OULUN AMMATTIKORKEAKOULU

Roxana Contreras

SWOT Analysis of Current State of Information and Communication Technology in Finnish Forest Sector

SWOT Analysis of Current State of Information and Communication Technology in Finnish Forest Sector

Roxana Contreras
Master's thesis
Spring 2023
Water and Environmental Management
Oulu University of Applied Sciences

ABSTRACT

Oulu University of Applied Sciences
Water and Environmental Management

Author(s): Roxana Contreras
Title of the thesis: SWOT Analysis of Current State of Information and Communication Technology in Finnish Forest Sector
Thesis examiner(s): Mohamed Asheesh
Term and year of thesis completion: Spring 2023 Pages: 26

The forest industry is currently experiencing rapid digitalization. The case of Finland is particularly important, due to the large impact that the information and communication technology (ICT) and forestry sectors have in the economy. Both sectors, ICT and forestry, individually constitute critical components of the Finnish economy, with large impact on the domestic turnover.

The objective of this thesis is to study and to evaluate the competitiveness and strategic position of the combined fields of ICT and forestry in Finland, mainly because as of now, this type of study addressing both components simultaneously has not been carried out.

The method chosen for this study is a qualitative analysis technique commonly used in strategic management to identify strengths, weaknesses, opportunities, and threats (SWOT). A wide variety of sources was used in this analysis, especially statistical analyses and reports published by public entities.

It was found that the prominence of both, ICT and forestry sectors in Finland have a main impact on the strengths, together with a solid infrastructure. On the other hand, high maintenance costs and the current state of deterioration of the vast forest road infrastructure, contribute to the main weaknesses.

ICT has great potential for ecologically sustainable digitalization in this evolving field, especially in forestry. Open data sources together with the widespread use of LiDAR technologies, were identified as opportunities. The main threats found correspond to issues with the right to privacy of forest owners. This is especially sensitive with the directive 2003/4/EC on public access to environmental information. The introduction of a new climate strategy creates uncertainty, and therefore it also represents a threat.

Two possible lines of research may be derived from this work for future analysis. Adding an analytical component to the analysis would be a natural step to follow, to assign weights to the elements identified in the SWOT analysis. This requires input and cooperation with local experts in each field at different levels of management within each organization and the assignment of weights must come from their expert opinion. Second, a deeper analysis of devices and software currently available and in use is needed; for this, a list of such applications should be proposed and tested individually.

Keywords: SWOT analysis, forestry, ICT solutions.

CONTENTS

1. INTRODUCTION

1.1 Evolution of Data and Availability of Solutions

The European Commission acknowledges that industry is experiencing a digital transformation, and therefore, a comprehensive strategy exists on digitizing the European industry. Technologies such as big data, artificial intelligence, internet of things, and robotics among others, are becoming central and they are rapidly occupying positions at the forefront of digitization and automation in key industry sectors (European Commission, 2018; COM (2017) 479). The availability and use of data undergo accelerated growth; digitalization, enabled by information and communication technology (ICT), is understood as the "continuing convergence of the real and virtual worlds" (Kagermann, H., 2015), and it is expected to be the main driver of change and innovation in all industrial sectors.

In any economy, industry is the component that produces material goods by means of highly mechanized and automatized processes (Kagermann, H., 2015). The so-called industrial revolutions are characterized by transitions in the mode of production led by mass industrial adoption of new technologies or innovations.

The first industrial revolution took place in the XVIII century with the introduction of steam power; this transition shifted the production mode from manual work to mechanized systems, having a major impact on productivity, especially in the textile industry (Kagermann, H., 2015; Lasi et al., 2014).

During the XIX century, technological advances in the field of electrical energy and its intense use catalyzed a transition, or second industrial revolution, which started a technological era; the introduction of the incandescent lightbulb led to the urban use of electrification, especially when the first central power stations were built. The transmission of information experienced a great leap during this era: the telegraph was invented. Factory electrification became common and as a result, production increased greatly, aided also by the ubiquity of research and development (R&D) in most of the industries, along with advances, particularly in the chemical and petroleum industries, the development of steel production and its impact on the construction of railways (Sharma & Singh, 2020).

A third major technological shift, that of widespread digitalization, began to develop during the second half of the XX century, with the introduction of transistors and integrated circuits which allowed the development of computers, and ultimately, the irruption and massive use of Internet and the World Wide Web (Smith, 2001).

Currently, a new fundamental paradigm shift is in progress. The term "Industry 4.0" was coined in Germany in the context of high-tech strategic initiatives supported by the federal government in recent years. Industry 4.0 refers to this shift towards advanced digitalization within factories, the interconnection given by internet of things and future-oriented technologies or smart objects, with future possible scenarios in which products control their own manufacturing process (Lasi et al., 2014). The virtual world is rapidly extending into the physical environment and having the ability to understand these current phenomena will help also understand how the economic, scientific, political, and social changes triggered by digitalization can be integrated in future innovation strategies (Kagermann, H., 2015). The intensive application of networked information-based technologies magnifies the complexity of manufacturing processes; smart factories make use of a manufacturing strategy which is highly integrated with digital information systems, machines, computers, and sensors; this concept is referred to as Smart Manufacturing (Davis et al., 2012). Internet of things (IoT) enables cyber physical systems (the actual fusion between the physical and virtual worlds through embedded computers and networks) to take over manufacturing, maintenance, inventory tracking and digitalization of operations; IoT can be defined as a network in which cyber physical systems cooperate with each other through unique addressing schemas, and in this sense, smart factories are application examples of IoT (Davis et al., 2012; Hermann et al., 2015).

The forestry industry is also changing and incorporating the use of new technology, although Choudhry & O'Kelly (2018), argue that forestry is lagging other industries in the adoption of digital technology, and that the forestry industry is traditionally regarded as low-tech, where processes are highly manual and analogue in nature. Conservative management styles, little corporate involvement (most forests worldwide are publicly owned), remoteness and difficult access, and lack of scale and expertise to adopt latest technologies in small privately owned forests, are some of the reasons supporting this idea of the forestry industry being delayed in the adoption of technology as compared to other industries.

This view, however, may be contested at least partially, considering the contrast in management practices and the state of development of the forestry industry in different countries. For example, the Finnish and Swedish forestry industries are usually seen as leaders in productivity and sustainability, while the Russian industry is considered to be more traditional in the sense of acquiring or using new technologies, as well as the infrastructure (Senko, 2021).

1.2 Aim

The aim of the thesis was to systematically analyse the general principles of strategic planning and thinking, which apply to the combined fields of ICT and Forestry in Finland. The purpose is to assess all the factors involved in the implementation of ICT solutions in the forestry industry, specifically in Finland, by means of integrating studies, statistics, technical articles and publications by policy makers and relevant stakeholders.

In the next chapters, a brief description of Finnish forests will be given and in the next sections some of the currently used technologies will be described.

2. BACKGROUND

2.1 Finnish Forestry Sector

The forestry industry in Finland is one of the key components of the economy, with a domestic turnover of EUR 31.6 billion in 2019, and a value of exported products of more than EUR 12 billion for the same year (Torvelainen et al., 2021). The territory of Finland is overwhelmingly represented by forests; forestry land corresponds to 26.3 million ha (86% of the territory), according to the Yearbook of Food and Natural Resource Statistics for 2020. A larger percentage of forestry land is located in Northern Finland (95%), while in Southern Finland, the share of the total land is 78% (Torvelainen et al., 2021).

The most general way of classifying land surface is by dividing it into forestry land, which corresponds to areas that are not used for any purpose other than forestry, and land used for other purposes (The Natural Resources Institute Finland, 2017). Three categories of productivity are assigned to forestry land: forest land, poorly productive forest land and unproductive land. Both, forest land and poorly productive forest land, correspond to wood-growing land, while unproductive land is usually depleted of trees or scarcely populated by trees. Furthermore, productive forestry land is classified according to the Nordic growth categories; forest land has an average tree stock annual growth of at least 1 m^3/ha, while on poorly productive forest land the average annual growth is in the range 0.1-1 m^3/ha, and on unproductive land, less than 0.1 m^3/ha (The Natural Resources Institute Finland, 2017; Metsähallistus, 2021).

The Nordic forestry sector, especially in Finland and Sweden, is characterized by high productivity and profitability, aided by investment in soil preparation, road construction (road density of approximately 10 m/ha), active silvicultural systems and the use of wood-based energy (Senko, 2021). Finland is often seen as a model of sustainable forest management, where the amount of wood that grows yearly exceeds the amount used (P&PC, 2018). In the last 50 years, the annual growth of forests has almost doubled; currently such growth is 125 million m^3 (as compared to the previous inventory of 2009-2013), and the biomass of growing stock, including stem wood, branches, foliage, stump, and roots, has increased by 65 million tonnes (Torvelainen et al., 2021).

The intensive forest management approach used in Finland allows increased timber quality and optimized forest structure. Under this type of management, active regeneration improves with artificial planting and soil preparation (even fertilization when needed) (Senko, 2021). Also, regular thinning is practiced over a forest rotation to maximize the forest crop; in Finland, forest management and wood production are based on thinning, and the preferred type is low thinning, in which, felling focuses on the smallest trees, which are lagging in competition. Normally, before the final cutting, thinning is carried out two or three times (Kärhä et al., 2004; Kontinen et al., 2014).

Having proper access to forest resources is key to the economic success of this activity; most of the raw wood is delivered by trucks, directly from forests to factories, which support transport around the year. The average forest road density is approximately 10 m/ha and the forwarding distance is on average 200 m (Greis et al., 2014). In Finland there is an extensive road network of almost 160000 km, exclusively for forestry activities. More than 60% of the roads are private, while 35% of them are located in state forests and areas belonging to forest companies (Greis et al., 2014).

2.2 Industry 4.0 Concepts in Forestry

The term "precision forestry" is sometimes used to refer to the approach of using advanced technologies to improve forest management results. The emergence and rapid evolution of digital information and communication technology (ICT) created new challenges and opportunities for the global forest sector (Choudhry & O'Kelly, 2018; Hetemäki & Nilsson, 2005). However, the impacts of emerging technology on forestry are less clear than in other industries. One aspect that makes forestry different to other sectors, is the natural cycle of forestry itself; for example, trees being planted currently, may not reach their optimal harvesting age for decades (depending on the species and type of forest), so, overall, forest-sector issues such as wood production, forest-product markets, forest conservation, or biodiversity require a long-term view that may contrast with the accelerated development the ICT, which evolves at a much faster rate (Hetemäki & Nilsson, 2005).

One of the earliest references to the impacts of ICT on forestry refers to the changes in the consumption of communication paper products, e.g., office paper, books, magazines, etc., to a "paperless" mode. Which soon after the massive introduction of computers, and before the introduction of smart phones, was perceived as a paradox, because such improvements, instead of reducing the use of paper, had apparently caused an increase in paper resource use (Hetemäki et al.,2005), but more recent studies suggest that indeed, although early displacement technologies served to increase paper use, it was probably due to lagged effects (Briscoe, 2022; Kim, 2021).

One of the challenges of clearly identifying the real impact of ICT on forestry, is that forestry is a heterogenous field, which comprises a series of business activities, such as management (inventory management, silviculture and plantation, operational planning), harvesting operations (harvest planning, felling, reforesting), manufacturing, and timber transportation (road construction, transportation planning, loading and unloading) (Feng & Audy, 2020). Accordingly, ICT applications for this sector can also be categorized depending on the core components of most forest business, which include several categories within management, operations, and logistics. ICT applications play important roles in areas such as manufacturing operations management, logistics, commercial forest management and supply chain, among others (Hetemäki et al.,2005).

Enterprise resource planning systems (ERP), for example, are tools for business management; usually ERP software contains modules supporting most of the functional areas within companies, such as planning, manufacturing, sales, marketing, accounting, etc. An ERP system usually combines information from transactional data, production planning and scheduling models to determine the manufacturing capacity and raw-material requirements needed to meet market orders, like manufacturing and transporting products to customers. These systems also support inventory tracking and even support controlling the material used in the paper-making process (Hetemäki et al., 2005; Do et al., 2014).

Forest inventory management is an essential aspect in forest management; forest resources are usually assessed by quantifying the volumes of tree stands. Tree species, their dimensions, ages, growth, and land use must be determined, and this is traditionally done through field surveying (Feng & Audy, 2020). In the last 40 years, there has been a rapid evolution in remote-sensing technology, which has high impact on forest inventory management. Light detection and ranging (LiDAR), is a remote sensing method which uses light in the form of a pulsed laser to measure variable distances (or range) between a target and the LiDAR sensor, which can be operated from airborne vehicles armed with a global navigation satellite system receiver, inertial measurement unit (IMU) and computational unit with storage capacity, that enables the system to accurately measure georeferenced 3D point clouds, generating precise three-dimensional information, containing the latitude, longitude and height that correspond to a particular point on the Earth's surface from which a laser pulse was reflected (Räty, 2020; Raj et al., 2020; NOAA, 2021).

There are two large components in logistics in commercial forestry, namely, the transportation of raw material from forests to manufacturing centers and transporting consumers products from manufacturing centers to the markets. However, the supply chain is a complex network involving organizations, technologies, and functions that enable the flow of either raw material, finished products or even services (Anderson & Mitchel, 2016), and the current development of IT systems, allows greater precision and efficiency in logistics. In Finland, particularly, a variety of such solutions are widely used, especially in storage management systems and multi-client or contractor-focused fleets (Väätäinen et al, 2021).

One of the immediate effects of ICT is the enhancement of productivity while the management of forest resources has been highly enhanced by the introduction of global positioning systems and satellite imaging. ICT can improve the performance of a business in three broad ways: automation of a process, thus saving labor costs; facilitation of process reengineering to align procedures with the company's strategy; and assisting companies to cross business boundaries to form collaborative, interorganizational relationships that will benefit all businesses concerned (Ravarini et al., 2000).

3 QUALITATIVE ANALYSIS OF ICT APPLICATIONS FOR FORESTRY IN THE FINNISH MARKET

3.1 Materials and Methods

A literature review was carried out, along with other publicly available material related to ICT, forestry and the current affairs in Finland, and in other regions as well, to use as comparison. A variety of sources were used, such as academic journals, professional magazines, statistical reports, and government and public entity reports.

A review of currently available ICT products and services for forestry in Finland was carried out, through an analysis of this sector, as a whole. All the information was summarized in the form of a SWOT analysis. SWOT is an acronym that stands for strengths, weaknesses, opportunities, and threats. SWOT analysis is a very common tool in strategic management and planning. The concept is widely used by consultants and researchers alike, not only within companies, but the level of analysis and usage of SWOT covers from organizational level to entire industries and even entire countries (Helms & Nixon, 2010; Sabbaghi & Vaidyanathan, 2004).

Normally, internal and external factors are considered, so that the internal factors of the organization being analyzed (or product and service, or sector, in this case), are under its control, while the external factors, are those over which, is not possible to have influence. Strengths (S) and weaknesses (W) correspond to internal factors, while opportunities (O) and threats (T) correspond to external factors (Sabbaghi & Vaidyanathan, 2004).

Under “Strengths”, individual qualities (either tangible or intangible) that support or increase the output of this industry or organization are included; here, only the positive aspects that are already in place must be added.

Under “Weaknesses”, the qualities that prevent success or further development are included, for example, the areas in which the organization struggles, possible inefficiencies or past mistakes are among the topics which are useful to address.

The external, positive factors must be listed under “Opportunities”. Here, the market or business environment must be analyzed in order to identify the factors that support prosperity.

Identifying the “Threats” requires conducting detailed research about the external factors that represent a risk for the business itself, such as shifts in consumer behavior, government regulations, technology becoming obsolete, or problems in the supply chain (Helms & Nixon, 2010; Fergison, 2019).

A SWOT analysis is an organized list of the organization’s or sector’s greatest strengths, weaknesses, threats and opportunities that can be used to assess a changing environment and respond proactively or as a part of a planning process. The most common practice is to organize the analysis in a 2x2 matrix as shown in the template in figure 1 below (Fergison, 2019).

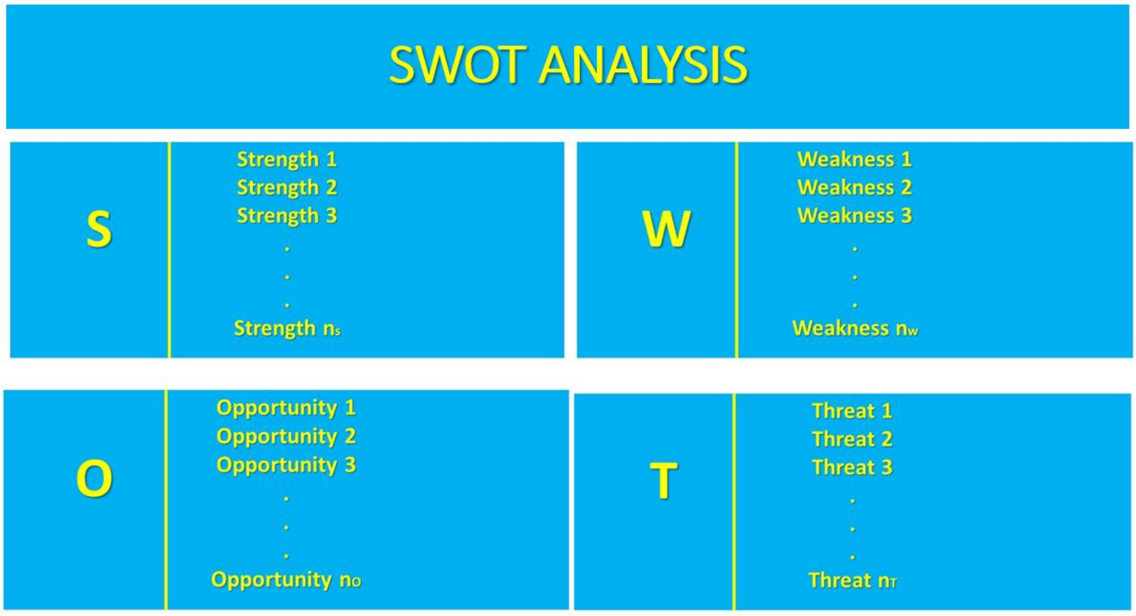

*FIGURE 1***.**Template of a typical SWOT analysis. The left column represents the positive aspects, and the right column represents the negative aspects. The top row represents the internal aspects while the bottom row represents the external aspects over which the organization does not have influence. Source: R. Contreras (2022).

The number of questions or aspects identified per category is not necessarily the same, that is why the template matrix may have a different number of items under strengths, weaknesses, opportunities, and threats.

Once the SWOT results have been identified, they can be used to develop short-term and long-term strategies; the purpose is to maximize the positive aspects and minimize negative ones (Fergison, 2019). A method often used for this purpose consists of studying how the strengths, weaknesses, opportunities, and threats overlap with each other. For example, using the strengths from the list, to build ways to use them to maximize the opportunities (this is known as strengths-opportunities strategy). Similarly, the same list of strengths can be used to minimize the threats that were identified in the analysis (Berry, n.d.).

3.2 Characterizing the ICT sector for the forestry industry in Finland.

The ICT sector is a key component of the Finnish economy; the turnover of the ICT industry in Finland in 2021 was 16.5 billion euros (Palokangas, 2022). In March of 2021, the Ministry of Transport and Communication announced a climate strategy for ICT sector: “Harnessing data bits to combat climate change” (Ministry of Transport and Communications, 2021). Even though the ICT sector, which uses digital technology to create value from data, is in general responsible for a considerable percentage of global electric power and, supposedly, for a considerable amount of greenhouse gas emissions. Moreover, digitalization is one of the main consumers of critical raw materials, which are demanded as well by other sectors like renewable energies, i.e., there is competition for the same raw materials or minerals (Eerola et al., 2021).

However, at the same time the ICT sector is a major resource sinkhole, it has also the potential to contribute to the resource consumption and emission reduction in other industries and sectors (like transport for example), by promoting ecologically sustainable digitalization. A six-goal strategy was proposed by a working group including business representatives, public organizations, and research institutions (Ministry of Transport and Communications, 2021): 1) Improving ICT infrastructure energy efficiency and introducing zero carbon sources of electric power. The goal is to decrease emissions from the ICT sector by aiming at energy efficiency through the design, construction, and operation of communication networks (for example by making greater use of the surplus heat generated by data centers). 2) Seeking a climate friendly data economy. Considering that data trafficking and electricity consumption has increased with the rising number of services, the design of software and services must favor the minimization of their energy consumption, avoiding developments that require more processing power and hardware capacity. 3) Longer hardware life and recycling of precious metals. The purpose is to aid the sustainability of primary material production and traceability of materials in Finland and the European Union. 4) An overview of the environmental impacts of digitalization. One of the main challenges is the lack of transparent and centralized data on environmental impacts of the ICT sector, both, regarding the carbon footprint, but also regarding the impact of information and communication technologies in reducing emissions in other sectors. 5) Making consumers aware of environmental impacts. Through availability of information, consumer behavior has the ability to influence the environmental impacts of the ICT sector. 6) Use of emerging technologies in climate work and environmental protection. It is expected that new technologies, including artificial intelligence, robotics, automated systems, and others, will provide solutions to environmental problems, such as reducing the energy and material consumption involved in processes.

From the previous paragraphs, weaknesses, threats, and opportunities can be identified. The perceived intrinsic negative impact of the ICT sector on energy and resource consumption is a weakness, while the prospect of ecologically sustainable digitalization represents an opportunity, since it would involve external factors, that is, the strategy as a whole may represent an opportunity for the sector, while the individual points of the strategy are mixed; some of them are actually threats: the fourth and the fifth strategies may be threats because they imply data that can work against the industry by restricting certain aspects and the expense of being fully environmentally friendly may be too high for some developers. They highlight that further studies are needed, therefore there is an unknown factor being introduced linked to threats.

This study must contemplate the intersection between the ICT sector and the forestry sector, hence, specific characterization of the local features of the sector must be carried out. Therefore, the following paragraphs will attempt to classify these features and put them in the context of this analysis.

3.2.1 Remoteness and Accessibility

Forestry operations and wood supply reliability depend heavily on the quality of forest roads. In addition to functioning mainly to serve the forestry sector, forest roads are also highly regarded for recreational functions (hiking, hunting, and fishing, for example), and they also play an important role in public safety, as emergency vehicles use them too. The existence and condition of a forest road network is one of the most important factors in assessing economic accessibility of the forest resources. Poor development of forest transportation infrastructure may negatively impact the level and efficiency of production (Karelia cross-border cooperation programme - CBC, 2018). In Finland, this is particularly critical, since forestry is one of the key sectors for the economy of the country, which accounts for approximately 17% of export revenue, and in 2021, the value of forest industry production was over EUR 18 billion (Ministry of Agriculture and Forestry of Finland, 2022).

One of the obstacles to forest operations and introduction of technology is the difficult access due to the remoteness of the terrain where forests usually locate (Choudhry & O'Kelly, 2018). But Finland has an advantage because the road density is rather high, with an average forwarding distance of 300-400 m in the southern areas and nearly 1000 m in the northern areas (Väätäinen et al., 2021). In the northern areas, also the availability of forest biomass is poorer than in the south; the longer forwarding distances for forest biomass result in higher supply-chain greenhouse gas emissions (Jäppinen, 2013). The length of the forest road network is approximately 160000 kilometers, of which, more than 60 % are located in private forests, 20 % belong to state forests and 15 % to forest companies (Greis & Kontinen 2014). Metsähallistus manages an area that contains more than 36000 kilometers of forest roads and nearly 1000 bridges. The yearly cost of forest road maintenance and extension is nearly EUR 17 million, and nearly 100 kilometers of new roads are built every year. Winter forest roads are different; they are built temporarily under winter conditions on top of snow and ice and they play an important role in providing access to roadless wilderness areas, and they are particularly important for timber harvesting in Lapland, where nearly half of the timber is harvested using winter roads. Besides winter forest roads built on top of snow and ice, 10 to 20 kilometers of ice roads, which are other type of winter roads, are built annually across water bodies, providing access to islands while reducing the need of building bridges (Metsähallistus).

The great extension of the forest road network in Finland has the disadvantage of requiring much maintenance and surveillance, especially due to deterioration. The condition of private forest roads has been deteriorating in the last years and the funding for their maintenance has decreased by 70%. One of the reasons for the deterioration has been the ever-increasing size of trucks, which on the other hand has the advantage of reducing the transport costs due to a decrease in fuel consumption, helping businesses to be profitable and maintaining the interest of forest owners in selling their raw material (Jäppinen, 2013, Waga, 2021).

For the surveillance and maintenance of forest roads, current inventory procedures still require visiting these locations. This is a case in which there is an obvious need for services to perform these duties remotely, without the need for on-site inspection, and LiDAR is one of the technologies with most potential to succeed in this task. LiDAR is currently used most commonly for forest resource inventories like species recognition or stock estimates (Waga, 2021).

3.2.2 Network coverage and digital divide.

Internet connectivity plays a big role in digital transformation. The remoteness of forests usually contributes to the lack of internet connectivity, that in turn limits the digital transformation of forest operations. Improvement of harvesting performance, transport operations, forestry worker safety and sustainability operations may be positively impacted by enhanced internet connectivity, as it can improve coordination and work planning through communication between machines; machine utilization can be optimized by remote control and automation, facilitating the diagnosis of mechanical problems and repair or purchase of parts while in a remote area (Anonymous, FPInnovations, 2021).

The concept of digital divide was introduced by the National Telecommunications and Information Administration of the United States Department of Commerce, in 1999 (NTIA, 1999). In that publication, the digital divide is defined as the gap between users who have access to new forms of information technology and users who lack access. Yet, other authors include more dimensions than just purely physical access to such technology, like skills, usage access and motivation; Van Dijk (2006) concludes that in terms of physical access, the gap has practically been removed in developed countries, while the gap regarding digital skills and the use of applications is more persistent. Van Deursen and Helsper (2015) refer to a “third-level” digital divide, which concerns disparities in the returns from internet use within populations with good and similar access to ICT and infrastructure, in other words, gaps in individuals’ capacities to translate their ICT and internet access into favorable offline outcomes. In this context, the first-level divide refers to physical access to technology, and the second-level divide refers to differences in skills and usage patterns. Analyzing the third-level divide is relevant in societies with near-universal internet access, such as the Netherlands, which was the topic of the study by Van Deursen and Helsper (2015). The study is pertinent here because Finland has similarities with the Netherlands in terms of access to ICT technologies. Among their findings, a relevant one regards the achievements of institutional outcomes related to public services of the government; they observed that in general, achievement was higher in the age group 35-65 as compared to the group aged 16-35; however, specifically in healthcare-related institutional outcomes, people aged 16-35 benefited more than the other group. Moreover, both, the level of education and frequency of internet use were found to be positively related to the ability to obtain government outcomes, like access to public information and ability to maintain contact (Van Deursen and Helsper, 2015).

Third-level digital inequalities have also been observed in Finland, mainly due to poor online access, poor digital skills and negative attitudes towards digital services, in areas such as social welfare and healthcare services (Heponiemi et al., 2021). The topic has been explored as well in the context of forestry; Pynnonen et al. (2021), analyzed whether decision-making about forest use may be enhanced by digitalization and e-services. More specifically, they focused on Metsaan.fi, which is a Finnish state-funded e-service portal for forest owners and forest service providers. The platform distributes free of charge forest inventory and environmental data that would otherwise be too expensive for individual actors to produce. It also acts as a common ground for forest owners and service providers allowing them to leave and receive offers and bids for forest-related work (Stenman, V., 2021; Pynnonen et al., 2021). The analysis about the features of forest owners that have relation with the use of Metsaan e-service showed that age is not an important factor to predict usage and level of activity; instead, the size of the forest property was found have an impact on using the service; the larger the forest property the higher was the probability of actively using Metsaan.fi. Also, the attributes of the service are more important in determining the use than the socio-demographic factors.

3.2.3 Type of forest ownership, management, and forest data

Approximately 60% of the forest land in Finland is privately owned by families, and the average size of this type of holding is 30 ha. State-owned forests account for 25% of the total forest area; 9% is owned by companies and 6% by municipalities and community groups Finland (Katila, 2017; Rantala et al., 2020). Flexibility in forest management approach in Finland is a strength that can facilitate the introduction of new digital services, particularly those linked to open forest services (Kankaanhuta et al.,2021).

The law on forest information, in Finland, was revised in 2016-2018 upon request of the European Commission (EC) concerning the lack of openness of forest data in order to comply with Directive 2003/4/EC on public access to environmental information, and within a national policy agenda to improve digital forest services and support the bioeconomy development (Rantala et al., 2020).

In many cases, there is a conflict between the right to information and the right to privacy, especially in Finland (Rantala et al., 2020).

The Finnish National Forest Program (NFP) has traditionally focused on aspects related to economic sustainability, such as diversifying and expanding forest-based business and entrepreneurship, and particularly increasing the use of wood. The main recent changes of this program have been the increased interest in developing services to contribute to diversification of the structure of forest industries (Katila, 2017).

Julhä et al., (2020) carried out a financial analysis of a sample of 83 wood-harvesting companies of different sizes (small, medium, and large) from Eastern and Northern Finland. One of their main findings is that small companies struggle with profitability and debt, although the short-term liquidity is on average good. Large companies have a competitive advantage, and they are able to attract and retain the most skilled forest machine operators, which is the most important resource for wood-harvesting enterprises. The educational level of the entrepreneurs is correlated to the profitability of the companies. The majority of the entrepreneurs (more than 80%) have educational degrees or practical knowledge, at least equivalent to vocational training in forestry or forest machine operation; however, higher degrees are rare among medium and smaller enterprises, especially education in business management (Julhä et al., 2020).

Some trends that can be observed in many countries where forestry is prominent, are particularly present in Finland. For example, the decline in employment in traditional forestry centered on timber production and logging, while harvest levels have significantly increased at the same time. The increased mechanization in logging operations and the widespread and rising use of contractors in harvesting operations, transport, and silviculture, are believed to be responsible for such job losses (Owuor et al., 2021).

The number of graduates from technician certificate and degree levels in Finland, grew from 1990, reaching a peak in 2000, when it started declining. The trend has been slightly different for bachelor's level where the number of graduates increased from 271 in 2000 to 405 in 2010 but dropped to 320 in 2015 (Owuor et al., 2021).

4 SWOT ANALYSIS

In the previous sections, a literature review was carried out to characterize the ICT sector for the forestry industry in Finland. Here, all the information is summarized in the form of a SWOT analysis, identifying strengths, weaknesses, opportunities, and threats of the sector.

4.1 Strengths

Forestry and the ICT sector represent the key components of the Finnish economy, and therefore they intrinsically, represent a strength. The fact that these two sectors are so important for the country requires big effort and investments to create solid infrastructure that supports the industrial activities related to their development. Accessibility and connection are facilitated by the vast forest road infrastructure that exists in Finland; the first-level digital divide is practically inexistent, and the great internet connectivity enables the possibility of development and improvement of forest operations through digital solutions in remote areas.

The forest management approach in Finland is characterized by its flexibility, which has the strength of facilitating the introduction of new digital services, especially services linked to open forest data and applications; moreover, in the recent years there has been an effort to expand the offer of open data for forestry, through public platforms available for owners, entrepreneurs and businesses.

4.2 Weaknesses

The ICT-related activities are currently considered to be responsible for a considerable percentage of global electric power, and at the same time, forestry activities, such as accessing the resources, harvesting, and forwarding, are also energy-intense activities; therefore, one of the first weaknesses that can be identified for this sector is the high consumption of energy resources, either fuel or electric power.

The nature of forestry activities in Finland is such that they require access to remote places through a well-developed road infrastructure. The intrinsic negative side of possessing a good road network is its high maintenance cost and current deterioration due to low budget; moreover, surveillance and maintenance of forest roads still relies on on-site inspection.

Third-level digital divide still exists in Finland, and it may prevent or difficult the access and correct use of digital resources. Besides this digital divide, there is a clear gap in education which relates also to profitability in businesses. Small businesses have more debt and more difficulties retaining well-trained workers.

4.3 Opportunities

At first glance, ICT is responsible for too much energy use; however, it is also acknowledged the potential to contribute to the resource consumption and emission reduction in other industries and sectors (like transport for example), by promoting ecologically sustainable digitalization. The current state of development of LiDAR technologies can contribute to reducing the need for on-site inspection, either for maintenance or for operations.

The existence of free-of-charge platforms, such at Metsaan.fi and the availability of open data can contribute to or encourage business development.

4.4 Threats

Changes in regulations always represent threats to established industries. The case is not different for both ICT and forestry; the climate strategy introduced by the Ministry of Transport and Communication adds uncertainties related to possible restrictions and future studies to determine them.

The ever-decreasing budget and resources for maintenance and repair of the extensive forest road network represent a moderate threat, which may be compensated if ICT technologies such as LiDAR continue to be implemented and used to support the infrastructure, to make its surveillance more efficient.

The directive 2003/4/EC on public access to environmental information, which has been revised in Finland in order to secure compliance is a strong threat to the right to privacy of forest owners, which creates a conflict with the right to information in Finland.

4.5 SWOT Analysis Summary

In the previous sections, the main components of the SWOT matrix were identified from the extensive document review. These results are summarized in table 1.

TABLE 1 *Summary of the SWOT analysis*

<table>
<tr><th colspan="2">SWOT Analysis</th></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>1. Highly developed ICT and Forestry industries
2. Solid forest road infrastructure
3. Great internet connectivity in remote areas
4. Flexible forest management approach
5. Open data availability</td><td>1. Energy-intense activities
2.High maintenance cost and deterioration of extensive forest road infrastructure
3. Third-level digital divide and educational gap
4. Profitability gap between small and large businesses</td></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>1. Potential for ecologically sustainable digitalization
2. LiDAR technologies
3. Open data and free platforms</td><td>1. Introduction of new climate strategy
2. budget and resources for maintenance and repair of forest roads
3. Threats to the right to privacy of forest owners</td></tr>
</table>

5 DISCUSSIONS AND CONCLUSIONS

This study was focused on the current state of development, understood as a new fundamental paradigm shift, sometimes referred to as “Industry 4.0”, in the context of the Finnish forestry sector.

The topic is particularly challenging because the use of data, and its availability are being adopted at a very accelerated rate, while forestry is a complex industry that comprises many fields, each with their own characteristic time scales and natural cycles.

Digitalization is being implemented in all relevant industries and at first glance, it seems like forestry may be lagging other fields. However, each example must be analyzed on a case-by-case basis. The Finnish case, for example, provides a good opportunity to study the impact of rapid digitalization on the forest industry, because both ICT and forestry, separately, constitute critical sectors for the Finnish economy, with large impact on domestic turnover.

A SWOT analysis was performed to identify, in a qualitative way, the strengths, weaknesses, opportunities and threats of the combined sector. As expected, the strengths were led by the prominence of both forestry, and ICT sectors in Finland. The availability of open data and connectivity encourages the penetration and acquisition of new technologies in the forest industry. Also, the flexible forest management approach and the existence of a solid infrastructure facilitate the use of new technologies.

Some weaknesses were identified, mainly related to the high energy demand of the sector. Also, while the network of forest roads is very extensive, the negative side is its high maintenance cost which requires a significant budget to cover for it. There are many small privately owned forests and small businesses related to forestry; a problem with profitability and debt was identified for small businesses as compared to large ones.

ICT has an enormous potential to contribute to resource consumption and emission reduction in other industries and sectors by promoting ecologically sustainable digitalization. Technologies such as LiDAR are currently contributing to the reduction of on-site management activities. Moreover, the availability of open data and platforms are seen as opportunities for this sector.

The literature reviewed here strongly suggests that changes in regulations are perceived as threats to established industries. In the case of both ICT and forestry, the climate strategy introduced by the Ministry of Transport and Communication creates uncertainties regarding possible restrictions in the future.

Another revision introduced in Finland, the directive 2003/4/EC on public access to environmental information, was also perceived as a strong threat, especially by forest owners in relation to the right of privacy and the conflict with the right to information.

A moderate threat comes from the decreasing budget and resources allocated for the maintenance and repair of the forest road network; it is identified as a moderate threat because technologies such as LiDAR support the efficiency of surveillance, and this continues to be a trend.

Two possible lines of research, which are well beyond the scope of this thesis, may be derived from this work for future analysis. First, adding an analytical component to the analysis would be a natural step to follow, to assign weights to the elements identified in the SWOT analysis. This would require substantial input and cooperation with local experts in each field at different levels of management within each organization and the assignment of weights must come from their expert opinion. Second, it would be important to perform a deeper analysis of devices and software currently available and in use; for this, a list of such applications should be proposed and analyzed individually.

REFERENCES

Anderson, N., & Mitchell, D. (2016). Forest operations and woody biomass logistics to improve efficiency, value, and sustainability. Bioenergy Research, 9, 518-533.

Anonymous. FPInnovations. Forest Operations. Advanced connectivity for digital transformation of forest operations (2021). https://web.fpinnovations.ca/advanced-connectivity-for-digital-transformation-of-forest-operations/

Berry, Tim (n. d.). How to Do a SWOT Analysis for Better Strategic Planning. Bplans articles. https://articles.bplans.com/how-to-perform-swot-analysis/

Briscoe, M. D. (2022). The paperless office twenty years later: Still a myth? Sustainability: Science, Practice and Policy, 18(1), 837-845.

Choudhry, H., & O'Kelly, G. (2018). Precision forestry: a revolution in the woods. Basic materials, paper & forest products.

COM (2017)479, Investing in a smart, innovative and sustainable Industry A renewed EU Industrial Policy Strategy, 13.09.2017.

Davis, J., Edgar, T., Porter, J., Bernaden, J., & Sarli, M. (2012). Smart manufacturing, manufacturing intelligence and demand-dynamic performance. Computers & Chemical Engineering, 47, 145-156.

Do, T. N., Moga, S., Lenca, P. (2014). Random Forest of oblique decision trees for ERP semi-automatic configuration. Advanced Approaches to Intelligent Information and Database Systems (Studies in Computational Intelligence 551) Chapter: 3. Publisher: Springer. Editors: Janusz Sobecki, Veera Boonjing, Suphamit Chittayasothorn.

Eerola, T. (Ed.), Eilu, P. (Ed.), Hanski, J., Horn, S., Judl, J., Karhu, M., Kivikytö-Reponen, P., Lintinen, P., & Långbacka, B. (2021). Digitalization and natural resources. Geological Survey of Finland. Open File Research Report No. 50/2021 https://tupa.gtk.fi/raportti/arkisto/50_2021.pdf

European Commission, Directorate-General for Research and Innovation, A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment: updated bioeconomy strategy, Publications Office, 2018, https://data.europa.eu/doi/10.2777/792130.

Feng, Y., & Audy, J. F. (2020). Forestry 4.0: a framework for the forest supply chain toward Industry 4.0. Gestão & Produção.

Furgison, Lisa (2019). SWOT Analysis Steps Series. Bplans articles. https://articles.bplans.com/swot-analysis-identify-your-strengths/

Greis I, Kontinen K (2014) Forest roads in Finland: practices for the development of forest roads in Russia. In: Itkonen K (ed) Ideas, practices and tools for the development of wood procurement. Mikkeli University of Applied Sciences. p. 35-42.

Helms, M. M., & Nixon, J. (2010). Exploring SWOT analysis–where are we now? A review of academic research from the last decade. Journal of strategy and management.

Heponiemi, T., Gluschkoff, K., Leemann, L., Manderbacka, K., Aalto, A. M., & Hyppönen, H. (2021). Digital inequality in Finland: access, skills and attitudes as social impact mediators. New Media & Society, 14614448211023007.

Hermann, M., Pentek, T., & Otto, B. (2015). Design principles for Industrie 4.0 scenarios: a literature review. Technische Universität Dortmund, Dortmund, 45.

Hetemäki, L., Nyrud, A., & Boston, K. (2005). ICT and the Forest sector: the history and the present. Information technology and the forest sector/Ed. Hetemäki, L. & Nilsson, S.

Hetemäki, L. and S Nilsson (Eds.). 2005. Information Technology and the Forest Sector. IUFRO World Series, Vol. 18.

Jäppinen, E. (2013). The effects of location, feedstock availability, and supply-chain logistics on the greenhouse gas emissions of forest-biomass energy utilization in Finland.

Jylhä, P., Rikkonen, P., & Hamunen, K. (2020). Size matters–an analysis of business models and the financial performance of Finnish wood-harvesting companies. Silva Fennica, 54(4).

Kagermann, H. (2015). Change through digitization—Value creation in the age of Industry 4.0. In Management of permanent change (pp. 23-45). Springer Gabler, Wiesbaden.

Kankaanhuhta, V., Packalen, T., & Väätäinen, K. (2021). Digital transformation of Forest Services in Finland—A case study for improving business processes. Forests, 12(6), 781.

Karelia cross-border cooperation programme – CBC. Logroad: Innovative forest road data for improving economic accessibility of Boreal forest resources (2018). https://kareliacbc.fi/en/projects/logroad-ka1024#home.

Katila, P. (2017). Forestry development priorities in Finnish national forest programmes. International Forestry Review, 19(1), 125-138.

Kim, J., Kim, Y., Oh, S., Kim, T., & Lee, D. (2021). Estimation of environmental impact of paperless office based on simple model scenarios.

Kontinen, K., Kutznetsov, E., Leinonen, T.A. (2014). Thinning practices in Finland. In: Itkonen K (ed) Ideas, practices and tools for the development of wood procurement. Mikkeli University of Applied Sciences. p. 13-17.

Kärhä, K., Rönkkö, E., & Gumse, S. I. (2004). Productivity and cutting costs of thinning harvesters. International Journal of Forest Engineering, 15(2), 43-56.

Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. Business & information systems engineering, 6(4), 239-242.

Metsähallistus. State-owned areas managed by Metsähallistus (2021). https://www.metsa.fi/en/lands-and-waters/state-owned-areas/

Metsähallistus (n. d.). We maintain a large network of forest roads. Sustainable forestry – work for the future. https://www.metsa.fi/en/responsible-business/metsahallitus-forestry/forest-roads/

Ministry of Agriculture and Forestry of Finland. Sustainable forest management. Forests and the economy (2022). https://mmm.fi/en/forests/forestry/sustainable-forest-management/forests-and-the-economy

Ministry of Transport and Communications. (2021, March 3). Finland announces climate strategy for ICT sector: harnessing data bits to combat climate change [Press release]. https://valtioneuvosto.fi/en/-/finland-announces-climate-strategy-for-ict-sector-harnessing-data-bits-to-combat-climate-change.

The Natural Resources Institute Finland. Quality description of Forest resources statistics (2017). https://www.luke.fi/en/tilastot/metsavarat/quality-description-of-forest-resources-statistics

NOAA. What is LiDAR? National Ocean Service website, https://oceanservice.noaa.gov/facts/lidar.html, 02/26/21.

NTIA (1999) Falling through the net: defining the digital divide. National Telecommunications and Information Administration. https://www.ntia.doc.gov/legacy/ntiahome/fttn99/contents.html.

Owuor, J.A., Giessen, L., Prior L.C., Cilio, D., Bal, T.L., Bernasconi, A., Burns, J., Chen, X., Goldsmith, A. A., Jiacheng, Z., Kallioniemi, M., Kastenholz, E., Larasatie, P., Lehikoinen, A., Lewark, S., Maciel Viana, C., Montero de Oliveira, F.E., Oberholzer, F., Sharik, T.L., Schwärzli, J., Schweinle, J., Viitanen, J., Wästerlund, D., Yovi, E. Y. and Winkel, G. (2021). Trends in forest-related employment and tertiary education: insights from selected key countries around the globe. European Forest Institute (EFI).

Palokangas, Jukka. Technology Industry/Finnish economic outlook, May 2022. (2022). Teknologiateollisuus-Technology Industries of Finland. https://teknologiateollisuus.fi/sites/default/files/inlinefiles/FinnishTechnologyIndustry_May%202022.pdf

Pynnönen, S., Haltia, E., & Hujala, T. (2021). Digital forest information platform as service innovation: Finnish Metsaan.fi service use, users and utilisation. Forest Policy and Economics, 125, 102404.

P&PC Staff (2018, May 18). Finnish forest digitalization transforming industry. Research & Innovation. Pulp & Paper Canada. https://www.pulpandpapercanada.com/finnish-forest-digitalization-transforming-industry-1100001160/

Raj, T., Hanim Hashim, F., Baseri Huddin, A., Ibrahim, M. F., & Hussain, A. (2020). A survey on LiDAR scanning mechanisms. Electronics, 9(5), 741.

Rantala, S., Swallow, B., Paloniemi, R., & Raitanen, E. (2020). Governance of forests and governance of forest information: Interlinkages in the age of open and digital data. Forest Policy and Economics, 113, 102123.

Ravarini, A., Tagliavini, M., Pigni, F., & Sciuto, D. (2000, November). A framework for evaluating ERP acquisition within SMEs. In AIM International Conference (pp. 1-11).

Räty, J. (2020). Prediction of diameter distributions in boreal forests using remotely sensed data. Doctoral dissertation, Dissertationes Forestales 294. 47 p. https://doi. org/10.14214/df. 294.

Sabbaghi, A., & Vaidyanathan, G. (2004). SWOT analysis and theory of constraint in information technology projects. Information systems education journal, 2(23), 1-19.

Senko, S. (2021). Nordic forest solutions as an opportunity to reform the forestry sector in Russia: A case study in the Republic of Karelia. Dissertationes Forestales 320. 61 p. https://doi.org/10.14214/df.320.

Sharma, A., & Singh, B. J. (2020). Evolution of industrial revolutions: A review. International Journal of Innovative Technology and Exploring Engineering (IJITEE), 9(11), 66-73.

Smith, B. L. (2001). The third industrial revolution: Policymaking for the Internet. Colum. Sci. & Tech. L. Rev., 3, 1.

Stenman, V. (2021). Finnish Forest Data-Based Metsään. fi-services. Big Data in Bioeconomy: Results from the European DataBio Project, 309-319.

Torvelainen, J., Forsman, L., Outa-Pulkkinen, P., Salo-Kauppinen, R., & Söderkultalahti, P. (2021). E-yearbook of Food and Natural Resource Statistics for 2020: Statistical facts on agriculture, forestry, fisheries and hunting in Finland.

van Deursen AJ and Helsper EJ (2015) The third-level digital divide: who benefits most from being online? Communication and Information Technologies Annual: Digital Distinctions and Inequalities Studies in Media and Communications 10: 29–53.

van Dijk JAGM (2006) Digital divide research: achievements and shortcomings. Poetics 34: 221–235.

Väätäinen, K., Anttila, P., Eliasson, L., Enström, J., Laitila, J., Prinz, R., & Routa, J. (2021). Roundwood and biomass logistics in Finland and Sweden. Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering, 42(1), 39-61.

Waga K. (2021). Unpaved forest road quality assessment using airborne LiDAR data. Dissertationes Forestales 316. 48 p. https://doi.org/10.14214/df.316.