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Measuring Digital Maturity in the CNC Manufacturing Industry

- A Maturity Evaluation Model

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Mäta digital mognad i CNC-tillverkningsindustrin - En utvärderingsmodell för digital mognad

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Sammanfattning

Tillverkningsindustrin står inför den fjärde industriella revolutionen, Industri 4.0, orsakad av snabb utveckling av teknik och implementering av digitalisering. Tillverkande företag måste skapa förståelse för och anpassa sig till dessa förändringar för att bibehålla sin konkurrenskraft. Många företag inom industrin har svårt att förstå hur de ska starta sin förändring och vilka fördelar som finns i anslutning till deras verkstäder. För att underlätta den komplicerade situationen finns idag mognadsmodeller utvecklade för att hjälpa företag i deras digitala förändringsarbete.

Sandvik Coromant är ett av de största företagen inom metallbearbetnings industrin och de vill hjälpa sina kunder genom att utveckla en utvärderingsmodell för digital mognad. I dagsläget finns det ingen modell på marknaden riktad mot CNC-tillverkningsindustrin och tidigare forskning har identifierat de existerande modellernas dåliga anpassning mot små- och medelstora företag. Därav är syftet med detta arbeta att undersöka vilka fördelar CNC-tillverkningsindustrin kan se genom digitalisering samt att utveckla en mognadsmodell genom att svara på följande forskningsfråga, *"Hur ska en mognadsmodell vara uppbyggd för att förse företag av alla storlekar och inom alla segment av CNC-tillverkningsindustrin med information kring hur de ska fortsätta framåt i sitt digitala förändringsarbete?"*

Den digitala mognadsmodellen utvecklades genom en grundlig litteraturstudie och en iterativ process med fokus på användaren av modellen. 28 inledande intervjuer hölls vilket ledde till sex konceptiterationer utvärderade genom 27 koncept test. Den slutgiltiga mognadsmodellen utvärderar ett företag genom frågor kring nuvarande situation samt framtida målbild inom 4 dimensioner, *Datainsamling, Dataanalys, Mjukvaror* och *Anställda & kompetenser*. Genom att besvara frågorna blir företaget försett med ett radardiagram vilket visar nuvarande och framtida situation i relation till varandra samt ett benchmark företag. De blir vidare försedda med historier från liknande företag med målet att föreslå sätt att ta sig framåt i deras förändringsarbete. Modellens struktur och frågor är skapade för att passa alla storlekar av företag inom alla segment av CNC-tillverkningsindustrin.

Nyckelord: *Mognadsmodell, Industri 4.0, digitalisering* och *företagsutvärdering*

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Abstract

The manufacturing industry stands before the fourth industrial revolution, Industry 4.0, caused by fast-changing technology and implementation of digitalization. Manufacturing companies need to realize and adapt to these changes to maintain their competitive advantage. Many of the companies in the industry struggle to understand how to start their transformation and what benefits are connected to their workshops. To aid in this complex situation there are maturity models developed to assist companies in this transformation.

Sandvik Coromant are one of the biggest companies within the metal cutting manufacturing industry and they want to aid their customers on the digitalization transformation journey by developing a maturity evaluation model. There is currently no model on the market aimed at the CNC manufacturing industry and earlier research have identified that existing models are ill-fitting towards small and medium enterprises. Therefore, this thesis aimed at investigating how the CNC manufacturing industry can benefit from digitalization and to develop a maturity model by answering the following research question, "*How should a maturity model be structured in order to provide companies of all scales and in all segments within CNC manufacturing with information regarding how to move forward on their digitalization journey?"*

The maturity model was developed through an extensive literature search and an iterative process with focus on the users of the model. A total of 28 initial interviews were performed that lead up to six concept iterations assessed by 27 concept tests. The finalized maturity model evaluates a company through questions regarding the current and future target state within 4 dimensions, *Data collection, Data analysis, Software and Employees & Competences*. By answering these questions, the company is provided with a radar chart displaying their current and future state in relation to each other and to a benchmark company. They are further provided with stories from similar companies aimed at contributing with suggestions for how to move forward in their transformation. The model structure and questions are developed to suit companies of all scales and within all segments of the CNC manufacturing industry.

Keywords: *Maturity model, Industry 4.0, digitalization* and *company evaluation*

FOREWORD

In this chapter those who have helped, assisted, inspired and cooperated in this thesis project will be acknowledged.

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Michaela Hillerström & Isabelle Petersson

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NOMENCLATURE

This chapter presents abbreviations used in this thesis together with their explanations.

Abbreviations

CAM	Computer Aided Manufacturing
CNC	Computer Numerical Control
CPS	Cyberphysical System
ERP	Enterprise Resource Planning
KPI	Key Performance Index
MES	Manufacturing Execution System
PLC	Programmable Logic Controller
SCM	Supply Chain Management
SMEs	Small and Medium Enterprises

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1 INTRODUCTION

This chapter presents the background of this thesis and provides information regarding the subject of digitalization and Industry 4.0 and will motivate the purpose of the study. It will also discuss delimitations that were set up for the thesis work.

1.1 Background

The first industrial revolution came at the end of 18th century and began with the introduction of mechanical manufacturing equipment (Gökalp et.al., 2017). The transformation towards mechanization was done by using hydro power and steam and was the turning point for going from agricultural to an industrial society. The second industrial revolution came around the shift of the 20th century and involved mechanics that consumed electric power and was originated by changes such as Henry Ford´s assembly line. In the end of 1969, the third industrial revolution came when the implementation of information and communication technology was introduced. This was the beginning of an automated industry with intelligent systems such as robotics (Gökalp et.al., 2017). Today the manufacturing industry stands on the verge of another major change, the fourth industrial revolution - Industry 4.0 - which is caused by digitalization of the industry (Kagermann, 2015; Ghobakhloo, 2018). These changes come through the rapid development of technology and impacts can be seen on society as well as businesses within all industries (Yuksel & Sener, 2017). Transforming into a digital industry means changing the ways of working, roles and business offerings as well as causing changes to processes, organizations, business and society (Parviainen et.al., 2017). The four industrial revolutions are visualized in Figure 1 below.

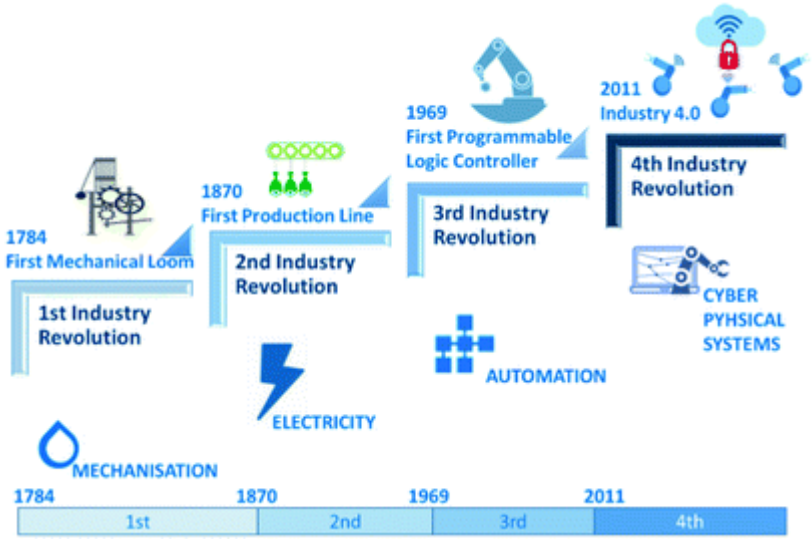

Figure 1. Visualization of industrial revolutions through time, from Gökalp et.al. (2017).

The digital transformation is according to Jacobi & Brenner (2018) due to customer demand on personalized services. This forces companies to adapt to digitalization in order to stay relevant and maintain their competitive advantage on the market (Quinton & Simkin, 2017). By digitizing and exploiting new technologies, a more flexible production and an ease to meet customer

requirements can be expected (Rojko, 2017). Many of the manufacturing companies are in the beginning of the digitalization journey and many struggles with defining a starting point for the transformation (Machado et.al., 2019). By not understanding the technology and processes for Industry 4.0 companies have a hard time seeing the potential (De Carolis et.al., 2017a). Companies need help finding solutions to a complex situation and how to utilize them to sustain their competitive advantages.

New technology is always seen as risky before enough knowledge and expertise is acquired. De Carolis et.al. (2017b) state that this is one of the causes for companies to hesitate before starting their transformation. To gain insights and help in this complex situation companies look for evaluation models to aid them in understanding their current situation, set up action plans to move forward and to show them the benefits with digitalization.

There are models on the market and under development from different companies and researchers created to aid in understanding the digital maturity and readiness of a company (Canetta et.al., 2018; De Carolis et.al., 2017a; De Carolis et.al., 2017b). Research suggests that the existing models need further development in areas relating to personnel, approach and implementation to provide usable results.

A company that would make use of implementing a maturity evaluation model to aid their customers is Sandvik Coromant. As one of the largest companies within the metal cutting manufacturing industry, they have a vision of shaping the future of manufacturing together with their customers and strives to develop services to increase efficiency, profitability, sustainability and knowledge for their customers (Sandvik Coromant, 2020b). They want to offer their customers adapted solutions that will help them save time and to help them move into a digitalized manufacturing. Sandvik Coromant currently provide digital offers in the areas of design and planning, manufacturing that can aid in lowering scrapping degree, effective machine maintenance, shorter set-up time, higher degree of flexibility for small batches and to bridge the competence gap (Sandvik Coromant, 2020a). Companies in the industry have come different far on the digitalization journey and possess different degrees of knowledge within this area (Schumacher et.al., 2016). Therefore, Sandvik Coromant would benefit from a maturity model to map their customers and through that offer suitable products and guidance for how to move forward.

1.2 Purpose

The thesis aims at investigating how the CNC manufacturing industry can benefit from digitalization and Industry 4.0 and to find out where the digital journey begins and what stages a company must pass through to become a digital company. This investigation will include both internal and external inputs and will result in a maturity evaluation model with connected methods for how to implement it for the CNC manufacturing industry. The maturity evaluation model should help investigate where on the digital journey a company is located. This should also assist Sandvik Coromant in providing suitable products depending on the customer maturity to help the customer forward in their digitalization transformation.

1.3 Delimitations

Focus for this thesis was put on digitalization of the CNC manufacturing industry since that is in line with Sandvik Coromant core business and a segment where they can further aid their customers. This is also where Sandvik Coromant current digital offers, which will be connected to the maturity model, are located. The model needs to provide the customers with comprehensible information while being tailored to Sandvik Coromant and the digital offers.

2 FRAME OF REFERENCE

This chapter presents findings from existing literature regarding the concept of digitalization and Industry 4.0. The literature research focuses on drivers and challenges for digitalization, how to manage such a transformation and a summary of existing maturity models of how to map a company´s digital maturity. In the end the research question is presented.

2.1 Digitalization and Industry 4.0

Digitalization, or Industry 4.0, is happening all around the world and in a study by Parviainen et.al. (2017) 92% out of 4800 business executives believed that in three years, digitalization and digital technology will be important for companies in order to stay relevant on the market. They further argue that it is apparent that this is a highly relevant topic and that the concept Industry 4.0 should be adopted sooner rather than later. Leyh et.al. (2016) state that Industry 4.0 is a concept that describes a shift from centralized production to one that is more flexible and self-controlled. Within this new type of production, everything from products to processes are digitized and interconnected to share and pass information and to distribute this along the value chain and networks. Parviainen et.al. (2017) say that there are mainly three reasons for a manufacturing company to start the digitalization journey and these are to improve internal efficiency, external opportunities and disruptive change. It is found that many companies often start the transformation focusing on the wrong things according to Schumacher et.al. (2016). They further state that this is connected to their inability to understand what the concept Industry 4.0 really is about and therefore set a misguided plan of action.

Technology

Many companies fear Industry 4.0 because it comes with a lot of changes and costly equipment, but it does not have to be that way according to World Economic Forum (2019). They state that the fourth industrial revolution will, by only replacing some of the equipment, have a high impact through connecting and optimizing existing infrastructure. For example, the first industrial revolution where 100% of the equipment was necessary to be replaced, and the third one where 80-90% needed to be replaced. Compare that to the fourth industrial revolution where only 40-50% needs to be replaced or upgraded. The key in Industry 4.0 is to take advantage of what is available and make the most out of that, learn how to utilize the capacity the machines possess and make the production as efficient as possible (World Economic Forum, 2019).

There are however a few concepts or keywords that are reoccurring in literature and that will play a huge role in digitalization. Some of them are listed below.

- ***Big Data & Data Analytics*** - Big Data is just data sets of high volume, but what makes it interesting is what the data can be used for (Mittal et.al., 2018). New technologies with analytic methods and tools are required to transform big volumes of data in an efficient way into useful information. Big Data can therefore be used as a tool for decision making by pattern recognition and not hypothesis driven decisions made by humans (World Economic Forum, 2019).

- ***Internet of Things, IoT*** - Internet of Things is a way to describe how physical "things" connect and communicate over the internet (Mittal et.al., 2018). The real-time information provided and shared will create an opportunity for business to improve their productivity, efficiency and give a better insight to their customers' needs and thereby secure their competitive advantage on the market (Siemens, 2020f).

- ***Cyberphysical Systems*** - Systems of which computational entities collaborates and how those system is connected to their surrounding physical world and their ongoing processes (Mittal et.al., 2018). These systems are providing and using data accessing and data processing services on the internet.

- ***Connectivity*** - To be able to build an intelligent factory and to fully explore the opportunities that comes with digitalization, connectivity among machines, systems and applications will play a huge role (Siemens, 2020b). It will let the companies master all the tasks of digitalization. Connectivity will bring systems together in a networked infrastructure consisting of smart objects, network and platform solutions, and it will allow machines and systems to be integrated and talk to each other.

- ***Cloud computing*** - Through the IoT a vast amount of data from different capital assets such as equipment, machines and controllers can be collected (Siemens, 2020d). Cloud computing will then provide the infrastructure for transmission of all data to the various applications used in the factory. Applications for example operators use on mobile devices or computers. Since companies work more and more with capturing all this data, cloud computing can be used to manage assets and overall operations.

- ***Cyber security*** - All these new opportunities with Big Data, IoT, connectivity and cloud computing will bring a great value to manufacturing companies (Siemens, 2020f). Despite the value given, companies need to prepare themselves for cyberattacks and online threats. Two essential steps here are to proactively prioritize cyber security and implement detailed incident response plans.

- ***Digital Twin*** - A Digital Twin is a virtual duplicate of a product, a machine or a process of a part or of a complete production site (Siemens, 2020c). The duplicate contains all the data relevant in order to create a simulation of the original. These types of simulations can help a company reduce both cost and time for a production process. Processes can for example be tested before commissioning and errors can be detected and fixed before coming to an expensive stage. Digital Twins can also be used as a tool for training operators and people responsible for maintenance, so they do not need to cause expensive delays when a process is stopped longer than necessary.

- ***Augmented Reality, AR & Virtual Reality, VR*** - These two technologies will help create a virtual environment using mobile devices, wearables etc. (Mittal et.al., 2018; Mittal et.al., 2019). This type of digital aids will allow for companies on different locations to help each other visually, it can for example be a supplier that needs to help a customer fix a broken machine from a distance.

- ***Advanced analytics / AI & Machine Learning*** - Intelligent software solutions can aid a manufacturing process to be more efficient and for example reduce its energy consumption by using the high volume of data generated on a shop floor by identifying trends and patterns without human interaction (Siemens, 2020a). AI software can eventually learn to detect many complex connections in systems that a human cannot. It can be everything from

autonomous transporters to machines performing quality control and adjust if needed. This technology is extremely important when striving towards an autonomous process (Siemens, 2020a).

- ***Overall Equipment Effectiveness, OEE*** - OEE analytics is a data-based equipment analysis that can help a company answer questions such as, why do machines sometimes stand still? How can the production run faster? How can rejects be avoided? (Siemens, 2020e). With an OEE analysis these questions can be answered by collecting, analyzing and act on data to make the most out of the equipment in the factory.

These are concepts or digital tools that will help a company make what they already have more efficient. It will allow manufacturers to maximize productivity and help them see the capacity that their existing workshop already holds according to World Economic Forum (2019). They also say that even though equipment does not need to be replaced to a 100%, there will be complementary solutions that will bring a certain cost.

One thing that companies need to keep in mind if they want to become a digitalized company is that there is a difference of being digitalized and digitized (Parviainen et.al., 2017). Digitalization is when changes in the organization occurs due to the adaption of digital technology. It is a more fundamental change then just digitizing existing processes. Because that is what digitizing is, it means to transform analogue data into a digital form. So, when implementing digital technologies, Parviainen et.al. state that a company needs to make sure that the digital capabilities support the business model transformation and that changes are made to make the most out of it. Otherwise a company will just have a lot of digital technology but are still not digitalized.

Drivers for digitalization

One thing that triggers a company to move into Industry 4.0 is the global competition and if a company wants to keep competing, they need to adapt fast (Rojko, 2017). Jacobi & Brenner (2018) say that it might not simply be enough to stay in the race and that not winning could mean not surviving at all. Winning this race could be hard since a simple change is not sufficient and a company needs to make a deep transformation to survive this transition. Castelo-Branco et.al. (2019) argue that a successful transformation towards digitalization can give the company new competitive advantages and change the position for the company on the market. Rojko (2017) says that even if this is a tricky journey it can be worth it and result in 10-20% and 10-30% in quality management, and production and logistic cost savings respectively. It can also shorten the time for new products to enter the market and contribute to a more friendly and flexible work environment. Making routine work automated can also contribute to a higher work satisfaction since it will free time for employees to develop new skills (Parviainen et.al., 2017).

Industry 4.0 will provide greater flexibility and robustness to production (Yuksel & Sener, 2017). The concept of Industry 4.0 includes the highest quality standards in engineering, planning, manufacturing, operational and logistics processes, and at the same time help to improve production processes, increase productivity by lowering party size values, and fulfill individual requests and short-term demands.

World Economic Forum (2019) highlights a few other drivers for this journey within production that will help a company become more autonomous. These are, connectivity that will create a link between data and therefore increase visibility, intelligence that will help with translation for decision-making and automate events, and flexible automation that will show remote movement and incorporate response mechanisms. They also highlight the importance of being an early adopter in order to get the biggest share of the benefits. They mean that companies that start early and does not sit around and wait for decreased technology and transition costs will gain the most and that the competitive advantage gained in the beginning outweigh the costs they have to put in at the start.

Challenges for digitalization

A major change such as digitalize an industry comes with a lot of challenges (Cordeiro et.al., 2019). A few challenges are, the lack of standardization of technology and regulation, requirement of high investment in technology, information security, and getting employees to accept this transformation as well as provide them with training of the new technologies. Sjödin et.al. (2018) have seen that a lack of a common vision among the employees are one of the main challenges when implementing Industry 4.0. They also mean that this is connected to an attachment to the old equipment combined with a worry regarding that new competences might be required. Jacobi & Brenner (2018) mean that acceptance among employees, and mainly older employees, will be a huge challenge as well as getting the shift towards a more risk-taking and open-minded organization approved in the company.

Digitalization means reduced operational complexity and at the same time increased complexity for digital components (Khajavi & Holmström, 2015). This technological change causes skepticism towards this transformation due to for example data loss, data integrity, data processing errors, problems with compatibility and information unavailability (Cordeiro et.al., 2019). With all the new devices connected to internet due to IoT, the threat of cyber-attacks will also increase. To prevent hackers from ruining factories or spread critical assets, both private and public sectors needs to make sure that the cyber security meets the highest standards (World Economic Forum, 2019). The complexity that comes with the technology causes many to doubt the connected benefits which creates hurdles for implementation (Sjödin et.al., 2019).

Other challenges that can occur and that a company has to overcome in order to survive is that they might be scaling too slowly, engage in too many proofs-of-concept, integrating to many isolated solutions and thereby create countless of data silos, or that they lack an integrated business case for Industry 4.0 technologies (World Economic Forum, 2019). Another challenge is that digitalization will increase the need for collaborations to make the shift easier and this will mean that challenges such as the need for new frameworks and standards, and new organizational models will be required (Kagermann, 2015).

According to Ghobakhloo (2018), Canetta et.al. (2018) and Parviainen et.al. (2017), these new ways of innovating will also affect the company's infrastructure, technology and management, manufacturing operations and their business model. Changes within these areas are a big challenge to overcome since many manufacturing processes have looked and been performed in a certain way for many years. This has established a culture that can be difficult to change according to Sjödin et.al. (2019).

2.2 Managing digitalization

World Economic Forum (2019) says that this revolution needs to be a common journey and that beacons from the industry leaders should lead the way. They want universities, start-ups and other technology providers to be involved in the innovation surrounding digitalization. Kagermann (2015) says that managing digital changes needs to play an important role already in universities, research institutes and government ministries. World Economic Forum (2019) also says, like Kagermann, that both the private and public sectors need to prepare the workforce for this transformation, change the education system and invest in lifelong training and learning to create workers suited for Industry 4.0 technologies. This, so companies can benefit from the opportunities of digitalization straight away. Below are three other topics presented, that highlights other areas companies must look at during this journey to be able to manage the transformation that follows.

Vison & Culture

For a company to make a successful digital transformation both Richter et.al. (2017) and Parviainen et.al. (2017) emphasize the importance of an organizational culture that can foster change. The culture needs to enable people to adapt and learn new technologies where machines are a tool to support the employees and not to replace them. For this to be possible, it is important for the company to alter their strategies where changes should be top priority in combination with bold digital leadership (Jacobi & Brenner, 2018). Jacobi and Brenner (2018) state that the ability of a CEO to communicate a clear digital vision backed with knowledge and actions is apparent for a successful transformation.

Strategy

Changing into Industry 4.0 does not require a completely new business model but requires companies to anticipate changes in customer needs and developments in technology. Lacking a digitalization strategy and not prioritizing competition will create obstacles for transformation (Parviainen et.al., 2017). A successful transformation is instead connected to constantly evolving the internal structures and beliefs surrounding innovation (Jacobi & Brenner, 2018). Siemens (2020f) says that manufacturing companies should have a “think big, start small, scale fast” approach when going into digitalization and incorporate for example IoT. This means that they should drive it from a business case and not pushing technology in just because of the potential benefits it shows.

According to World Economic Forum (2019) there are two routes to go by and these are not mutually exclusive and can complement one another on the digitalization journey. These two are, innovation in the end-to-end value chain and production system innovation. In the first route companies create new business by changing the economics of operation by innovating the whole value chain and offering new or improved value to their customers. In the second route they increase their competitive advantage by operational excellence and thereby increase productivity and quality performance (World Economic Forum, 2019).

Leadership and people

Inspiration and motivation within a company should come from the management and leaders who need to inform, guide and support their employees to get them onboard the change (Richter et.al., 2017). The leaders therefore require characteristics such as courage to change structures and processes combined with deep knowledge of digital business models (Jacobi & Brenner, 2018).

Employees stand in front of changes in processes and need to understand and handle new technology (Ghobakhloo, 2018). This can lead to a fear among older employees who may struggle with technology and feel that they will be exchanged for machines. This fear needs to be recognized by management who should emphasize the need for handicraft but also put focus on recruiting multi-skilled and flexible talents who by nature adopt to new technology (Ghobakhloo, 2018). World Economic Forum (2019) emphasized the need for understanding that the machine operators should not be replaced but enhanced by focusing on value-adding activities where human skills are needed. This will then create a more attractive workplace with less repeatability in work tasks and result in more interesting, productive and diversified routines. They mean that all employees enjoy responsibility that comes with new tasks that demands their skills to make dynamic decision-making in a changing work environment. They also say that the fourth industrial revolution has the potential to transform manufacturing sites to creative and exiting places to work and with the right training and preparation among employees they can play valuable roles as innovators and problem-solvers. If a company can do this, they will be able to attract the best and most talented employees of the next generation (World Economic Forum, 2019).

2.3 Digitalization for companies of all scales

The World Economic Forum (2019) have identified 16 lighthouse companies around the world, consisting of both larger corporations and small and medium sized enterprises, SMEs. These companies are frontrunners in the technological change towards Industry 4.0 and are leaders who can help others embark on this journey by providing insight into their own success stories. These lighthouses are also seen to change the financial and operational factors connected to benchmarking. World Economic Forum (2019) highlights differences for large corporations and SMEs when transforming into digital companies.

SMEs

Small and medium enterprises, SMEs, stand before a challenge of integrating Industry 4.0 (Müller et.al., 2017). Many are skeptical about the transformation and struggle to understand the financial investments needed combined with how it should be integrated in the current business model (Schumacher et.al., 2016). There is also a lack of knowledge regarding the basic Industry 4.0 technology and how it should be implemented (Mittal et.al., 2018). It is believed that these companies will struggle more than large companies when adapting to Industry 4.0 due to less resources and market shares (Ghobakhloo, 2018). This is a view that is not shared by the World Economic Forum (2019) who believe that SMEs will succeed by implementing solutions that do not require large investments. They also believe that SMEs are an essential part of the supply chain and it is therefore vital that they do this transformation to optimize the supply chain for companies of all scales.

To enable a successful transformation, it is more important than ever for SMEs to collaborate and assist each other in the transformation, promote innovation and achieve public acceptance (Kagermann, 2015). The author further states that it is necessary to create new frameworks for the collaborating companies to share strategies and organizational models for employees to perform a wide variety of tasks after short learning periods.

For SMEs to start their digital transformation a need of success stories is seen (Wiesner et.al., 2018). This is needed to provide guidance regarding how the transformation should be done and will according to the authors provide SMEs with the tools for how to start their own implementation.

Large companies

It is said that larger companies will have an easier time to adapt to the new ways of working since they have a large economic ground and have more resources than many of the SMEs (Ghobakhloo, 2018; Müller et.al., 2017). The larger companies are also thought to have better technological grounds than many of the SMEs, which is considered an important steppingstone for starting the transformation (Mittal et.al., 2019). There are other issues that comes with being a big cooperation when implementing bigger changes. According to Jacobi & Brenner (2018) one of the main problems is the bureaucracy.

Large companies are in some cases choosing to develop their own software platforms to support the IoT solutions which can force them to have to wait for their own development to succeed instead of buying a finished solution from other brands (Bilgeri et.al., 2017). The authors state that this can create internal tensions between the departments of the company regarding the question of the platforms market responsibility.

2.4 Existing maturity models

To start the digital transformation, it is important for companies to assess their digital readiness and gain a view of the goals and barriers connected (De Carolis et.al., 2017b; Cordeiro et.al., 2019). Digitalization has shown benefits that outweigh the associated costs of the change, but success is also connected to the company readiness. This is seen as evidence for the importance of understanding the company readiness and use it as a starting point when beginning the transformation journey (Ghobakhloo, 2018; De Carolis et.al., 2017b).

Maturity can be defined as a state of being ready, perfect or complete and the goal of using such models is to understand the current position for implementing aspects of Industry 4.0 and to identify measure for how to become more mature (Weisner et.al., 2018). Maturity models are a way to aid manufacturing companies in this analysis towards Industry 4.0. The models are built upon assumptions of predictable patterns for an organization to move forward through a development (Gottschalk, 2009). Since there is a big diversity of companies in the industry, Ghobakhloo (2018) suggests that maturity models need to focus on assessing company's core competencies, capabilities, intent, goals, priorities and budget.

The existing models all aim to create an understanding of companies' digital maturity and aid them in the transformation to Industry 4.0. Models on the market can be divided into descriptive purpose, prescriptive purpose and comparative purpose (De Carolis et.al., 2017a). A descriptive model tries to display how the current situation looks while a prescriptive model aims at assessing the current situation and provide guidance in how to move forward. Comparative models aim at benchmarking the evaluated company towards others in the industry. The presented models below are examples covering all three purposes. Some of the models provide an initial analysis, descriptive purpose (Schumacher et.al., 2016), others take it a step further and provide future actions, prescriptive purpose (De Carolis et.al., 2017b), while some uses the model to benchmark against the rest of the industry, comparative purpose (Canetta et.al., 2018).

Below follows a shorter description regarding identified maturity models from literature, the descriptions cover areas presented in the source.

- ***Klötzer & Pflaum, 2017*** - This model is based on a multidimensional view of digitalization and focus on the areas of "smart product realization" and "smart product application". These areas are investigated through the help of the same nine dimensions, and maturity is described by the same five levels within both areas. The two focus areas are displayed on each half of the same radar chart aiming at providing decision makers with a rapid identification of the company's digitalization activities.

- ***Schumacher et.al., 2018*** - The researchers have identified 65 items of digital maturity and developed a questionnaire with 65 individual questions connected to one item each. Each of the questions consist of four separate maturity levels created to describe the specific item. The evaluated company will answer the questions with regards to their current state and where they wish to be. The researchers have set up 10 steps for the investigated company to go through starting with an introduction and alignment of Industry 4.0 and ending with a company specific roadmap.

- ***Schumacher et.al., 2016*** - This model is based in 62 items grouped into 9 dimensions that are evaluated in order to place the company within one of five maturity levels. The maturity is determined through a questionnaire consisting of one question per item where a closed ended question is answered on a scale from 1 – "not distinct" to 5 -" very distinct". The items are weighted based on expert opinion from 23 researchers and practitioners. The result is presented in a report where the maturity of each level is visualized in a radar chart, then each dimension in more detail and finally a detailed presentation of each item. The aim is to provide companies with knowledge about their current digital maturity.

- ***Canetta et.al., 2018*** - This model is structured in three phases where the first phase is a five-section questionnaire. This phase provides an assessment of the company within five different dimensions. The second phase focuses on analyzing the process towards Industry 4.0 and the third phase creates an in-depth analysis of each activity within the process. The result is presented in a radar chart visualizing the weighted maturity of each dimension. The aim is to provide a descriptive analysis of the company and to benchmark it against other companies in the industry.

- ***De Carolis et.al., 2017b*** - The aim of this model is to not only provide an assessment but also a structured guide on how to face digital transformation. The model is structured through four steps: maturity assessment, identification of strengths and weaknesses, identification of opportunities and digital roadmap definition. The first step investigates four dimensions

within the company and the company can then be placed within one out of five maturity levels.

- ***Lichtblau et.al., 2015 (see Gökalp et.al., 2017)*** - This model consists of 6 dimensions and 6 maturity levels. The maturity is presented as a percentage score with an action plan to improve readiness with regards to technology, organization and environment. The maturity level of competitor organization affects the maturity of the evaluated company.

- ***Gill & VanBoskirk, 2016*** - The model is built to assess companies overall digital readiness through a questionnaire that covers four dimensions and places the company in one out of four maturity segments. The questionnaire consists of 28 questions equally divided over the four dimensions. The model works with maturity segments instead of levels where each segment is characterized by demographics and behaviors based on actual companies' digital competences. This model is used for both assessing maturity and to benchmark against other companies.

- ***Gökalp et.al., 2017*** - The model aims at helping companies understand their weaknesses and problem areas by providing guidelines and a roadmap for how to transform into Industry 4.0 in a consistent way. By assessing 5 dimensions the model can place companies in 6 different maturity levels.

- ***PWC, 2016 (see Rajnai & Kocsis, 2018)*** - The model aims at, through a qualitative assessment, provide the evaluated company with an action plan. It is constructed of seven dimensions and four maturity levels that are defined for each dimension.

Maturity levels

Maturity levels are used to try to describe how mature the evaluated company is, or how far they have come on the digital journey. Where the company places within these levels or segments will then determine a suitable starting point for the continued transformation (Gill & VanBoskirk, 2016). The maturity levels presented span from level 1, least mature, to gaining more maturity the higher the number of the level. The maximum level differs between the different models. Table 1 shows an overview of the above presented models and their maturity levels with explanations if provided in the articles.

Table 1. Maturity levels from different models found in literature where level 1 is the level with least maturity.

Model	Maturity level	Description
Klötzer & Pflaum, 2017	**1.**	Digitalization awareness - no development but an understanding of disruptive challenges and changes
	2.	Smart networked products – embedded microelectronics in physical objects, CPS
	3.	The service-oriented enterprise – smart services formed from the basis of the earlier levels
	4.	Thinking in service systems – aggregated or interconnected demand-actuated service systems, along whole value chain

	5.	The data-driven enterprise - data and information gets higher interests and forms basis for data-driven business models
	6.	-
Schumacher et.al., 2018	**1.**	-
	2.	-
	3.	-
	4.	-
	5.	-
	6.	-
Schumacher et.al., 2016	**1.**	-
	2.	-
	3.	-
	4.	-
	5.	-
	6.	-
Canetta et.al., 2018	**1.**	Absence
	2.	Novice
	3.	Intermediate
	4.	Expert
	5.	-
	6.	-
De Carolis et.al., 2017b	**1.**	Initial - poorly or not controlled process, reactive management, no infrastructure for scalability
	2.	Managed – process is partly planned and implemented, specific objectives for single projects or experience of planner is the drivers
	3.	Defined - good planning and implementation practices have defined the process. Gaps of integration and interoperability due to constrains on responsibility and technology
	4.	Integrated and interoperable - common and shared standardization based on best practice. Integration and interoperability of applications and some information exchange build the process
	5.	Digital oriented – process is digital oriented and based on technology infrastructure supporting speed, robustness and security in information exchange
	6.	-

Lichtblau et.al., 2015 (see Gökalp et.al., 2017)	**1.**	Outsider
	2.	Beginner
	3.	Intermediate
	4.	Experienced
	5.	Expert
	6.	Top performer
Gill & VanBoskirk, 2016	**1.**	Skeptics – beginning the journey
	2.	Adopters – prioritizing customer relations and investing in skills and infrastructure
	3.	Collaborators – use digital for competitive advantage, breaking traditional silos
	4.	Differentiators - blending the digital and physical world by leveraging data
	5.	-
	6.	-
Gökalp et.al., 2017	**1.**	Incomplete - aspect practices are not performed, basic business operations
	2.	Performed – attempts to transition, aspect practices are performed
	3.	Managed - virtual worlds are used for physical items, infrastructure of smart technology is operating independently
	4.	Established – standardized process and operations, vertical integration and networked systems
	5.	Predictable - controlled process and operations, horizontal integration, Big Data analytics/Machine learning and AI
	6.	Optimizing – innovative business processes, self-optimization, continuous adaptation by digital integration throughout value-chain
PWC, 2016 (see Rajnai & Kocsis, 2018)	**1.**	Digital novice
	2.	Vertical integrator
	3.	Horizontal collaborator
	4.	Digital champion
	5.	-
	6.	-

Dimensions & Item types

To enable the evaluation of the companies and to place them within different maturity levels the models have identified item types grouped in thematic dimensions representing areas that the researchers feel should be evaluated within a company (Rajnai & Kocsis, 2018). Table 2 presents an overview of the dimensions presented in the compared maturity models. The models presented here ranges from 15 to 65 item types where each dimension consists of different number of items (Schumacher et.al., 2016; Schumacher et.al., 2018).

Table 2. Overview of dimensions from the compared maturity models.

Model	Number of dimensions	Dimensions
Klötzer & Pflaum, 2017	9	Strategy, culture, processes, organization, offering to customer, "smart" product, complimentary IT system, cooperation, competences
Schumacher et.al., 2018	8	Strategy & leadership, customers & partners, employees, corporate standards, data & information, value creation process, products, technology
Schumacher et.al., 2016	9	Strategy, leadership, customers, products, operations, culture, people, governance, technology
Canetta et.al., 2018	5	Strategy, technology, processes, products & services, people
De Carolis et.al., 2017b	4	Organization, process, monitoring & control, technology
Lichtblau et.al., 2015 (see Gökalp et.al., 2017)	6	Strategy & organization, smart factory, smart operations, smart products, data-driven services, employees
Gill, & VanBoskirk, 2016	4	Culture, technology, organization, insights
Gökalp et.al., 2017	5	Asset management, data governance, application management, process transformation, organization alignment
PWC, 2016 (see Rajnai & Kocsis, 2018)	7	Business, products & services, integration of value chain, data analytics, agile IT architecture, compliance & security, organization & culture

2.5 Research question

Most existing maturity models need to be tested and further developed to provide the best recommendations (Canetta et.al., 2018; De Carolis et.al., 2017b; De Carolis et.al., 2017c). Mittal et.al. (2018) have recognized that most of the existing maturity models focus on larger companies which causes them to be ill-fitting for SMEs who in many cases start their journey under other circumstances. There is also no model today that mainly focuses on CNC manufacturing or take in consideration what type of production a company has. These gaps in literature lead to the following research question.

- How should a maturity model be structured in order to provide companies of all scales and in all segments within CNC manufacturing with information regarding how to move forward on their digitalization journey?

3 METHODOLOGY

In this chapter the research approach and methods used during the thesis will be presented. This includes the reasoning behind the methods for literature research, data collection, data analysis and model development.

3.1 Research approach

The methodology applied to the thesis work consisted of Literature research, Data collection, Data analysis and Model development. The Literature research contained two focus areas, concepts connected to Industry 4.0 and existing maturity models. Information from this phase was used during the interviews in Data collection and served as a base for concept creation in Model development. In Data analysis, interview findings were analyzed and compared to literature to validate areas from existing maturity models that were relevant to the industry today. Model development focused on iteratively creating and testing concepts of the maturity model and methods for implementation until a finalized result was reached. These phases and an overview of their content are described in Figure 2 below and more thoroughly explained in the following chapters.

The methodology of Design Thinking was applied to the project to ensure an iterative process with a broad research phase. This ensured that focus was aimed at the user of the developed maturity model and on framing the problem correctly (Brown, 2009). Iterations of the concept were applied to enable adaptation to new findings throughout the process. This was done to ensure that the evaluation model was better based on user needs and that it was going to be user friendly and understandable.

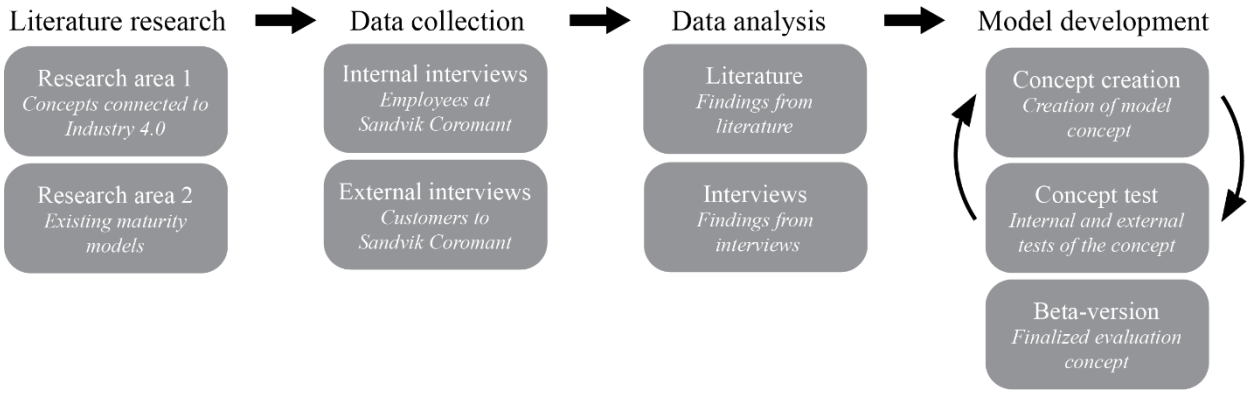

Figure 2. Phases of the thesis work and an overview of content involved in each phase.

3.2 Literature research

The literature research for the thesis was conducted within two focus areas. The initial research aimed at gaining understanding of the concepts connected to Industry 4.0 within the manufacturing industry. To gain the broad knowledge needed, areas such as *Digitalization, Industry 4.0, Managing digitalization* etc. were researched. The research covered technologies connected to digitalization, drivers and challenges for implementation, how a company can survive the journey towards Industry 4.0 and differences between large corporations and SMEs. The second research aimed at investigating and understanding existing evaluation models connected to digitalization that were under development, or on the market, and how they are constructed to aid companies. Areas investigated for this research were *Road maps for Industry 4.0, Maturity models for Industry 4.0, readiness for digitalization,* among others. The primary goal for this research area was to investigate factors connected to digitalization in the manufacturing industry from the perspective of different researchers. It also covered how they were used to map the company maturity with regards to digitalization. The knowledge gained from both the literature research formed the research question for this paper and provided knowledge used for the interview guides as well as the basis for the continued work.

3.3 Data collection

The data collection consisted of initial meetings, qualitative interviews and meetings regarding Sandvik Coromant existing digital offers and corelating areas. Initial meetings were carried out internally with Sales Managers to gain an overview of their perspective of digitalization in the CNC manufacturing industry today. They also provided further contacts to employees in the organization who could provide useful information regarding digitalization and how the market perceives digitalization today. These initial meetings were held with employees from Sweden and France in order to investigate the similarities and differences concerning digitalization between countries. The qualitative interviews were first carried out internally with salesmen and other employees at Sandvik Coromant which in turn provided contacts to customers who were interested in participating in interviews to provide their view of digitalization. These interviews were held to get different perspectives on how digitalization is perceived on the market today, both from a customer point of view and from an internal perspective from different countries. The interview findings served as a basis for the concept creation. In Table 3 below a full disclosure of the collected data and its use in the thesis is presented.

Table 3. Disclosure of collected data and its role in the thesis.

Collected data	Role in thesis
Weekly meetings with supervisors at Sandvik Coromant (January-June 2020) Weekly check-up meetings with three supervisors from the Business Development department and one supervisor from the Digital Machining department at Sandvik Coromant.	*Complementary data* The weekly check-up meetings worked as a forum for discussions and questions regarding anything that concerned the thesis. They also served as a way for Sandvik Coromant to steer the direction if necessary and make sure the work was in line with the initial scope.

Meetings with Sales Managers (February 2020) Initial meetings with two Sales Managers at Sandvik Coromant, one from Sweden and one from France.	*Complementary data* These meetings were held to gain an initial overview of the market and the view on digitalization from different countries. They also generated contact for further interviews.
Meetings with employees from the Digital Machining department (April-May 2020) Meetings with four managers from the Digital Machining department at Sandvik Coromant.	*Main data* Two of these meetings were held to get a presentation on the digital offers Sandvik Coromant has today and in the nearest future. The other two were held to gain input on the developed model and to make sure that it was in line with Sandvik Coromant core business and perspective.
Internal interviews at Sandvik Coromant (February-March 2020) A total of 23 internal interviews with employees at Sandvik Coromant were conducted with 23 individuals. More information of the respondents and the interviews can be found below under *Interviews.*	*Main data* The interviews were held to get an overview of the internal perspective on Industry 4.0 and digitalization. Most interviews were held with salesmen but also employees from other departments. The interviews served as a basis for the developed model.
External interviews with Sandvik Coromant customers (February-March 2020) A total of 5 external interviews with customers to Sandvik Coromant were conducted with 5 individuals. More information of the respondents and the interviews can be found below under *Interviews.*	*Main data* The interviews were held to get an overview of the external perspective on Industry 4.0 and digitalization. The respondents came from companies of different scale and segments to get a broad overview. The interviews served as a basis for the developed model.

Interviews

The interviews were carried out through February-March 2020 and there was a total of 28 interviews out of which 23 were internal at Sandvik Coromant and 5 were held with external parties. Out of the 23 internal interviews from both Europe and USA, 8 were with employees working with digitalization and 15 were with salesmen. All the external interviews were with customers to Sandvik Coromant including their own production site Gimo. The interviews were semi-structured with open-ended questions which allowed the interviewee to answer the questions without directions and depending on the answers the interview could be guided towards areas of interest but without steering the interviewee off topic. The average interview lasted for 50 minutes and were recorded with the interviewees consent, with the promise that they would be kept anonymous. For each interview, one of the researchers was appointed the main interviewer while the other was responsible for detailed documentation. See Table 4 below for further information about the interviews. All external companies have been differentiated by a separate letter.

The first round of interviews was held with internal interviewees to gain a perspective of their view of digitalization and to determine which areas were important to investigate when mapping a company's maturity level. Questions regarding model structure and performance were also asked. The interviews were used to understand companies' and the interviewees perception of digital maturity and through that form a basis for the developed model. The customer interviews were the second round of interviews and were apart from gaining their perspective on digitalization, also used to investigate current digital products and their fit towards customer needs. The aim was to discover possible gaps in the current offerings and through that define new business opportunities.

Furthermore, the interview guide varied slightly depending on the interviewees role to make sure the information gained would be relevant for the continued work. The guide also varied slightly between the internal and external interviews to gain the right information from their perspective. The customer interview guides also contained information obtained in the first round of interviews to be verified by the customers.

Table 4. Information regarding conducted interviews and interviewees.

Role/Position	Internal/ External	Country	Type	Length
7 Sales Engineers	Internal	Sweden	Teams	36-53min
4 Application Specialists	Internal	Sweden, Denmark	Teams	37-48min
3 Sales Region Managers	Internal	Sweden, France, Russia	Teams	38-59min
2 Employees - R&D	Internal	Sweden, Germany	Face-to-face, Teams	52-57min
2 Managers	Internal	France, USA	Teams	48-51min
3 Employees – Digital Machining	Internal	Sweden, USA	Face-to-face/Teams	38-52min
2 Sales Managers – Digital Machining	Internal	Sweden, USA	Teams	61-66min
Production Technician	External, Company A	Sweden	Phone	31min
CEO	External, Company B	Sweden	Teams	52min
CEO/Owner	External, Company C	Sweden	Phone	83min
Communication	External, Company D	Sweden	Teams	63min
Production Technician	External, Company E	Sweden	Teams	38min

3.4 Data Analysis

Analysis of the collected data was performed through clustering, which was used to find commonalities from the different interviews and map them towards findings from the literature research. This was used to identify problem areas, potential solutions and improvements. Clustering also creates a good overview of the situation and shows areas that need more attention (Doorley et.al., 2018). Clustering was performed for three aspects: existing maturity models, internal interviews and external interviews. The internal and external interviews were divided into two areas, general view of digitalization and model structure. The purpose of dividing the collected data into areas while clustering was to gain a wider perspective of the information. The three different aspects were clustered through the help of the same procedure, which is presented below, to enable comparable and visual results (Liedtka et.al., 2013).

When analyzing the existing models, they were investigated based on maturity levels, dimensions, items and execution. The maturity levels and execution of each model were analyzed and compared to each other. The information regarding dimensions and items from each maturity model were written on individual post-its' for each piece of information which were then clustered to identify commonalities and differences for the investigated areas. The findings gained from existing maturity models were used as a basis for the developed model. Findings that lay outside of the scope and that was not verified through interview findings were not used in the developed maturity model.

The interview documentation formed the basis for information identification for the clustering of the interviews. If the documentation was insufficient the researchers went back and listened to the recording of the interview. Information seen as important from the interviews were first marked within the interview documentation and then written on post-it notes. The post-its' were clustered into areas based on contradictions and commonalities from the different interviews. Each post-it was marked with an identification number for the interviewee. The internal interviews also differentiate the employees working with digitalization from the other interviews since they possessed a higher knowledge and understanding of the area. No differentiation more than the interviewee number was made for the external interviews. After the clustering of each individual area they were compared to each other to draw conclusions regarding which aspects were to be included in the maturity model and which areas were important to keep in mind when developing the model.

The researchers identified important information from half of the interviews and existing models each, where factors of interest had been established beforehand. These factors included among else *knowledge regarding digitalization, view of how the market will change, enablers and important factors for digitalization.* The researchers were free to mark information outside these areas if it was seen important for development of the result. Clustering of the information was done collectively to enable discussions and to improve the understanding of the information provided which was necessary to move forward with the creation of the maturity model.

3.5 Model Development

The model was developed through an iterative approach consisting of 5 iterations to ensure that relevant areas were covered and that the model would fit the needs from both the internal and external stakeholders (Doorley et.al., 2018). The development of the model passed through some distinct steps before it was finalized.

Dimensions and maturity levels

The analyzed data from literature and interviews formed the basis used for creating maturity levels and identifying items that then formed dimensions seen as relevant for what the model aimed at achieving. The data from the interviews determined what data that were seen as relevant from the literature regarding existing maturity models. Data from literature that were outside of the scope and not seen as relevant in interview findings were removed.

First concept creation

This step focused on creating a Minimum Viable Product, MVP, based on the defined dimensions and maturity levels that were to be used during concept testing (Ries, 2011). The MVP was created to ensure that the model would be suitable for its purpose and that the correct initial parameters and final evaluation result would be in line with what was expected from external stakeholders. For the first concept, questions were created to cover the defined dimensions and through which the maturity level of the company should be decided.

Iterative testing and Beta-version

The concept of the model, its content and the simplicity of the questions were tested on both internal employees and external customers. This was done iteratively where the concept was tested an average of 5 times before it was updated for the next round of tests. The iterative approach was chosen to ensure the models fit towards the users and that different perspectives were taken into consideration (Doorley et.al., 2018). After the final iteration of the concept was done a beta-version of the model was created. At this point the questions and structure were finalized and only smaller changes were to be made. The beta-version of the model was created as an interactive PowerPoint to test usability towards customers (Sonderegger & Sauer, 2010). This version was tested by customers to ensure that the model provided evaluations in the correct way. This step also aimed at collecting stories from companies that were to be used as one of the sections in the final models' provided evaluation.

Testing of the model was carried out through April-May in 2020 and consisted of a total of 27 tests out of which 12 were internal and 15 were held with externals. Out of the 12 internal tests, two were with employees working with digitalization and 10 were with other employees from Sandvik Coromant. Four of the people participating in the test had not been a part of the interview phase and these were provided with a few initial questions regarding their general view of digitalization. All the external tests were with customers to Sandvik Coromant including their own production site Gimo. By testing the model on both customers and internal employees it was possible to develop a model that both parties felt comfortable with. When testing the model, the same format was used for all participants, but the content was updated between each iteration. A more detailed overview about the participants can be found in Table 5 below.

Table 5. Information about concept tests and participants.

Role/Position	Internal/External	Country	Type	Concept
CEO/Owner	External, Company F	Finland	Teams	1, beta
Key Account Manager	External, Company G	Sweden	Teams	1, beta
Communication	External, Company D	Sweden	Teams	1, beta
Production Technician	External, Company E	Sweden	Teams	2, beta
CEO	External, Company H	Sweden	Phone, Teams	2, beta
Application Specialist	Internal	Sweden	Teams	2
Sales Engineer	Internal	Sweden	Teams	2
CEO/Owner	External, Company C	Sweden	Teams	2, beta
Production Technician	External, Company A	Sweden	Teams	2
3 Sales Engineers	Internal	Sweden	Teams	3
Sr. Supervisor, Production	External, Company I	Sweden	Teams	3, beta
Sales Manager - Digital Machining	Internal	USA	Teams	3
Employee - Digital Machining	Internal	USA	Teams	3
Sales Region Manager	Internal	Russia	Teams	3
2 Sales Engineers	Internal	Sweden	Teams	4
Application Specialist	Internal	Sweden	Teams	4
Sales Region Manager	Internal	Sweden	Teams	4

Mapping of digital offers

The existing digital offers from Sandvik Coromant were investigated and mapped into the maturity model to provide the customers with tangible suggestions on how to reach a higher maturity. The products were mapped into both a defined item and a maturity level. The mapping was validated by product owners from the Digital Machining department at Sandvik Coromant. Since this is confidential information the result of this mapping will not be shown in this report and will be given straight to Sandvik Coromant.

Finalization

In the final step the focus was on ensuring that all the parameters of the resulting model were finalized. Visualization and design of the final model was done in collaboration with two Marketing Platform Specialists from Sandvik Coromant. This was to ensure that the functioning maturity model followed the company guidelines and that all collected data will be stored in a correct way at the right place.

4 RESULTS & ANALYSIS OF INTERVIEWS

In this chapter the results that were obtained during interviews are presented and analyzed. The interviews were analyzed in contrast to the theory and knowledge presented in the chapter Frame of reference. The analyzed results are further used as a basis for the developed maturity model.

4.1 Results from interviews

Areas surrounding digitalization and model structure were identified from the conducted interviews. Findings have been collected and categorized to enable easier understanding.

Internal interview findings

Findings from internal interviews conducted with employees from Sandvik Coromant are presented below and have been divided into the general view of digitalization, and model structure and content.

General view of digitalization

Many of the interviewees stated that the view of Industry 4.0 differs from country to country, but there is a big general interest. Their perception is that many customers and companies in the industry struggle with understanding the benefits connected to their own workshops and where to start the digital journey. Many of the interviewees believed that the customers need proof of efficiency and suggestions from companies that have come further in the transformation. For companies to succeed with digitalization they need to understand how to take advantage of data, analyze it and make decisions based on what the data tells them. There needs to be a digital thread throughout the organization which requires both competence and interest in this area. Several of them further highlighted that someone therefore needs to be responsible to get the transformation started and it is equally important to get all employees onboard. Another common view from the interviewees were that a big change will come with the generation shift where younger people who want to digitalize enter decision making roles. Many of the interviewees highlighted the need to not lose the knowledge from the older generation when they exit the companies.

Several of the employees expressed the importance of understanding customer value and needs when at the same time being aware of non-classical competitors, since many large customers develop their own systems in collaboration with these new competitors. Digital products are perceived to be niched and complex which limits the customer base according to many of the interviewees. To be successful in distributing digital products the responsibility needs to fall on someone with knowledge in the area and understanding in how to present these offers to customers. The general view is that there is a need for more support and education connected to digitalization to gain further knowledge within the organization.

A more profound overview of the findings from the internal interviews regarding the general subject of digitalization is as follows:

- ***The industry*** - The industry view of Industry 4.0 differs from country to country, but many seem to need more evidence of efficiency to back up the large investments connect to Industry 4.0 according to many of the employees. The industry is still in the early adopters' phase where old plants struggle to handle the transition. The majority of the interviewees expressed that it is more important with good products than high productivity. They further believed that SMEs move quicker with digitalization and will bring the big companies with them.

- ***Knowledge of Industry 4.0*** - Many interviewees believed the mindset connected to Industry 4.0 to be important in understanding and seeing the benefits with implementation. Companies need to analyze and act on what the data tells them. Several of the interviewees further stated that the customers do not know where to start or what is possible with Industry 4.0 and therefore need to listen and get inspiration from what others have done and through that find proofs of the benefits.

- ***Arguments for Industry 4.0*** - Industry 4.0 is something that will offer better interaction, connectivity and bring people and functions together through an overarching picture of the workshop according to many of the employees. They expressed that only a small amount of data is analyzed today which shows room for enormous improvements.

- ***Digitalization vs. Digitization*** - There is a difference between adding digital components and to become a digital company, stated by one interviewee. It is expressed that to become a digital company there needs to be a digital thread through the entire company.

- ***Think big, start small*** - Start the transformation by looking at the overall picture and decide one place where there is most to gain and start there according to many of the employees. They believed in continuing the implementation stepwise to meet customers wishes, good results can come from small scale changes.

- ***Sales competence*** - Several of the employees expressed a need for further knowledge regarding digitalization and how it can be implemented at customer site. They see a need for someone responsible for this area that can support the organization.

- ***Recommendation of products*** - Products are recommended based on knowledge regarding the customer site, they need to sell based on customer needs stated by many of the interviewees. They further believed that customers should be presented with the full offer since needs can change, but digital offers are not prioritized due to lack of time.

- ***Product maturity*** - Many of the interviewees stated that the digital offers today are suited for differently mature companies where some offers need a higher degree of maturity to be useful.

- ***Digital offers*** - The common view is that digital offers need to be able to reach the general customer, something that more companies can take advantage off such as standalone solutions for operators. Several of the employees expressed that customers are looking for something that will help them predict when things will go wrong and communicate high priority information in an efficient way.

- ***Customer interest*** - Several of the employees believed that many are interested in digitalization but there is a long way from interest to investment since customers are focused on price and not used to buying digital products that are in a higher prize category. They further believed that customers feel that it is a complex situation and they do not know where to start. They stated that interest mainly comes from SMEs since bigger companies in many cases have their own development department.

- ***Customer value*** - Many of the interviewees expressed difficulties in visualizing customer value and depending on the customer the value is found in different parts of the company. They believed that customers do not look for digital products but see it more as a part of a solution. It is therefore important, but hard, to find the customer need and offer the right products. A lot of value lays in minimizing waste and to work proactive instead of predictive, according to many of the employees.

- ***Customer maturity*** - There is a difference in how far companies have come with digitalization, the difference can be seen in both segments and scale of the companies, but SMEs are further behind, according to many of the interviewees. The once that have come far are pushed by their customers. The employees declared that companies far ahead in the transformation have the knowledge to question the digital offers, they will not accept anything and knows what they want. They further stated that there are two sides of digitalization, the once that go for it and the once that need a push.

- ***Customer competences*** - Several of the employees stated that without the right competences the transformation will be hard. It takes time to obtain the right competences, but it is needed to take advantage of digitalization and to utilize the benefits. They further expressed the need to have someone that knows how to take care of the gathered data.

- ***Champion for Industry 4.0*** - There needs to be someone responsible for digitalization and that is passionate about the subject within a company for a successful transformation according to several of the interviewees. They further stated that it is equally important to get all customers employees onboard for them to accept the changes.

- ***Generation shift*** - The common view among many of the employees is that the generation shift in the industry will be one of the main reasons for a broader implementation of digital solutions. They expressed the need for the solutions to utilize knowledge and competences from the older generation. Younger people are more adapted to digitalization and have the correct way of thinking for it to be utilized in the best way according to many of the interviewees.

Through the interviews some enablers for digitalization were identified:

Wireless connectivity & communication, modern machine park, sensor technology & data collection, digital software, constant improvements & efficiency through digital solutions, cloud computing, smart tools, will to move forward, IoT, Big Data, Machine Learning, AI, automation, data analytics, standards & platforms, Cyberphysical systems, AR, data security, remote control, digital strategy, collaborate productivity, reliance on data, business management system, Digital Twins, infrastructure for data collection, tool management.

Model structure and content

When evaluating a company's' digital maturity, management and people on the floor need to be included to gain understanding of the company vision according to several of the interviewees. These people need to be approached in different ways, but they will only contribute if they have an interest in digitalization. The general opinion is that the evaluation should be conducted during a face-to-face meeting to ensure truthful responses. Some believed that the analysis should be done in conjunction with answering the model while others want time to prepare before presenting the result to the customer. It is further believed by most interviewees that the once responsible for evaluating digital maturity at the customer site need knowledge within this area for best result.

A more profound overview of the interview findings regarding model structure and content are as follows:

- ***Who to talk to at the customer site*** - Many of the employees expressed a need for digitalization to come from the top in order to begin. It is therefore important to talk to management, or someone with economical insights. They further stated the need to approach different levels within a company to get the whole perspective, but people on the floor may not have all the information needed. The most important aspect is interest in digitalization according to the majority of the interviewees.

- ***What and how to ask*** - Several of the employees believed that focusing on understanding customer needs and why they want to go digital through open ended questions is important. They stated that questions should include age of machines, connectivity, automation and competences. Many of the interviewees further stated that it is also important to consider strategy and if the customer is currently working with digitalization.

- ***Time and spot for the model*** - The general opinion among the interviewees is that there is a need for the evaluation to be done face-to-face otherwise the response rate will be low, if the customer will do it themselves it needs to be easy to understand. They further stated that it cannot take more than one hour to do the evaluation.

- ***Time and spot for the analysis*** - The common thought of many of the interviewees is that the analysis of the evaluation should take a maximum of one hour to perform and should be done during a meeting. There are different views on whether the analysis should take place in the same meeting as answering the model or at a separate one. Several of the interviewees further stated that if it is simple, and depending on the answer, it should be conducted on the spot to ensure that interpretations are done in the correct way.

- ***Preparations*** - Several of the employees stated that preparations for the meeting should take as long as necessary, if you are unprepared it is a waste of time for both parts. They believed that the more you learn the less preparations should be needed.

- ***Responsibility of the model*** - The belief of many of the interviewees is that the responsible for the evaluation need extensive knowledge within the area of digitalization and it should therefore be put on an own department. They further believed that this is necessary for being comfortable while presenting the result to the customer.

External interview findings

Findings from the external interviews conducted with customers of Sandvik Coromant are presented below and have been divided into, just as the internal interviews, the general view of digitalization, and model structure and content.

General view of digitalization

Most of the customers believed that Sweden has come further on the digital journey than other countries. They further believed that the view and knowledge of digitalization varies amongst the companies in the industry, and there need to be more examples from companies who have come a long way to convince the sceptics. The need differs from company to company and it is hard to see the benefits with digitalization and how it can be the solution. Several of the interviewees expressed that development of competences and younger people will be main characteristics of the transformation.

A more profound overview of the findings from the external interviews regarding the general subject of digitalization are as follows:

- ***View of digitalization*** - This is a fast-developing area which is so much more than production and what is happening in the machines according to most customers. They believed that to be successful there is a need to work with digitalization and to see it as an aid, but it will be different for everyone. Many customers expressed that companies should improve their processes to be more effective while creating a work process suitable for digitalization. They further stated that digitalization will help automize monotone tasks and therefore create more interesting jobs, digitalization is not about replacing the human.

- ***Knowledge of Industry 4.0*** - Many have not understood what it is, and projects have been stopped since management lack the knowledge needed according to several of the interviewees. They believed that practical examples from other companies are required to move forward. The general perception is that customer employees may think they know what it is, but mostly they do not.

- ***Starting points for digitalization*** - Several of the interviewees suggested that the first important thing is to have a strategy and a plan. The next natural step would then be to install an OEE system.

- ***Customer value with digitalization*** - Many of the customers stated that it is hard to see value in something that is not possible to touch, there is a need to translate the reduced time to cost. They believed that the need differs from company to company so the technology needs to fit the company and what they want to achieve.

- ***Interest in digitalization*** - Everyone need to be a part of the journey, if the customers employees do not see the benefits it is hard to implement changes according to many of the interviewees. They believed that younger people and people with interest in technology are the once interested in digitalization changes.

- ***Competences*** - Many of the interviewees expressed the need for working with competence development, it also allows the customer employees to be a part of creating the digital solutions. There need to be competences that can utilize the systems. They further believed that many are concerned that programs cannot reach the same quality as humans.

- ***Company maturity*** - The companies in Sweden have come further in digitalization than many other countries according to most of the customers. They believed that there still is a big difference regarding the understanding of maturity since the term is not coherent over the industry. They further stated that a company may say that they have come far but looking at their manufacturing it shows something different.

- ***Digitalization towards their customers*** - Changes will come faster if it is required by customers according to several of the interviewees. They further stated that companies want to help their customers understand benefits with digitalization and through that form partnerships.

- ***Generation shift*** - It is a conservative industry with mainly older men who are not susceptible to change, the big changes will come when these people retire stated by several of the interviewees. They believed that companies that have come far in digitalization should be able to attract a younger workforce.

- ***Digital offers*** - Many of the interviewees stated that companies look for products to aid with material flow and something that can help the industry work in a more sustainable way.

Through the interviews some enabling factors for digitalization were identified:

CAM, communication to and from machines, automation, Machine Learning, AI, responsible/interest.

Model structure and content

Evaluating company maturity needs to be done together with someone who has the correct knowledge regarding digitalization and has a management position according to many of the interviewees. They felt that the model firstly should be a form that will be filled out alone to then have a deeper discussion during a face-to-face meeting. They further stated that it is important that the result is presented in person by the representative and the evaluation should cover the whole value chain of the company.

A more profound overview regarding model structure and content from the external interviews are as follows:

- ***Who to talk to*** - This will differ from company to company, but it needs to be someone with the correct knowledge of digitalization according to several of the customers. They believed it should be the person responsible for digitalization, production manager or higher.

- ***What to ask*** - Many of the customers expressed a need to look at the whole value chain to gain the right understanding. They believed that productivity, digital thread, and design and manufacturing need to be investigated.

- ***Time and spot for the model*** - Several of the customers said that it should take a maximum of 30 minutes to answer the model. They would prefer it to be performed as a webform or the ability to answer the questions alone at first to then have the possibility to book a meeting for a deeper discussion.

- ***Time and spot for the analysis*** - Most of the interviewees believed that it is important to have a walkthrough of the result together with the representative from Sandvik Coromant. They stated that this is to gain more understanding of the result and it will create a platform for discussions.

4.2 Analysis of interview findings

The results from both the internal employees from Sandvik Coromant and the external customers have been analyzed towards each other and literature and divided into general view of digitalization, and model structure and content to enable better understanding. Found enablers are also presented and analyzed towards literature.

General view of digitalization

The general view of digitalization today from both an internal and external perspective is that many people within manufacturing lack knowledge of the subject and what benefits customers can get from it. This is something De Carolis et.al. (2017a) agree with and say that the lack of understanding is why the potential is hard to see. Therefore, many from both the internal and external interviews highlighted the need for examples from others in the industry to get inspired and see the potential. Several of the internal interviewees also believed that customers need more evidence in order to invest since that is a big step for most companies. This is something Wiesner et.al. (2018) also agree with. The authors say that, at least SMEs, needs to see success stories from others to be able to start their own journey. Many of the internal employees further believed that customers think digitalization is complex and need to be provided with a starting point for their journey. They also believed that there is a need to understand the whole transformation and to start where the most gain is identified to continue stepwise from that point and transform in small steps. Several of the external interviewees said that many customers might think they know what they are doing but they do not. They also highlighted, as well as many of the internal employees, that the need to make all employees see the benefits and to be onboard for an implementation to happen is extremely important. This is something that Ghobakhloo (2018) also points out.

Several of the internal interviewees' idea of the market today is that companies have come different far on the digitalization journey and many of the external interviewees believed that companies might not even know what "far" is. The internal perspective is split when it comes to SMEs. Some thought that SMEs are further behind on the journey and some thought that SMEs have a bigger interest and move quicker than larger companies and will therefore bring larger companies with them. Some of the internal employees however stated that large companies have their own development for digital offers, and it will take longer for them since they cannot just buy it from others. This is a topic that is also split in literature. Ghobakhloo (2018) believes that SMEs will struggle more due to less resources and market shares. World Economic Forum (2019) however believe the opposite. They say that SMEs will succeed by implementing solutions that does not require large investments and that they are an essential part of the supply chain and will therefore bring others with them. Bilgeri et.al. (2017) agree with the internal interviewees that believed large corporations will move slower due to their own development. Jacobi & Brenner (2018) also say that large companies might experience problems with bureaucracy.

The value connected to digitalization is according to internal interviewees hard for customers to see since they do not look for digital solutions and they will most likely see value in different things. According to several customers themselves, they believed that everyone has different needs and the solution needs to fit the company. The journey will be different for everyone. Schumacher et.al. (2016) believe that this comes from a lack of knowledge towards the subject and in forms of how to implement solutions. Many of the internal employees saw that a lot of value lays in minimizing waste and to work proactive instead of predictive and that the transformation should start in one place and then expand from there. Many customers saw the need to translate the value into reduced time and cost. Furthermore, several of both the internal and external interviewees saw a need in looking at digital strategy. Many of the customers saw this as a starting point and that companies need to create a suitable process for digitalization. Parviainen et.al. (2017) believe that lacking a digital strategy will create obstacles for the company.

The general digital offers today are too narrow and limited for the whole market according to many of the internal interviewees. They also said that the coming offers needs to reach the general customer. Several of the customers said that they have heard about offers but do not use them or know about others that uses them. Mittal et.al. (2018) believe that companies lack knowledge regarding the basic Industry 4.0 technologies and therefore struggle to implement them. Many of the internal employees however felt that the existing digital offers are suited for different mature companies.

Several from both the internal and the external interviews brought up the need for the right competences. The general view from the internal employees is that the right competences are needed to move forward in digitalization and to be able to take advantage and utilize the benefits it provides. Many of the customers thought that competence development is important and that competences that can utilize the systems are needed. These findings are in line with Jacobi & Brenner (2018) who discuss the need for new competences connected to digitalization. This also correlates with World Economic Forum (2019) and Kagermann (2015) who present the need for hiring the right competences.

There is a common view between internals and externals and that is that digitalization will be given a huge boost with the coming generation shift in the industry. Since it is a conservative industry, they both believed that when the older generation retires, and the younger generation brought up with technology takes over, digital solutions will be broader implemented. The resistance of the older generation can, according to Ghobakloo (2018), be connected to their fear of getting replaced by machines. However, several of the customers points out that it is important that digitalization is only an aid and not a replacement of humans, which is in line with World Economic Forum (2019). Higher work satisfaction and fewer monotone tasks are connected to automation which will create a more dynamic and interesting workplace (Parviainen et.al., 2017; World Economic Forum, 2019). This is an area seen as interesting to most of the internal interviewees as well as the external.

Model structure and content

To ensure the correct understanding of the company´s needs towards digitalization, many of the internal interviewees suggested open-ended questions for the maturity evaluation while most of the external interviewees saw a need in understanding the whole value chain of the company. The two interview groups only highlighted one common area, connectivity, as being of interest when investigating digital maturity, but all found areas are brought up in the existing maturity models from literature. Many of the internal interviewees brought up connectivity as an important factor to bring people and functions together, which according to Siemens (2020b) creates infrastructures that allow smart objects, network and platforms to communicate with each other. This aligns with most of the external and internal interviewees, and the interest in investigating a digital thread through a company to understand maturity. Several of the internal employees stated that adding digital components is not enough to become digital.

Several of the internal and external interviewees highlighted the need to perform the evaluation with a respondent who has knowledge and interest in the area of digitalization. Many of the internal interviewees also focused on the need for knowledge of digitalization and competences regarding digital offers for the representative from Sandvik Coromant. In the two sets of interviews, the production manager is mentioned as a suitable respondent for a maturity evaluation. The general belief from the internal interviews was that the production manager, or higher, is suitable since digitalization changes need to come from a management level. This is in line with the thoughts of Richter et.al. (2017) who say that motivation to change needs to come from management and leaders and that it is their responsibility to make sure employees get onboard. The authors also say that leaders require characteristics and courage to change structures and processes in combination with knowledge of digital business models.

As of how the model should be performed the two groups differ in opinions. Most of the internal employees saw a need in performing the evaluation face-to-face to increase response rate while most of the customers would like the opportunity to first answer questions alone. To satisfy both internal and external wishes the evaluations should be between 30 minutes to one hour long. Most of the respondents from the two interview groups wished to perform the analysis of the evaluation during a meeting to enable discussions and easier understanding of the results.

Enablers for Industry 4.0

Many of the interviewees from the two groups expressed enablers for Industry 4.0 where the group of internal interviewees stated a significantly larger set of enablers than the externals. Interviewees from both groups mentioned communication and connectivity between machines, automation, AI and Machine Learning which are all brought up as enablers in literature by Siemens (2020a;2020b) and World Economic Forum (2019). Communication and connectivity between the machines are according to Siemens (Siemens, 2020b) something that will play a huge role for digitalization. AI and Machine Learning are important factors since it is used to identify trends and patterns for a more efficient manufacturing process. It is also a big part of moving towards an autonomous manufacturing process (Siemens, 2020a). Several of the internal interviewees brought up the importance of having the will to change which is enabled by having the interest and someone responsible, also pointed out by most of the external interviewees. The company need a culture that foster change together with a leader who can communicated the vision backed with knowledge for a successful transformation (Richter et. al., 2017; Parviainen et.al., 2017; Jacobi & Brenner, 2018).

By looking at Big Data and data analytics it is possible to understand what the data is used for and how a company transform data into useful information that can be used for pattern recognition and decision making (Mittal et.al., 2018; World Economic Forum, 2019). This is an area suggested by several of the internal interviewees and seen in existing maturity models, for example in the model by Schumacher et.al. (2018). Many of the internal employees emphasized the importance of analyzing and acting on data, there is only a small amount analyzed today which shows room for improvements. Cloud computing is also expressed by most of the internal interviews as an important area. This is used to understand transmission of data between entities, manage assets and overall operations within a company (Siemens, 2020d).

Several of the internal interviews brought up the concept of IoT as important for digitalization which is also stated by Mittal et.al. (2018). The authors explain that this will create an opportunity for companies to increase efficiency and productivity by letting physical things connect and communicate over the internet. The common belief by the internal employees is the need for looking at cyber security. It is important to actively work with it in preparation for possible cyberthreats (Siemens, 2020f).

Many of the internal interviews brought up the concept of Digital Twins which is seen in both existing maturity models and literature where it is used to reduce time and cost for production, as well as early detection of errors (Siemens, 2020c).

5 MATURITY MODEL PRESENTATION

The model is developed to help customers on their digitalization journey and to provide them with guidance. The developed model and methods for implementation is presented in the following chapter and analyzed against literature and interview findings.

5.1 Maturity levels, Dimensions & Items

The developed model consists out of 6 different maturity levels, 4 dimensions and 9 items. The maturity levels will serve as a guidance for where on the digital journey a company is located. The dimensions are identified areas important to look at when determining a company's maturity. The items in this model are the basis for the questions a customer will be given when using the model to evaluate the company maturity. The maturity levels, dimensions and items are adapted towards Sandvik Coromant core business and will only cover areas that they have a connection to, currently work with or will work with in the near future. A more thorough explanation of the maturity levels, dimensions and items can be found below, and how they will function in the model is explained under chapter 5.2 Structure overview.

Maturity levels

There are 6 levels of maturity, level 0 to level 5, where level 0 is when a company lacks the basic factors for digitalization and no transformation has begun. The basic factors used in this model were identified through interviews and testing. Level 0 was developed to cover the gap that Mittal et.al. (2019) brought up regarding that many existing models assume that the company has started to transform and that the company has all the basic factors in place. Which according to tests conducted in this study is not true in many cases. Therefore, level 0 will serve as a "check" to see if a company is ready to start the digital journey and level 1 will be an entry level to Industry 4.0 which Mittal et.al. (2019) highlights the need for. Level 1 to level 5 will increase in complexity regarding digitalization, where level 5 is the highest possible today. A more thorough explanation of the maturity levels is described below.

Level 0

The company lacks one or more of the basic factors for digitalization. They do not have anyone that is responsible for the digital development and/or lacks network connection and the possibility to connect their machines to a network. The company is interested in digitalization but do not know what it could do for them. They need to see benefits provided by digitalization and needs help to know where to start and what to do.

Level 1 - "Descriptive"

The company is in the beginning of their digital journey and needs help understanding where to start and how to gain the most benefits from digitalization. They have the basic factors in place which means that they have someone that is responsible for the company´s digital development and they have the possibility to connect their machines to a network. They work descriptive to understand the current situation and to understand what has happened in the event of a failure connected to the manufacturing process. The employees do not work with any digital aids, the processes are still performed traditionally through manual work and human interaction. The company does not work with understanding existing competences or gaps and a digital strategy for where the company should be in 3 years does not exist. People responsible for digital development and management communicate only with each other regarding digitalization changes.

Level 2 - "Diagnostic"

The company has started the digitalization journey by implementing some digital aids such as a first step data collection tool, for example an OEE system. There is no infrastructure or continuous improvement structure around it. They look at data from the built-in sensors of the machines and work with diagnostic analysis to recognize patterns and understand why events take place on an overall level, for example to understand why machines are standing still. Analysis of the data form the basis for decision making. Data can be accessed from different points of the factory, but it is not updated fast enough to prevent a failure while machines are running. Most of the processes are still manual but some digital aids, such as tools and software, are implemented in the manufacturing process. The company tries to understand existing competences but not gaps and a digital strategy for where the company will be in 3 years does not exist. Digital developments are communicated between the people responsible for digitalization development, i.e. management and the people it will directly concern.

Level 3 - "Predictive"

The company has started the digitalization journey by acting predictively to forecast events on a more detailed level, for example tool breakage or why different machines run with different feeds and speeds for the same product. There is no overall infrastructure or plan for how different systems should communicate or sum up data for an overall analysis, there is still no clear digital thread through the factory. There is a continuous improvement structure around the digital development and analysis of collected data are used for a higher degree of decisions. Data is utilized from machines through both built-in and added sensors and the company have looked at how to best gain tool performance data. Values and information can be viewed from anywhere, not just in the factory, but is not updated fast enough to be able to prevent a failure while machines are running. They use stand-alone digital aids in most process steps and are moving away from individual manual process decisions. The company works with mapping existing competence to find gaps and a digital strategy for where the company will be in 3 years starts to take place. Digital developments are to some extent communicated to all employees but the once concerned receives more information.

Level 4 - "Prescriptive and standardized"

The company has come a long way on the digitalization journey by utilizing collected data to work proactively. Decisions are manually taken based on analysis of the digitized data and they have started to form an infrastructure to connect systems for example ERP, MES, CAM, SCM and PLC to enable analysis of data and form a digital thread through the factory. The manufacturing process is standardized, and deviations are reported and acted upon through a continuous improvement structure. Employees receive notifications if something is wrong with a process but must manually correct the issue. The company knows about existing competences and gaps and a digital strategy for where the company will be in 3 years are in place. The digital strategy reaches all employees and they know to some extent how it will affect them. Employees also understand and see the benefits of moving into a digitalized company. The company is experiencing measurable gains and improvements through digitalization which is shown in the company KPI´s.

Level 5 – "Towards an autonomous manufacturing"

The company is utilizing most of what is possible today from a digital perspective. They are utilizing collected data through a digital thread and connected company systems, to work with prescriptive analytics through autonomous processes and machine learning. There is an infrastructure in place that enable on demand information through connectivity between systems and machines. Employees receive notifications if something happens, but the machines can to some extent correct the issue autonomously or detect and suggest changes before a problem occur. The company proactively work with bridging competence gaps through standardization and digital work instructions and they have a clear digital strategy that all employees support by continuous development through new suggestions. The digitalization, standardization and autonomy has now transformed the company into partly lights out production. The company are experiencing a higher degree of measurable gains and improvements through digitalization which is shown in the company KPI's.

Dimensions & Items

Four dimensions were identified as necessary to cover in the evaluation of a company's digital maturity in consideration to the delimitations. These four dimensions are: *Data Collection, Data Analysis, Software,* and *Employees & Competences*. Within each dimension there is between 2 and 3 items that will help guide what to search for when evaluating a company. The dimensions with connected items are displayed in Table 6 below.

Table 6. Dimensions and connected items.

Dimensions	Items
Data Collection	*Connectivity, Sensor equipped tools, Sensor equipped machines*
Data Analysis	*Utilization of collected data, Connection to machine data*
Software	*Machine programming, Software*
Employees & Competences	*Digital strategy, Competence gaps*

Areas found relevant from both internal and external interviews were communication and connectivity, creating a digital thread and infrastructures, AI and Machine Learning. These were also brought up as enablers for digitalization by literature (Siemens, 2020b; Siemens, 2020a). Many of the internal interviews further brought up the concept of Big Data, data analytics and Digital Twins. Areas also found in literature and existing maturity models (Mittal et.al., 2018; World Economic Forum, 2019; Schumacher et.al., 2018; Siemen, 2020c). Communication and connectivity, and Big Data were incorporated in the item *Connectivity* and data analytics were incorporated in the item *Utilization of collected data*. Machine learning, and digital thread and infrastructure were incorporated in the higher maturity levels i.e. all items. Digital Twins and AI were discarded from the items after concept tests. Other fields brought up from both internal and external interviews were the need for getting acceptance among employees and to have the right competences. These were also highlighted in literature and incorporated in the Employees & Competences dimension (Ghobakhloo, 2018; Jacobi & Brenner, 2018).

5.2 Structure overview

The developed model consists out of 4 different phases, P*reparation, Company maturity evaluation, Analysis and Follow-up,* that will in the end help a company see where on the digital journey they are and how they can move forward to gain even more benefits from digitalization. Just as said in De Carolis et.al. (2017a) article, companies need help understanding this complex situation. They need an evaluation to aid them with understanding their current situation, provide action plans to move forward and to see the benefits with digitalization. This was the general view from both internal and external interviewees as well. In accordance to De Carolis et.al. (2017b), Schumacher et.al. (2016) and Canetta et.al. (2018) this model will be a combination of a descriptive, prescriptive and comparative model. The developed model will display the company's current situation in a radar chart, descriptive, it will provide the company with an action plan on how to move forward, prescriptive, and it will use benchmark companies to show what is possible and how to benefit from it, which makes it comparative. How the model is structured and what purpose every phase has is shown in an overview in Figure 3 below and a more thorough explanation follows in the coming chapters.

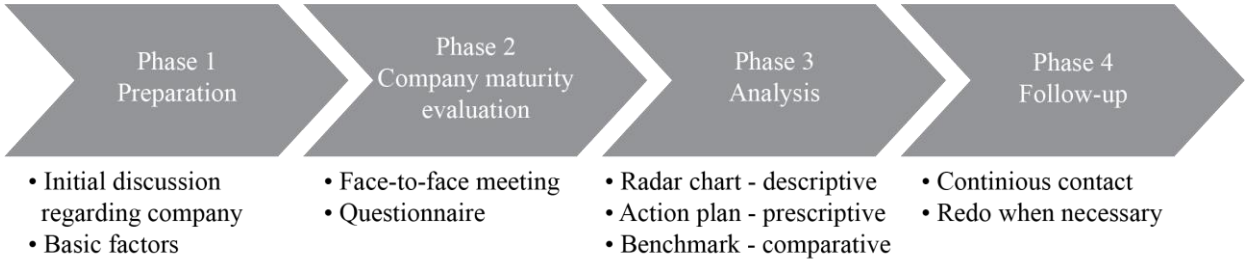

Figure 3. An overview of the model structure and the purpose of each phase.

Phase 1 – Preparation

In the first phase it is assumed that the company being evaluated are interested in digitalization but need guidance in some way. A preparation meeting is set up with a representative from Sandvik Coromant, who is assigned to and prepared for this task, and a production manager or someone with a similar or higher role from the company being evaluated. It can also be someone responsible for the company's digital transformation, but the person should have a decision-making role and knowledge regarding the company's manufacturing process. In the analysis of the interview findings it was agreed that a production manager or higher would be a suitable respondent. Literature said that a production manager or higher would be suited since digitalization changes needs to come from a management level (Richter et.al. 2017). Several of the internal and the external interviewees highlighted the need for both the customer and Sandvik Coromant representatives to have at least basic knowledge regarding digitalization. Many of the internal employees also pointed out that the representative from Sandvik Coromant should have knowledge regarding their digital offers.

The preparation meeting will take place if the customer reaches out and ask for help or if Sandvik Coromant reaches out to the customer. The preparation meeting is being held to discuss the company and get background information. The discussion includes *if the company has a digital strategy or plan to move forward in digitalization, how this evaluation could help them or what the goal is by doing it.* Another thing to discuss is the company´s view on digitalization and if they have gotten any help with it before. The last but equally important thing to discuss is about the company´s view on releasing data to a cloud service and how they work with cybersecurity. These discussions are to ensure that both parties are on the same page and they both know what the company needs help with. The digital strategy was seen as important for most of both the internal and external interviewees. Many of the external interviewees saw this as a starting point for digitalization and literature found say that a lack of strategy will create problems (Parviainen et.al., 2017). Cloud computing and cyber security were also areas pointed out by internal interviewees and brought up as important areas in literature (Siemens, 2020d; Siemens, 2020f).

It will be determined in this phase if the company is a level 0 or a level 1 in maturity with the help of two questions. These questions will cover the basic factors for starting a digital transformation. The two basic factors are to have someone responsible for the digital development, it does not need to be an assigned role but should be someone that is interested and drives the transformation, and to be able to connect at least one machine to a network. Connectivity were something both internal and external interviewees saw as important and found in literature (Siemens, 2020b). Many of the internal interviewees also pointed out the importance of having someone at the company that is responsible for and interested in digitalization. If the company lacks one of these factors the first recommendation will be to get those in place before moving forward. When this is completed another meeting will be booked for conducting the maturity evaluation. Relevant information regarding the customer, such as scale of the company and type of segment, will be collected in this first phase.

Phase 2 – Company maturity evaluation

The second phase will be to evaluate the customers maturity with the help of a questionnaire. This will be conducted in a face-to-face meeting with the same representatives as in phase 1. The idea with a face-to-face meeting is so that the representative from Sandvik Coromant should be able to help and clear up any misinterpretations and to make sure that the answers are in line with how the customers workshop looks. This is in line with several of the external interviewees impression about that many customers might think they know what they are doing but they are not.

The questionnaire that the customer will answer is built upon the defined dimensions and under each dimension, a number of questions will be asked. The questions will be based upon the items each dimension holds. The items can be found in Table 6 in the previous chapter. There is a total of 10 questions. Every question has 5 answers where each answer fits one maturity level. The answers increase in maturity so the first answer matches maturity level 1 and the fifth answer matches maturity level 5. The questions and related answers can be found in Appendix A - Maturity Evaluation Questions from Phase 2. The customer then gets to place themselves within the level most suited for where they see themselves today and the level where they want to be in three years. This is to discover where the customer wants to develop within digitalization. If a company would say that they are on a level 5 today within an item, a sixth alternative would pop up for where they want to be in three years. This alternative would be to keep developing within this item, which is in line with interview findings and as stated by the interviewee of Company D.

"*You cannot stop developing, it is important to always keep improving! You should never sit down and be satisfied with the situation!" - Interviewee Company D*

Mittal et.al. (2018) recognized that existing models mainly focuses on larger companies which caused them to be ill-fitting for SMEs, who in most cases do not have the same circumstances and starting points. It was also noted during testing that depending on what type of production a company has they could get a misleading maturity. Most of the external interviewees expressed a need for a solution that could fit all types of customers since they feel that everyone has different needs. The journey will be different for everyone and this is connected to how companies implement solutions in different ways (Schumacher et.al., 2016). This caused a need for a model that could cover all types and scales of manufacturing companies. To make the model suited for that, it contains an option which makes it able to disregard some of the items in the analysis. If a company for example do not use any kind of software programs or similar, and only program manually directly in the machines due to the type of production they have they will get a low maturity in that item. This will drag down the maturity for the whole dimension and that will be misleading since they do not see that kind of tool as something they would benefit from. Therefore, if they choose the same level today as they want to be in three years, they will be able to explain their reasoning behind it. That item can then be chosen to be ignored in the analysis if both the representative from Sandvik Coromant and the customer see it fit. A discussion about the item will be made to see if the item might provide any gain for the company in the future.

Phase 3 – Analysis

When the questionnaire is filled out it is time for the analysis. This will be performed at the same meeting directly after the questions so that everything is still fresh in mind and if more information is needed about the workshop it will be easy to gather.

The analysis presents an overview of the evaluation in form of a radar chart, see Figure 4 for an example. This will be automatically generated when the questionnaire is filled out. For each dimension, the diagram shows an average of the degree of maturity based on the answers to the questions within the dimension. It shows both where the company is today and where they want to be in three years. Note that the maturity levels presented in chapter 5.1 Maturity levels, Dimensions & Items are general descriptions. A more thorough explanation of how the maturity levels relate to each dimension can be found in Appendix B - Maturity Level Overview and Technology. The gaps that will appear between where the company is located today and where they want to be in three years makes it easy to find areas of development. The diagram also shows customers of Sandvik Coromant that have come the longest on the journey today as benchmark companies to visualize what can be done. This is to show the customers what is possible today and to provide with examples from their journey. The benchmark companies' position will continuously be reviewed to show a diagram that is up to date.

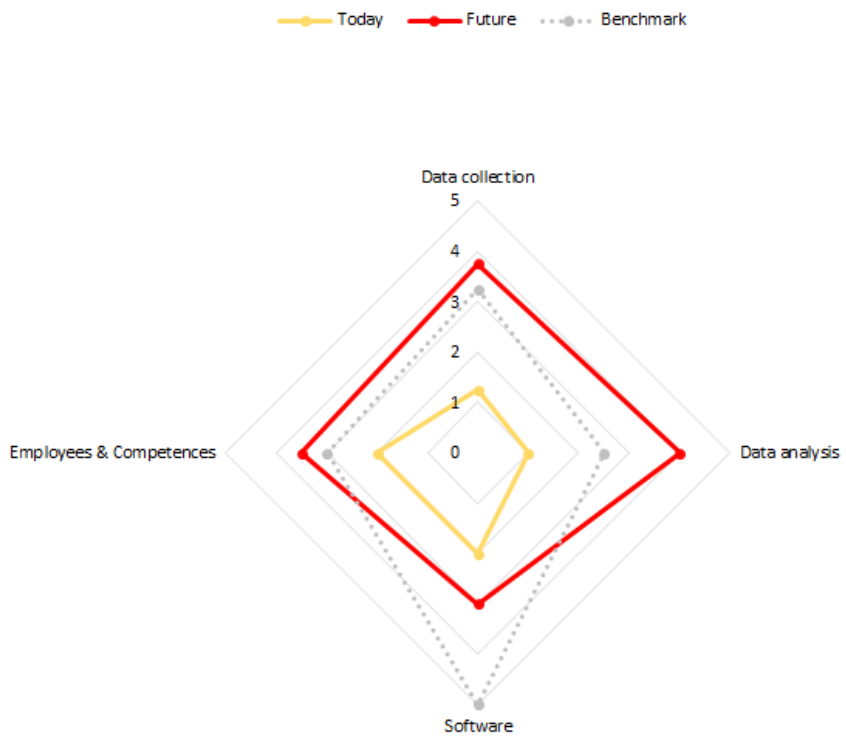

Figure 4. Example for how the radar chart visualizes maturity in different dimensions. This chart show company G:s beta testing.

There is also the possibility to go in deeper in the dimensions and look at the maturity on each item. The customer will be provided with examples from other companies of similar scale and segment that has gone through these steps that they want to pass thorough as highlighted as important by many interviewees and by Wiesner et.al. (2018). The examples will contain stories of what actions the other company took and what they gained by doing so. This is to show them what they can do and what they can benefit from doing it. One example of such a story can be found below and more examples from different segments and in different levels can be found in Appendix C - Success Stories From Evaluated Companies. Machado et.al. (2019) said that many of the manufacturing companies are in the beginning of the journey and struggles with defining a starting point from where they are now. Therefore, the customer and the representative from Sandvik Coromant will decide together in what dimension and item the customer will begin or move further in, and a more detailed action plan will be created. This correlates with many of the internal interviewees view of starting the transformation where most is to gain and change in smaller steps. The analysis will also contain a mapping of Sandvik Coromant current digital offers, and the offers that will be released in the nearest future. This mapping will be used internally by Sandvik Coromant so that they easily can see what products are suited for their customer depending on their maturity level and dimension to develop within.

Example provided in the analysis phase

According to the diagram in Figure 4 the evaluated company, Company G who participated in the beta testing (introduced in table 5 in chapter 3.5 Model development), wants to develop from a maturity level 1 to a level 4 in the Data analysis dimension. The first focus will therefore be to move up to a level 2. The evaluated company is a large-scale company and has a medium- to large series production. Company D from the beta testing is of the same size and has a similar production as Company G. They took the step forward from maturity level 1 to level 2 just like Company G wants to do. Company D realized that they did not need to buy new machines to increase the production capacity. They installed an OEE system which is about utilizing the machines that exist and plan the production in the best way possible to make use of existing capacity. It then became possible to plan when the machines are standing still and when they are running. Company D used this to plan more efficient production and utilize capabilities by understanding data regarding how much the machines are standing still.

This story provides Company G with information of what can be done and what others have gained on doing it. They will get examples of digital aids that worked for others in the same situation and can bring these with them to show other employees in the company what can be done and what they can gain from it in order to start their transformation.

Phase 4 – Follow-up

The last phase will be a follow-up to make sure the company gets the help they need along the digital journey. It will be a continuous contact between Sandvik Coromant and the customer. When the company has developed within recommended dimensions, they will get help with deciding on where to put focus next. The company will be offered to redo the evaluation if they feel it would be necessary.

5.3 Continued updates

Since digitalization is a fast-changing area and new offers continue to be introduced, the model will need to be updated on a regular basis. New digital offers need to be mapped, new stories will be collected, and new dimensions discovered. For example, it was discovered during testing that items such as AI and Digital Twins were to new and complex today for such a conservative industry and that many customers had not even heard about them. Even so, it was also discovered that those most likely would be relevant in the future and they were therefore moved to chapter 7 Future work & Recommendations. This also makes it necessary for the customer to redo the evaluation regularly, so they get to discover new technology and benefits connected to digitalization. The idea is that the model will be a living document. This means that the structure is built in a way that makes it easy to add new dimensions and areas, as well as remove those that becomes “every day” items, meaning they are a standard component in every company. With these fast changes there will also come a need to continuously update the maturity levels. Level 5 today might be level 3 in a few years and level 1 today might be a level 0. Alongside these updates every new customer will bring more example stories and eventually there will be stories for every type and scale of company in every dimension and maturity level. The model will also grow in line with Sandvik Coromant offers within digitalization.

6 DISCUSSION & CONCLUSION

In this chapter the authors discuss the results and correlating topics of this thesis. A conclusion is presented with the aim of answering the formulated research question and purpose of the thesis.

5.1 Discussion

The discussion will start with an assessment of the conducted method. It will then cover the area of general view on digitalization and lastly a discussion regarding the developed maturity model.

Method

Because of the current pandemic and the connected restrictions, it was not possible to visit any of the interviewees. This may have caused some important aspects to be overlooked such as body language and reactions. It has also not been possible to visit the manufacturing sites of the customers which was initially thought to be a way to ensure that the provided information was accurate towards their production facility. To try and minimize the impact from not being able to have physical interviews, they were to the furthest extent possible held over videocalls. The restrictions also caused planned educations regarding Sandvik Coromant digital offers to be canceled. These educations would have provided useful information regarding necessary factors around the digital products. This information was instead acquired through meetings with two Managers from the Digital Machining department.

There is a clear overrepresentation of internal towards external interviews throughout the study. This was caused by not finding customers who had time to participate due to the circumstances of the pandemic. To ensure the customer perspective, the once participating has been contacted on multiple occasions to review progress and changes.

The aim of the method was to gain a global perspective of the CNC manufacturing industry and how digitalization is affecting it. The conducted interviews have mainly been held within Sweden which may have caused the maturity model to be beneficial towards the Swedish market. Being aware of this there have been efforts to try and validate findings towards other markets, but there is a need to cover more geographical markets to ensure the assumptions to be correct on a global perspective.

General digitalization

During the interviews and concept tests there was a clear overrepresentation of internal interviewees which may have caused results to be more affected by their thoughts. The internal interviews were performed with employees from different departments but mainly Sales and Digital Machining. The interviewees from Digital Machining are working with digitalization on an everyday basis and therefore possess a higher degree of knowledge regarding digitalization than many of the other interviewees. The higher number of identified enablers is one area that can be connected back to the broader knowledge of these digitalization professionals. During the analysis

of the interviews it was therefore important to not discard information that was only presented by the internal interviewees. Important areas identified here were instead investigated during concepts tests with the external interviewees and after that either discarded or included in the evaluation model.

The external interviewees came from companies of different maturity and with different individual knowledge regarding digitalization. This provided the opportunity to gain knowledge from companies in different places of the digital journey, which was positive in the creation of a model that was to be suitable for differently mature companies. Results from these interviews were therefore spread and, in some cases, hard to analyze. The analyzed information was used to try and create a general market view of digitalization and was therefore presented to internal interviewees for validation.

The metal cutting industry is generally seen as a very conservative industry, which has been confirmed through interviews and literature. Many of the older generation are skeptical to the changes brought by Industry 4.0 but it seems to be connected to a lack of knowledge rather than only resistance to change. Both interviews and literature believe that when the generation shift comes digitalization will get a big push forward. What is seen is that there is not only age that puts a stop to the transformation but also not seeing possibilities and benefits. These are aspects that need to be better communicated towards the companies and employees in the industry for them to take the leap. It is believed that this change on the market not only will increase the interest in digitalization and Industry 4.0 but also increase the need for assistance in the transformation. It will therefore be higher pressure from the market on performing these kinds of assessments and to receive aid from companies providing systems of solutions.

Because of the generation shift a lot of knowledge is believed to vanish from the industry. It is therefore important for companies of all scale to work in a way that will preserve this knowledge and skills, either through development of products or other systems. This creates a great opportunity to develop solutions suitable for this coming need where they can help save and improve the handicraft of the industry.

Maturity evaluation model

The maturity levels were created to describe the different stages a company can go through during the digitalization journey. The finalized maturity levels are a result of multiple iterations containing areas connected to digitalization. These areas were reviewed based on their importance for digitalization and on how they can develop from least advanced to most advanced. Through this iterative work, areas were added, deleted and modified. The areas that are now included, together form the foundation of digitalization as seen from a CNC manufacturing point of view with focus on the workshop. Because of the fast changes within digitalization, these levels and the model are constructed as a live document where areas can be added or changed depending on the industry transformation.

The recommendation is to perform the evaluation with a production manager. The production manager was decided as a suitable respondent due to their overview of the workshop and knowledge regarding the manufacturing processes. It was also believed that the results may not be received with the same recognition of importance if it was presented to company management by

someone within a lower position. Since the model is aiming to be helpful for companies of all scales within different segments, it is also understood that a production manager may not exist in all companies or that the responsibilities differ. It is therefore also recommended that the respondent should be a person with knowledge of digitalization, in a decision-making position and who have knowledge regarding the company's manufacturing processes.

It is decided that the company maturity evaluation, phase 2, should be performed during a face-to-face meeting as suggested by the internal interviewees. The external interviewees preferred to do the evaluation alone, but since it was discovered that the knowledge heavily varied depending on interviewee it was decided that a face-to-face meeting with discussions would bring more value to the customer. To enable a more standardized questionnaire, it was decided to not go with the suggestion of open-ended questions. The format as it is today is believed to ease both the further expansion of the form but also the analysis of the results. This also enables the analysis, phase 3, to take place during the same meeting as answering the questionnaire.

The included dimensions and items are believed to cover the important aspects of digitalization as it is today. During internal interviews, areas such as Digital Twin, AI and Machine Learning were discussed but when validated with customers they were seen as too complicated and therefore moved out of the model. In the end it was possible to incorporate Machine Learning in the model as a maturity level 5 in other items. Machine Learning connects to autonomy which is a big part of digitalization according to both literature and interviews. Due to the flexibility of the model structure, these areas and others can easily be added either as their own dimensions or incorporated in future maturity levels for all dimensions. The importance here is that they are not added until the market is ready for it and understands the surrounding concepts.

During the concept tests, it became clear that some companies already reach level 5 within some dimensions. To understand if these companies see a possibility to develop further, an alternative 6 that they still want to develop, was added. This was done to continue the inclusions of these companies and to ensure that when a suitable product was developed these companies can be approached first. This can also be used to map areas where development is needed, and possible businesses can be identified. This shows which companies are interested in moving beyond what is seen as possible today. During the concept tests, it was further discovered that all segments do not benefit from the same kind of digital development and products. If a company do not see a reason for developing within an item, it opens a discussion between the company and the Sandvik Coromant representative regarding why. Knowing this creates an opportunity to develop new products suitable for this segment. It will be possible to approach customers for interest in pilot installations of new products suitable for their needs.

The visual representation of the analysis is something that will help the evaluated company gain an overview of their individual results. It will also aid in assisting with deciding what dimension the company should focus on first. Visualizing the current and future state of the company will aid in creating a common ground of discussion within the company which will be helpful when the benefits and value of digitalization is discussed. Usage of the model will continuously collect more example stories from companies of all segments and sizes which will further aid companies in their transformation. When more example stories are collected it ensures that the model accomplishes the goal of being a tool used for all kinds of CNC manufacturing companies.

5.2 Conclusion

The purpose of this thesis was to investigate how the CNC manufacturing industry can benefit from digitalization and Industry 4.0 and to find out where the digital journey begins and what stages a company must pass through to become digital. This investigation should result in a maturity model with connected methods for implementation for the CNC manufacturing industry to locate where on the digital journey companies are. By doing so the companies could be offered the right digital products to help them move forward on the digital journey. This model should be structured in a way to aid companies of all scales and in all segments within the CNC manufacturing industry, which would also answer the research question. The purpose of the thesis was also to help Sandvik Coromant provide suitable products depending on the customer maturity to help them forward in their digitalization transformation.

The thesis work resulted in a maturity model that can map companies of all scale and in all segments in a maturity level within 4 different dimensions. There are 6 maturity levels, level 0 to level 5, where level 0 represents a company that has not started the digital journey and level 1 represents the beginning of the journey. These maturity levels represent the stages a company must pass through to become a digital company, where level 5 is the highest level seen today. This model is constructed in 4 phases, *Preparation*, *Company maturity evaluation*, *Analysis* and *Follow-up*. The first two phases will collect information regarding the company being evaluated and the last two phases will show where on the digital journey the company is today and provide help and actions for how to move forward. The analysis will show where on the digital journey the company is located today and where they want to be in three years by mapping them into one maturity level within each dimension. When the company is mapped into a maturity level, they will be provided with actions for how and in what dimension to move forward in first. They will also be provided with example stories from similar companies that have passed through the steps the evaluated companies are about to. This will show them how other companies that have been in their position have benefited from digitalization and Industry 4.0. The example stories will show how a CNC manufacturing company can benefit from digitalization within different maturity levels and dimensions. The analysis will also contain a mapping of benchmark companies that will function as a tool to show companies what is possible with digitalization and Industry 4.0. Sandvik Coromant own products have also been mapped into the different maturity levels and dimensions which makes it easy to recommend the right products and to see gaps where new products could be developed. The final phase will allow Sandvik Coromant to keep helping their customers develop and move forward on the journey. This thesis work further resulted in methods for how the maturity model should be implemented for gaining best output.

The structure of the model enables it to be used on companies of all scale and in all segments, which was identified as a need by earlier research. The developed maturity evaluation model with connected methods for implementation will enable Sandvik Coromant to aid their customers in the CNC manufacturing industry by mapping their digital maturity and provide suggestions for how to move forward in a transformation.

6 FUTURE WORK & RECOMMENDATIONS

This chapter presents future work and recommendations for Sandvik Coromant that is seen as important for the development of the presented maturity model and surrounding areas.

The results from this thesis work have shown the importance of having the right competences responsible for evaluation of customer maturity and the presented model. The recommendation is that this task should fall on a department, or group, who possess a large amount of knowledge within this area while at the same time managing good customer contact. This is needed both to provide the customer with the best help possible within the field of digitalization but also for Sandvik Coromant to continue their development within this area. Customers will expect the person performing the analysis to be knowledgeable within all aspects of digitalization while at the same time understanding their workshop and communicate the correlating benefits.

The dimensions and items that form the model today lay within the scope and core business of Sandvik Coromant but will need to evolve as the industry do. Sandvik Coromant cannot cover the whole value chain on their own and with their current offerings, it will therefore be a future recommendation to take in partners that can cover those parts they cannot. This will make the model even more attractive for customers if they can get help with a larger range of area. It will also allow Sandvik Coromant to help new customers that need guidance in other parts of the value chain. A recommendation is to look at dimensions from existing maturity models that were discarded for this thesis.

The fast pace of the digitalization development requires that the model will be continuously expanded. A recommendation is that new questions are tested on different customers to ensure that they are understood in the correct way. This applies to adding or changing questions and the answer levels. This is especially applicable when adding dimensions such as AI and Digital Twin. These areas were excluded from the current model due to their complexity and the more theoretical stage they are in today. In the future it will be important to add these areas to the evaluation model as they become a bigger part of the market and to adapt the maturity levels based on the customers understanding of the concepts. Therefore, customer involvement throughout future developments of the maturity model is necessary and recommended.

More example stories need to be collected as well as more stories from benchmark companies to provide more content to the model. Example stories from customers will be collected over time and mapped into the model. Stories from benchmark companies will from start be collected from Sandvik Coromant own lighthouse production in Gimo but more benchmark companies from other segments and scales needs to be contacted. These companies will show what is possible with digitalization and Industry 4.0 for all segments, to provide suitable examples for the model to continue to be useful for different companies. This will also help present possibilities with digitalization to companies in different segments and of different scale.

A further recommendation for the future development of the maturity model is to include companies that are involved in pilot installations of digital offers. These companies are perfect to be used as success stories and examples in the analysis phase of the model. The benefit here is that tangible results can be recorded such as percentage increase in efficiency or machine utilization depending on the implemented product.

The perspectives of the production technician and machine operator should be more thoroughly investigated in the future. These positions are to a high extent affected by the introduction of digitalization that causes new work tasks and need for new competences. In line with getting all employees onboard for a digitalization transformation these positions need to be understood in their expectations and needs connected to digitalization. It is recommended to further explore the example stories provided to include how the changes also have affected the everyday tasks of the employees. This is seen as a possible way to provide tangible examples that will show the employees benefits and positive changes connected to digitalization and through that increase their interest in the subject.

It should further be investigated how the model can be adapted towards different countries. This current model is, as previously mentioned, tested mainly towards a Swedish perception of digitalization of the industry, but other countries may need levels or areas to be changed. Language barriers may occur which can cause wrong interpretation of questions. It is therefore recommended to adapt the language to where the maturity evaluation is performed.

The model will eventually be able to be used for collecting statistics over customers. When a larger quantity of customers has performed the evaluation, it will be possible to aggregate the data into statistics over the industry. These statistics can then be used to better understand the different needs from companies within the different segments of the industry and on different markets. By better understanding market shifts it is possible to identify business opportunities to further aid the CNC manufacturing companies.

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APPENDIX A: MATURITY EVALUATION QUESTIONS FROM PHASE 2

This appendix presents the questions asked in phase 2 in the developed maturity model. The questions will be presented after which dimension and item they belong to. The answers for each question are related to maturity levels 1-5, where the first answer is related to maturity level 1, the second answer is related to maturity level 2, etc. The evaluated company will choose one answer corresponding to their current state and one that represents their target state in 3 years.

Data collection

Connectivity

Are the machines in the shop connected to a network?

1. No, but we have the possibility to connect relevant machines
2. Yes, we have some relevant machines connected
3. Yes, we have all relevant machines connected
4. Yes, we have all relevant machines connected and we have started to integrate machines and systems
5. Yes, we have all relevant machines connected and have integration between machines and systems that let them communicate

Sensor equipped tools

Do you use tools that are equipped with sensors to monitor tool performance in real time?

1. No, we do not use that kind of tools and are not interested in tool performance data
2. No, we only look at data from the machines regarding tool performance
3. Yes, we have or are trying this kind of tools but only utilize the data to a smaller extent
4. Yes, we use that kind of tools and utilize the data manually
5. Yes, we use that kind of tools and utilize the data autonomously

Sensor equipped machines

Are your machines equipped with sensors to monitor the manufacturing process?

1. Yes, but no additional sensors are added, and we do not utilize the data
2. Yes, but no additional sensors are added, and we are utilizing data in the machines to form the basis for decision making
3. Yes, some machines are equipped with additional sensors and we are utilizing data in the machines to make decisions

4. Yes, we have added additional sensors and utilize data through standardized procedures
5. Yes, we have added additional sensors and are utilizing the data for autonomous decision making

Are your machines equipped with sensors to monitor the machine condition?

1. Yes, but no additional sensors are added, and we do not utilize the data
2. Yes, but no additional sensors are added, and we are utilizing data in the machines to form the basis for decision making
3. Yes, some machines are equipped with additional sensors and we are utilizing data in the machines to make decisions
4. Yes, we have added additional sensors and utilize data through standardized procedures
5. Yes, we have added additional sensors and are utilizing the data for autonomous decision making

Data analysis

Utilization of collected data

How do you utilize collected machine data?

1. We use descriptive analytics to understand what happened if something goes wrong
2. We use diagnostic analytics to understand why something happened and to find patterns
3. We use predictive analytics to understand what will happen by forecasting events
4. We use prescriptive analytics to understand what can be done proactively to prevent events
5. We use prescriptive analytics autonomously to understand what can be done proactively to prevent events

Connection to machine data

Do you have any connection to the manufacturing process to access information?

1. No, I have no connection to the manufacturing process
2. Yes, I can view values and information from anywhere in the factory and can generate a daily production report
3. Yes, I can view values and information from anywhere
4. Yes, I can view on demand values, information and I get notifications if something happens, but I must go and manually correct the process
5. Yes, I can view on demand values, information and I get notifications if something is happening. The machines can autonomously correct the process

Software

Machine programming

Do you use any software to aid with programming of the CNC-machines?

1. No, we are manually programming the machines
2. We have it but mainly use manual programming
3. We have it and use it for all relevant parts
4. We use it and we also have a separate simulation and verification software for more advanced parts
5. We use a program that in an automated way generates CNC code from a 3D model

Software

To what extent are software used to aid the manufacturing process?

1. Not at all
2. We have invested in standalone software's to support the manufacturing process
3. We use software's to make analysis on a more detailed level for tools and/or machines
4. We have started to connect different software systems to follow the digital thread through the manufacturing and are using it to prevent failures by fast data.
5. We have connected the major systems needed and can follow the digital thread through production both on an aggregated level and on a detailed edge data level in the machines.

Employees & Competences

Digital strategy

Does the company provide employees with information regarding the digital strategy?

1. No, the information is only communicated between the responsible for digitalization and management
2. The information is only communicated to the people it concerns
3. Some parts of the strategy are communicated to everyone, the ones concerned receives more information
4. A more thorough plan reaches all employees, and everyone know to some extent how it will affect them
5. Yes, everyone knows about the strategy, how it will be implemented and how the changes will affect everyone's work

Competence gaps

How does your company work with existing digital competence gaps?

1. We do not work with understanding existing competence or gaps
2. We try to understand existing competences but not gaps
3. We work with mapping existing competences in order to find gaps
4. We know about existing competences and gaps
5. We proactively work with bridging competence gap

APPENDIX B: MATURITY LEVEL OVERVIEW AND TECHNOLOGY

This appendix presents the developed maturity levels in a table structure to provide a comprehensive overview of how they connect and change in relation to the dimensions of the evaluation model. Some technologies connected to digitalization are also presented in relation to in which maturity level they are introduced to a company.

The maturity levels described in chapter 5 Model Presentation are the general overview of the stages that a company in the CNC manufacturing industry goes through during a digital transformation. To provide an easier understanding of a company's maturity development within each dimension brought up in phase 2 of the evaluation model, the levels have been divided and are shown in Table 1 below. The table only covers the topics related to the defined dimensions. Areas connected to digitalization that are covered within the first phase of the evaluation and found in the maturity levels, such as strategy, are not mapped into this table. Those areas are still developed through the maturity levels and discussed with the Sandvik Coromant representative.

Table 1. Maturity levels mapped in the dimensions of the evaluation model.

		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Data Collection	*Usage of sensors*	-	*Built in the machines*	*Built in and additional*	*Built in and additional*	*Built in and additional*
	Infrastructure	-	-	-	*Started to connect systems*	*Digital thread*
Data Analysis	*Usage of data*	*Descriptive*	*Diagnostic*	*Predictive*	*Proactive*	*Prescriptive with autonomous processes and Machine Learning*
	Prevention of failure	-	*Data is not fast enough to prevent failure*	*Data is not fast enough to prevent failure*	*Operators are notified but manual correction is needed*	*On demand data, machines can to some extent self-correct*

Software	*Use of digital aids*	-	*Some tools and software are implemented*	*Use stand-alone solutions*	*Started to connect systems and machines*	*Connectivity between systems and machines*
Employees & Competences	*Competence gaps*	-	*Tries to understand existing competences*	*Mapps existing competences*	*Knows about competence gaps*	*Proactively work with competence gaps*

To create further understanding of the differentiation between the maturity levels the technology connected to each level has been mapped in Table 2 below. This table is created to gain an overview of some technologies and when they are supposedly implemented during a digitalization journey.

Table 2. Technologies connected to digitalization mapped against the maturity level where they are introduced to a company.

	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
OEE System		*x*	*x*	*x*	*x*
Process Control			*x*	*x*	*x*
Smart tools			*x*	*x*	*x*
Machine sensors/data	*x*	*x*	*x*	*x*	*x*
Additional sensors			*x*	*x*	*x*
Basic analytics		*x*	*x*	*x*	*x*
Advanced analytics			*x*	*x*	*x*
Machine learning					*x*
On-premises data storage		*x*	*x*	*x*	*x*
Cloud storage				*x*	*x*
Digital thread in machining				*x*	*x*
Digital thread from design & planning					*x*

APPENDIX C: SUCCESS STORIES FROM EVALUATED COMPANIES

This appendix presents examples of success stories from companies of different scale, segment and maturity to be used in the analysis phase of the evaluation model. The stories will be used to provide companies with suggestions of what can be done to move from one maturity level to the next within the different dimensions.

Data Collection

Level 3 to level 4, Sensor equipped machines

- **Small company with small scale production regrading added sensors** – By adding sensors to the machines, the company has been able to measure the exact things that are interesting to them in the way they want it presented. The existing sensors in the machine did not show the correct values compared to reality, according to the company. Everything is about collecting the right data to take decisions from, and the company was able to do that through added sensors. This gave the company more correct values that were used to form statistics from, to then work together with the employees to understand what could be done differently.

Level 3 to level 4, Connectivity

- **Small company with high precision production regrading integration of systems -** The company has worked a lot to create good integration between different systems. Standardization and connection have been big challenges. It exists a lot of good standalone solutions but when they are to be integrated it gets harder. The company work with integrating sensor equipped tools, sensors in machines and measuring equipment since they are all affecting each other. The company states that it is important to think about the bigger picture to ensure that there is a plan for integration. The more work that is put into it the more solutions will come up.

Data Analysis

Level 3 to level 4, Utilization of collected data

- **Small company with small scale production regarding analyzing data** – Data can be misleading if it is not analyzed and compared in the correct way. The company investigated the degree of utilization of two machines but first when the data was compared to the weekly revenue, they realized that the machine with lower utilization degree produced a higher value. The company used that data for strategic decisions and changed the direction of the company. This shows the importance of knowing the numbers and how to analyze them.

Software

Level 1 to level 2, Software

- **Small company with small scale production regarding starting points** - The company tries to implement smart and easy tools that already exist but is suitable for their company and production. A good place to start is with easier manual tasks around the machines. All employees have an app where they report actions and problems which then is used as a platform for improvements. It is about digitalizing the parts where most value is found, and it does not need to be connected only to production.

Level 4 to level 5, Machine programming

- **Large company with small- to large scale production regarding automatically generated code** – The biggest win seen in having automated generation of code for the CNC-machines is that the code is always optimized and that the company always use the latest version since it is created automatically. Otherwise there may be different versions that creates confusion. Automatically generated code has also created higher flexibility for the customers to create their own parts within some parameters. They can go online and design their product, press order and the program run everything on its own.

Employees & Competences

Level 3 to level 4, Competence gaps

- **Large company with small- to large scale production regarding competences** – The most important thing in a company is the people. It is therefore important to know the competences, especially what is needed for "tomorrows production" and for that a company need to know what exists today. The company are mapping competences twice each year and do self-assessments with the managers, if an employee are on a level 1 they should learn more and on a level 5 they are so good in one area that they can teach their colleagues. This works great because it lets the company see where there are gaps in certain departments and what is vulnerable in case of specific events. This is a big part of success.

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