution similar to that which can normally only be found in costly time study experiments (Arlinger & Jönsson, 2013; Arlinger et al., 2014). Collection of such time consumption data from forest machines represents a promising development. Together with data from other sources, such as the GPS and the measuring system in the harvester, such data could not only facilitate analysis and study of various machine concepts, working methods, and systems, but also facilitate a new level of control over operations in general and machine work in particular.

4.2 …through relying on the market…

Through the latter half of the 20th century, methods and practices of forest operations engineering have greatly contributed to improving forest operations efficiency and thus to fulfilling the industry's primary need for a cost efficient wood supply. However, development since the 1990s has taken some turns that have made today's demands on forest operations more complex than they used to be, and introduced additional challenges. More specifically, outsourcing of forest work, reduced density of personnel in supervisor positions, tightly linked supply chains, and more complex demands by the mills and from external stakeholders have all contributed to making management of forest operations more challenging. The uncertainty of supply experienced by some organizations further complicates management of forest operations (Erlandsson, 2013).

However, the most significant change may have been the outsourcing of most forest work to independent contractors, which at least partly disabled the use of direct instructions as a means of controlling and developing operations. This change probably made it more difficult to implement the previously successful forest engineering methods and practices, which could explain the declining interest in forest engineering in the 1990s, manifested by massive cutbacks in Swedish forest engineering research.

Outsourcing of forest work, comparatively limited research and development activities, and a fairly stable technology are characteristics that today's forest operations share with the forest operations that preceded the organized rationalization movement that started in the 1930s. This does not necessarily have to be negative though, since the laissez-fare attitude towards development in that era led to significant improvements due to the competitive mechanisms of the free market (Geete, 1927).

As has been described previously, today's markets for harvesting services are often characterized by unionized labor, few buyers of such harvesting services, and few manufacturers of machinery. Furthermore, the number of competitors in the harvesting services market as a whole may be sufficient for us to expect that the competitive forces of the market should be effective. Nevertheless, long distances due to the geographically dispersed operations act as effective barriers to entry into local markets. The dispersed operations probably lead to many areas being characterized as local oligopolies rather than competitive markets. In such conditions, contractors may gain substantially in bargaining power in relation to the customer. Cox (1999) describes several cases of such supplier dominated relationships, in which the supplier rather than striving to delight the customer focuses on maximizing their own value appropriation while minimizing the efforts needed to keep the customer satisficed (i.e. just enough satisfied to stay in the relationship). When considered together, the factors described above raise doubts about whether the competitive forces of today's market are the best means to promote development.

Two empirical observations can be made that further strengthen these doubts. First, despite a much more competitive market for harvesting services than today, the period before the 1930s in which the laissez-fare attitude was the dominant paradigm, showed much slower productivity increases than the following period, which was characterized by organized rationalization efforts. In fact, the pace of productivity development seems to have doubled when implementation of forest work science started in the late 1930s (table 1), despite the slow development of technology. However, this observation needs to be considered with caution since the sources from that time are anecdotal and does not necessarily represent mainstream development. Second, results from study I show that several inventions leading to significant gains in harvesting (e.g. multi-stem handling equipment) and forwarding (e.g. adjustable load space) work were far from fully implemented more than a decade after knowledge of the inventions' benefits were freely available (e.g. Bergkvist, 2003; Brunberg, 2001). A possible reason for this is related to contractors balancing reluctance to take the risk of being early adaptors of new technology, and satisficing the customer's preference for low cost and efficient operations. In a market characterized by strong competition, contractors would be forced to adopt the most efficient technology quickly in order to be able to price their services competitively and defend their market share, whereas satisficing the customer may be sufficient to defend a contractor's market share in a less competitive market (Cox, 1999). The slow adoption of technical advances consequently suggests that the competitive force of the market (at least the part of the market examined in study I) may not be sufficiently strong in itself to promote development to align contractor performance and customer expectations.

Even though the examples above indicate that the market for forest work still seems to suffer from problems, there have been some important efforts made to improve its function in recent years. Large scale calls for tenders, in which all of an organization's need for harvesting work in an area has been open for bids, have been used to ensure that all the organization's contractors are subject to effective competition from their peers (Furness-Lindén & Norin, 2007). Even though this approach could certainly be effective in breaking up entrenched structures, which may be a benefit in some scenarios, it seems unclear how the method would work in a market where contractors are scarce, if the method was applied repeatedly, or if the contractors in the market were larger and more powerful. Furthermore, agreed documents and more or less standardized contracts have been developed with the aim of reducing transaction costs in the forest service market (Furness-Lindén, 2013; Williamson, 1979). Probably, this will facilitate mobility and consequently increase competition within the market somewhat. Even so, it seems unlikely that the effect from this is going to be sufficient to affect the functioning of the market in a major way due to the aforementioned barriers to entry and of oligopoly-like situations in many areas.

If we switch focus from the market as a whole to the relationships between single contractors and their customers, two additional issues with outsourced operations can be identified. First, contractors may not always act in the best interest of their client, which from the client's or the whole supply chain's perspective may lead to negative consequences. The primary reason for this is the 'agency problem', which arises when the desires or goals of the client and contractor conflict, and it is difficult or expensive for the client to verify what the contractor is actually doing (Eisenhardt, 1989). Considering findings from Canada that contractors' motivation to be in business seems to vary considerably (e.g. Drolet & LeBel, 2010), and the low density of personnel supervising Swedish forest operations (LeBel & Norin, 2008), it appears that there is a high risk of such problems occurring. However, few if any studies seem to have addressed the issue of agency problems in forest operations. The second issue is that even if a contractor genuinely strives to satisfy downstream needs, this is bound to fail if the contractor is missing the necessary resources (in a broad sense, see Wernerfelt, 1984). Study I showed that much of the work is conducted using less efficient equipment (such as harvesters without multi-stem handling heads), and this makes it difficult for the owners of that equipment to maintain efficiency in alignment with the customer's expectations. Furthermore, results from studies II and III indicate managerial problems in some contractor firms and this correlates to poor performance in several other attributes of the harvesting service that the customer perceives as important, such as machine productivity and log quality. Consequently, it is necessary to consider contractor capabilities when promoting forest operations alignment with downstream needs.

Study II identified several attributes of the forest harvesting service that a customer considered important, of which several were deemed more important than productivity and capacity utilization by the customer's officials. However, lists and rankings of such attributes are bound to be case specific to some extent due to differences in the customer's supply structure, resources, delivery requirements, etc. The realization that harvesting operations performance cannot necessarily be thought of as only related to efficiency is important. The main implication of this finding is that to align performance of a supply chain with industry needs, several dimensions (in this thesis mainly represented by harvesting service attributes) need to be taken into account to avoid suboptimal outcomes.

A seemingly not very dynamic market for a fairly complex service paired with poor alignment between contractors and their client, possibly due to potential agency problems and lack of contractor resources, makes it unlikely that continued reliance on laissez-fare as the primary driver of change will be successful. The next section discusses a possible alternative that may better suit the problems and opportunities of today's forest operations.

4.3 …to managing performance

So far I have described how the previously very successful doctrine of organized and determined engineering efforts to develop forest operations, stemming all the way back to the introduction of forest work science in the 1930s, gave way to a new market-oriented doctrine with the outsourcing of forest work in the 1990s. Furthermore, I have argued that today's market alone is unlikely to promote development of performance sufficiently to satisfy downstream needs. Ultimately, this may represent a threat to the industry's competitiveness, which should make reconsideration of how management of forest operations is conducted a priority.

Drawing on the power advantage that customers of harvesting services normally have over their contractors, study III suggests a process for performance management that forest companies can use to align the performance of harvesting contractors with their needs in a structured way. By using this performance management process, a company moves from relying on the competitive forces of the market to promote development towards actively using a set of tools to deliberately foster and facilitate contractors' alignment with its needs. These tools utilize both the competitive forces of the market as well as the benefits associated with organized efficiency engineering, which should give the proposed process an advantage over both the 'pure' efficiency engineering or market based doctrines. Market forces put pressure on contractors to align if clients incorporate active sourcing in the performance management process, whereas use of supplier development programs facilitate, for instance, effective promotion of the most efficient technology or ways of work identified by forest engineering scholars or others. Agency problems are primarily addressed by adapting the incentives structure to avoid them, but may also be corrected through using the customer company's power advantage, which can encompass anything from exercising influence by sharing knowledge to plain coercion (Maloni & Benton, 2000).

Performance of operations is a complex issue, and any efforts to improve performance need to be situation specific. This means that performance management efforts need to be adapted to both the performance aspects that need to be improved, and the abilities of the contractor to affect these particular aspects. Developed follow-up systems for at least the most important service attributes, like the system used to collect data in study I, would be a great help for implementing such performance management. The process developed in study III is fairly generic and should be applicable to other similar contexts as well, although it was originally developed for performance management in harvesting operations. However, the suggested process was specifically developed for buyer dominated relationships. Cox et al. (2004) investigated the appropriateness of sourcing strategies under different power regimes in buyer-seller relationships, and found that a selected strategy need to be in alignment with the prevailing power regime of the relationship to be effective. Furthermore, they conclude that sourcing strategies commonly associated with best practice in supply chain management mostly require buyer dominance in order to work when applied to practical cases. Consequently, if the customer and contractor are interdependent, or if their relationship is dominated by the contractor, the performance management process suggested in this thesis is likely to be inappropriate, since the contractor then can use its power advantage to dictate the conditions of the relationship. In such cases, some other more appropriate alignment strategy needs to be applied.

In practice, it may be too cumbersome for managers to handle a portfolio of contractors who would each require a uniquely tailored development program of some sort. One way of dealing with this problem is to classify contractors and let at least some of the customer's development efforts depend on which class each contractor belongs to. Furness-Lindén (2008) describes some companies who have used such classification to discriminate supplier access to packaged bundles of various activities and programs from the customer company's side. Such activities included, for instance: joint ventures; access to support staff; incentives programs; benchmarking; and long-term contracts. This way of conceptualizing and packaging development activities and offering them based on pre-determined conditions is likely to be of great help to managers who may have little time for development activities (e.g. Erlandsson, 2013). Worthy of note, however, is the fact that the described case companies in Furness-Lindén's (2008) study all had personnel dedicated to supplier relations management, which may be a necessity if a company wishes to engage successfully in more active performance management (Draulans, et al., 2003).

A potential risk with performance management from the customer's perspective is that their increased involvement may be perceived as an intrusion by entrepreneurial contractors, or may encourage contractors who react to the customer's wishes rather than proactively developing their business. Benton and Maloni (2005) found that buyers' use of coercion to affect their suppliers indeed had a detrimental effect on the buyer-supplier relationships. However, if the buyer used other power bases, such as giving expert advice or mediating rewards, the relationships were positively affected. Since the performance management process suggested by this project only promotes the use of coercion in one specific case (i.e. contractors who refuse to perform according to requirements despite the capability to do so), any negative effects because of this should be minimal. In study IV, contractors who had quit working for the customer relatively frequent reported conflict with the customer's officials. Possibly, this may be related to the negative effect of coercive behavior on supplier satisfaction suggested by Benton and Maloni (2005). Another very interesting finding from their study is that the buyer's use of power in the buyer-supplier relationship has an overall positive effect on the supplier's satisfaction, *and on supplier performance.*

Consequently, there seems to be strong arguments for customers of harvesting services to judiciously involve in the contractors' operations to ensure alignment and development. Study III identified contractors' management and collaboration with the customer as important factors for high performance in most harvesting service attributes. This together with the findings of Benton and Maloni (2005) suggests that helping contractors develop managerial skills, by providing, for instance, access to coaches or other experts, should be prioritized by companies who wish to improve contractor performance. To be successful, this may require companies to themselves develop the capability to provide such help, or to acquire it through consultancies or other sources.

In situations with limited or balanced availability of contractors (or few customers if taking the contractor perspective), the proposed scheme to promote alignment by employing supplier development activities and handling agency problems may be the best way forward. However, when there is a surplus of contractors or when there is severe misalignment between contractor performance and customer requirements, an alternative focus may be advisable. In such situations it may be best instead to engage more in sourcing activities to replace misaligned contractors and secure contracts with contractors better in alignment with one's needs. Similarly, contractors who can choose between several different clients will benefit from choosing the client who offers a business environment best in alignment with the contractor's preferences and resources, and focusing efforts on building a strong relationship with that client (study IV, Benton & Maloni, 2005; LeBel & Stuart, 1998; Mäkinen, 1997).

If better alignment between forest companies and their contractors is achieved, results from study IV suggest that both parties would experience an improved situation manifested in better contractor profitability, harvesting services in better alignment with requirements, reduced risk of conflict, and low risk of relationship breakdown. An interesting result from the study is the increased risk of customer-contractor relationship breakdown associated with high performance in the service attribute core solution. This attribute included measures of log quality, thinning quality and environmental considerations, all considered very important by the customer company's officials (study II). This certainly must be considered a problem from the perspective of the service customer, and clearly indicates the challenge of managing complex operations. To offer an adequate incentive structure and a business environment that contractors perceive as positive would reduce their desire to find other employers. Study IV did not find a significant relationship between contractors' perceived alignment and their performance as perceived by the customer; or contractor profitability, but found indications that poor perceived alignment was related to conflicts between contractor and customer. This is in line with the findings by Benton and Maloni (2005) in the automotive industry, which showed significant effects of relationship quality on supplier satisfaction, but found no effect of supplier performance on supplier satisfaction, indicating that these results from study IV may be generalizable to some extent.

Study IV demonstrated that contractors who no longer worked for the customer had satisfied their customer to a much lower degree than their peers who maintained their relationships. This is indicating that the competitive force in the market is to some degree shaping a contractor force better in alignment with the customer's needs. However, a large proportion of the contractors with poor performance remained in service, which suggests that competition has a limited effect which further strengthens the argument for companies to actively engage in performance management. Nonetheless, the results show that it is beneficial for harvesting contractors to deliver high quality services, similar to the situation for companies in most businesses (e.g. Anderson et al., 1994).

This project has focused on alignment within the harvesting operation of the wood supply chain, which is an important issue to consider for development oriented managers. However, in order to foster performance of the supply chain as a whole, this scope may be too limited. The wood supply chain normally consists of several functions (e.g. harvesting, transport, wood yards, mills, etc.) and organizations (e.g. contractors, forest companies, forest owners associations, industrial companies, etc.). To ensure optimal supply chain performance, all actors need to be in alignment to each other (Lee, 2004). Further, participants in a supply chain each need to address their internal alignment and ensure that problems are not hidden within the boundaries of organizations along the supply chain (van Hoek & Mitchell, 2006). Managers who primarily hire the services of small firms may not need to worry much about the internal alignment of these contractor firms. Nonetheless, this could be an important issue to consider for managers who are dealing with larger contractor enterprises that, for instance, include other businesses besides harvesting, or who simultaneously deal with other clients.

From a wider perspective, it is worth to contemplate on whether the Swedish forest sector of today really has the capabilities necessary to effectively align its supply chains. As was shown in figure 1, the Swedish forest operations started to decrease in efficiency around 2005 which must be seen as a dangerous failure to perform considering the importance of cost efficient wood supply for the forest industry (Nellbeck, 2015; Rennel, 2010). The only major event identified in this thesis that coincided with the productivity decline is the beginning of retirements for the babyboomers, which drained the forest sector of operational experience and knowledge. This would not necessarily have been a problem if there had been a supply of people with comparable knowledge to recruit. However, the cutbacks in forest operations research and shift towards more academic forestry education in the 1990's had reduced the educational system's ability to meet this demand. Most likely, this led to losses in operational and technical knowledge throughout the forest industry when experienced personnel were replaced with new recruits.

A theoretical perspective on this shift offers a conceptual understanding of what occurred, and may give some indications of how the development may be turned. Amit & Schoemaker (1993) describes 'resources' as tangible or intangible assets of the firm, whereas the term 'capabilities' indicates a firm's ability to combine and utilize a set of resources to produce a certain effect. In these terms, the declining productivity is likely to have been caused by a declining capability to conduct efficient operations, which in turn likely was caused by some shift in underlying resources. Grant (1996) suggests that knowledge (in a broad sense) is the critical input (i.e. resource) in all production processes and that knowledge is the primary source of value. If decreased operational capability due to loss of knowledge was what caused the downturn in productivity, it becomes important to consider how this capability can be restored and eventually improved. Grant & Baden-Fuller (2004) makes the important discrimination between the exploration, or creation, of knowledge, and the exploitation, or use, of knowledge. Further, they state that firms need to acquire knowledge to use it, or access it by allying with some organization that already possesses the particular knowledge in question.

Here, I will use these terms of Grant & Baden-Fuller (2004) in an attempt to make a schematic description of the historical generation and dissemination of knowledge in Swedish forest operations. Until the 1990's, cutting edge knowledge on forest operations was generated in reasonably large scale within the Swedish research institutions (i.e. SLU, Skogforsk, and their predecessors). Forestry students then acquired this knowledge bound within the research institutions in their education, which subsequently allowed forest companies to acquire it themselves by employing the students. Harvesting contractors were typically too small to acquire knowledge in this way, but had good access to advanced knowledge through the usually close relationship with the customer's support staff. Further, the forest companies had more direct access to state-of-the-art knowledge, for instance through their "development triangle" collaboration between research institutions, forest companies, and machine manufacturers in the mechanization era (Thor, 2012). Seen from this perspective, it seems clear that the reductions in forest operations research and the changes in education in the 1990's were bound to eventually have consequences for the sector's operational capability. This was anticipated by the well-known Norwegian professor in forest technology, Ivar Samset, who at the time of the reductions in research warned that this would have negative consequences a decade later (Fryk, 2013).

Reductions in research reduced the creation of new knowledge, but what was worse was that the mechanisms for transferring knowledge – both new and old – of forest operations to practitioners were largely dismantled. This happened in two ways. First, the closedown of ranger schools and a change in focus of the higher forestry education diminished the supply of students knowledgeable in forest operations, which limited the supply of people the forest companies could acquire knowledge from. Second, the reduction in support staff at forest companies during the streamlining efforts in the 1990's removed important agents of knowledge integration from the forest companies (Grant, 1996). Such specialized support staff had previously acted as intermediaries between the research community and field personnel, contractors, and other practitioners who otherwise had difficult to create, acquire, or access advanced knowledge (Grant & Baden-Fuller, 2004). Notably, lack of such specialists was pointed out as a major weakness in the forest industry in interviews with Swedish harvesting contractors in 2006 and 2007 (LeBel & Norin, 2008).

If the description and analysis of the causes behind the efficiency decline outlined above is correct, it is possible to draw some conclusions of what is required to resume the previously almost constant increases in forest operations efficiency. First, a strong forest operations research community needs to be reinstated, that has the capability to constantly identify more efficient ways of conducting operations. Second, forestry education needs to, at least in part, be refocused to transfer state-of-the-art knowledge of forest operations to students. Third, forest companies need to build the capacity to access external knowledge (for instance in the research community), to internalize this knowledge, and to disseminate it to front line staff and contractors. However, the increased requirements on today's forest operations compared to previous periods suggests even more far-reaching changes to ensure alignment between forest operations and downstream needs. Outsourced operations, more tightly linked supply chains, and the industry's transition towards more customer service means a much more complex operating environment, and that cost efficiency no longer can be thought of as the single goal for operations. Consequently, the three steps suggested above may need to encompass not only subjects traditionally pertaining to forest operations, but also subjects such as general operations management and supply chain management in order to align with the requirements of modern forest operations.

In today's education of Jägmästare, even those who choose to enroll in the wood supply program only get a minority of their education in operations related subjects. This is likely not enough to prepare students for today's operational environment, and may as previously have been indicated be a major problem for the forest sector. To train students to know the trade, be proficient both in more traditional forest operations subjects, and in more generic management sciences, it seems necessary that more time and effort than currently needs to be assigned to operations related subjects. One way of achieving this would be to expand the part of the Jägmästare education that is dedicated to the students' chosen specialties, which in this case would be the specialty of wood supply. This would hopefully allow students more opportunities to acquire the knowledge needed to manage the Swedish forest industry's supply chains of the future.

4.4 Methodological considerations

This PhD project set out to improve alignment between harvesting contractors and forest companies, primarily with the intent to find ways to improve on the forest industry's supply systems. In many such systems, large forest companies are acting as channel leaders (c.f. Kotler, 1967), controlling most operations either directly, or indirectly by relations with contractors or other associates. In such forest company dominated systems, the company's satisfaction with contractors' services should be a good indication of the value of the respective contractors' services to the downstream supply system.

Customer satisfaction has in the service management literature often been associated with the customer's perception of the received value of a service (e.g. Cronin et al., 2000), which is commonly understood as the difference between perceived benefits and perceived sacrifices associated with receiving the service (e.g. Ravald & Grönroos, 1996). A common concept for addressing customer benefits from a service is service quality, which is defined as the service provider's performance in relation to the customer's expectations (e.g. Parasuraman et al., 1988). In long-term business relationships, customers tend to extend their valuation of a service provider to include also the supplier's resources, competencies, trustworthiness, and other aspects that is perceived to affect the service provider's long-term performance (Grönroos, 1997; c.f. Das & Teng, 2003).

Studies II, III, and IV all build on measures of a customer's perceptions of its harvesting contractors' services. Grönroos' (1997) definition of customer-perceived value was used as a framework to identify a set of case-specific attributes covering both benefits and sacrifices of the harvesting service as perceived by the customer. The identified benefits included both attributes which can be associated to service quality (e.g. log quality) and to contractor resources (e.g. contractors' managerial skills). The customer's perceptions of contractor performance in these attributes were measured and used in subsequent analyses, as have been described in section 3 above. A new term, performance alignment, was suggested for relationships in which the customer perceived high performance in quality associated service attributes, low sacrifices needed to obtain the service, and the contribution of key resources from the contractor. This method stands in contrast to much research regarding service quality in two important aspects. First, the attributes included in the studies reflect sacrifices and resources in addition to quality related attributes, which gives a more complete picture of the customer's valuation of the contractors. Second, the developed measures only consider contractor performance in each attribute, whereas service quality studies often also takes customer expectations into account. The primary benefit of using only performance measures is that the number of items needed for the measurement is reduced considerably in comparison to measures including also expectations, whereas the drawback is that the herein used method cannot be used to directly assess the degree of disconfirmation of customer expectations.

The dilemma of choosing between using supplier performance on its own or to include also customer expectations in the analysis of customer value is not new and may best be illustrated by the debate between proponents of two service quality scales: SERVQUAL, and SERVPERF.

SERVQUAL was developed first of the two as a generic scale that measures service quality (i.e. service performance in relation to customer expectations) in five dimensions: tangibles, reliability, responsiveness, assurance, and empathy (Parasuraman et al., 1988). It quickly became widely used throughout the research community, but was soon challenged by an alternative concept: SERVPERF. This concept used the same dimensions as SERVQUAL, but only measures perceived performance while omitting the measures of customer expectations. The rationale behind this was an assumption that expectations are already taken into account in customers' assessments of service performance, which had support in previous marketing literature in which simple performance measures had worked well (Cronin & Taylor, 1992). This sparked a debate in the research community on which method to use, but both perspectives are common in recent studies even though SERVQUAL seems to currently have a larger following. A meta-study covering 17 years of research using the SERVQUAL and SERVPERF scales indicated that the two scales have similar qualities as predictors of overall service quality, which may explain the continued popularity of both (Carrillat et al., 2007). This finding that performance-based and quality-based scales behave similarly indicates that the use in this study of performance-based measures should be largely unproblematic.

The performance scores obtained in study II was used to identify areas to which the customer should prioritize its improvement efforts. The analysis was made using importance-performance analysis (albeit presented in a bar chart instead of the traditional scatterplot), which is an intuitive and easily applicable way of analyzing customer satisfaction (Martilla & James, 1977). The ease of use associated to importance-performance analysis may be appealing to practitioners, which likely explains its popularity. However, the concept has been loosely defined in literature, and has been applied inconsistently by different studies (Oh, 2001). Further, it has some conceptual problems pertaining to its implicated assumptions of independence of attribute performance and attribute importance, and of linear relationships between attribute performance and overall performance (Matzler et al., 2004). In studies II, III, and IV, some examples of attributes were identified where the relationship between performance and supply chain utility can be assumed to be nonlinear. It seems likely for the attributes environmental considerations, and thinning quality, for instance, that the customer is interested in performance above a threshold level rather than in maximized performance. If this is the case, the applied methodology may have failed to correctly describe their meaning to the customer and their role in the relationship to the contractors.

Future researchers addressing similar research questions are advised to carefully consider which measure of customer perceptions to use in their studies. The inclusion of customer expectations could improve the diagnostic power of analyses. However, inclusion of customer expectations would likely not improve the predictive power of the constructed measures, and lead to drawbacks such as sensitivity to context, more data collection, and somewhat more complicated analytical work (Carrilat et al., 2007). Consequently, managers and researchers who prioritize simplicity, possibility to automatize measurements (as was done with the price-related attributes in studies II, III, and IV), and ease of interpretation of longitudinal data, may prefer performance-based measures similar to those used in this project. Despite the indicated problems with importance-performance analysis, its ease of application still is an important strength of the method, as long as it is used with discretion. However, future studies of harvesting contractor performance may benefit from developing more delicate performance measurements. An important improvement would be to develop a methodology that better handles nonlinear relationships between contractor performance and supply chain utility. Further, future researchers in this field may find it beneficial to explore other methods to aggregate attribute scores. A weighting procedure, for instance using attribute importance scores as weights, may add explanatory power to constructs measuring overall alignment, such as the customer-perceived value and contractor-perceived alignment indexes used in study IV.

Since the topic of this thesis has not received much interest in the past, this project has, to large extent, been characterized by a search process. Findings from literature studies in various fields have been contrasted against quantitative and qualitative observations made in case studies of a company and its employed contractors in an iterative process aiming to increase the understanding of alignment and how it can be fostered. Consequently, this project can be said to adhere to a hermeneutic rather than positivist tradition of science, based as it is on my interpretation and understanding of findings rather than on pure hypothesis testing. Having established this, it becomes clear that my own experience and understanding is a critical part of the research process, which means that any preconceptions may, despite my intentions to be as objective as possible, unintentionally have affected the studies in ways that are not apparent to me. Hopefully, researchers with alternative perspectives will interest themselves in the issues presented here and fill out any gaps.

This project was partly funded by the company SCA, where I have been working since 2005. The original aim of the project was formulated by the company, and the scope has, throughout, been to produce results that in one way or another are of use to the company. One effect of this is that all four studies described below were conducted within the boundaries of the company. Nonetheless, the operations in many other forest companies and other organizations around the world are fairly similar to the operations of SCA. Thus, I believe that most of the results and conclusions presented in this thesis are relevant in many other contexts, even though the reader's discretion is advised. Studies II, III, and IV all to some extent rely on sensitive information that was requested from contractors and company officials in interviews and through surveys, and which potentially could present an ethical problem. Consequently, some general remarks regarding the use of informants are necessary. This is especially important since I have been working for their employer during the time of the studies, albeit independently. I have handled this by promising strict anonymity to all respondents and given them full information about how I intend to use any information they provide before asking them to participate in the studies. Not one respondent declined to participate because of this or even raised any questions about it. Furthermore, I have critically examined the information obtained to see if my relation to the respondents' employer could have somehow affected the information they provided, without finding any indications of consciously withheld information or misinformation.

Hopefully, better customer-contractor alignment could reduce some of the stress in the wood supply chain and allow participating actors to shift the focus from day to day problems to more productive development issues (c.f. Erlandsson, 2013). More specifically, this could provide a basis for collaborative efforts to utilize the results of various research and development initiatives. If such efforts were well organized, they could represent important steps towards reintroducing and implementing the previously very successful engineering approach to development in today's outsourced business environment. However, this would require companies to change their approach to contracting and contractors to be open to a different kind of customer relationship. Even though this may seem like a difficult challenge, this PhD project has shown that it would probably be worth the effort.

5 Future research

In this thesis I have shown that the contractor-forest company relationship does not always work well, and that there may be significant benefits associated with developing better alignment between the parties. However, the scope of this project has been limited to outsourced harvesting operations and has, for the most part, taken the perspective of a large scale buyer of harvesting services from small scale contractors. Consequently, the field is open for other researchers to continue to expand our understanding of how alignment can be fostered by other kinds of service buyers with different needs and resources (e.g. independent sawmills or other smaller organizations). Another interesting question to address is how large scale contractors, such as some of those active in Finland and Quebec, affect the preconditions for alignment, and how that can be handled by the client. Any such studies of alignment may want to consider the methodological issues presented herein (4.4) and improve on the methods for measurement of performance and alignment.

Apart from broadening understanding of how alignment can be fostered in harvesting operations, it would be fruitful to direct efforts towards other functions within forest operations as well, such as transport or silviculture. Further, expanding the scope of alignment from single functions to the supply chain level could contribute to reducing suboptimalities that can be assumed to occur when optimizing each function individually. On a more conceptual level, the notion of resources and capabilities in forest operations deserves more attention. Which resources that drives performance, how these resources can be developed, and how resource complementarity between actors in the supply network can be achieved most effectively may be important questions for the future.

This project suggested an approach to performance management comprising use of active sourcing, adapted incentives, supplier development, and use of power advantage. However, the project did not go into any depth regarding how these respective tools can be applied most effectively, which calls for further study.

One issue that was identified in study II is the different management strategies that can be used to meet mill quotas. In the study, the production managers questioned solved the problem either by distributing the mill quotas across their contractors, or by not using quotas at all but closely monitoring the wood flow and taking corrective actions as needed. Researchers interested in operations research methods may be able to make a significant contribution here by determining the best strategy for different circumstances and developing relevant decision support systems. Current opportunities to examine continuous and detailed production data (study I; Manner, 2015) are likely to be essential for such analyses. On a side note, such data flow from forest machines could be used for all sorts of future research purposes, with only the researchers' own imagination setting the boundaries for its application.

In a broader context, the suggestion in this thesis that the forest industry should abandon its reliance on the market as the primary driver of development in favor of more active performance management would, if implemented, benefit from changes in the research community as well. A shift towards performance management would depend on forest companies possessing sufficient knowledge to be able to take the right decisions and act as a competent counterpart to their contractors. In practice, this means that the companies need to have knowledgeable employees, since most knowledge tend to be tacit and thus bound within the minds of people rather than associated, for instance, with systems, publications, or reports (Grant, 1996). However, since the dismantling of research related to forest operations has resulted in decreasing knowledge and theoretical academic education in the discipline in the 1990s, this likely presents a problem in today's Swedish forest industry. Consequently, it may be advisable to expand forest operations research efforts in general, and also to examine whether current education really is able to deliver tomorrow's needs.

6 Conclusion

Productivity in Swedish forest operations has exhibited remarkable development since at least the 1950s (fig. 1). Seemingly without any easily identifiable reason, productivity per man day started to decline in 2005, and this could not be described as anything other than a failure of Swedish forest operations performance. However, even though productivity per man day is an important performance measure, many other performance measures can be identified in the literature: customer satisfaction, for instance. Based on customer-perceived value theory, study II demonstrated the multi-facetted nature of performance in forest operations by identifying a range of harvesting service attributes in a case study. Many of the identified attributes, such as log quality and environmental considerations, were considered equal to or more important than productivity by the production managers of the company studied. All important service attributes should be accounted for in efforts to improve operations, and performance should ideally be measured for each attribute. Automated collection of follow-up data represents a convenient way to measure performance for such purposes and can, in addition, be used for many other purposes, some of which were demonstrated in study I.

In the case study (studies II and III), performance among harvesting contractors exhibited wide variation, with some of them clearly not in alignment with the customer's standards. When detecting misalignments, forest companies would benefit from having a strategy outlining how to take corrective action. In study III, a process was suggested that, based on contractors' alignment with customer requirements and their ability to improve their own operations, identifies the strategy most likely to align contractor performance with customer needs. Further, several benefits of alignment for both harvesting contractors and customers of harvesting services were demonstrated in study IV, which suggests that fostering contractor-customer alignment is of high importance for both parties.

Historically, forest operations were conducted by employed personnel, which facilitated the engineering of operations to foster efficiency. However, the competitive forces of the market have been the primary drivers of development since the outsourcing of forest operations in the 1990s. In this thesis, I have argued that these forces may not be sufficiently effective in promoting development. Consequently, forest companies who wish to experience better alignment from their contractors should engage actively in performance management. Such a shift may initially require efforts from the forest companies to develop or acquire good knowledge of forest operations and forest technology, and the capability to leverage this knowledge in the relation to the companies' contractors. However, any costs associated with such development should be easily outweighed by the benefits associated with better alignment within the companies' supply chains.

References

6.1 Literature

Adelhult, S. (2014) En norrländsk teknikhistoria (A technical history of Norrland). *Västerbotten No. 1, 2014.* Västerbottens läns hembygdsförbund. [In Swedish]

Ager, B. (2012) Skogsbrukets rationalisering och humanisering 1900–2011 och framåt. (The rationalization and humanization of forestry 1900–2011 and onwards) *Arbetsrapport 378*. Swedish University for Agricultural Sciences, Umeå. [In Swedish with a summary in English]

Ager, B. (1961) Motoriserad terrängtransport i Nordamerika – en diskussion kring aktuella maskiner och metoder. (Motorized offroad transport in North America – a discussion of current machines and methods). *Norrlands Skogsvårdsförbunds Tidskrift, Vol. 4, 1961.* [In Swedish]

Amit, R., Schoemaker, P. J. (1993). Strategic assets and organizational rent. *Strategic Management Journal, Vol. 14, No. 1, pp. 33-46.*

Anderson, E. W., Fornell, C., Lehmann, D. R. (1994) Customer satisfaction, market share, and profitability: Findings from Sweden. *Journal of Marketing, Vol. 58, pp. 53–66.*

Andersson, S. (1964) Den tidavlönade personalens verksamhet på några mellansvenska skogsförvaltningar (Work of personnel on time based pay at some forest districts in mid Sweden) In: Andersson, S. 1973. *Skogsteknisk Driftsekonomi del 3.* (Economy of forest operations, part 3) SHS Kompendieförmedling, Stockholm. [In Swedish]

Anon. (1976) *Skogsarbetarstrejken - våren 1975.* (The forest worker strike – spring 1975) Arbetarpress, 1976. [In Swedish]

Arlinger, J., Brunberg, T., Lundström, H., Möller, J. (2014) Jämförelse av JD1170E och JD1470E i slutavverkning hos SCA Skog AB hösten 2013 (Comparison of JD1170E and JD1470E in final felling at SCA Skog AB, autumn 2013). *Arbetsrapport från Skogforsk, No. 817-2014.* [In Swedish with a summary in English]

Arlinger, J., Jönsson, P. (2013) Automatiska tidsstudier i skogsmaskinsimulator – Driftuppföljning och produktionsdata enligt StanForD 2010 (Automatic time-studies in forest machine simulators – Operational monitoring and production data according to StanForD 2010). *Arbetsrapport från Skogforsk, No. 808-2013.* [In Swedish with a summary in English]

Arvidsson, P.-Å., Eriksson, P., Eriksson, I., Rönnqvist, M., Westerlund, A., Igeklint, P. (1999) Smartare vägval i skotningen – bra för både ekonomi och miljö [Smarter route planning for forwarders benefits both profitability and the environment]. *Skogforsk Resultat, No. 22, 1999.* [In Swedish with a summary in English]

Athanassiadis, D., Lindroos, O., & Nordfjell, T. (2011). Pine and spruce stump harvesting productivity and costs using a Pallari KH 160 stump-lifting tool. *Scandinavian Journal of Forest Research, Vol. 26, No. 5, pp. 437-445.*

Audy, J.-F., Pinotti Moreira, M., Westlund, K., D'Amours, S., LeBel, L., Rönnqvist, M. (2012) *Alternative logistics concepts fitting different wood supply situations and markets.* CIRRELT.

Axelsson, S.-Å. & Pontén, B. (1990) New ergonomic problems in mechanized logging operations. *International Journal of Industrial Ergonomics, Vol. 5, No. 3, pp. 267–273.*

Axelsson, S.-Å. (1975) Mätning, analys och optimering av skogsmaskiners driftsäkerhet (Logging-machine failure avoidance: Identification and measurement of key parameters). *Studia Forestalia Suecica, No. 124, 1975.* [In Swedish with a summary in English]

Axelsson, S.-Å. (1968) Analysis of vibrations in power saws. *Studia Forestalia Suecica, No. 59, 1968.*

Beamon, B. M. (1999). Measuring supply chain performance. *International Journal of Operations & Production Management, Vol. 19, No. 3, pp. 275-292.*

Bendz, M. (2011) Forestry education and research. In: Jansson, U. Agriculture and forestry in Sweden since 1900 – a cartographic description. *National Atlas of Sweden.*

Benton, W. C., Maloni, M. (2005) The influence of power driven buyer/seller relationships on supply chain satisfaction. *Journal of Operations Management, Vol. 23, No. 1, pp. 1-22.*

Berg, S. (2014) Technology and systems for stump harvesting with low ground disturbance. Doctoral thesis. *Acta Universitatis agriculturae Sueciae, 2014:95*. Swedish University for Agricultural Sciences, Umeå.

Bergkvist, I. (2003) Flerträdshantering höjer prestationen och ökar nettot i klen gallring (Multitree-handling increases both productivity and profitability in smallwood thinnings). *Skogforsk Resultat, No. 14, 2003.* [In Swedish with a summary in English]

Bergkvist, I, Nordén, B., Hallonborg, U. 2003. Drivaren är konkurrenskraftig (Harwarders now competitive). *Skogforsk Resultat, No. 5, 2003.* [In Swedish with a summary in English]

Bergström, D., Nordfjell, T., & Bergsten, U. (2010). Compression processing and load compression of young Scots pine and birch trees in thinnings for bioenergy. *International Journal of Forest Engineering, Vol. 21, No. 1, pp. 31-39.*

Brunberg, T. (2012) Skogsbrukets kostnader och intäkter 2011 – kraftig ökning av skogsbrukskostnaden. (Forestry costs and revenues 2011 – major increase in costs) *Skogforsk Resultat, No. 6, 2012.* [In Swedish with a summary in English]

Brunberg, T. (2001) Hydroflex – nytt koncept för att utnyttja skotarnas lastkapacitet bättre (Hydroflex – a new system for maximizing forwarder payload). *Skogforsk Resultat, No. 13, 2001.* [In Swedish with a summary in English]

Bryant, R. C. (1913) *Logging – The principles and general methods of operation in the United States*. 1st edition, 1st thousand. John Wiley and Sons, New York.

Camp, A. (2002) Damage to residual trees by four mechanized harvest systems operating in small-diameter, mixed-conifer forests on steep slopes in Northeastern Washington: A case study. *Western Journal of Applied Forestry, Vol. 17, No. 1, pp. 14-22.*

Carlgren, M. (1925) *Skogsbruk och skogsindustrier i norra Sverige* (Forestry and forest industry in Northern Sweden). Almqvist & Wiksells Boktryckeri A-B, Uppsala and Stockholm. [In Swedish]

Carlsson, D., Rönnqvist, M. (2005) Supply chain management in forestry – case studies at Södra Cell AB. *European Journal of Operational Research, Vol. 163, No. 3, pp. 589-616.*

Carrillat, F. A., Jaramillo, F., & Mulki, J. P. (2007). The validity of the SERVQUAL and SERVPERF scales: A meta-analytic view of 17 years of research across five continents. *International Journal of Service Industry Management, Vol. 18, No. 5, pp. 472-490.*

Chorn, N. H. (1991) The "alignment" theory: Creating strategic fit. *Management Decision, Vol. 29, No. 1, pp. 20-24.*

Cox, A. (1999) Power, value and supply chain management. *Supply Chain Management: An International Journal, Vol. 4, No. 4, pp. 167-175.*

Cox, A., Watson, G., Lonsdale, C., Sanderson, J. (2004) Managing appropriately in power regimes: relationship and performance management in 12 supply chain cases. *Supply Chain Management: An International Journal, Vol. 9 No. 5 pp. 357-371*

Cronin, J. J., Brady, M. K., Hult, G. T. M. (2000). Assessing the effects of quality, value, and customer satisfaction on consumer behavioral intentions in service environments. *Journal of Retailing, Vol. 76, No. 2, pp. 193-218.*

Cronin Jr, J. J., Taylor, S. A. (1992). Measuring service quality: a reexamination and extension. *The Journal of Marketing, Vol. 56, No. 3, pp. 55-68.*

Cummings, T. G. 1978. Self-regulating work groups: A socio-technical synthesis. *Academy of Management Review, Vol. 3. No. 3, pp. 625-634.*

D'Amours, S., Rönnqvist, M., Weintraub, A. (2008) Using operational research for supply chain planning in the forest products industry. *INFOR: Information Systems and Operational Research, Vol. 46, No. 4, pp. 265-281.*

Das, T. K., Teng, B. S. (2000). A resource-based theory of strategic alliances. *Journal of Management, Vol. 26, No. 1, pp. 31-61.*

Das, T. K., Teng, B. S. (2003). Partner analysis and alliance performance. *Scandinavian Journal of Management, Vol. 19, No. 3, pp. 279-308.*

Dodson, E., Hayes, S., Meek, J., Keyes, C. R. (2015) Montana logging machine rates. International *Journal of Forest Engineering, Vol. 26, No. 2, pp. 85-95.*

Draulans, J., deMan, A.-P., Volberda, H. W. (2003). Building alliance capability: Management techniques for superior alliance performance. *Long Range Planning, Vol. 36, No. 2, pp. 151-166.*

Drolet, S., & LeBel, L. (2010). Forest harvesting entrepreneurs, perception of their business status and its influence on performance evaluation. *Forest Policy and Economics, Vol. 12, No. 4, pp. 287-298.*

Dyrendahl, S. (1988) Från arbetshäst i jordbruk och skogsbruk till sport- och rekreationshäst (From working horse in agriculture and forestry to the sport and leisure horse). *Kungliga Skogs- och Lantbruksakademiens Tidskrift, No. 20 (supplement), pp. 239-262.* [In Swedish]

Edlund, J. (2012) *Harvesting in the boreal forest on soft ground – Ways to reduce ground damage.* Licenciate thesis. Swedish University for Agricultural Sciences, Umeå.

Eisenhardt, K. M. (1989) Agency theory: an assessment and review. *The Academy of Management Review, Vol. 14, No.1, pp. 57-74.*

Ekman, W., Eneroth, O., Hanngren, H., Hellström, O., Kinnman, G., Klason, P., Löf, A., Magnuson, G., Nordquist, M., Sundblad, G., Wesslén, G. (1922) *Handbok i skogsteknologi* (Forest technology handbook). C. E. Fritzes, Stockholm. [In Swedish with a table of contents in German]

Elmuti, D., Kathawala, Y. (2001) An overview of strategic alliances. *Management Decision, Vol. 39, No. 3, pp. 205-217.*

Eliasson, L. (2005) Effects of forwarder tyre pressure on rut formation and soil compaction. *Silva Fennica, Vol. 39, No. 4, pp. 549–557.*

Eliasson, L., Lageson, H. (1999) Simulation study of a single-grip harvester in thinning from below and thinning from above, *Scandinavian Journal of Forest Research, Vol. 14, No. 6, pp. 589-595.*

Eliasson, L., von Hofsten, H., Johannesson, T., Spinelli, R., Thierfelder, T. (2015) Fuel consumption and chip size distribution for open drum chippers. *Croatian Journal of Forest Engineering, Vol. 36, No. 1, pp. 11-17.*

Enander, K.-G. (2011) Forestry policy in the 20th century. In: Jansson, U. (2011) Agriculture and forestry in Sweden since 1900 – a cartographic description. *National Atlas of Sweden.*

Eriksson, A., Eliasson, L., Hansson, P.-A., Jirjis, R. (2014) Effects of supply chain strategy on stump fuel cost: A simulation approach. *International Journal of Forestry Research, Vol. 2014.*

Erlandsson, E. (2013) The impact of industrial context on procurement, management and development of harvesting services: A comparison of two Swedish forest owners associations. *Forests, Vol. 4, No. 4, pp. 1171-1198.*

Ersson, B. T. (2014) Concepts for mechanized tree planting in southern Sweden. Doctoral thesis. *Acta Universitatis agriculturae Sueciae, 2014:76*. Swedish University for Agricultural Sciences, Umeå.

Farrel, M. J. (1957) The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General), Vol. 120, No. 3, pp. 253-290*

Flodman, B. (1942) Skogsarbetsläran – dess arbetsfält och mål (Forest work study – Its aims and field of study). *SKOGEN 1942, p. 137.* [In Swedish]

Fryk, J. (2013) *Skogforsk 20 år – Forskning och utveckling för ett långsiktigt, lönsamt skogsbruk på ekologisk grund* (Skogforsk 20 years – Research and development for a long term profitable and ecologically based forestry). Skogforsk.

Furness-Lindén, A. (2013) Agreed documents – Lowering transaction costs in forestry contracting. In: Belbo, H. 2013. Contractor forestry. Proceedings of the 2013 OSCAR workshop in Honne, Norway, 11-13 November 2013. *Rapport fra Skog og Landskap, No. 17, 2013.*

Furness-Lindén, A. (2008) Affärsutveckling i relationen stor kund/liten leverantör – vad kan skogsbruket lära? (Business development: large customer–small supplier relations what can forestry learn from the process?) *Redogörelse från Skogforsk, No. 1, 2008.* [In Swedish with a summary in English]

Furness-Lindén, A., Norin, K. (2007) Erfarenheter från Södra Skogs anbudsupphandling av drivningstjänster (Experiences from Södra Skog's call for tender in silvicultural services). *Skogforsk Resultat No. 14, 2007.* [In Swedish with a summary in English]

Geete, E. (1927) Nya redskap och andra förbättringar vid skogsavverkningen. *SKOGEN, 1927 s.57-61.* [In Swedish]

Gellerstedt, S. (1998) A self-leveling and swiveling forestry machine cab. *International Journal of Forest Engineering, Vol.9 No.1, pp. 7-16.*

Grant, R. M. (1996) Toward a knowledge-based theory of the firm. *Strategic Management Journal, Vol. 17, Special issue 2, pp. 109-122.*

Grant, R. M., Baden-Fuller, C. (2004). A knowledge accessing theory of strategic alliances. *Journal of Management Studies, Vol. 41, No. 1, pp. 61-84.*

Grönroos, C. (1997) Value-driven relational marketing: From products to resources and competencies. *Journal of Marketing Management, Vol. 13, No. 5, pp. 407-419.*

Guimier, D. Y. (1999) Canadian forestry operations in the next century. *International Journal of Forest Engineering, Vol.10 No.1, pp. 7-12.*

Hagner, S. (2005) Skog i förändring (Forests in transition). *Skogs- och lantbrukshistoriska meddelanden nr 34*. Kungl. Skogs- och Lantbruksakademien. [In Swedish]

Hansson, J.-E. (1965) Samband mellan personvariabler och prestation vid huggningsarbete (The Relationship between individual characteristics of the worker and output of work in logging operations). *Studia Forestalia Suecica, No. 29, 1965.* [In Swedish with a summary in English]

Heinimann, H. R. (2007) Forest operations engineering and management – the way behind and ahead of a scientific discipline. *Croatian Journal of Forest Engineering, Vol. 28, No. 1, pp. 107-121.*

Henriksson, R. (1990) Den stora norrlandsutredningen vid IUI 1939-1948 (The big Norrland investigation at the Industry's Institute for Investigations 1939-1948). *IUI Working Paper, No. 269.* [In Swedish]

Hägglund, B. & Lundell, S. (1994) Framtidens skogsarbetare (The forest worker of the future). *SKOGEN, No. 6/7, 1994, p. 38.*

Häggström, C. (2015) Human factors in mechanized cut-to-length forest operations. Doctoral thesis. *Acta Universitatis Agriculturae Sueciae, 2015:59*. Swedish University for Agricultural Sciences, Umeå.

Ketchen, D. J., Hult, T. M. (2007) Bridging organization theory and supply chain management: The case of best value supply chains. *Journal of Operations Management, Vol. 25, No. 2, pp. 573–580.*

Kinnman, G. (1925) Flottning (River floating). In: Carlgren, M. *Skogsbruk och skogsindustrier i norra Sverige* (Forestry and forest industry in Northern Sweden). Almqvist & Wiksells Boktryckeri A-B, Uppsala and Stockholm. [In Swedish]

Kinnman, G. (1930) Skogsteknologi (Forest technology). *Svenska jordbrukets bok*. [In Swedish]

Kotler, P. (1967) *Marketing Management – analysis, planning, and control.* Prentice-Hall.

LeBel, L., & Norin, K. (2008, June). From reactive contractors to proactive entrepreneurs, a comparison of the Canadian and Swedish approach. *In Proceedings of the 31st Annual Meeting of the Council of Forest Engineering (pp. 22-25).*

LeBel, L. G., Stuart. W. B. (1998) Technical efficiency evaluation of logging contractors using a nonparametric model. *Journal of Forest Engineering, Vol. 9, No. 2, pp. 15-24.*

Lee, H. L. (2004) The triple-A supply chain. *Harvard business review, Vol. 82, No.10, pp. 102-113.*

Lindberg, K. E. (1917) Svensk och norsk flottningslagstiftning och flottningsförhållanden – Intryck från en studieresa (Swedish and Norwegian river floating law and river floating conditions – Impressions from a study trip). *Finska Forstföreningens Meddelanden, Specialundersökningar No. 8.* Helsingfors. [In Swedish].

Lindroos, O. (2012) Evaluation of technical and organizational approaches for directly loading logs in mechanized CTL harvesting. *Forest Science Vol. 58, No. 4, pp. 326-341.*

Lundgren, N., Sundberg, U. (1958) Tekniska och fysiologiska studier av maskinbarkning (Technical and physiological studies on mechanical barking). *Meddelanden från statens skogsforskningsinstitut, Vol. 48, No. 1, pp. 1-72.* [In Swedish with a summary and discussion in English]

Lundgren, N., Sundberg, U., Lindholm, A. (1955) En undersökning av arbetstyngden vid användning av motorsågar i skogen (A study of work strain while using power saws in the forest). *Meddelanden från statens skogsforskningsinstitut, Vol. 45, No. 10., pp. 5-46.* [In Swedish with a resumé in English]

Lähtinen, K., Haara, A., Leskinen, P., Toppinen, A. (2008) Assessing the Relative Importance of Tangible and Intangible Resources: Empirical Results from the Forest Industry. *Forest Science, Vol. 54, No. 6, pp. 607-616.*

Maloni, M., Benton, W. C. (2000) Power influences in the supply chain. *Journal of Business Logistics, Vol. 21, No. 1, pp. 49-74.*

Manner, J. (2015) Automatic and experimental methods to studying forwarding work. Doctoral thesis. *Acta Universitatis agriculturae Sueciae, Vol. 128, 2015*. Swedish University for Agricultural Sciences, Umeå.

Martilla, J. A., & James, J. C. (1977). Importance-performance analysis. *Journal of Marketing, Vol. 41, No. 1, pp. 77-79.*

Mattsson-Mårn, L. (1953) Science of forest labour, its objects, methods, application in Sweden and present position at the Royal School of Forestry. *Bulletin of the Royal School of Forestry, No. 18, 1953, pp. 108-130.*

Matzler, K., Bailom, F., Hinterhuber, H. H., Renzl, B., Pichler, J. (2004). The asymmetric relationship between attribute-level performance and overall customer satisfaction: a reconsideration of the importance–performance analysis. *Industrial Marketing Management, Vol. 33, No. 4, pp. 271-277.*

Mellgren, P. G. (1989). More Reliable Multi-Function Wood-Harvesting Machines In the Future?. *Journal of Forest Engineering, Vol. 1, No. 1, pp. 17-22.*

Mäkinen, P. (1997) Success factors for forest machine entrepreneurs. *Journal of Forest Engineering, Vol. 8, No. 2, pp. 27-35.*

Morales, D. O., Westerberg, S., La Hera, P. X., Mettin, U., Freidovich, L., Shiriaev, A. S. (2014) Increasing the Level of Automation in the Forestry Logging Process with Crane Trajectory Planning and Control. *Journal of Field Robotics, Vol. 31, No. 3, pp. 343–363.*

Möller, J. (1998) Virkesmätning med skördare [Harvester-based wood scaling]. *Skogforsk Resultat No. 16, 1998.*

Nellbeck, L. (2015) Sågverksindustrin och kontakterna med marknaden (The sawmilling industry and its market relations) In Pettersson, R. (2015) Sågad skog för välstånd – Den svenska sågverksindustrins historia 1850-2010 (Sawn forests for welfare – The history of the Swedish sawmilling industry 1850-2010). *Skogs- och lantbrukshistoriska meddelanden nr 70*. Kungl. Skogs- och Lantbruksakademien. [In Swedish]

Nilsson, P. O. (2011) Energy production. In: Jansson, U. (2011) Agriculture and forestry in Sweden since 1900 – a cartographic description. *National Atlas of Sweden.*

Nordansjö, I. (2011) Technical advances in forestry. In: Jansson, U. (2011) Agriculture and forestry in Sweden since 1900 – a cartographic description. *National Atlas of Sweden.*

Nordfjell, T., Björheden, R.,Thor, M., Wästerlund, I. (2010) Changes in technical performance, mechanical availability and prices of machines used in forest operations in Sweden from 1985 to 2010. *Scandinavian Journal of Forest Research, Vol. 25, No. 4, pp. 382-389*.

Nuutinen, Y., Väätäinen, K., Asikainen, A., Prinz, R., Heinonen, J. (2010) Operational efficiency and damage to sawlogs by feed rollers of the harvester head. *Silva Fennica, Vol. 44, No. 1, pp. 121-139.*

Oh, H. (2001). Revisiting importance–performance analysis. *Tourism Management, Vol. 22, No. 6, pp. 617-627.*

Orgård, O. (2006) *Skogen blev till guld – Skoglig utveckling under 1950-60-talen* (The forest became golden – Development in the forest through the 1950's and 1960's). Bräcke Tryckeri.

Palm, R. (2011a) Sawmill industry. In: Jansson, U. (2011) Agriculture and forestry in Sweden since 1900 – a cartographic description. *National Atlas of Sweden.*

Palm, R. (2011b) Forest industry. In: Jansson, U. (2011) Agriculture and forestry in Sweden since 1900 – a cartographic description. *National Atlas of Sweden.*

Parasuraman, A., Zeithaml, V. A., Berry, L. L. (1988). SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing, Vol. 64, No. 1, pp. 12-40.*

Pettersson, R. (2011) Economics in the forest. In: Jansson, U. (2011) Agriculture and forestry in Sweden since 1900 – a cartographic description. *National Atlas of Sweden.*

Pettersson, R. (2015a) Sågverksindustrins stagnationstid 1900-1950 (The stagnation period for Swedish sawmilling industry 1900-1950). In Pettersson, R. (2015) Sågad skog för välstånd – Den svenska sågverksindustrins historia 1850-2010 (Sawn forests for welfare – The history of the Swedish sawmilling industry 1850-2010). *Skogs- och lantbrukshistoriska meddelanden nr 70*. Kungl. Skogs- och Lantbruksakademien. [In Swedish]

Pettersson, R. (2015b) Sågverksindustrins storhetstid 1850-1900 (The heydays of Swedish sawmilling industry 1850-1900). In Pettersson, R. (2015) Sågad skog för välstånd – Den svenska sågverksindustrins historia 1850-2010 (Sawn forests for welfare – The history of the Swedish sawmilling industry 1850-2010). *Skogs- och lantbrukshistoriska meddelanden nr 70*. Kungl. Skogs- och Lantbruksakademien. [In Swedish]

Ravald, A., Grönroos, C. (1996). The value concept and relationship marketing. *European Journal of Marketing, Vol. 30, No. 2, pp. 19-30.*

Rennel, J. (2010) *Långsiktigt värdeskapande och värdeförstöring – Framgångsrika och misslyckade investeringar i skogsindustrin* (Long-term value creation and value destruction – Successful and failed investments in the forest industry). Spearhead Production, Solna. [In Swedish]

Ringdahl, O., Hellström, T. and Lindroos, O. (2012) Potentials of possible machine systems for directly loading logs in cut-to-length harvesting. *Canadian Journal of Forest Research Vol. 42, No. 5, pp. 970-985.*

Sarkar, M. B., Echambadi, R., Cavusgil, S. T., Aulakh, P. S. (2001). The influence of complementarity, compatibility, and relationship capital on alliance performance. *Journal of the Academy of Marketing Science, Vol. 29, No. 4, pp. 358-373.*

Schön, L. (2000) *En modern svensk ekonomisk historia: tillväxt och omvandling under två sekel* (A modern Swedish history: growth and development through two centuries). Studentliteratur. [In Swedish]

Segebaden, G. v. (1964) Studies of cross-country transport distances and road net extension. *Studia Forestalia Suecica, No. 18, 1964.*

Sjunnesson, S. (2011) Associations and organisations in the forestry sector. In: Jansson, U. (2011) Agriculture and forestry in Sweden since 1900 – a cartographic description. *National Atlas of Sweden.*

Smith, A. (1776) *An inquiry into the nature and causes of the wealth of nations.*

Stigler, G. J. (1957) Perfect competition, historically contemplated. *The Journal of Political Economy, Vol. 65, No. 1, pp. 1-17.*

Sundberg, U. (1991) An energy analysis of the production at the Great Copper Mountain of Falun during the mid-17th Century. *Supplement to the Journal of Forest Engineering, pp. 4-16.*

Taylor, F. W. (1911) *The Principles of Scientific Management*. Harper & Brothers Publishers. New York and London, 1911.

Teljstedt, H. (1974) Maskinellt skogsarbete i konstljus – Ergonomiska aspekter på syn- och belysningsförhållanden (Artificial lighting in forest machine operations – Ergonomic aspects of sight and light). *Studia Forestalia Suecica, No. 120, 1974.*

Thor, M. (2012) Forskning och innovation för produktiv och skonsam skogsteknik (Research and innovation for productive and environmentally friendly forest technology). *Kungl. Skogs- och Lantbruksakademiens Tidskrift, No. 1, 2012.* [In Swedish]

Tikkanen, L., Ovaskainen, H., Palander, T. (2009) Adaptive tree bucking using group-guiding of harvesters: A simulation approach. *Scandinavian Journal of Forest Research, Vol. 24, No. 3, pp. 258-263.*

Uusitalo, J., Kokko, S., Kivinen, V.-P. (2004) The effect of two bucking methods on Scots pine lumber quality. *Silva Fennica, Vol. 38, No. 3, pp. 291–303.*

Van Hoek, R. I., Mitchell, A. J. (2006) The challenge of internal misalignment. *International Journal of Logistics: Research and Applications, Vol. 9, No. 3, pp. 269-281.*

Vannby, K. (2011) *Skoglig organisation, historik och förändringar, samt befattningshavare inom Svenska Cellulosa AB SCA och dess fusionerade skogsföretag 1930-2011* (Organization, history and development, and officers of the forest division of Svenska Cellulosa AB SCA and its merged forest companies 1930-2011). SCA. [In Swedish]

Von Eckermann, H. (1925) Träkolstillverkningen i Norrland (Charcoal production in Norrland). In: Carlgren, M. (1925) *Skogsbruk och skogsindustrier i norra Sverige* (Forestry and forest industry in Northern Sweden). Almqvist & Wiksells Boktryckeri A-B, Uppsala and Stockholm. [In Swedish]

Wernerfelt, B. (1984) A resource-based view of the firm. *Strategic Management Journal, Vol. 5, No. 2., pp. 171-180.*

Williamson, O. E. (1979) Transaction-Cost Economics: The Governance of Contractual Relations. *Journal of Law and Economics, Vol. 22, No. 2, pp. 233-261.*

Yang, C.-C. (2005) The refined Kano's model and its application. *Total Quality Management, Vol. 16, No. 10, pp. 1127–1137.*

Yang, J., Wang, J., Wong, C. W., Lai, K. H. (2008). Relational stability and alliance performance in supply chain. *Omega, Vol. 36, No. 4, pp. 600-608.*

Öhman, E. (2013) Hjulskotarens tekniska utveckling (The wheel forwarder's technical development). Master's thesis. *Arbetsrapport No. 395, 2013,* Swedish University for Agricultural Sciences. [In Swedish with a summary in English]

6.2 Unpublished literature

Byström, F., Troedsson, H. (2010) Stora Skogs utveckling 1940 – 2009, ett försök till historieskrivning (The development of Stora Skog 1940-2009, a historical description). [In Swedish]

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