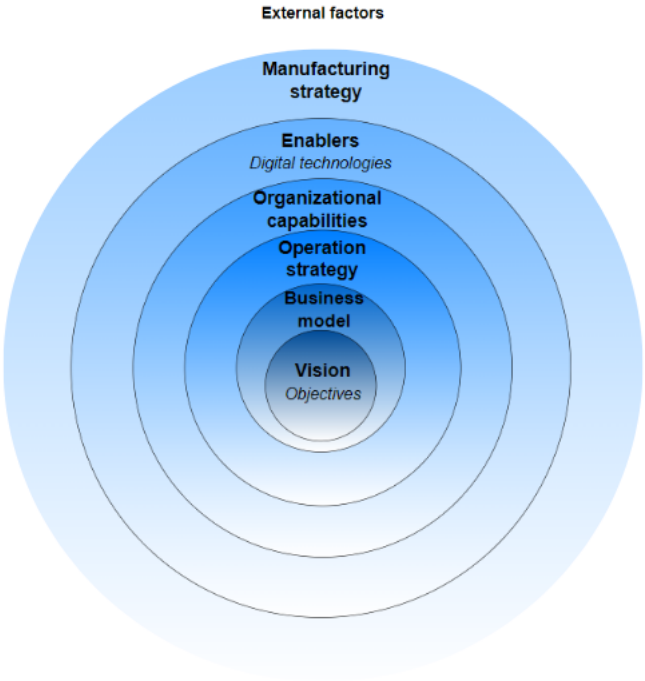

Guiding firms in the automotive industry with digital transformations

A conceptual framework and case study in a Swedish car manufacturer

Master's thesis in Production Engineering

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Department of Industrial and Materials Science
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2022
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Abstract

The automotive industry is characterized by high competitiveness and rapid development. One of the most recent drivers for technological innovation is electrification, which is currently reshaping the industry. Car manufacturers are rapidly adapting to the new dynamics of both increased competitiveness and changing customer requirements. To satisfy customer demands and remain competitive, car manufacturers need to be flexible in their production and adapt to the increased complexity as a consequence of higher levels of customization and shorter lead times. In addition, the growing availability of more advanced technologies to create better products also increases the complexity of the production processes. One way to meet these demands is to increase the level of digitalization by implementing digital technologies. However, a common challenge for manufacturing companies is to understand how to adapt digital transformation to enhance value creation and increase the utilization of digital implementations. To address this gap, this thesis explores the organizational capabilities needed to enable the development of a digital twin and how operational strategy and digital technology can be interpreted to support digital transformation. Through a literature review, interviews and a case study, this thesis concludes that there are five essential capabilities that organizations must have to advance in digital transformations. Also, by integrating the development of these capabilities into strategies, they can be better utilized. Secondly, operation strategies can be used to support car manufacturers to successfully undergo a digital transformation and enable the implementation of digital technologies by aligning the way of working with the vision to reach the organization's goals. This thesis proposes a framework for automotive companies to support them in creating new ways of working to advance in digitalization by proposing seven dimensions to consider. By doing so, the results of this thesis can support automotive companies to overcome the most common obstacles faced when advancing in digitalization and increase the utilization of their capabilities, hence, easing the digital transformation process.

Keywords: organizational capabilities, operation strategy, digital technologies, digital transformation, Industry 4.0, automotive industry, manufacturing, framework, digital twin.

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Koiar Ahmad & Rami Dukhan, Gothenburg, June 2022

List of Acronyms

3D	Three-dimensional
BM	Business Model
DM	Digital Model
DTM	Digital Transformation Model
DS	Digital Shadow
DT	Digital Twin
I4.0	Industry 4.0
IoT	Internet of Things
KPI	Key Performance Indicator
OEM	Original Equpment Manufacturer
RQ	Research Question
SMS	Smart Manufacturing Systems
WCM	World Class Manufacturing
WoW	Way of Working

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1
Introduction

This chapter introduces the thesis by providing the project's background and describing its relevance. The aim, objectives and research questions are also presented in this chapter. In the last section, the limitations and delimitations for the project are evaluated to clarify the scope of the thesis.

1.1 Background

As the world faces huge environmental challenges, world-leading manufacturing companies need to switch focus towards new innovative solutions. At the same time, during the 21st century the world is experiencing the fourth industrial revolution accelerating digitalization in all industries [1]. Besides the environmental challenges, modern society is undergoing rapid growth in technological development on all scales. From a manufacturing perspective, the challenge of producing higher quantities, faster, cheaper and more efficient is still as relevant today as it was during the first industrial revolution [1]. The automotive industry is characterized by fast changes and a highly competitive global market. Also, the complexity in the supply chains is one of the characteristics with new Original Equipment Manufacturers (OEM) entering the market as the technology in the product increases fast [2]. Except for these characteristics, customers' consumption behavior has also changed. Today, customers' demand shorter time to market and higher customized products which have increased the complexity in production systems by more product variants and the need for fast adaptability [3].

New laws and regulations are forcing the automotive industry to quickly adapt its products and processes to more sustainable alternatives. One of the most critical environmental issues is carbon dioxide emissions from passenger cars, which must be drastically reduced [4]. This pressures the industry to quickly change their engines to more sustainable ones and, therefore, there is now a growing interest in electrification. The electrification of cars places completely different demands on both manufacturing methods and technologies. This represents an incredible change for the whole industry, requiring massive investment in new skills, new equipment and new processes. A prerequisite for this change is digitalization and automation, which can facilitate the transformation through a range of benefits and cost savings.

The fourth industrial revolution is commonly referred to the concept of Industry 4.0 and is a local initiative from Germany that has recently become strongly associ-

ated with digitalization in the automotive industry [5]. The concept of Industry 4.0 is today extended to include the whole value chain, from manufacturing to the consumer, requiring a digital transformation on all scales [1]. To withstand these fast changes in the market the digital transformation becomes an essential tool for flexibility and adaptability [6]. As a result of increased digitalization, business decisions can be made faster and with greater precision, quality can be improved through easier access to data and capital investment can be reduced [3]. These are some of the many potential benefits of digitalization for manufacturing companies, and these benefits will determine the profitability and competitiveness of companies in the near future. However, to reach this level of digitalization and its advantages, organizations must undergo digital transformations. Nowadays, companies have to consider more dimensions rather than just the technology of the transformation itself [7]. Organizational, environmental and social aspects become fundamental considerations to successfully implement digitalization. Because of this, more needs and requirements for internal capabilities have to be covered in addition to the technical aspect. Companies must have a clear vision and formulate a step-by-step plan to continuously develop the maturity of digitalization by introducing new methods and Way of Workings (WoW) [3].

1.2 Aim

The thesis aims to support car manufacturers with digital transformations to facilitate the development of a digital twin (DT) as the long-term goal. The project will support car manufacturers by finding correlations, conclusions and proposing a framework based on compiled data collected through the methods. By considering the framework, car manufacturers can implement its essence in their organization and create new WoW to accelerate and simplify work towards the vision. In addition, the thesis aims to contribute to production and management research with new findings and information based on primary data from the industry to encourage future research related to the topic.

1.3 Research questions and objectives

From previous research, it is shown that there is currently a lack of knowledge when it comes to capabilities, operation strategy and digitalization. For example, literature suggests potential research questions and directions within the field of digital transformation for manufacturing companies [8]. There is a strong interest in research on how to guide companies through the digital transformation phase and how technology can help overcome the challenges associated with the implementation of digital transformations [8]. Both these aspects are related to the second research question of this project. Moreover, the article points out several potential research questions to investigate how different types of capabilities relates to digital transformation, which is associated to the first research question of the thesis [8]. In addition, less attention has been laid to the organizational and managerial approaches to digital transformation [9]. Another reason why the thesis is relevant

is that the project partner, a Swedish car manufacturer, needed support to create a framework to guide them through a digital transformation. In addition, this facilitates their work towards their vision, which will be described later in the thesis. Thus, there is an interest from both the academia and the manufacturing industry to investigate how to facilitate digital transformation to reach specific objectives.

Based on this and the background of the project, the following two research questions (RQs) was formulated:

RQ1: *What organizational capabilities could enable the development of a Digital Twin in the automotive industry?*

RQ2: *How can operational strategies and digital technologies support the digital transformation of an automotive manufacturer?*

For the first RQ, the objective is to state the crucial capabilities to have as an organization to enable development of DTs. The objective of the second RQ is to analyze how to integrate operational strategies and digital technologies in order to support digital transformations in manufacturing companies. These objectives are interdependent because digital transformation enhances the DT development process, which is a step of the digital maturity. These objectives will be fulfilled by the proposed framework, which is the aim of the thesis.

1.4 Scope of the project

The main constraint for the project is the 20-week time period, and the project must be designed accordingly. From a manufacturing point of view, there are many potential areas of improvement that can be explored to facilitate the development of a DT. However, the limited timeframe of the project will restrict the project to only investigate organizational capabilities needed in the development phase. Furthermore, in terms of strategies to support digital transformations, only operational aspects and how digital technologies can facilitate the process will be considered without delving into the technologies.

In addition, the information that will be provided by the data collection will mainly be gathered from companies operating in the Swedish manufacturing industry, although many of these companies are international. Moreover, it is known in advance that working methods, organizational and cultural capabilities within the same company may differ between countries. Hence, the results of the project are only relevant for Swedish organizations.

2
Theoretical framework

In the following chapter, the theoretical framework of the thesis is presented. An extensive literature review was conducted to find theoretical definitions and perspectives on various topics related to the subject of the project. The baseline of the theory is presented in the following sections while the rest is presented in the results chapter. The chapter is divided into sections with areas related to the background and RQs. First, an introduction to the concepts of Industry 4.0 and its technologies is presented, focusing on the different levels of integration in a DT. The second section evaluates the digital transformation process, the impact of digital transformation on business models and the challenges associated with it. As a result of digital transformation, the dynamics of an organization's structure and culture will be affected, but it can also be a strength for organizations by facilitating transformations, as described in section 2.3. Finally, in the last sections, operational strategy is introduced, defined and evaluated on how it is used theoretically. An overview of the chapter and its content is illustrated in Figure 2.1.

Figure 2.1: Summary of the theory structure.

2.1 Industry 4.0

Throughout history, the world's manufacturing conditions have been in different stages of development from Industry 1.0 to Industry 4.0 [10]. Currently, the development is in the era of the fourth revolution, also knows as Industry 4.0, which was invented by German engineers in 2011 and is still evolving the industries [11]. Furthermore, Industry 4.0 has been approached, but also developed, in different ways worldwide and there is no clear definition of the revolution [12]. However, the revolution can be described as a driver that empowers digital transformation to revolutionize and change the current factories into smart manufacturing systems (SMS) that can offer higher productivity with lower cost and more rapid responses to customer demands [13]. Moreover, one of the main aims of Industry 4.0 is to integrate

all the available resources, such as machines, robots and sensors, to create automatic data exchange to facilitate the monitoring of production systems with Digital Twins [5]. Furthermore, to enable SMS and achieve the desired outcomes of Industry 4.0, it is crucial to utilize digital technologies, such as Internet of Things (IoT), which will be explained in section 2.1.1 [13]. Besides better production planning and optimization through DT, the concept of Industry 4.0 also provides competitive advantages in terms of customer service, product development and co-operations with external companies.

2.1.1 Internet of Things

The IoT is one of the core elements within the concept of Industry 4.0 and is the key for converting companies to be more intelligent and accomplish DT [14]. It can be described as a network of physical objects that are constantly linked through network and embedded technologies, such as software and sensors, that enables devices to communicate and interchange data [15]. This is developed to integrate the physical world with devices and facilitate the data collection that is required to enable working tasks, such as virtual simulations, without human support. Furthermore, the data collection will make it possible to control machines and resources, but also monitor the units and perform predictive maintenance [16]. However, the concept of IoT is growing rapidly and is still undergoing a development to enable handling of the large amount of data from production systems in an intelligent way [16].

2.1.2 Digital twin

A term that has been widely used, in the context of Industry 4.0, is the concept of DT [13][17][18]. The definition of the concept was initially mentioned in a presentation held by Grieves in 2003 at the University of Michigan [19]. Moreover, DT is undergoing continuous development across industries and academia, hence there are various interpretations of the concept and there is no precise definition of the term that everyone agrees on [17][20][21]. Furthermore, the incomplete definition of the concept has resulted in the emergence of the rise of two concepts, Digital Shadow (DS) and Digital Model (DM), that can be distinguished depending on the level of integration [20][17]. However, DS and DM will be further described in section 2.1.2.1.

Nevertheless, in this paper, DT will be defined as a digital representation of the current state of physical objects or systems that is, through real-time data collection, being continuously updated [13][17][20]. The digital duplication of the reality is achieved through fully integrated automated data flow, as shown in Figure 2.2, between the digital and the physical object, that enables changes in the digital state and vice versa [20]. The fully integrated data flow is something that can be achieved by connecting smart devices, as mentioned in section 2.1.1, and gather real-time data with sensors [16].

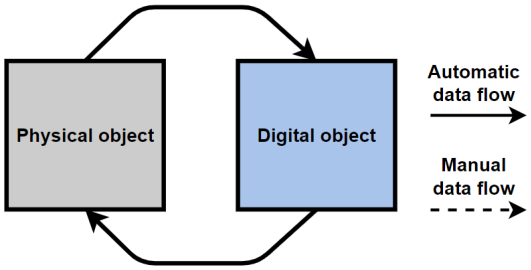
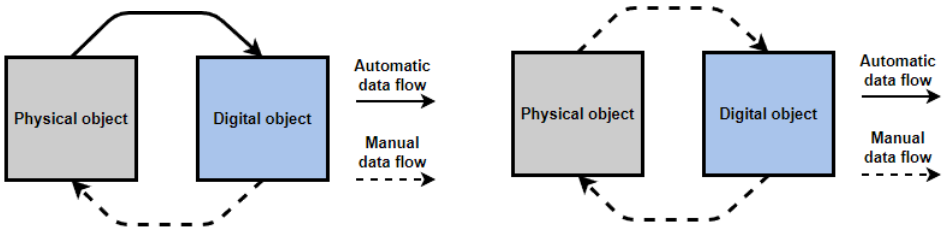


Figure 2.2: A representation of the data flow in a Digital Twin. Adapted from [20].

With the shift towards Industry 4.0, production lines within the automotive industry that are striving for mass production must be able to manage increased complexity and a wider range of customer demands [17]. To overcome this challenge and reach higher levels of productivity, simulation-based planning, but also optimization, of the reality can be useful. In other words, DT is an beneficial concept to implement in the automotive industry since it provides a virtual representation of the reality that can facilitate simulation related tasks [16]. Furthermore, DT can be used in the early phase for robot simulations and virtual commissioning to eliminate potential failures in the design phase and reduce lead time, but also the cost for rework [21] [22]. Besides the decreased time to the market, this will also enable clear and direct monitoring of the physical production system. Moreover, the real-time analysis that a DT offers will make it possible to do in-time adjustments to achieve an optimal production line in several ways. For instance, a DT based on real-time data will facilitate the detection of degraded machines that must be replaced to prevent additional energy consumption and cost. Additionally, the large amount of data that is transferred between the physical and digital object, will make it possible to foresee downtime and reduce costs by performing maintenance before failure. Moreover, analysis with a DT can inspire employees to come up with improvement suggestions of the production line to provide the customers with better product [21] [22].

2.1.2.1 Levels of integration

Even though the concepts of DT, DS and DM are often used in a similar context, the concepts differ in the level of data integration between the digital and physical object. As mentioned, in a DT the data flow between the physical and digital counterparts are fully integrated, hence a change in the state of the physical object will result into a change in the digital environment and vice versa. A lower level of data flow integration is defined as DS, which can be seen in Figure 2.3, and it consists of only one automated data flow. Therefore, a change in the physical state will result into a change in the digital object, but not vice versa. Moreover, the lowest level of integration is often named DM, which is presented in Figure 2.3, and has automated data flow. Thus, all data exchange are made manually and the objects are fully interdependent [20].



(a) Digital Shadow **(b)** Digital Model

Figure 2.3: A representation of the data flow in a Digital Shadow and a Digital Model. Adapted from [20].

2.2 Digital transformation

Ever since the Industrial Revolution in the 18th century, technology in its various forms has revolutionized the way work is accomplished. Digital work began during the third industrial revolution when computers had a huge impact on industries. Computerization allowed automated processes to take over manual work and were faster, more accurate and consistent compared to manual work. Today, the transition to the fourth industrial revolution, also known as Industry 4.0, is taking place. Entire business models (BM) and industries have been transformed by digital technologies [23]. Digitalization is a commonly used word in all industries and the topic itself is a key issue in all businesses [24]. The fear of not adapting to change quickly enough is something that all businesses face, given that technological developments are moving faster today than ever before. There are many examples in history when the dynamics of a traditional market are disrupted with entrance from innovators and established organizations that neglected the transformative power adapted too slowly and lost their competitiveness [24]. In comparison, embracing digital technologies and encouraging new solutions by adapting to the changes have had new market opportunities and solved previous unsolved issues [23].

According to [23], the meaning of digital transformation is more than digital technologies, stating that companies need to consider more than just implementing different technologies. Thus, digital transformation can be seen as a "holistic socio-technical challenge", affecting employees, structures, tasks and organizational practices beyond technologies. This definition implies that digital transformation also requires contemplating customer and partner relationships, organizational alignment and the appropriateness of the organizational culture. Another perspective of the definition of digital transformation is that the meaning refers to "the IT-enabled change in organisations through the digitalisation of products, services, coreprocesses, customer touchpoints, and business model" [25]. This approach implies that it is the IT-related changes to an organization's offerings through digitization that constitute the digital transformation. However, same as [23], [25] also indicates that the speed and holistic nature of digital transformation are different from previous IT transitions due to the rapid global, economic and digital developments. The holistic nature of a digital transformation means that the change spans all parts of

the organization, across all dimensions, to the customer.

2.2.1 Business models in digital transformation

An obtained digital transformation creates opportunities for new BMs where digital meets physical. An essential prerequisite to successfully transform BMs is to have a cohesive strategy to integrate the physical and digital elements. Specifically, there are two suggested strategies to focus on: reshaping the customer value proposition and reshaping the operating model. These two dimensions stand for the “what” and “how”. The "what" dimension should be considered to answer what products and services that are on the physical-to-digital continuum in the industry and to satisfy customer expectations and needs. On the other hand, the “how” question is regarding how to operate accordingly to these and how to adjust the operating model. To the “what”-question, reshaping the customer value is divided into three phases; create, leverage and integrate. The other dimension answers the “how”-question, reshaping the customer value proposition and includes the following phases of enhancing, extending and redefining. This is illustrated in Figure 2.4. To transform profitably and efficiently, the path through these dimensions should be linear with a focus on both, as the green arrow illustrates in Figure 2.4. However, according to [6], many organizations focus on one dimension at a time as a consequence of individual initiatives. Instead, the customer value proposition and the operational models should simultaneously be considered by an integrated and holistic approach. Additionally, new BMs based on customer input will enhance the benefits from the digital transformation. [6]

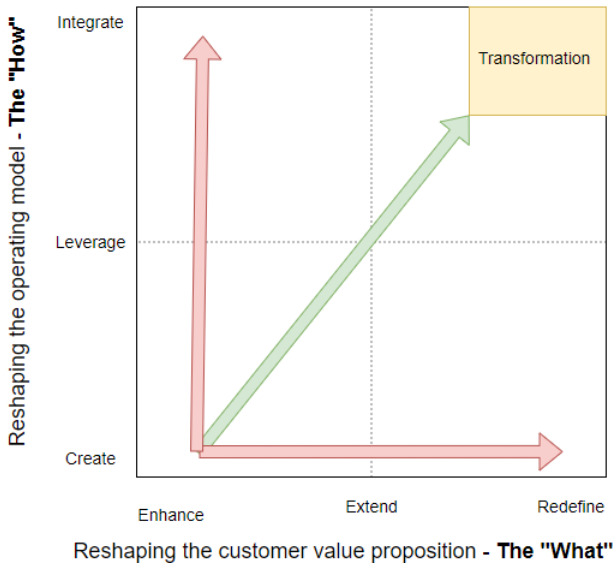


Figure 2.4: Paths to digital transformation. Adapted from [6].

2.2.2 Challenges with digital transformation

There are many reasons why companies are struggling with digital transformation as there are several challenges associated with such an extensive transformation. Be-

cause the holistic nature of digital transformation spans over several different areas of an organization's business, as described by [25] and [23], by default the challenges of implementation also becomes multifaceted. Studies investigating the challenges with digital transformation in manufacturing companies found 28 challenges in six categories, which are summarized in table 2.1 [8]. The article also states that there are interrelationships between these challenges, thus, they are correlated.

Table 2.1: Summary of challenges and framework. Adopted from [8]

Technological level	BM value architectural level	Strategic level
It infrastructure and data security:	***Value creation:***	***Organizational commitment:***
- Shortcomings on IT and scalability - Lack of standards and reference architecture - Risks with data integrity and security	- Technological and process integration - Lack of technical integration of the supply chain - Lack of appropriate development of competences	- Absence of a DT-oriented strategy - Lack of leadership commitment - Lack of cultural value to support digital transformation
	Value delivery:	
	- Adapting the customer relationship processes - Lack of relational capabilities	
	Value capture:	
	- High investment in digital technology implementation - How to managing the financial risks	
	Value proposition:	
	- Lack of customer value understanding - How to realize digital technologies	

Related to these categories, there is also a suggested framework by the authors [8]. The framework is comprising three elements; business value process, supporting forces of the digital transformation and the digital transformation phases [8]. Moreover, the framework is divided into three phases starting with the digitization, digitalization and digital transformation phase. Besides Table 2.1, Figure 2.5 also illustrates the levels of digital transformation and the relationship between the phases, categories of challenges, etc. The purpose with Figure 2.5 is to illustrate how the challenges in Table 2.1 stream upside and downside the levels within an organization and through all phases.

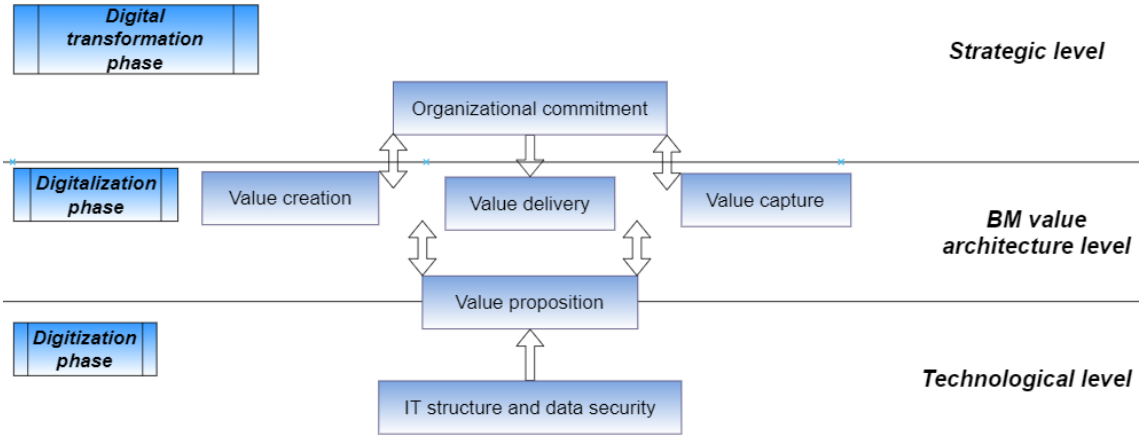


Figure 2.5: Structure of suggested framework. Adapted from [8].

2.3 Organization

An organization is a group of people who collectively works together to achieve common goals, such as Industry 4.0, digital transformation and DT. Commonly, an organization has a structure with some form of hierarchy, division of labor and distributed responsibilities between the employees, which is the main difference between organizations and other types of groups [26]. Furthermore, organizations can come in different sizes, ranging from small teams to corporations with thousands of members, but also in various levels of formality [26].

Besides that, organizational capabilities, which can be defined as the expertise of an organization, is also something that is important to consider in an organization. The organizational capabilities are the outcomes of company investments in different areas, such as training and human resources, that represent how people and resources are being combined to accomplish work [27][23]. It can be defined as intangible assets that are difficult to measure compared to tangible assets, such as capital market assets and technology, thus companies tend to pay less attention to capabilities. Furthermore, it is challenging for competitors to copy organizational capabilities, hence it can result in increased competitiveness and future earnings [23].

Moreover, the transitioning towards Digital Twin requires that companies make changes in their WoW, from an organizational point of view, to successfully adopt the ideas of Industry 4.0 [28]. It is necessary to implement the right organizational structure, but also organizational culture and soft factors, such as competence and collaboration, at the company [3]. To execute a digital transformation at a company there are four structural areas, which can be seen in Figure 2.6, that must be considered, all of which are dependent on different capabilities. In other words, the maturity level of a digital transformation at a company is dependent on the extent to which these crucial capabilities are implemented. The structural areas are divided into four areas, *Resources*, *Information systems*, *Organizational structure* and *Organizational culture*, whereas *Resources* and *Information systems* will be combined in section 4.1.1.1 [3].

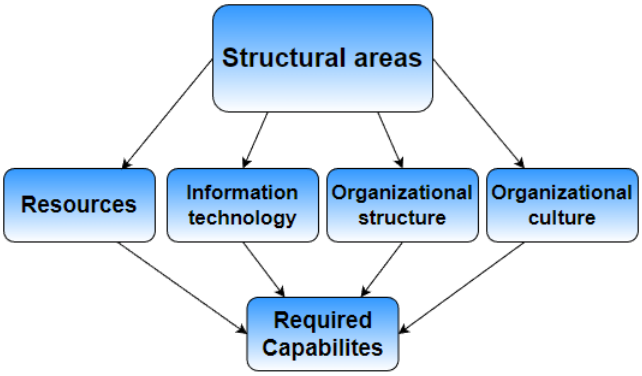


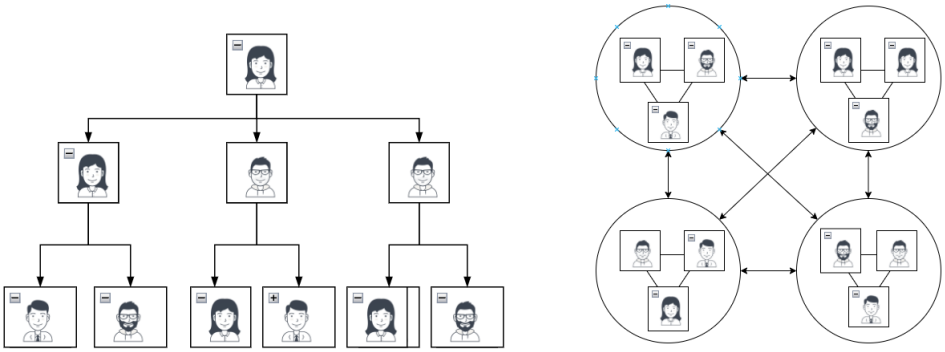
Figure 2.6: The four structural areas that a company must consider to perform a digital transformation. Adapted from [3].

2.3.1 Organizational structure

Organizational structure can be defined as a mechanism that clarifies how the internal relations, communication channels, responsibilities and roles are being divided at a company to achieve goals [29]. The structure is often manifested in organizational charts, which facilitates the understanding of the information flow at a company. In addition to that, it also outlines the different responsibility areas different individuals have in a company, which can be used as support during decisions-makings and conflict resolution between departments [29].

Furthermore, the structure of an organization is related to the success of the company since it is something necessary in order to provide internal strengths and achieve goals through operational tasks. The reason behind this is that a suitable structure in a company will enable process standardization, flexibility in operations and brings out internal capabilities. Therefore, companies need to determine which organizational structure is most aligned with the organizational strategies, individual needs and internal, but also external, working conditions to bring out the most advantages [28].

The most common structures that are being used in organizations are mechanistic and organic structures, which is illustrated in Figure 2.7 [30]. These types of structures differ in informality, centralization, communication, decision-making system, etc [31]. However, the mechanistic structure tends to have a high level of formality, standardization and the units are usually more centralized. Furthermore, the individuals within a mechanistic organization have a clear responsibility division and are expected to follow certain procedures, but also policies when tasks are carried out. In contrast, organic structures are less horizontally differentiated, the working procedures are less formal and it can be seen as a cross-hierarchical structure where the information flows freely. In addition to that, organic structured organizations, compared to mechanistic structured, are more flexible and can adapt to different types of situations since the employee's behaviors are dependent on shared values [30].



(a) Mechanistic structure **(b)** Organic Structure

Figure 2.7: The most common structures in organizations.

2.3.2 Organizational culture

The concept of organizational culture can be defined as the underlying beliefs, values and ways of interacting among the employees at a company, which contributes to a unique social environment, but also the way an organization conducts its deliveries [32][33]. Furthermore, organizational culture does also influence how employees tend to identify themselves with the organization and interact with external individuals, such as clients and stakeholders. The vital part of the desired culture at a workplace is business leaders that appreciate establishing illustrations of how employees should behave and communicate internally, but also externally. However, an established working culture can influence the type of leaders that fits into a company [33]. Organizational culture includes several types of cultures, some of them can be seen in Table 2.2.

Table 2.2: Different Cultures. Adapted from [23][32][33]

Types of culture	Definition
Learning by mistakes	Everybody can be open about mistakes and learn from it.
Open communication and collaboration	It is allowed to communicate and collaborate freely within the organization
Responsibility	The employees have a feeling of accountability to finish their tasks
Supporting leadership	The management is supportive towards company goals.
Willingness to change	The employees and management are not resistant to change.
Shared mind-set	Common set of beliefs and visions among the employees.

Organizational culture is a concept that companies should take into account, such as the operating system of a computer, since it enables an organization to implement things, but also can become an obstacle for changes if it is not considered [34]. Thus, a cultural transformation is necessary before a digital transformation can be initiated [35]. In other words, companies will be unable to achieve the desired outcomes of an digital transformation without changing the mentality of the employees. For instance, the employees must have a culture that makes them trust in the digital assistance technologies and accept their suggestions, otherwise the digital systems will not add any value to the company [3]. It is clear that culture development is crucial to foster the innovativeness of enterprises, but it is a difficult and time-consuming process to undertake and must be implemented with patience [23][36].

2.4 Change management in digital transformation

To undergo a digital transformation, implementations of new WoWs are inevitable which will affect the current way things operate. Except for the change in the working methods, by implementing new technologies companies must adjust accordingly. In order to successfully implement these new operations, changes at all levels are

needed. These changes affect everything from top management to the daily work of employees. However, change is a complex process that sometimes creates resistance among the people concerned. The reasons for resistance can be many, but a well-known concern about implementing new technologies is to be replaced by machines. It becomes easier for an organization to change if the changes are considered as necessary and adapted quickly but, in most cases, changes are considered unnecessary, and people do not adapt to the new context of processing quickly. [37]

Change can be described as the transition (C) from a current state (A) to a future state (B) [38]. In terms of digital transformation, this definition is applicable as the future state (B) is the vision characterized by a higher level of implemented Industry 4.0 technologies and the transition (C) is the actual digital transformation starting from the current state (A) with a low level of digitalization. This transition is complex and involves high risk as nearly 70% of all change initiatives fail to reach the goal [39]. If the involved people are truly invested in the change, the likelihood of sustained change is 30% higher. Some of the major reasons for the change to fail are: *employee resistance, lack of clear and feasible objectives, lack of managerial support, but also commitment, and bad communication* [9].

Change management is a systematic approach to guiding organizations during a change, i.e., from a current state (A) to a desirable future state (B) [9]. Moreover, change management is the process and tools to support people during the transition (C). There are many change management models suggested by different literature. The most well-known models are synthesized and compared which are the following: *Kurt Lewin's Change Management Model, Kotter's 8 Step Change Model, GE's Change Acceleration Process and Prosci 3-Phase Change Management Process* [9]. Based upon these models, a list of salient change management activities is listed and further explained. These are the activities that are the most critical in order for an organization to successfully change [9]:

- Define a strong leadership;
- Generate the awareness of the need for change;
- Define a clear vision and strategy;
- Communicate the vision and strategy;
- Define a change management team;
- Identify short-term goals and test the change in pilot projects;
- Identify and manage resistance to change;
- Train people;
- Monitor change;
- Celebrate the successes and implement corrective actions; and
- Consolidate the change.

Each of these activities is not explicitly envisaged in all change management models, e.g. "train people" is only included in the *Prosci 3-Phase Change Management Pro-*

cess while "define a clear vision and strategy" is included in all. The list of activities is thus a compilation that brings together the core elements from all models. There is also a logical order in these activities, chronologically in their sequence. In the case of a change, the first consideration should be the first one, i.e., "Define strong leadership" and end with "Consolidate the change". [9]

2.5 Operation strategy

Operation strategy is a key concept used in the thesis that needs to be defined and clarified due to its complexity and to some extent ambiguity. All organizations regardless of the sector have operating functions internally, also referred to as operations management. However, in manufacturing contexts operations refers to "*the activity of managing the resources and processes that produce and deliver goods and services*" [40]. Moreover, a commonly used term in operations is the "input-transformation-output model" which represents the objective of operations to transform the inputs of resources into products and services as outputs. Strategy is another complex word that can be described in different ways depending on the context. However, in business contexts, it can be described as "*setting broad long-term objectives that direct an enterprise towards its overall goal*", "*planning the general path to achieve these goals*" and "*dealing with the total picture rather than stressing individual activities*"[40]. Concluding the concept of strategy, it can be interpreted as *setting the long-term objective according to an enterprise's goals and guiding the company towards them by formulating a holistic approach to achieving these objectives*. Operation strategy relates to the overall transformation process of firms and consider changes in the external competitive environment [40]. It shapes the business to meet these challenges in terms of competitiveness and customer needs without going into the details of individual operations [40]. In other words, it describes the meaning of the combination of the definition of operation and strategy.

3

Methods

This chapter aims to explain and describe the methodology used in this project. Appropriate methods for the specific research were selected and are motivated in the following sections. The methods used to gather data and information for the research can be summarized with the following three methods: case study, interviews, and literature review. All collected data will be of qualitative form due to the nature of the project. Moreover, the approach and strategy of the research will also be described during the first section of the chapter.

3.1 Research approach

There are different research approaches and this section aims to provide a deeper perspective on the research approach. In this thesis, five main dimensions have been considered to form the overall research perspective. Some of these were cleary based on the background, purpose and objectives of the project, while others were more complex. The five dimensions are evaluated below and are the following: research direction, research strategy, study time scale, empirical data types, and the scientific approach. A summary of the research approach is illustrated in Figure 3.1.

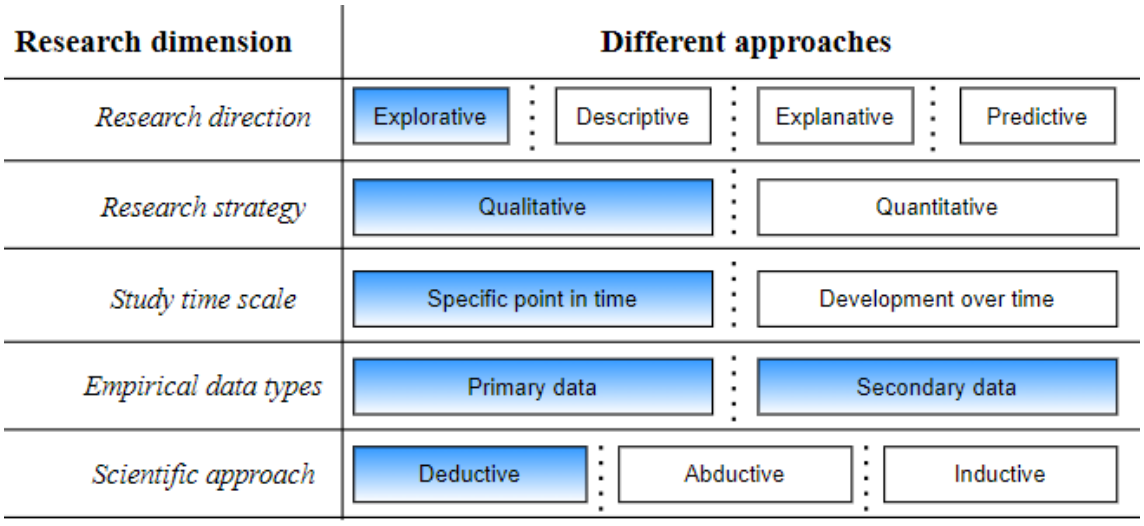


Figure 3.1: Summary of the research approach.

3.1.1 Research dimensions

The first line in Figure 3.1 shows that the thesis has an exploratory research focus. The different research orientations depend on the research design. In this case, the nature of the project is more exploratory based on the objectives. The project aims to investigate the organizational capabilities required to develop a digital twin and how strategies, but also technologies, can support a digital transformation. Based on this, the nature of the project is exploratory. Exploratory research tend to have a unclear problem definition and aims to summarize the problem and suggest future research [41]. Gathering preliminary data and knowledge to define the problem and propose hypotheses is also one of the characteristics of these studies. Furthermore, [41] notes that studies with exploratory orientations may lose the structure with the objectives of the results when proposing future research, which must be taken into account during the thesis.

The strategy of the thesis is qualitative, as shown in Figure 3.1. For exploratory research, both qualitative and quantitative methods are appropriate and can be used [41]. Quantitative strategies are usually used to measure the problem of collected information in the form of numerical data, which is not in line with the core of the thesis. On the other hand, a qualitative approach will support the procedure to understand the underlying opinions, motives and processes for the implementation of digital twins and digital transitions. In addition, the methods used to collect information in the project are more suitable for a qualitative approach, such as interviews, case studies and literature studies. The study thus draws on data through qualitative methods.

The third line of Figure 3.1 describes the time frame of the project, which has a major impact on the research methodology [42]. The two different time frames are "research at a specific point in time" or "research on development over time" [42]. When a research collects data from a specific point in time it is called cross-sectional studies, which is aligned with the approach for this thesis. On the other hand, studies with collection of data several times over a period of time is refereed as longitudinal studies [42]. The main argument for the project is classified as "research at a specific point in time", i.e., cross-sectional, is that the time limit of the project is 20 weeks. Therefore, the study is limited to a shorter period. In addition, the research questions do not require an examination of developments over time but rather an analysis of the industry at present. It is also considered that digital transformation evolves, but digital development is changing rapidly, and therefore the evolution over time may be interesting for future research focused on monitoring digital transformations.

During the project, data will be collected to find correlations, insights and strengthen arguments. Data can come in different forms in surveys, numbers, words or pictures [41]. For this report, qualitative data will be collected, i.e., in the form of words from interviews, case study and literature studies, etc. Figure 3.1 shows two different types of empirical data, primary and secondary data [41] [42]. The difference between these is whether the data has been collected directly or whether it has been taken from previous studies [41]. For example, data from interviews with experts in

the manufacturing industry will be primary data and data from previous literature such as articles, case studies, publications and books will be secondary data. Hence, both types of data will be used in the project as both methods will be used. A more detailed explanation of the strategy of how the data is planned to be collected will be further during Chapter 3.

Lastly, the fifth dimension in Figure 3.1 presents the scientific approach of the research. Mainly, there are two different scientific orientations that can be applied, inductive and deductive research [41]. In summary, these differ in how new knowledge is created from the research, i.e., the relation between theory and the conclusions. In a deductive study, the starting point is the theory from where to search for new observations and findings. On the opposite, in an inductive study, the starting point is from empirical observations to create new theory. Therefore, the difference between the two relates to the outcome from the study; theory versus observations/findings. The third abductive approach is a type of combined deductive and inductive approach. With abductive reasoning, empirical observation is the starting point and aims to find new understandings. However, due to the incomplete observations, these understandings are based on predictions from logical reasoning [41]. Compared to the predictive outcome from an abductive approach, deductive reasoning provides a specific conclusion that is always true and the inductive approach provides general conclusions that may be true under specific circumstances. Since the project aims to provide findings from theory, it relates strongly to the deductive approach. Moreover, the gathered information from the qualitative methods will be used to conclude the observed findings, which is the main logic behind a scientific deductive approach.

3.2 Research design

The research design provides an illustration or framework for the data collection and analysis [41]. In Figure 3.2, a holistic view of the research design is presented. It is stated that there are several different research designs applicable for research with this approach, qualitative, explorative, etc. [41]. As illustrated in Figure 3.2, all needed data in this project was collected by three methods: case study, interviews and literature review. After the interviews and the literature review, the research questions were revised to confirm the alignment of the project. However, before the RQs were answered and the findings of the projects were presented, all data were compiled and analyzed.

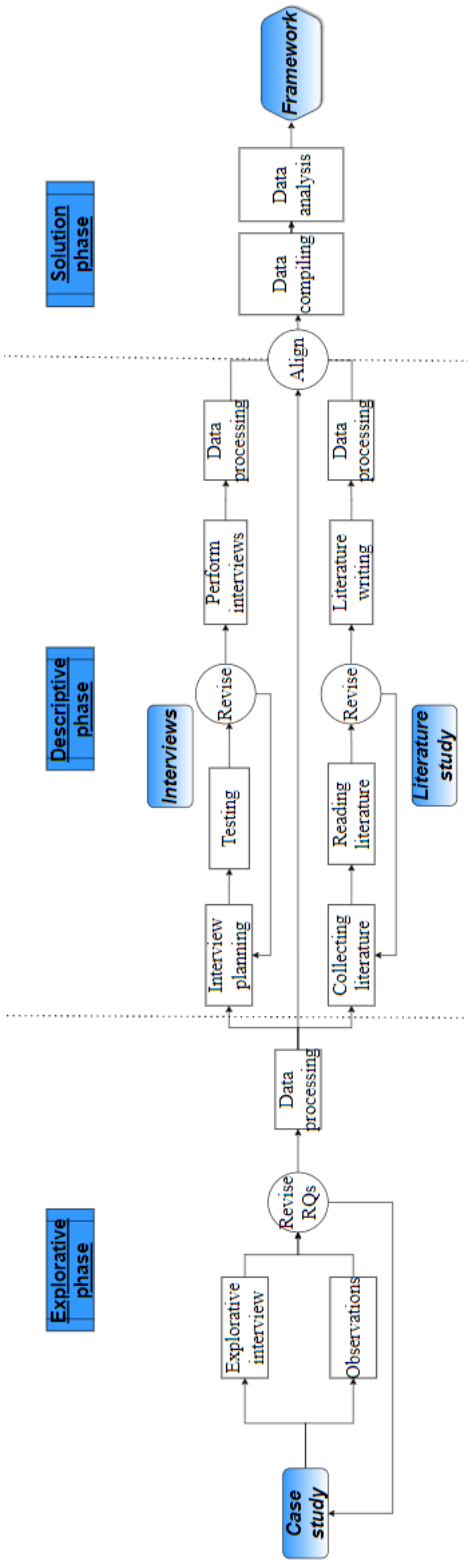


Figure 3.2: Summary of the research design.

3.3 Research quality

The quality of the research is one of many important factors to improve the credibility, reliability and validity of a project [41]. Specifically, the quality of qualitative research has been particularly questioned in relation to the latter two. Based on this, [41] proposes a list of four criteria that should be considered in qualitative research in order to maintain the quality of research and improve these factors. The first criteria is *sensitivity to context*, which should include not only the social environment but also theoretical positions and ethical issues. This will be explained more in 3.3.1 where the ethics of the work are evaluated. The second criteria is *commitment and rigour* to the subject through having the right skills and through data collection and analysis. In terms of this criterion, the commitment and rigour is strong given the context of the project and the fact that it is a Master's thesis where the topics were chosen by the authors. The third criterion is regarding *transparency and coherence* where the importance of a clear and specified research method, clearly stated argument and a reflective approach is stated. Therefore, these statements have been taken into account throughout the project, especially during the elaboration of the methodology. Lastly, the fourth criteria is the *importance to have an impact on theory, practitioners and community related to the topic*. As the project aims to provide support to car manufacturers, it is in the project's best interest to have an impact by providing new theory. [41]

As mentioned above, reliability and validity are two factors related to the quality of research [41]. In addition, replication is also a factor that is listed as prominent in the quality assessment. Reliability is often concerned with whether the research can be replicated to achieve the same results. For example, the term is often used to question whether the measures developed are consistent or not [41]. Hence, reliability is to have faith in the research's consistency. To strengthen the reliability of this thesis, the methods were diligently developed so that it can be replicated. Speaking about replication, which is one of three factors stated as important for the quality, the clearness of the procedure to the conclusion is fundamental, i.e., the methodology. The most important criterion of research is argued to be validity [41]. Validity in a research context often concerns the integrity of the conclusions. It can also be explained by asking how accurately the method is measuring what it is intended to. To ensure the validity of this research, the interviewees were carefully selected through dialogues before the interviews to ensure their relevancy. In addition, the number of interviews was chosen to allow for confirmation of the findings from several sources, not just primarily from individuals.

3.3.1 Research ethics

During the research phase, ethical considerations were taken into account when conducting the case study and interviews, but also when doing the literature review. This was done to protect the anonymity of the participants and to produce results that are not influenced by the writers. Furthermore, ethical issues were considered as they are directly related to the integrity of the project and of the participating

individuals. [41] [1]. In addition, the ethical principles discussed can be separated into four categories: *harm to participants*, *lack of informed consent*, *invasion of privacy*, and *deception* [41]. These four domains, however, should not be considered separately because they are interrelated and overlap in various ways.

To ensure that the participants were comfortable during the case study and interviews, the individuals were always offered the option of remaining anonymous, as well as the option of negotiating whether or not the event could be recorded. Regardless of the requirements of the participants, the obtained data was kept privately, and information was only shared with third parties with the permission of the participants. For instance, the transcriptions of the interviews were always sent to the participants so that they could approve the content before it was shared further. Furthermore, the participants were always given information about the thesis background and how the collected information will be used to decide whether they wish to be involved in the study or not. This was made to ensure that the respondents were given enough informed consent and minimize the risk of deception. Moreover, to protect the individual's privacy, the session guidelines were made with accuracy and they were given the possibility to leave topics unanswered. In addition, the guidelines were also created in a clear way, with clear questions and topic discussion, in order to prevent deception. In regards to the literature study, all collected data was referred to sources with respect to copyright and the author's privacy [41].

3.4 Data collection - Qualitative methods

As shown in Figure 3.2, the project methodology began with a case study at a Swedish car manufacturer to enable interacting with individuals that are involved in a digital transformation process in real-life and to identify challenges that would be beneficial to use as a base for the research questions in the project. Moreover, the findings that were made during the initial case study were, together with semi-structured interviews and literature review, utilized qualitative methods to collect data. Through these methods, data were gathered directly from experts employed by automotive manufacturing companies, but also other relevant firms, that is striving for increased digitalization. The purpose of these methods were to obtain insightful perspectives both from the industry, but also academia, in order to gain a broader perspective on the findings to the research questions. Furthermore, the methods are described in detail in this chapter.

3.4.1 Intrinsic case study

Initially, a case study of a Swedish car manufacturer were conducted as the first collection method. Besides collecting additional information related to the project topic, the case study was also made to identify improvement areas, that was used as the baseline for the research questions in the project. A case study approach was utilized since it is considered as a useful method to gather additional in-depth information of complex issues in real-life context. The type of the case study that were conducted is called intrinsic case study, which means that a particular organi-

zation that is of primary interest is being investigated [43]. To develop a thorough understanding of the case and increase the validity of the collection method, two qualitative techniques were used on site at the Swedish car manufacturer [44]. The qualitative methods were exploratory interviews and observations on site at the organization.

The study were conducted at a Swedish car manufacturer that strive towards visions that are strongly related to digital transformation towards digital twin. Moreover, in the beginning of the study twelve exploratory interviews were conducted with individuals with different positions, but also from different departments, in the organization. Furthermore, real-life observations of different obstacles and improvement areas, that were highlighted as crucial to become more digitalized in the interviews, were made with the guidance of employees at the organization. The interviews and observations made it possible to draw a mapping of the organization and identify challenges in the organization. This made it possible to see if a real-life scenario corresponds to the presented literature review, but also to identify necessary issues, in terms of digital transformation, that were not highlighted. Moreover, the case study facilitated the preparation for the semi-structured interviews since the study, in combination with the theory, identified important areas that were included in the interview guide.

3.4.2 Interviews

Besides the intrinsic case study, interview studies, which is defined as a efficient way to gather useful information, was also used as a second data collection method. However, an interview study can be either structured, semi-structured or unstructured depending on the desired output that the interviewers are striving for [41]. For this project, a semi-structured interview approach was used because it was deemed more appropriate than unstructured interview since it will make it possible to address issues that is only related to the established project aim. Furthermore, a semi-structure, compared to a structured, the interview will result into more dynamic dialogues were the interviewers are allowed to ask supplementary questions if needed. Dynamic dialogues and flexibility during the interviews are desirable as it allows the interviewers to cover different areas that feel important depending on the nature of the interviews, even if it is not included in the semi-structured interview guide. [41].

3.4.2.1 Planning

The questions from the interview guide, that can be found in Appendix A, were based on information that is needed to be attained to facilitate answering the two RQs. The content of the guide was based on the findings of the literature review, which were deemed necessary given the subject matter of the project. Moreover, some basic elements were considered during the preparation of the guide to gather as much valuable information as possible [41]. The different sections of questions were ordered in a certain way to create a reasonable and logic flow during the interview that will allow the interviewee to gradually delve into the depth of the

project topic. Furthermore, the questions was formulated in such a way that they answers to the two RQs, but also with a level of language that is understandable to the interviewee. To ensure that the interview guide would enable collection of useful qualitative data the questions were stated after multiple iterations. In addition, pilot tests of the interview were conducted with two appropriate respondents from a Swedish car manufacturer to identify missing questions, ensuring that the guide provides variable answers and to determine whether the outcome of the questions are desired [41]. Presented below, in Table 3.2, a summary and overview of the different sections in the interview guide.

Table 3.1: An summary of the interview guide.

Section	Content
Introduction	The interviewee was provided with information regarding the interview session and how the collected data will be used in the project report. Furthermore, it was clarified whether the interviewee allowed the interview to be recorded and if the respondent preferred to be anonymous or not.
General information	An introduction of the interviewers and their backgrounds were presented to the interviewee. Moreover, the aim of the project and the purpose of the interview were described.
Map the interviewee and the company	In this section, questions regarding the interviewee and its role at the company was asked. In addition to that, this the section was used to retrieve information about interviewee's knowledge level in terms of Industry 4.0 and Digital twin.
General questions	The objective of this section was to retrieve information in regards to digital transformation and the company's vision.
Organizational capabilities	This section was designed to gather further information about organizational related areas, such as capabilities, culture and structure, according to the interviewee.
Digital technologies	This section was designed to gather further information about digital technologies and how they can support a digital transformation, according to the respondent.
Operation strategy	This section was designed to gather information about operational strategies and ways of working in regards to both organizational aspects and digital technologies.
Sum-up	Finally, the interview was summed up by giving the respondents the possibility to ask questions and arise relevant things that had been missed out during the interview. Moreover, this section was designed to retrieve further suggestions of individuals that could provide useful information through an interview.

Furthermore, the research questions put emphasis on strategies and requirements towards a digital transformation in manufacturing companies, hence individuals with knowledge or experience within the topic area were considered as necessary respondents. Therefore, the target group for the interview study consisted of individuals from companies that are familiar with the research topic and are striving to achieve

a complete digital transformation with digital twin as the final outcome. In addition, individuals that are doing research's that is relevant to the topic will also be interviewed. The chosen interviewees were based on the author's contact network, but also recommendations from the supervisor from Chalmers University of Technology and a Swedish car manufacturer. Moreover, it was also considered necessary to gather information from different companies to collect a broad spectrum of data, that will provide various type of answers during the interviews. However, quality were prioritized over quantity for the interviews, hence five interviews that went into the depth of the project topic with the respondents were conducted. The chosen interviewee's is presented below in Table 3.3.

Table 3.2: Summary of participating interviewees.

Company	Interviewee's role	Length (min)	Date
Company 1	Automation expert	80	2022-03-04
Company 2	Digital manufacturing manager	50	2022-03-14
Company 3	Simulation engineer within final assembly	65	2022-03-15
Company 4	Digital strategy and manager	65	2022-03-22
Company 5	Scrum master	50	2022-03-28

In order to prepare for the interviews, the interviewers had to ensure sure that they were familiar with the settings in which the interviewees works. This is necessary in order to adapt the interview guide to each interviewee, but also to interpret their answers in a reasonable way [41].

3.4.2.2 Transcription

During the interviews, the interviewers were supposed to be alert to what is being said and follow up with appropriate questions to gather as much useful data as possible. Therefore, the interviews were audio-recorded and transcribed afterwards, even though it was time-consuming. This is a strategy that was used to prevent the interviewers from being distracted due to writing down notes during the interviews [41]. Moreover, the transcriptions of the interviews were divided into separate documents in accordance with the sections in the interview guide. In other words, documents for each section from the interview guide were created and filled with comments from the five respondent's. This was made to ease the identification of results in regards to each part of the interview guide, but also to facilitate further analysis and identify similarities and differences between the conducted interviews.

3.4.3 Literature study

In chapter 2, an extensive literature review was presented for topics related to the thesis. The literature review was a major part of the collection of information to

the thesis. This was done in the theory chapter which was divided into five main sections with subsections. The logic behind the structure was to categorize areas in which more information was needed to evaluate the research questions. The goal was to get a profound understanding of these topics and to create an information base on the ground of strongly accepted academic sources. As illustrated in Figure 3.2, after the literature review, the RQs were revised. The reason for this was to reconcile that the project was aligned with the needs and interests of both the industry and the academic world.

There are two different ways of conducting a literature study, narratively or systematically [41]. The difference between these comes down to the level of structure in the scope of the review. A narrative review is broad in terms of the search, source and selection strategy while a systematic review is specific [41]. Thereby, a narrative review suits research that aims to find initial insight and finding to a topic. Due to the characteristics of this thesis, a systematic review was selected by having a specific and structured approach during the review. In accordance with a systematic approach, predetermined keywords, strings and search engines were selected beforehand. The search engines used were *Google Scholar* and *Chalmers Library* to find reliable and trustworthy sources. These search engines includes several data bases which provides the result. For example, *Chalmers Library* includes 178 data bases which the search results is filtered through [45]. The keywords used to find relevant literature in these search engines were the following: *digital transformation, Industry 4.0, automotive industry, digital Twin, digital technology, digital capabilities, change management, value, strategy, operations and organizations*. However, to get even more specific results in the searching combinations of these keywords were used by creating search strings, which are presented in Table 3.1. The table also presents what keywords and strings are used in each section in the theory chapter.

Table 3.3: Combination of keywords in the literature review.

Theory area	**Strings**
Digital transformation	Digital transformation AND (Automotive industry OR Car manufacturer)
Change management in digital transformation	Change management AND digital transformation
Organization	Organization AND digital capabilities Organization AND digital transformation
Operation strategy	Operation strategy AND (digital transformation OR digital twin) Strategy AND digital twin Strategy AND digital transformation
Industry 4.0	Digital twin AND automotive industry Digital twin AND Value Digital technologies AND automotive industry Digital technologies AND digital transformation Industry 4.0 AND value Industry 4.0 AND automotive industry

Considering all results from these search strings, presented in Table 3.1, the next step was to screen all literature found. In the screening process, there were mainly

two dimensions considered. Firstly, the papers were sorted according to the number of citations, i.e., the papers with the highest numbers of citations first. Secondly, the year of publication was also taken into account in order to use the latest information within the fields by using the newest published papers. This was important because the development within the area of the thesis is fast with new groundbreaking research. The outcome from the literature review founded the fundamentals of the findings of the project. Except for the strong theoretical understanding of the topic of the research, it also helped to find insights from both the industry and academic community that contributed to the conclusions, of course in combination with the findings from the qualitative data collection.

3.5 Data analysis

The main primary data collected was through interviews and case studies, as the information from the literature was secondary data and referred to by references. This data had to be analyzed before the results could be presented. The interviews were transcribed to facilitate the analysis process. During the analysis process, interesting parts of the interviews were highlighted and marked in separate documents. After reviewing all transcripts and marking the parts that were relevant to proceed with, they could be categorized into both RQ1, RQ2 and subcategories such as *digital twin, digital transformation, value creation, etc.* This was done to facilitate the presentation of the results later, but also to classify the statements in order to aggregate all the data. Having a structure for all the interview data made it easier to identify similarities, correlations and patterns. Finally, it also simplified the process of sort the data and clean out what had already been used, was beyond the scope of the project and what contributed to answering the RQs.

The second type of data analyzed was the case study. In order to describe how the data was analyzed, it is fundamental to understand the type of data that was collected from the case study. As described earlier, two qualitative data collection methods were used: exploratory interviews and observations. The exploratory interviews followed the same procedure as the official interviews, as described in the section above. However, the observations followed a different procedure. During the case study, notes, summaries and illustrations were continuously taken. This means that the data was analyzed continuously throughout the project and not as a specific part of the process.

3.6 Data compiling

In the final stage of processing the collected data, the data were compiled. This was to facilitate the drawing of conclusions from the results of the project and facilitate the creation of the framework. In addition, the aggregation allowed the identification of similarities, differences and perspectives in terms of the capabilities required for both a digital transformation and a DT. However, the main reason for the data compilation is to connect and combine the perspectives from academia and

industry to find conclusions based on both. This would also increase the validity and reliability of the framework by using an approach based on both perspectives.

4

Results

This chapter presents the findings based on the data collected from the literature review, the interviews and the case study, which were the methods used in the project. The aim of the results is to answer these questions presented in the introduction, which also form the basis of the logic of the chapter's structure. The structure of the chapter is presented below in Figure 4.1.

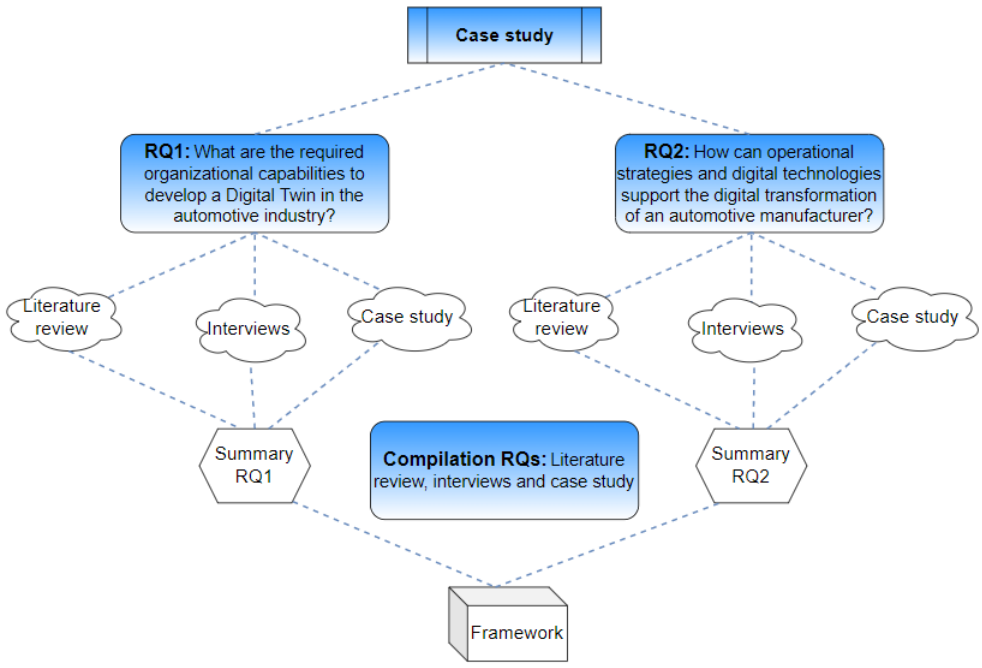


Figure 4.1: Summary of the result section structure.

4.1 Summary of the case study

In this project, a Swedish car manufacturer was involved to collect information directly from the industry to find interesting insights. The company's production plant is divided into three sections, A, B and C, which together make up the entire production of cars. This thesis examined the C factory, since the project was initiated in this department due to their immaturity, in comparison to other departments, in terms of digitalization. The main reason for this, according to the company, is the low level of automation in production, as many of the operations require manual

assembly in the C plant. It has also been noticed that the integrated IT systems related to final assembly are outdated and that there is a need for new flexible and transparent systems. To remain competitive and maintain its position as one of the leading car manufacturers, all departments in the company need to adapt and work at the same level of digitalization. In addition, the long-term goal of implementing Industry 4.0 technologies requires both the necessary internal resources, capabilities and new WoW guided by operational strategies.

Some of the main problems identified in the C-factory and associated departments are that the digital models are not updated in real-time. This becomes a major obstacle when the goal is to increase the level of digitalization in the organization. Moreover, the lack of updated models indicates that there are more critical barriers, such as lack of data integrity, poor data exchange and interrupted data flow. As these models are not updated in real-time, also given the lack of transparency in information exchange, it has been shown that many repeated failures, both organizational and technical, are related to the same problem, i.e., struggling with digital transformation. In addition, the company has operational problems in realizing the digital transformation.

The manufacturer has the vision to be "best in class in manufacturing" or to work according to the World Class Manufacturing (WCM) philosophy, which is what they strive for. There are no precise definitions of any of these concepts, but there are ten pillars that various authors suggest should be included in the WCM philosophy. The concepts are similar to the established manufacturing processes of the *Toyota Production System, Just-in-time, Total Quality Control and Lean Production*, but with a more modern approach [46]. Most of the ten pillars of WCM can be classified as development stages into three phases: *reactive, preventive and proactive*. These pillars are summarized in Figure 4.2 [46].

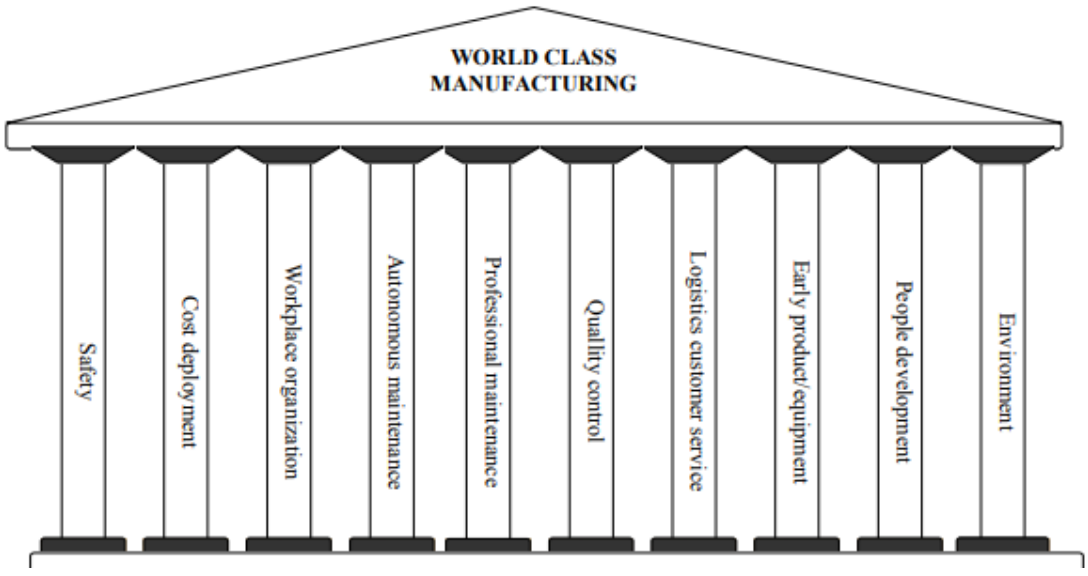


Figure 4.2: Summary of the pillars in WCM [47].

Based on the vision of the company, to become "Best in Class" and soles that operating as WCM, there are objectives that must be met step by step to successfully strive towards the vision. These objectives are converted into Key Performance Indicators (KPIs) and measured to continuously monitor performance. The five KPIs that the manufacturer want to meet are the following:

- Lost Time Case Rate: -50%;
- Defects/unit: -50%;
- Leadtime: -20%;
- Total manufacturing cost: -30%; and
- Tied up capital: -20%

4.2 RQ1: Identified capabilities

In this section, the results from the literature study, interviews and case study will be presented to answer the first RQ: *What organizational capabilities are needed to enable the development of a Digital Twin in the automotive industry?*

4.2.1 Literature review

To answer RQ1, the literature review presents analyses of different authors' perspectives on capabilities in the automotive industry related to digitalization and digital twins development. The capabilities are divided into structural and cultural from the literature, hence the structure of the following sections.

4.2.1.1 Digital capabilities

It is obvious that tangible resources and information systems, such as machines, equipment, and materials, are required to support a digital transformation [48]. Employees, on the other hand, must have the necessary qualifications to ensure proper resource management and achieve the required results. For example, if employees do not know how to use the resources, the company will not be able to advance toward a digitalized community [49]. As a result, the digital skills required for this structural area are crucial and must be integrated from the beginning of a transition [3].

Moreover, it is critical to give digital capabilities to the workforce as the use of communication and information technology increases in a digitalized firm [3]. As a result, it is important to provide internal training to employees and to give additional individual tasks to increase their proficiency in terms of knowledge and technology use. Furthermore, workers must be able to access, gather, and interpret information in order to make smart decisions, which is a crucial part of Industry 4.0. Moreover, when a business decides to move toward increased digitalization, personnel will work with IT systems more frequently, resulting in more frequent

touch with sensitive data. Accordingly, it is important to guarantee that employees are aware of IT security and that sensitive data is not leaked to third parties [48].

The later stages of the development towards Industry 4.0 requires companies to enable visibility, transparency and predictive capacity in their organizations. With other words, it means that organization must be able to see what is happening, know why something is happening and what will happen in the future. These steps are heavily dependent on correct data, collected through sensors and actuators, since incorrect aggregated data will make it impossible to achieve data-based decision-making. Therefore, it is necessary that the employees have the competence to master data management systems and acquire the relevant technical knowledge to improve the quality of poor data. Furthermore, in order to enable rapid actions, such as decision-making, it is necessary to have efficient communication and information flow inside the organization [50]. Documents, for example, should be traceable and saved in a central data storage system through connected IT systems so that employees can access relevant data as needed for various tasks. To make this possible, the organization must create universal standard procedures, interfaces and data exchange formats to make it easier for employees to interpret information. Furthermore, staff must learn how to give contextualized information quickly, tailored to the needs of organizational tasks and current usage [3].

4.2.1.2 Structural capabilities

Companies are often unable to implement a complete digital transformation and achieve the full potential of Industry 4.0 since they do not perform the shift over step-by-step. Companies often tend to overlook the organizational structure that is crucial to successfully create an agile organization, which is one of the prerequisites for a complete digital transformation [3]. Furthermore, a company must be equipped with the required capabilities, such as openness and value communication, without being held back by the organization's structural characteristics [23]. Therefore, the organic structure, compared to the mechanistic structure, is preferable since it provides rapidness and unlocks more values [51]. The organizational structure must be less hierarchical and employees must be allowed to collaborate, but also deliver information internally, between different departments. This will result into flexible departments that can adapt to different circumstances rapidly, but also move towards the goals without risking that any department falls behind in the transformation. Moreover, this will ensure that tasks are performed by the employees with suitable knowledge, regardless of position in the hierarchical distribution. Therefore, companies must combine the organic structure with a balanced decision-making between centralization and decentralization [3] [52].

A decentralized organization that has an organic structure will allow decentralized decision-makings, which is also beneficial for a successful transformation. Decentralized decision-makings is preferable since the organization will allow local decision-makers that have better understanding of a specific situation, compared to central departments, to take decisions. Furthermore, it will also result into reduced cost since information is not needed to be delivered to centralized decision-makers. How-

ever, it is clear that some decisions, that require additional input to align with the company strategy and goals, should still be taken centrally [3].

4.2.1.3 Cultural capabilities

The crucial change in culture in regards to digital transformation is encapsulated in two key areas, willingness to change and social collaboration [3]. The first cultural area, willingness to change, is based on several capabilities that should not be treated separately since it is necessary to combine them to achieve successful results. Firstly, it is important to create a positive attitude towards mistakes in the organization and clarify that mistakes is accepted rather than something that will led into strict penalties. Organizations must recognize the value of mistakes and inform the employees that change processes, such as learning, can only be triggered by the willingness to disclose mistakes. Companies that is based on a systematic avoidance of failures are usually not enable to eliminate errors since their attitudes inhibits their willingness to change [3]. Moreover, openness to innovation and development of new WoW is also an important capability to enable the willingness to change in an organization. Therefore, the management of a firm, that is going through a digital transformation, must ensure that the employees have a good understanding of new technologies and how they can add value to the company. That knowledge is crucial for the implementation of digital technologies, such as data-based learning and decision-making, which is an desired outcome of an digital transformation. To create confidence among the employees and convince them to base their decisions on data-based machines it is necessary to make them aware of the advantages. This can only be ensured if the employees are participating and involved in the transformation from the outset [3].

Moreover, the social collaboration is also an important aspect to consider in regards to digital transformation and is mainly enabled by a combination of democratic leadership and open communication. As a result of a transformation, it is common to have an increased frequency of changes in the organization, which requires a more flexible approach to decision-takings. This in turn will demand that the employees have the right competencies to enable correct decision-takings, but also a management that values the expertise the employees bring up and allow them to take decisions [3]. The underlying capability to achieve is democratic and supportive leadership style, which is something that can be a major barrier in this part of the digital transformation in complex business models [36]. In addition, to take rapid decisions and respond quickly to unforeseen events it is crucial to have a working environment that permeates direct communication in organizations. Therefore, the "us and them" mentality should be be eliminated to let employees share knowledge with each other and act accordingly towards the company goals. Once the employees, with support from the management, are willing to share information with each other, the total sum of the knowledge will increase in the organization and the transformation will accelerate [3].

4.2.2 Interviews

The results from the interviews revealed that collaboration and efficient communication are important capabilities to have in an organization to enable advancement in a digital transformation process. According to the interviewees, these are crucial capabilities since increased digitalization demands that an organization can manage data based decision-makings, which is something that must be made in collaboration between different kind of experts in the organization. Therefore, it is necessary to offer the possibility to have cross-functional collaboration between different departments in an organization and enable the employees to cooperate and share information freely to advance in the transformation process. This is something that can be established by having a less hierarchical organizational and more transparent structure. Furthermore, the respondent's from companies that have several plants also clarified that collaboration between central and local units is a key driver in a digital transformation process. A good collaboration between central and local units is an efficient way of sharing information and knowledge in regards to digitalization between the different units, but also to ensure that everyone is on the same track towards the goal.

"I would say that collaboration and avoiding the highly hierarchical structure in the organization is the most crucial capability to manage a digital transformation process." - Company 4

According to the interviewees, collaboration and efficient communication are also capabilities that will provide a shared mind-set among the employees and create an alignment in the whole organization in the digital transformation process. As explained by the interviewees, shared mind-set among the employees during a transformation process and that everyone strives towards the vision is important, especially in large companies with several departments and plants. This is important to ensure that all employees and departments are aligned in the development and that new solutions are being made in a generic way that is useful for the majority of the company. Furthermore, this is something crucial for companies that are divided in central and local units to ensure that the central units are delivering information that all the local units can interpret and utilize to advance in the process.

"Now when we have a central unit, it is very important that we have a shared mind-set in the different plants to ensure that the local units are using the spread information in correct way towards the goal." - Company 2

As stated by the interviewees, competence is another crucial capability that is necessary to have when a company is working with transformations that requires knowledge in new working areas, such as digital transformation processes. Lacking in competence is often a challenge that companies can overcome for the majority of tasks through internal redeployment of employees. For instance, the companies with several plants tends to redeploy local employees with useful knowledge to cen-

tral units in order to let these individuals spread their knowledge with the rest of the local units. However, this type of solution can not provide enough competence to fill in the gaps everywhere in an organization, hence internal education and recruitment of new employees is a requirement to solve the problem. According to the respondents, a digital transformation process requires implementation of new competence since the increased digitalization will result into implementation of new machines and technologies that requires IT skills and knowledge in terms of machine learning, cloud systems, IoT etc. In addition, it is important that the employees are aware of the core element in Industry 4.0 and digitalized working environment to ensure that they work in a way that facilitates the transformation process. Besides competence, it also very important to employ individuals with the correct mind-set and that are comfortable in an agile working environment where you have to take rapid decisions, work with several tasks simultaneously and strive towards short-term goals, which is something that is uncommon in the traditional development project. As claimed by some of the interviewees, correct type of individuals goes hand in hand with agile WoW and mind-set, which is a necessary capability to enable development and good results in the process.

"Compentence and individuals with agile mind-set are crucial to become more digitalized and this will of course always be a challenge when new things are being implemented." - Company 5

Moreover, as believed by the respondents, willingness to change is a further capability that is necessary to include in the company during a digital transformation process, especially to ease the organizational changes that are needed. This is a challenge that tends to be underestimated in transformation changes and that takes long time to implement in a company. Initially, it is important to create a sense of why the organization is making a change and make the employees aware of the possible outcomes. Otherwise, a lot of confusion can be created among the employees that will turn into resistance to change. For instance, it emerged that it is necessary to create acceptance toward errors and make the employees dare to fail and learn from mistakes, which probably will increase their willingness to change. This is a challenge since the majority of companies still have a traditional mind-set that have a negative attitude towards costly mistakes. Speaking of cost, some of the interviewees stated that the way to success in a digital transformation is to realize that it is a cost driven process that will lead to savings and benefits in the future.

"I think willingness to change is an important and a major challenge among employees, but also at managerial level from time to time. To encourage this it is necessary to create acceptance toward mistakes, which is something that will happen when a company is implementing new things." - Company 4

Lastly, as explained by the interviewees, a supportive management is crucial during a digital transformation process, especially in the early phase, since their opinions

and actions can facilitate the process, but also aggravate it if they act unaligned to the requirements to advance in the process. According to the respondents, the majority of the needed capabilities are strongly dependent on how they managers involves themselves and what regulations they have set in the organization. Firstly, it emerged that a successful transformation process is often driven by strict costs with no result in the beginning, hence it is necessary to have leaders that are supportive in the development process and allows the organization to invest the money that is needed to advance in the process. Moreover, the implementation of cross-functional collaboration, less hierarchical organizational structure, open communication and learning by mistakes are also strongly dependent on supportive leaders that push and encourage the organization to implement, instead of preventing, these capabilities. In addition, it is also important that the managers strive to create a willingness to change by providing detailed information about why the change is being made and how it can affect the organization in the future, but also the employee itself. With that being said, it was also clarified that it is important to have transformation leaders that have deep knowledge in the digitalized visions to ensure that the provided information in the organization is leading the employees towards the right direction and minimize the need of rework due to wrong directives from managers.

"To success in a digital transformation process I think it is crucial to have supportive leaders that encourage the employees through out the whole process. In my opinion, leaders are the enablers in processes like this and without their support it will be difficult to advance" - Company 3

4.2.3 Case study

As mentioned in section 3.4.1, a case study was made in order to create a relevant baseline for the project topic, but also to gather additional useful information from a real-life context that was not highlighted in the semi-structured interviews and the literature study. Initially, a mapping of the organization, which can be seen in Figure 4.2, was made in order to enable identification of challenges and improvement areas in the Swedish car manufacturer that were related to RQ1. The information that were needed to create the mapping was collected through observations on-site and exploratory interviews with employees, but also managers at the company. Moreover, the real names of the different departments and units at the company were not used in the mapping. However, brief descriptions of the working tasks that are being executed at the different branches will be highlighted in Table 4.1.

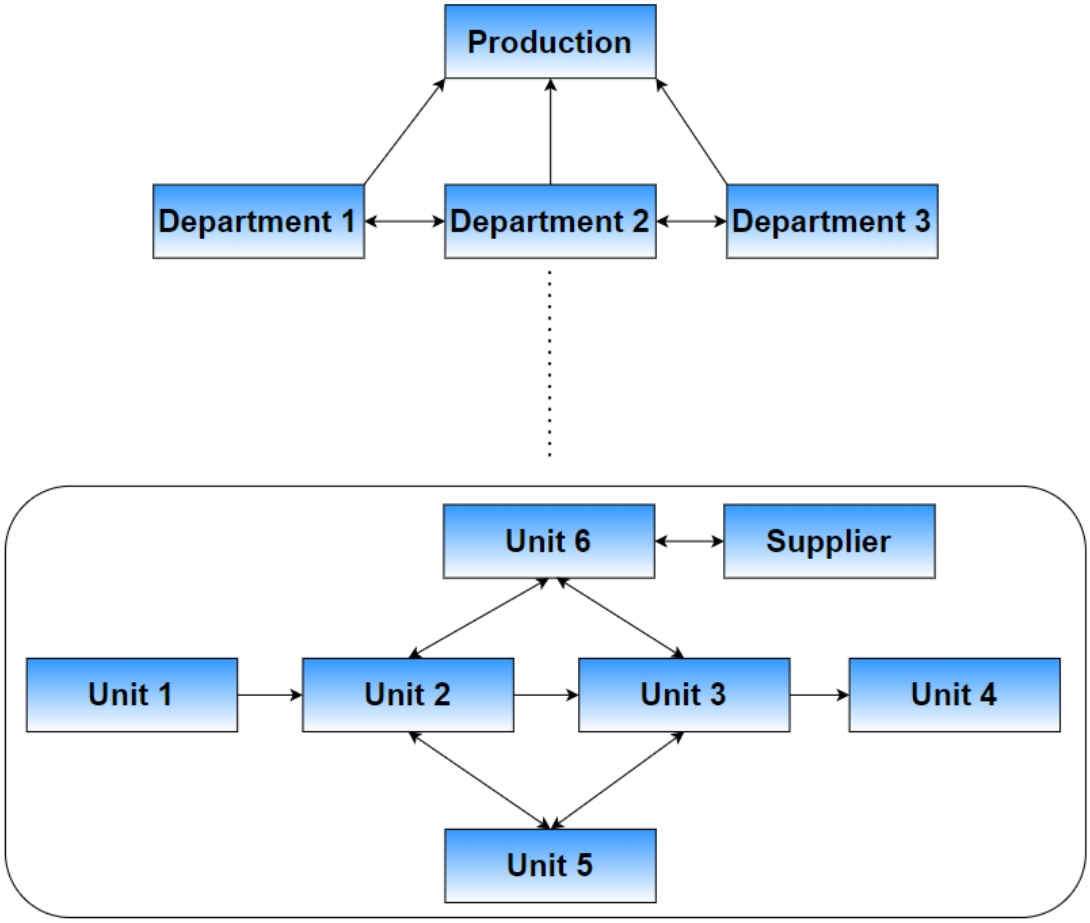


Figure 4.3: Mapping of the organizational departments and units.

As seen in Figure 4.3, the organization is divided into three different departments, each of which are working to ensure that everything that is being manufactured in the production system is producible with no obstacles. The focus areas and responsibility for each department differs, hence the WoW in the departments are not completely similar. In this case study, the second department and its units were investigated in depth in regards to their digital transformation. However, it emerged that the first and third department have been more successful in their transformation processes, therefore some exploratory interviews were conducted with individuals from those departments to facilitate the identification of challenges at the second department. Short descriptions of the branches can be seen below in Table 4.1:

Table 4.1: Description of the branches.

Branch	Description
Production	The whole manufacturing plant where the product is being manufactured.
Department 1	Responsible for manufacturing the surface and the body of the product.
Department 2	Responsible for the manufacturing of the final parts of the product.
Department 3	Responsible for the painting of the product.
Unit 1	R&D unit that strive to introduce innovative ideas, such as improvement areas and the development of new products.
Unit 2	Ensuring that the products will be producible in the production floor.
Unit 3	Ensuring that the products will be producible in the production floor.
Unit 4	A pilot plant where the product is being tested and manufactured before it is put into the actual production.
Unit 5	A global team that support the local teams in unit 2 and 3 by verification and validation through virtual simulation tests.
Unit 5	A global team that facilitates the work for local teams in unit 2 and 3 by ordering the needed equipment and tools from suppliers.
Supplier	Delivering the demanded equipment and tools to ordered by unit 6.

4.2.3.1 Identified challenges

The finished mapping made it possible to get an complete overview of the organization, that simplified the identification of challenges in the company. In addition, the identification process of obstacles were further facilitated through collected information from the exploratory interviews, but also real-life observations.

Through the exploratory interviews, it emerged that there is a lack of competence and skills among the employees at department 2 regarding the ongoing digital transformation process. As believed by the employees, there is a clear gap that must be filled to advance in the process and manage all the newly implemented technologies, but also, working methods. For instance, it was clarified that the employees in unit

6 do not always have the correct competence to interpret the received information from the supplier and ensure that it is correct. The consequence of this issue often lead to further problems in unit 2 and 3, where the incorrect data from the supplier is usually being detected by employees with more competence and rework has to be done. Moreover, some respondents also stated that there is a lack of competence in unit 5 and there is a need for internal education in terms of virtual validations and verifications. As claimed by the interviewees, the lack of expertise must be eliminated to increase the lead time in the organization, increase the trust between the employees and enable further advancement towards increased digitalization. However, this was not an identified challenge in the two other departments and some individuals claimed that it is due to the uneven distribution of employees between the departments in the organization, hence there are fewer employees and available knowledge in department 2.

Furthermore, it was identified that the willingness to change is quite low and the digital transformation process is going slow in department 2. The employees are comfortable in the traditional WoW and it is difficult to convince them about the new and modern working methods that must be implemented to advance in this kind of process. Moreover, some of the interviewees stated that this is mainly due to the lack of knowledge in terms of digitalization and its possible outcomes, but also because of low support from the managers. For instance, it was stated that the managers must inform the employees why a transformation is taking place to convince the employees and minimize their resistance to change. In addition, the top managers at the company must invest more in the transformation process and offer more internal education in regards to digitalization, but also invest more in the digitalization groups that are constantly striving to move the organization towards the goal. It emerged that department 2 has currently two people who are pushing the organization towards the vision step-by-step as daily work, which, according to the respondents, requires more than two individuals to manage.

Moreover, the case study further clarified why there is a difference between the departments in regards to how far they have advanced in the digital transformation process. It emerged that the organization is strongly divided and there is a low level of cross-functional, but also a social collaboration between the departments. For instance, the departments do not cooperate sufficiently to solve problems together or share ideas internally in the organization, instead the different departments are mostly working independently towards the visions. This in turn leads to the fact that sometimes one of the departments has the solution to a problem or has a data file that another department has to generate on their own, which is seen as poor cooperation among the employees. In regards to data management, the departments have different methods of handling data, which makes it even more difficult to share data information with each other. Furthermore, it was revealed that the social communication between the units, internally at department 2, but also with suppliers can sometimes be poor. The consequences can be that the deliveries can be delayed or incorrect due to misunderstandings and lacking of communication.

4.2.4 Summary of RQ1

The presented information that has been found through the three methods, literature review, interviews and case study, clarifies the importance of the different types of capabilities that an organization should consider in a digital transformation process to enable the development of a digital twin. Moreover, it is obvious that an organization that is lacking in needed capabilities will have difficulties advancing in a digital transformation process since this type of shift over requires new WoW and implementations that demand certain capabilities. The capabilities that are stated as needed to become more digitalized are several and the answer to RQ1 is not straightforward since the interviewees, but also the scientific papers, highlight different capabilities as important. Nevertheless, there are five capabilities, among the eight identified ones, that are found in all of the methods used in the project. Therefore, these are the capabilities that will be considered the most important ones and will be included in the framework that is presented in section 4.4. Furthermore, all of the identified capabilities can be seen in Table 4.2, where the five capabilities that have been identified through every method are marked in green.

Table 4.2: Overview of the identified capabilities through each method.

Capability	Literature review	Interviews	Case study
Competence	X	X	X
Shared mind-set	-	X	X
Supportive management	X	X	X
Recognize the value of mistakes	X	-	-
Open communication and collaboration	X	X	X
Willingness to change	X	X	X
Decentralized decision-making	X	X	-
Less hierarchical structure	X	X	X
Agile management	-	X	-

4.3 RQ2: How to support digital transformation

In this section, the results from the literature study, interviews and case study will be presented to answer the second RQ: *How can operational strategies and digital technologies support the digital transformation of an automotive manufacturer?*.

4.3.1 Literature review

To answer the RQ, the literature review presents perspectives on how digital technologies and strategies are related to digital transformation in terms of topics such

as challenges, business models and change management etc. By starting from this, a broader and deeper approach to answering the question can be achieved.

4.3.1.1 Overcoming digital transformation challenges

Based on the formulation of RQ2, presented above, the answer to the question will be of an argumentative nature. As the questions are about "how" operational strategies and digital technologies can support digital transformation, the literature review has presented various considerations and key elements on the topic. These key elements and considerations will be summarized and the rationale will be presented. In addition, the collected data and perspectives need to be put into the context of digitalization and the automotive industry as some literature speaks more generally about transformation and digital technology.

With digital transformation comes many challenges due to the holistic complexity and widespread transformation affecting the entire organization. To successfully support a digital transformation, strategies and technologies must overcome these challenges, or at least take them into account so that they do not hinder the digital journey. Thus, the implementation of new digital technologies should be to support the transformation and overcome the challenges associated with it, not just to increase the level of digitalization. By implementing the right strategies and technologies, the challenges can be overcome if they are considered from the start. The challenges with digital transformation are divided into six categories into three levels as below:

- *Technological level:*
  - IT infrastructure and data security

- *BM value architecture level:*
  - Value creation;
  - Value delivery;
  - Value capture; and
  - Value proposition

- *Strategic level:*
  - Organizational commitment

All these challenges identified in the literature review are strongly related to the challenges identified in the case study and will be described in more detail in chapter 4.2.4. At the technical level, the challenges are strongly related to technology scalability and data management, e.g., standards and reference architecture. At the BM value architecture level, the challenges relate to how to manage resources and capabilities to maximize the value of the implementation. In addition, integrating new technologies and processes into existing operations appears to be difficult. Ultimately, at the strategic level, the lack of a digital transformation strategy is explicitly listed as one of the challenges along with leadership commitment and cultural values within the organization. Therefore, operational strategies could facilitate digital

transformation, by decisions and directives made at the strategic level. However, there is a link between these levels as they span over the organization and the activities at the strategic level affects the other levels, in this case, the BM value architecture and the technological level, and vice versa.

4.3.1.2 Operation strategy and capabilities

At the strategic level of digital transformation challenges, also interpreted as the digital transformation phase, one of the challenges stated was the lack of digital transformation-oriented strategies. The implementation of a digital transformation strategy and the capabilities of an organization go hand in hand. The absence of one affects the other, i.e., it becomes more difficult to implement a strategy if the correct capabilities are lacking and vice versa [53]. A well-known four-stage model within operation strategy regarding the operations effectiveness and contributions are aligned with this statement since the model divides the contribution of operations into two axes, the strategic impact and the operations capabilities [40]. Rather than assuming that employees will adapt in line with the strategy, which only works for organizations that are highly adaptable, fast learners and flexible, capability development should be an integral part of the strategy [53]. In addition, the core idea is to link each strategic priority to the required capability by designing accountability for these around performance and capability development [53].

4.3.1.3 Digital transformation and business models

As a result of the digital transformation, the opportunity for new BMs is becoming real. There are not only new opportunities for companies to expand, reshape or redefine their offerings and customer segments through the availability of new BMs, but also to become more efficient and profitable. However, as described earlier in 4.2.2.1, realizing the value of digital transformation is challenging in several aspects, not only in terms of creating value but also in terms of delivering, capturing and offering value. Because of these challenges, organizations can adapt accordingly and create optimal conditions to maximize value. One suggestion on how to do this is to consider two dimensions, one of which response to "how" and the other to "what". The first dimension is about how to adapt the business model to the digital transformation and the second dimension is about what to focus on according to customer requirements. The strategy should simultaneously consider both dimensions in a holistic approach to achieving the best possible results. Moreover, the aim is to achieve transformation while integrating the BM and operating model and redefining the customer value proposition at the same time. In this way, both dimensions are taken into account and provide the best baseline for leveraging the benefits of digital transformation.

4.3.1.4 Change management activities and digital transformation

As described previously, a digital transformation means a holistic transformation for the whole organization. A lot of changes must be made which can be guided by the established change management theory. However, it is interesting when these theo-

ries combines and the considerations from change management can be implemented in strategies to support a digital transformation.

Chapter 2.4 presented a list of change management activities. These activities was transformed into activities in terms of digital transformation [9]. By doing this, based on the theory from change management, lessons learned could be applied in digital transformations. Potentially, it could ease and smooth the transition in terms of change for organizations during a digital transformation. While forming a strategy to support a digital transformation these activities could be considered in order to minimize failures based on the lessons learned and smoothing the change process by eliminate common challenges such as resistant to change [9]. The change management activities transformed into digital transformation activities are presented in table 4.1.

Table 4.3: Change management activities in terms of digital transformation [9].

Change Management Activities	Digital Transformation Activities
Define a strong leadership	- Define a strong leadership
Generate the awareness of the need for change	- Analyze I4.0 environment to identify opportunities and threats - Conduct a digital maturity assessment - Generate awareness on the need for I4.0 transition
Define a clear vision and strategy	- Define a clear vision, a strategy and a roadmap for the I4.0 transition
Communicate the vision and strategy	- Communicate the vision, strategy and roadmap for the I4.0 transition
Define a change management team	- Define an I4.0 change management team
Identify short-term goals and test the change in pilot projects	- Identify short-terms goals and pilot projects of digitalization
Identify and manage resistance to change	- Identify and manage resistance to change
Train people	- Define digital capabilities and skills - Train and/or recruit people
Monitor change	- Collect and analyze feedbacks and monitor the digital transformation process
Celebrate the successes and implement corrective actions	- Celebrate the successes and implement corrective actions
Consolidate the change	- Consolidate the change

4.3.1.5 Operation strategy and digital transformation

One fundamental aspect within the field of operation strategy is the consideration of two dimensions, operation resources and market requirement. Operation strategy aims to bring these together by building the operations capabilities and by satisfying the organization's market through strategies [40]. The satisfaction of the market by the organization's performance can be evaluated through five performance objectives. Worth mentioning is that different objectives are suggested by different authors, however, these are the most commonly used [40]:

- quality;
- speed;
- dependability;
- flexibility; and
- cost

There are four different perspectives on operation strategy [40]. Again, these strategies link the resources of the organization and the demands of the market to become more competitive by adapting to market changes and the competitive landscape. However, what the strategy should be based on and whom the strategy should primarily satisfy are differences between the strategies. Table 2.4 presents a core question that represents the starting point for the different perspectives and relates, as mentioned earlier, who to satisfy and what to prioritize internally. In Figure 2.8, the four perspectives *top-down, bottom-up, market requirement (outside-in) and operations resources (inside-out)* are summarized.

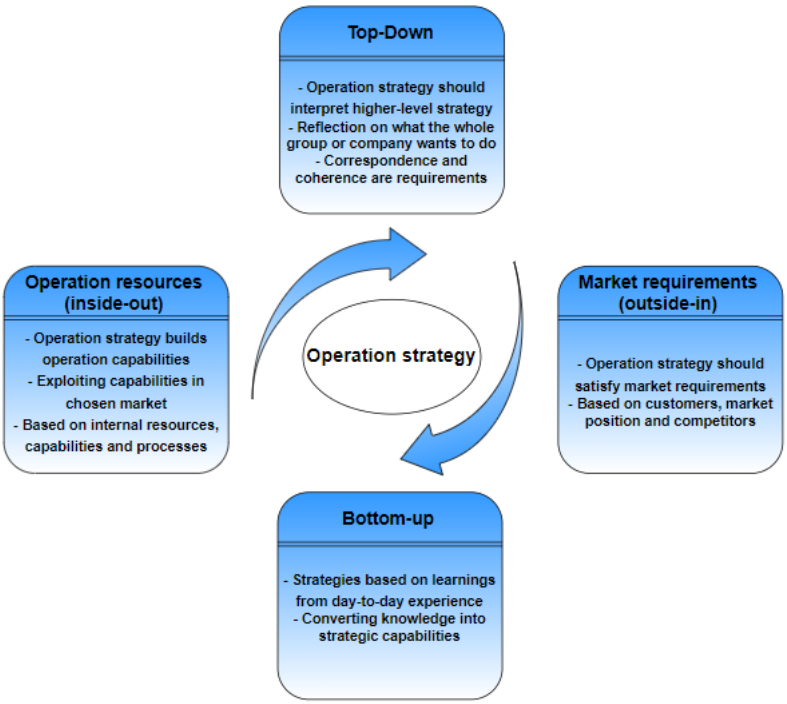


Figure 4.4: Summary of the four operation strategy perspectives. Adapted from [40].

Table 4.4: Core questions to the four operation strategy perspectives

Operation strategy perspective	Guiding question to ask:
Top-down	What does the business want?
Bottom-up	What capabilities do you need to develop?
Market requirement (outside-in)	What do customers want?
Operations resources (inside-out)	How do you organise resources and processes?

4.3.2 Interviews

In designing the interview guide, which can be found in Appendix A, one of the sections included questions about operational strategy. During the interviews, direct questions were asked about what and how strategies were implemented in their companies, but also more general questions that allowed the interviewee to evaluate their opinions and thoughts. As the interviews were semi-structured, this also opened up opportunities to have discussions with the interviewee to delve deeper into interesting topics, based on their previous answers and the direction of the conversation. As a result, many interesting findings were made after analyzing the data (transcripts). Both similarities and differences were found in the way companies work with strategies and in the reflections from the interviews. All these findings will be presented in this section.

4.3.2.1 Strategies to develop flexible organizations

In the interviews, it emerged that an organization that allows rapid change and is flexible is an important step in digital work. Having clear walls between departments, for example between R&D and production, appeared to be a common structure in industrial companies. However, according to the interviewees, companies are moving towards creating a more flexible organization where collaboration between departments is facilitated by breaking down these walls. It was also found that processes are made more efficient by including development and production at the same time. One of the many reasons why it is difficult to design strategies that enable this kind of flexible WoW is due to the history of how people have always worked in the past. People become comfortable with the way they work, and it is difficult to change this unless both management and employees have a clear direction for change. Therefore, management has an important role to play in encouraging these types of changes.

"Right now, we have just done a reorganization, breaking down the walls between R&D and production. It is something that takes time though, but I believe in trying to tear down some of the walls. We are generally good, but there are a lot of gaps because of walls between production and development" - Company 1

When talking about strategies to steer organizations towards becoming more flexible and cross-functional, it is very much linked to how resources are allocated. During a digital transformation, it is important for organizations to have the right skills. However, having the right skills and how to use those skills are two different things. Therefore, it becomes even more important to have the ability to move employees around the organization to spread the knowledge and use it in the right place at the right time.

"Moving good people around is something managers should be able to do, to spread knowledge where it is needed. This is important in all kinds of transformations in

business development, not least for digitalization" - Company 1

A further dimension of fundamental importance in how strategies can support digital transformation is how they shape interdepartmental collaboration. As mentioned earlier, clear walls between departments can prevent digital transformation. This will prevent departments from collaborating, which is important during transformation. It is particularly important that organizations enable collaboration between the digital team and the IT department. This will not only increase the level of digital solutions that can be implemented but also support the creation of standards and communication protocols. In some cases, it may also be beneficial to place the work on digital transformation within the IT team. In these cases, the work can be more solution- and work-oriented as IT is an operational-oriented department, according to interviewees. For example, if the digital transformation group and the IT department work together, it will be easier to write procedures and definitions for how to work with digital twins and IoT.

"Two years ago, our work became more formalized as we received support from our IT organization. More structure started to come in and we defined together with IT how to work with technologies like IoT as standards for communication protocols started to be written." - Company 5

Lastly, another aspect of the interview related to the importance of flexible organizations is that placing a digitalization team in the right place organizationally can increase credibility and help the rest of the organization understand the relevance of digitalization. For example, when a digitalization team is placed separately and freely in the organization, people are more likely to question the work due to a lack of understanding. In addition, it is harder to have a clear WoW and strategy because the main responsibility becomes to make things happen, such as enhancing digitization or automation. Conversely, if a company's strategy is to place the team in an overly formal department, such as RD, the digital work may become too long-term in focus. So, it is about finding the balance between formality, freedom, strategic work and operating. Additionally, the positioning of a team working on digitalization also affects the credibility and questioning of digital work. One interviewee suggests that a good place for a digitalization group is in the strategic department of an organization. Another argument for this, according to the person, is that the digital work will be given higher priority and thus be taken more seriously and exposed to the rest of the organization.

"Previously, we have been free in the organization (was then the cowboy team), which did not work completely credit-wise because people asked why we did what we did, had no organization or WoW [...] But now we work under a free strategy department, which has been the biggest strategic decision. They prioritized the issue by putting it under the strategy department. Today, my team are the ones who develop and write strategies for what digital strategies, technologies and skills

we should have." - Company 5

4.3.2.2 Prioritization in different stages – maturity

In terms of how operational strategies should enable the implementation of digital technologies, it proved important to do this incrementally in order to increase the maturity of the organization. For example, there is no point in introducing new technology if employees do not understand how it will be used or see its value. One interviewee from the company described how digital technology was used for equipment maintenance in manufacturing. Currently, operators have access to direct data from the machines and were able to make analyses based on the data stream that was visualized, i.e., usage of a digital shadow. The interviewee was asked if they needed further digitalization for this specific operation, such as the implementation of a fully digital twin. The interviewee argued that since the operators are happy with what they can do today, there is no need to digitalize further until maturity has increased and they can see the value of what a potential digital twin can enable. It is also worth mentioning that according to the interviewee, the organization could benefit from a digital twin, but the level of maturity must first increase soles the operator found it valuable.

"We certainly have, but we need to let the user mature a little further. Because right now, they are very happy to be able to visualize and do their own analysis. Step two is to be able to do some smarter analysis. And then we start to get into the real twins." - Company 5

Moreover, when an organization is in the early stages of digital transformation, the focus should be on doing and making things happen. This has to do with increasing the level of maturity within the organization, but rather than waiting for operators to recognize the need for new technology, it is up to the responsible team to push out solutions as quickly as possible. However, the idea is not to force employees to work with digital technology, but to create solutions to problems using digital tools. So, it is still important to put the digital solutions in context to solve an issue in order for making it valuable. This will make employees more comfortable with working with digital technologies and increase the level of maturity as a whole in the organization at the same time. In addition, the interviewee stated that the response team should have an agile WoW to be able to react quickly and deliver quickly.

"In my experience, a lot of it is about doing and not talking [...] You assign a small group that works agile and delivers solutions quickly to increase the maturity level to grow the need for further digitalization." - Company 5

4.3.2.3 Value creation of digital technologies – pull strategy and business cases

When introducing new technologies in organizations that are less advanced in terms of digital maturity, it is particularly important to be able to illustrate the value of digitalization. Apparently, relating digital technologies to a business case for each implementation makes it clearer for employees and management teams to understand the value of digitalization. In addition, the usefulness of digitalization and its potential results also become clearer for the remaining organization. This is because these digital technologies are realized and related to practical examples.

"In the beginning, you may not need a lot of strategies either, the most important thing is that there is a business need that we can back up with a business case when the question comes directly from our business unit." - Company 5

A similar approach to digitalization was found in three of the five companies interviewed. However, the way it was expressed differed between the companies but had the same basic idea. From one of the interviews, the approach was expressed more in terms of business cases and the main focus was on the ability to prove value by assigning digital technology to a real issue. An obstacle that was mentioned several times during all interviews was that the management of the companies often does not see the value in digitalization. To overcome this, according to one interviewee, it is easier for top management to understand the value in business cases that are commissioned from departments that have a direct relationship with the business. The main reason for this is that digital implementation can be illustrated in terms of costs.

"Yes, you need to show the benefits always. Company XX is quite big, therefore we need heavy commitments. Because it is just a cost, strict investment, and later you can see the returns. But it will take some time." - Company 1

Another way to work on value creation in the context of digital technologies and digitalization is to have a pull strategy. The relationship between the group working on digitalization implementations and the remaining employees should be that they want new digital solutions, rather than it being forced out, i.e. a push strategy. This was sometimes reported to be a challenge, therefore, as mentioned earlier, it is important to make operators comfortable with working with digital technologies in the early phases. During these early phases, training operators and educating them in digitalization was a strategy that one company used to successfully create a pull within the organization.

"We start with the factory manager level with digitalization training about a year ago and just educated them in digitalization and its possible outcomes to create a pull from them." - Company 2

By doing so, i.e., creating the conditions for the organization itself to have a pull and want digital solutions, you can instead focus on delivering quality solutions that actually solve the problem. It is also in these cases that the digital work has been most successful. However, it is also worth mentioning that every organization is different and during the interviews, it was mentioned that this is what has worked for them and it does not mean that it will work for all organizations automatically.

To summarize the data collected from the interviews in terms of value creation related to digitalization, it is the use of digital technologies that creates value. Based on the interviews, from an industry perspective, digitalization itself is not value-adding. In order to create a digital work that can be integrated into the company's already established WoW, more easily accepted by all parts of the organization and that creates value, it is important to link each individual digitalization to an existing and concreate problem. This is most easily done by creating the conditions for the organization to want new solutions, i.e., through a pull.

"Because it is when digitalization is used that it becomes powerful, digitalization itself is not valuable in itself if it is not used to improve something." - Company 5

4.3.3 Case study

In the sections below the results for RQ2 from the case study is presented.

4.3.3.1 Operation strategy related to identified digital transformation challenges

As described in chapter 2.2.2, a proposed framework that compiles digital transformation challenges is presented. The framework classifies the challenges into different phases, levels and areas. The case study found that the company's digital transformation challenges were very aligned with the theory. Table 4.3 presents the challenges of digital transformation for a Swedish car manufacturer according to the classification from the theory. From the beginning, problems and challenges were identified from observations, exploratory interviews and pilot tests in the practical work which were mapped out. Then the challenges were classified according to the level they belonged to. There are three different levels proposed from [8]: *technology, BM-value architecture* and *strategic level*. For example, challenges were identified in terms of how to integrate digital technologies into the already established WoW, which was classified as a BM value architecture. In addition, at each level, there are categories related to the specific level. This was the next step in the formation of Table 4.3, to categorize each challenge and problem in the levels. In the example of the challenge of integrating new WoW with digital technology in the organization, it was categorized in the value proposition. The reason for this was that it is strongly related to how to realize digital technology, which was an explicit challenge from [8]. In addition, to make the digital technology valuable, it should somehow enhance the customer experience, i.e., have an indirect or direct impact on the product, which

is in line with the value proposition of the category.

The most critical problem and challenge found internally in the company was the lack of a digital transformation-oriented strategy. Since this is a challenge at the strategic level, challenges in the levels below become secondary challenges due to the absence of a clear baseline in terms of the strategy. As illustrated in Figure 2.5 in chapter 2.2.2, it is at the strategic level the digital transformation phase is formed which also becomes the primary and fundamental level, compared to the levels below. More concretely, the strategy could form WoWs for digital technologies and create new standards by also considering how to operate in these environments. Therefore, by forming a good strategy regarding digital transformation many of the challenges in the technological and BM-value architecture level can be overcome.

Table 4.5: Applied framework for digital transformation challenges in identified challenges from the case study.

Technological level	**BM value architectural level**	**Strategic level**
It infrastructure and data security:	*Value creation:*	*Organizational commitment:*
- Lack of scalability in 3D-scanning	- Technological and process integration	- Lack of clear and communicated digital transformation oriented strategy
- Lack of standards and reference architecture in data management regarding 3D models of tools and equipment	- Lack of technical integration of with suppliers regarding 3D models of equipment	- Lack of cultural value to support digital transformation
	- Lack of IT and digital knowledge compared to other manufacturing departments	- Poor operating model to execute digital transformation related work
	- Value delivery:	
	- Lack of standardized quality demands in digital models from suppliers	
	Value capture:	
	- How to manage the financial risks with digital technologies, such as XR tools licenses - How to capture value from digital twins - Data driven decisions based on real-time data	
	Value proposition:	
	- How to integrate digital technologies in established WoW or form new WoW, such as IoT in a digital twin - How to gain value from implementing new digital tools	

4.3.3.2 Shortcomings in digital work

The challenges identified in the company and presented in 4.2.3.1 prevented the company from making progress in digital transformation and digitalization. As mentioned in the chapter, the main underlying cause of most of the challenges was the lack of a strategy that guided the operating model and prevented the implementation of new WoW. Because of this, shortcomings were also identified within the department. Compared to the challenges identified, these shortcomings and gaps are broader and more holistically considered.

Firstly, one of the clear shortcomings of the lack of a digital transformation strategy

was poor interdepartmental collaboration. From interviews and conversations with employees, it appeared that, overall, knowledge and expertise to enable digitalization and to undergo digital transformation were there. However, these competencies could not be utilized in the specific project as there was no strategy in place to enable collaboration between divisions and departments. In these cases, collaboration refers to the exchange of knowledge and expertise that are not spread across the organization to be used in projects where they are needed. For instance, training and workshops to disseminate knowledge internally could be a strategy to implement. However, another aspect of this divide is the clear walls between departments. Having an organizational structure that separates departments makes it even more difficult for employees to support and share their expertise in projects. A typical example of this, mentioned by several employees, was that some departments are much further ahead in terms of digitalization compared to others. In theory, departments could benchmark WoW for digital work, but the lack of collaboration prevents this.

Secondly, there are no clear strategies on how to allocate and assign responsibility for digital transformation. Currently, the unit responsible for digitalization has no previous experience in the area nor expertise in the subjects. In addition, the group has several other responsibilities that are being prioritized. Therefore, it becomes difficult to implement any real practical solutions or to drive the digital work forward as the main focus is on delivering the day-to-day work, such as ergonomic analysis. Except for this unit, the department is supported by one employee who is responsible for the digitalization of the whole department. The vision and objectives of this person and the units seemed to be different, for example regarding 3D scanning of the plant. This illustrated the lack of alignment between the operational teams and the strategic part. In addition, one person responsible for the digital work of an entire department is clearly too little. Having a team working between the strategic work and the teams dealing with day-to-day operations would facilitate the digital transformation.

4.3.4 Summary RQ2

It is obvious that operation strategies should be implemented in the early stages of digital transformation to support and facilitate this work. An operation strategy can be formed by approaching one of the four perspectives *top-down, bottom-up, market requirement (outside-in) and operations resources (inside-out).* By forming the right strategy, it can support organizations in digital transformations by developing flexibility that enables collaboration, knowledge sharing and rapidly adaptable organizations. In the industry, it was found that a common way to implement strategies to support digital transformation is to link each digitalization to a business case. By doing this, the organization becomes more receptive to digitalization and resistance to change can be minimized, which was one of many challenges associated with digital transformation. In addition, there are activities from change management theories to consider by simply applying them to digital transformation activities. It will simplify the change process and make the transformation smoother. However, it is also important to take into account the different stages of digital transformation

in order not to become too formalized by focusing too much on creating strategies, especially at the beginning when the main focus should be on providing solutions to increase the maturity level and having a more operating direction. It could also be beneficial to assign a responsible group for digitalization implementations and digital transformations. Furthermore, digital technologies should be interpreted as enablers of the vision, rather than as goals and targets to strive towards. In a digital transformation process, digital technologies, such as the digital twin, are the pillars that enable the achievement of the objectives that the digital transformation aims at.

4.4 Compilation and suggested framework

After presenting the results to both RQs, this subsection proposes a synthesis of the data collected and analyzed. In Figure 4.5, the final summary can be seen presented in a form of a framework. The main focus of this framework is to support companies in the early phases of digital transformations by indicating fundamental factors to consider. In addition, the framework is specifically targeting car manufacturer that aims to implement digital twins as their long-term goal. It is also worth mentioning that the main thought behind the creation of the framework was how organizational, managerial, operational and strategic dimensions can support the use of digital technologies, i.e., not on the technology itself. This aligns with the scope of the project and the RQs. Each of the levels illustrated in the framework represents an important area to consider, ranging from the company's vision to the external factors outside the company and everything in between. In addition, within each level (circle), there are dimensions and factors to consider specific to each area.

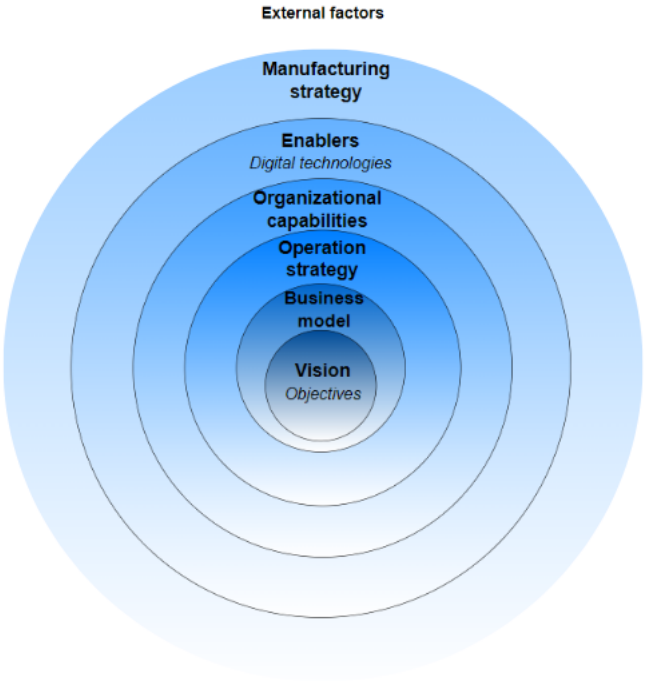


Figure 4.5: Overview of the suggested framework.

The *vision* is the central circle of the framework, which is the level from which the whole framework emanates. Figure A.1 in Appendix A is a more detailed illustration of the role of the vision in the framework. There are four main points to consider in relation to the vision found, based on the results:

- The first point is that the purpose of the vision is to answer what future position the organization is aiming for. Therefore, it becomes particularly important not to confuse the vision with goals or objectives.
- Secondly, the vision must be clear and understandable to the rest of the organization. A clear vision should be concrete and unambiguous.
- Once the vision has been formulated and describes the future position the organization is aiming for, it needs to be communicated so that all employees strive in the same direction.
- Finally, milestones, objectives and targets should be formulated that break down each step towards the vision. KPIs are a common way of formulating objectives because they can be measured and monitored.

The second level from the inside of the framework concerns the *BM*. It should be aligned according to the vision in order to have a customized product, service and offerings to the direction the companies are heading towards. It also affects the levels outside the business model in the framework. To create the optimal baseline for all transformations, including digital transformations, two dimensions should be considered simultaneously: “What to do” and “How to do it”. With regard to the "what" dimension, organizations should aim to move from creating to leveraging and finally integrating. In the second dimension, the goal is to redefine when considering the how dimension, but the first step is to enhance and after this, one can extend and finally redefine. In summary, a transformation stage is about integrating the customer value proposition and redefining how to work. All this is illustrated in Figure A.2 in Appendix A.

The third level of the framework concerns the *operation strategy*. It is relevant to consider the operation strategy because it was found to have a significant impact on the support for digital transformation. In short, operation strategy has four perspectives that an organization can apply: *top-down, bottom-up, market requirements (outside-in)* and *business resources (inside-out)*. By doing so, the BM and vision can be more easily adapted to the practical work and activities taking place. It also proved beneficial to have a specific group in charge of digital transformation which should be placed in the strategy department for maximum value creation. In addition, there are other strategies that can be implemented to facilitate transformation, such as working with pull strategies instead of pushing new digital solutions. This is summarized in Figure A.3 in Appendix A.

The fourth level of the framework considers the *organizational capabilities* that were presented in section 4.2. However, as mentioned in section 4.2.4, only the five capabilities that were identified through all of the three methods were selected for inclusion. The selected capabilities are highlighted in Figure A.4 in Appendix A and are the following: *competence, supportive management, open communication*

and collaboration, willingness to change and *less hierarchical structure.*

The fifth level in the framework highlights the importance of *enablers* in changing processes and that new technology, but also WoW, should only be implemented for obvious purposes to somehow gain value.This part of the framework is summarized in Figure A.5 in Appendix A.

- Firstly, it is necessary to consider digital technologies since it is identified as an enabler to achieving advancement in a digital transformation process and reaching the final vision, a digital twin.
- Secondly, it is important to ensure that the employees at the organization are using the technologies, such as simulation software, machines and data management system, in a standardized way that everybody is following. This is necessary in order to ensure that the different departments internally at the organization are aligned and are using the technologies in a similar way, which will facilitate the sharing and interpretation of collected data.
- As mentioned earlier, it is important to connect each implementation during the transformation process to a specific value since increased digitalization WoW only becomes powerful when it is used to improve something in the organization.

The last level is called *manufacturing* and includes the outcome of how the operating model is related to manufacturing performance. There are mainly five objectives from the theory that can be considered in the context of operation strategy and digital transformation. The overall work executed, for instance, WoW, decisions and how organizations utilize their capabilities have a direct impact on these five objectives: *costs, dependability, flexibility, speed* and *quality.* All these are quantitative objectives that measure performance. However, there is always a trade-off between these and the focus objectives should be based on the vision. The objectives can be transformed into KPIs that are being measured and controlled according to the chosen area of focus. Moreover, they are general and holistic objectives that can be broken down into several sub-objectives. See Figure A.6 in Appendix A.

Outside the framework, there are also *external factors* to take into account and are summarized in Figure A.7 in Appendix A. These are all factors that affect the organization but are beyond its control. Although these considerations are outside the scope of this thesis, it is clear that there are factors that have an indirect impact on an organization's digital transformation, hence, they were chosen to be included in the framework. These seven following factors were chosen to be included in the framework: *competitors, customers, economy, laws and regulations, megatrends, raw material and suppliers* and *supply chain.* All these factors together make up the surrounding environment that must be taken into account as a global car manufacturer.

- The first factor, competitors, are important to consider since they have a significant impact on the positioning in the market. As stated earlier in the report, the automotive industry is a highly competitive market that should be taken into account.

- When it comes to the customers, changes in customer behavior are normal and one of the most recent characteristics in the market where, for example, new demand on a short time to market is one of the changes [3]. This also affects how to adjust as an organization regarding digitalization in general.
- The third factor is the economy, specifically, the macro-economy. What type of economy there is can highly affect the automotive industry, not to mention how it is related to the customers' purchasing power [54].
- In addition, laws and regulations have a major impact on automotive companies by setting the framework to which the industry must adapt to, such as restrictions on engine emissions, which have a major impact on production due to changes from combustion engines to electric motors.
- However, it is not only laws and regulations that drive these changes. Global megatrends are also influencing the way industry behaves. Examples of megatrends include climate change and technological breakthroughs [55]. Due to these megatrends, the industry is currently affected by a huge transformation that is taking place as manufacturers move towards electrification, which is one of the reasons for the need for digitalization.
- The last two variables within the external factors are raw materials and suppliers and the supply chain. The importance of these to manufacturing is obvious as the entire production process is dependent on materials and parts. Currently, the supply chain is being disrupted due to pandemics and other global situations, which affects global manufacturing eminently [56].

5
Discussion

This chapter discusses the process and contributions of this research work, as well as reflect on the future steps that could further develop this research. Aspects, in terms of economical, environmental and social sustainability, are also included and discussed regarding increased digitalization and DT.

5.1 Methodology

In the following sections, the methodology used in the three data collection methods will be discussed and evaluated. The discussions will mainly focus on recognizing the limitations of the results, concerning the methods, and can also be considered as improvement areas for authors working towards similar research objectives.

5.1.1 Literature review

The papers that were used as primary sources in the project have had a clear impact on the final answers of the two formulated RQ. For instance, the selection of the most crucial capabilities that were presented in section 4.2.4 had a large impact on the answer to RQ1 and the content related to RQ1 in the presented framework. The selection was made by extracting those capabilities that were identified through all of the data collection methods and considering them as the most important ones to have during a digital transformation process. Therefore, it is important to consider that some of the excluded capabilities may still be crucial according to other projects on the same topic since it partly depends on what papers, among all, the authors base their literature review on. The chosen papers in this project provided a theoretical background that may not correspond to other investigations on the same topic that is based on different papers that highlights other capabilities as crucial in a digital transformation. Furthermore, the chosen papers in this project formed a list of important capabilities that were used in the semi-structured interviews, hence the papers also affected the outcome of the interviews and the final answer of RQ1. Most likely, the used papers did also affect the answer to RQ2 and how a digital transformation can be supported, but not to the same extent since it did not affect the creation of the interview guide in regards to the stated questions that were connected to RQ2. However, since a strict process, focusing on extracting learning from reliable sources, has been used and that there are connections in the referencing in the papers, the belief is that the answers of the RQ provide a fair view of the project topic.

5.1.2 Interviews

To gather useful information from companies that are striving to become more digitalized, five semi-structured interviews were conducted with interviewees with different working roles at different companies from the same region. The answers from the interviewees' were strongly considered and some of the collected information was used to formulate answers for both of the RQ. Therefore, it is clear that the interviews had a large impact on the project and the outcome could have been different if other participants, or more, were chosen for the interviews. The answers from the respondents were obviously based on individual interpretations, knowledge in terms of digital transformation and the current situation of the interviewees' company in the transformation process. Therefore, the answers can have a certain degree of bias, which is intrinsic of the participants background. For instance, to get a better overview of the different companies and improve the data collection it would be better to interview several people from the same company to get insight into their digital transformation process from several points of view instead of collecting information from one individual. Furthermore, the interviews were only conducted with companies from the same region in Sweden and the final result of the project would most likely be different if the participants were from different regions or countries where the maturity level, regarding digitalization, differs in the manufacturing industry. Thus, considering different maturity levels in digitalization could be constructive for further development within this research field. However, the focus in this project was to interview respondents in a similar geographical location to have less variability and ease the description of the situation for an area in Sweden.

5.1.3 Case study

In addition, a case study of a department at a Swedish car manufacturer was conducted as a further collection method to include information from a real-life scenario into the conclusions. Exploratory interviews and observations were the two methods that were used to investigate the company and identify obstacles that prevent the organization from advancing in its digital transformation process. Even though useful information was gathered through the study, it is not generalizable since it describes a specific scenario. Therefore, it must be considered that the collected data only applies to the department and not to the whole organization or other car manufacturers. The individuals that were interviewed did share their thoughts, in terms of digital transformation, from their point of view and did explain what challenges they have identified in their working role. Hence, the outcome of the case study could have been different if other employees were interviewed in the study. In addition, the managers at the department had also a clear impact on the results of the case study by highlighting specific challenges that they view as bottlenecks in the transformation process. Therefore, the study was less objective since it was directed by the managers and was strongly dependent on the goals of the company and what they prioritize the most in their way towards increased digitalization. For instance, the observations contained problem areas that the managers wanted to visualize and the possibility to look into other things was low. The outcome from

the exploratory interviews can also be considered skewed since the managers did participate in some of the interviews. This can have affected the answers of some of the interviewees since they may have adapted their answers to satisfy the manager and avoid internal disagreements.

5.2 Results

This section analyses the final results in relation to the framework and DT. First, the applicability of the framework's content to different firms is discussed. It also highlights the disagreement on the definition of DT and a possible solution to this problem.

5.2.1 Framework

The compilation of the gathered information in this project report resulted in a proposed framework that is provided to be used as a guideline with highlighted dimensions to consider by companies in the automotive industry. More specifically, it aims to support organizations within the industry that are in the early phase of a digital transformation process. As mentioned in chapter 4.4, the main focus in the creation of the framework was strongly based on the formulated RQ and the scope of the project. Therefore, it can be discussed to what extent this framework applies to different car manufacturers that are undergoing a digital transformation. It may be applicable and valuable for companies that are lacking in the included dimensions, but not for companies that have control over these by already implementing the dimensions. Another perspective on the applicability of the framework is that a digital transformation is a very complex transformation process and therefore, there is not only one way to success. Thereby, the framework should be interpreted as one possible type of guideline during a digital transformation, not as the only right way. Even though the framework may be considered supportive for a specific car manufacturer, it is difficult to say whether these steps will result in desired outcomes and increased digitalization at the company. The reason for this is that the project is mainly based on papers that are, from a theoretical point of view, evaluating how these types of transformations should be executed to achieve beneficial outcomes. However, there is a lack of papers that discusses how manufacturers, that have managed to carry out a digital transformation successfully, have made their transition from the beginning until the end of the process with practical examples. Hence, academia needs to strive to include more papers on how successful digital transformation processes have been performed by manufacturers that have reached a higher level of digitalization in order to facilitate the transformation processes for other companies.

5.2.2 Digital twin

The concept of DT, as mentioned in section 2.1.2, is undergoing continuous development across industries with different interpretations of the concept, thus there is no precise definition of the concept that everyone agrees on. This is something that

was noticed during the conducted interviews since everyone had their understanding of DT dependent on how the companies have explained the vision with DT and the desired outcomes of the concept. The majority of the interviewees tended to refer to virtual representations, such as 3D-CAD models and scanned plant views when they shared their thoughts concerning DT. Therefore, it is important to address whether the implementation of digital twins is a must to overcome challenges or whether it is beyond what the industry requires. According to literature, lower levels of data integration, such as DS and DM, can enable the creation of the desired virtual representations, that were referred to in the interviews, with lower investment requirements. Hence, DS and DM are sufficient concepts that should be stated as the visions at many companies, instead of DT, to achieve the desired outcomes at a lower cost. However, DT seems to be stated as the target in many companies regardless of the purpose behind the implementation of the concept. This is something that increases the confusion regarding the definition of DT, which is being highlighted in papers, and must be changed if there is to be a final definition of the concept that everyone agrees on.

5.3 Sustainability aspects

This section discusses economic, environmental and social sustainability with regard to the concept of DT and increased digitalization.

5.3.1 Economical and environmental sustainability

Many companies that undergo a digital transformation eventually manage to achieve a DT. However, it has been made clear that digital transformation processes toward DT require certain capabilities and a strategy that permeates the entire organization to be successful. Moreover, digital technologies, which is classified as an enabler in this project, must also be implemented to achieve beneficial outcomes from the process, such as DT. From an economical point of view, the implementation and development of these needs can lead to strict costs at the beginning of the process without any benefits in return, which was, according to the interviewees, something common in the early phase of a transformation and is something that must be accepted to achieve progress. However, it is important to be aware of the economical advantages the investments, in the beginning, can result in, in the long-term, when a DT has been achieved. A DT offers a precise view of the physical object, such as a production system, that can be seen and monitored in the virtual world. This will, for example, minimize the working load in the development phase since the DT will facilitate the verification and validation of innovative ideas that are planned to be built in the production system. Furthermore, the level of monitoring that is being offered by DT will make it possible to predict unit failures by analyzing the condition of equipment and performing maintenance in time. It will also enable reliable commissionings and simulations in the virtual world of new implementations that will make it possible to detect errors before installations. With these being said, the DT will enable an organization to predict the future and minimize costs by forecasting errors in the production system. Hence, it is necessary to accept the

strict costs that are required in the early phase of digital transformation processes and consider it as an investment that will provide increased capital in the future.

The outcomes of DT and increased level of monitoring provide, besides economical, also environmental sustainability. As mentioned, a DT can facilitate the verification and validation of new products before they are produced in the production system by enabling tests with a virtual copy of the real-world environment. The concept of DT also makes it possible to forecast failures and machine downtimes in the production systems through advanced monitoring. These characteristics of DT will prevent companies from doing wrong decision-makings that may result in rework and minimize the probability of using energy on machines that are temporarily out of order. Hence, DT will minimize waste, decrease the usage of resources and optimize production efficiency which results into increase environmental sustainability. Moreover, the advanced monitoring of DT will also make it possible for the user to identify units that are bottlenecks in terms of energy consumption and water usage, which can further ease the elimination of units that are consuming too many resources.

5.3.2 Social sustainability

Despite that digital transformation processes and Industry 4.0 encourages companies to implement advanced digital technologies, digital processes and become more data-driven, the concept of Industry 4.0 is still about people. A digitalized world with high connectivity and data transparency will enable the manufacturers to serve the needs of customers, employees and partners, but it also fosters collaborations that facilitate the development of new products and services with their stakeholders at the forefront. Moreover, some people and companies are unfamiliar with DT and they argue that this concept can, in the long term, lead to fewer job opportunities for people. On the other hand, it is important to be aware of those who argue that DT will rather rearrange monotonous working tasks into more demanding ones instead of reducing job opportunities. A digitalized company will require employees with different skills, capabilities and preferences, which will contribute to a more interesting working environment with more opportunities for self-development and increased autonomy. Hence, it is more appropriate to say that the concept of digitalization and DT will demand employees with various skills instead of reducing jobs.

It is clear that a company that strives to become more digitalized indirectly aims to rely more on information and seeks to become more data-driven. Therefore, it will be a lot of data that might be confidential, in regards to the company's security, but also to individuals that are providing the data. From an ethical point of view, data that is being shared internally, but also externally, at a company and connected to specific individuals could be harmful to workers' integrity. Hence, it is important to ensure that the connection between individuals and stored data is eliminated to protect the employee's integrity.

5.4 Future research

During the project, it was identified that Industry 4.0 is a revolution that empowers digital transformation in order to change the current factories into SMS and facilitate the monitoring of production systems with DT. To achieve a DT it is clear that an organization must undergo a digital transformation process and consider the conclusions that have been made in terms of organizational capabilities, strategies and digital technologies in the project. Hence, digital technologies have been presented in the framework as an enabler to advance in a digital transformation process. However, how and what type of certain digital technologies should be implemented step by step have not been investigated in this project and is something that could be examined in future research. For instance, it has been clarified that one of the core elements within the Industry 4.0 is IoT since networks of embedded technologies that enables devices to communicate and interchange information are crucial in the production systems. Therefore, future research on how IoT can be achieved step-wise in a digital transformation process would be beneficial for academia and companies in the industry that strives to integrate their resources to become more competitive by improved system monitoring.

Besides investigating digital technologies, more detailed investigations of the presented segments in the framework could be a further alternative for future research areas to support organizations to accomplish a digital transformation successfully. For example, in regards to strategies, this project only highlights the importance of using strategies and how they can support an organization towards increased digitalization. Even though it has been explained that an organization can form an operation strategy in four different ways, it would be beneficial to conduct future research that investigates these four approaches more in detail. The support for companies would increase even more if future research could provide the organizations with information that describes exactly what type of strategies has proven to work in different stages of transformation processes by investigating companies that have achieved a high level of digitalization. Moreover, the identified crucial capabilities, such as competence, provide a wide scope for future projects. The capabilities in this project are only being presented as crucial capabilities that are important to possess as an organization, but it would be useful to provide academia and the industry with information that explains the presented capabilities in full detail and how they can be developed. Similarly, the rest of the segments of the framework could be further investigated in depth.

6
Conclusion

The need for more flexibility in production processes in the automotive industry has increased due to more complex manufacturing processes as cars are electrified. One approach to overcome these challenges is through digital transformations by implementing digital technologies step by step. This thesis has explored the capabilities that can enable the development of a digital twin in the early phase of digital transformations and how operation strategies and digital technologies can support these transformations in the automotive industry. A total of nine capabilities were identified in the development of a digital twin, but only five capabilities were identified in all three methods used. Therefore, the most important capabilities to have as an organization are *competence, supportive mindset, open communication and collaboration, willingness to change* and *less hierarchical structure*. Both operation strategy and digital technology were found to play a significant role in supporting organizations through digital transformations. Operation strategy can support organizations in the automotive industry by aligning the operative model with the vision, i.e., towards the direction they aim at, and by influence the WoW to satisfy demands by creating the baseline for capability development. Moreover, operation strategy can support organizations throughout digital transformations by providing the prerequisites for digitalization implementations, such as competences, and by enhancing value of digitalization. In addition, strategies and an organization's capabilities are related in that they influence each other. Having the right capabilities can facilitate the implementation of a strategy and vice versa. Digital technologies are tools to achieve organizations' goals and must be interpreted accordingly, hence, setting a clear vision with measurable objectives is essential.

Based on the results of the thesis, a framework was proposed to facilitate early phases of digital transformation in the automotive industry. The included levels are the most important ones to consider from a holistic perspective. It can also be concluded that there are external factors outside the control of organizations that influence digital transformations. They are worth to consider, but the main focus should be on the internal factors that can be controlled which are the following: *vision, business model, operation strategy, organizational capabilities, enablers (digital technologies)* and *manufacturing strategy*. The framework facilitates the digital journey of an organization by pointing out where to focus before implementing new WoWs. For future research, it would be interesting to examine what the processes might look like in organizations that have successfully undergone digital transformations to find important steps to take based on real cases. In addition, it would be insightful to see how well the frameworks could be implemented in real cases.

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A

Extended version of the framework

Figure A.1: Part 1 of the suggested framework: Vision

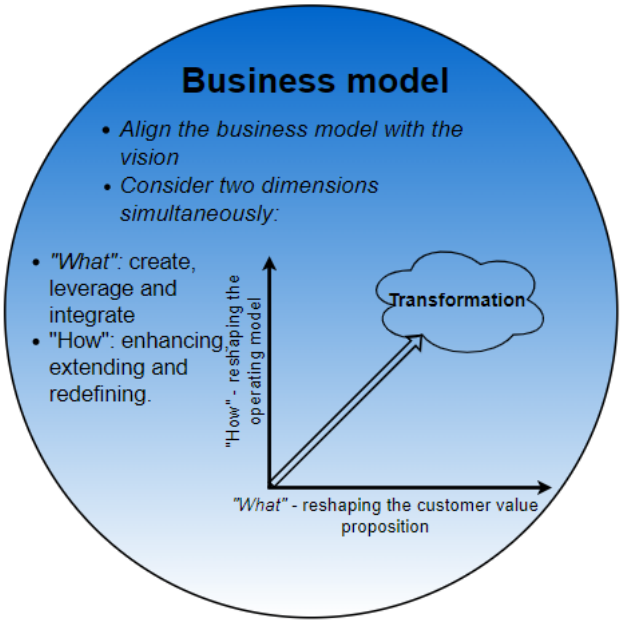

Figure A.2: Part 2 of the suggested framework: Business Model

Figure A.3: Part 3 of the suggested framework: Operation strategy

Figure A.4: Part 4 of the suggested framework: Organizational capabilities

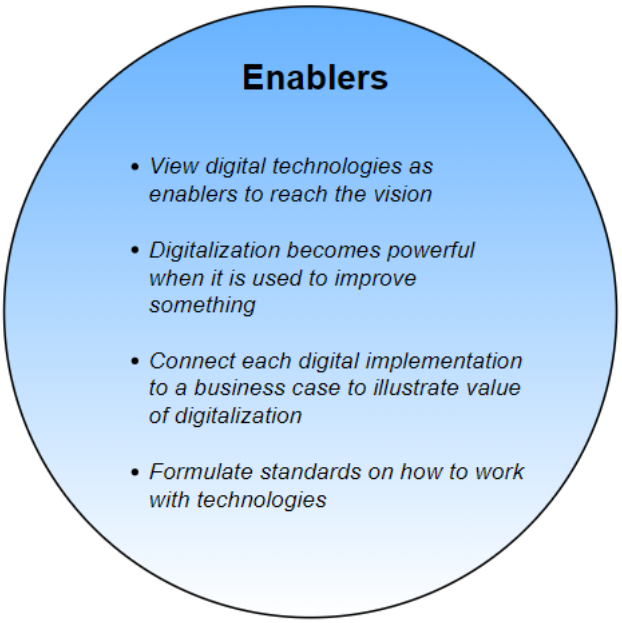

Figure A.5: Part 5 of the suggested framework: Enablers

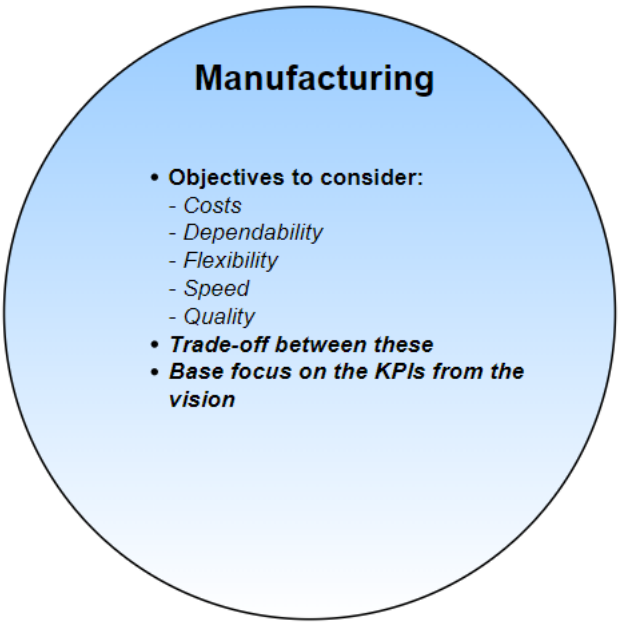

Figure A.6: Part 6 of the suggested framework: Manufacturing

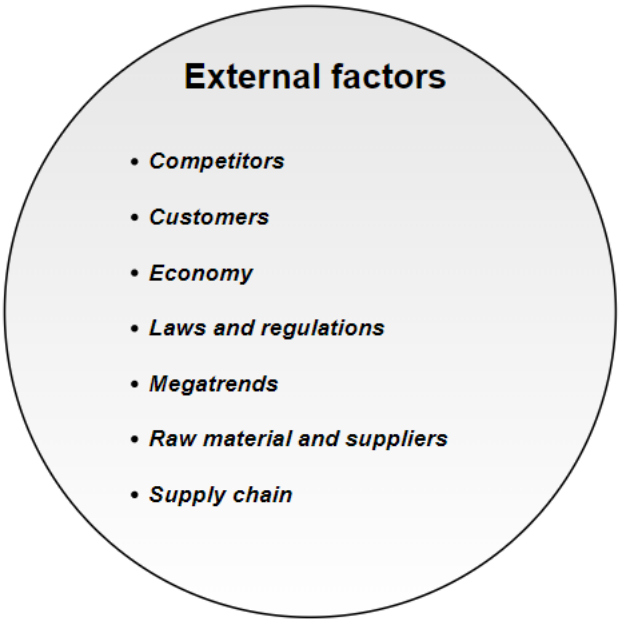

Figure A.7: Part 7 of the suggested framework: External factors

B

Interview guide

1. **General information:**
   (a) Introduction of ourselves
      i. *We are two students from the masters programme Production Engineering at Chalmers University who are doing our master thesis at company XX in Gothenburg.*
   (b) Aim of project
      i. *The first part of the project is to identify organizational capabilities that are necessary for the development phase towards a Digital Twin. Furthermore, we want to investigate how operational strategies and digital technologies can support a digital transformation.*
   (c) Purpose with the interview
      i. *The purpose of this interview is to get further information in regards to the aim of the project, which is related to organizational capabilities, operational strategies and digital technologies.*

2. **Introduction:**
   (a) What is your full name and current title?
      i. Would you like to keep your identity anonymous in our project report?
      If yes → Can we use your job title without mentioning your name?
   (b) Are we allowed to record this interview, we will delete the recording directly after the project is finished?
      i. *The information that we will receive from the recorded material can become a part of our project report, which will be published publicly at the beginning of June.*
   If no → Can we, at least, use the information we receive from this interview?

3. **Information about the interviewee and the company the interviewee work:**
   (a) What educational background and/or past experiences do you have?
   (b) Can you briefly describe your role at your company at what you are working with?
   (c) How do you work with digitalization in your company?
   (d) How have you integrated it in your WoW?

(e) How do you think digitalization can impact your organization?
(f) Digital twin is one example of what could be achieved from increased digitalization, when you have access to real time based data such as updated 3D-models. Is this something you consider a need in your job?

4. **General questions:**
   (a) What are the needs of your work role that lead you towards more digitalized options? How would it facilitate your work and the company vision/goals?
   (b) Do you think your company has a clear vision of your goal with the digital transformation and a structured plan on how to arrive there?
   (c) How far do you think you have reached in terms of digitalization?

5. **Organizational capabilities and culture:**
   Definition:
   Organizational capabilities: *Intangible expertise, skills and culture of an organization that is combined with resources to accomplish work.*

   (a) Do you think one or several of these organizational capabilities has facilitated your way towards your level in regards to digitalization?
   If yes →
      i. Which ones of these?

Table B.1: Organizational capabilities

Organizational capabilities:	***Description:***
Agile management	Agile project management is an iterative approach to delivering a project throughout its life cycle.
Allocation of resources	How resources are divided into departments, groups, etc. internally.
Collaboration	The action of working with someone to produce something.
Correct Competencies	Talented employees with the right competencies to support the digitalization
Data management	Data management is the process of ingesting, storing, organizing and maintaining the data created and collected by an organization.
Decentralized decision making or data-based driven decisions	Decentralized decision-making is any process where the decision-making authority is distributed throughout a larger group or completely driven by data.
Efficient communication	How colleges, groups, departments, suppliers, etc. are communicating. For example, transparency of 3D-models.
Strategic Alignment	Strategic alignment is a process that ensures an organization's structure, use of resources (and culture) support its strategy.

      ii. In what way do you think this/these capabilities have facilitated your digitalization process?
   If no →
      i. Are there any other capabilities you can think of?

(b) Moreover, is there any capability that you are lacking in to become even more digitalized? *You are allowed to mention capabilities besides the ones in the table.*
(c) Which of the mentioned capabilities are the most difficult versus easiest to develop in an organization?
(d) Do you think your organizational culture and standards have limited/enabled your ability to become more digitalized? Consider the following cultural factors:

Table B.2: Cultural capabilities

Cultural capabilities:	***Description:***
Learning by mistakes	Everybody can be open about mistakes and learn from it.
Open communication and collaboration	It is allowed to communicate and collaborate freely within the organization.
Responsibility	The employees have a feeling of accountability to finish their tasks.
Shared Mind-Set	The employees have a common set of beliefs and visions.
Supporting leadership	The management is supportive towards company goals.
Willingness to change	The employees, but also the management, are not resistant to change.

If yes →
i. Please explain, how?
If no →
i. Are there any other cultural aspects you can think of?

6. **Digital technologies:**
Definition:
Digital Technologies: *Supportive programme system in general, but also technical tools that are required to reach a Digital Twin, such as sensors, connected platforms and cloud based storage.*

(a) Do you think any programme systems or technical tools have facilitated the process towards your level in regards to digitalization?
If yes →
i. Could you mention what type of technologies?
ii. In what way do you think this/these capabilities have facilitated your digitalization process?
(b) What digital technologies do you think you are in need of to increase your digitalization level even more? Are there any working areas where you think you are just in need of new technology to facilitate the tasks?

7. **Operational strategies:**
Definition:

Operational strategy: *Operational strategy helps a company examine and implement effective and efficient systems to achieve the corporate objectives. Operational strategies also guide the company with operative support to achieve the corporate objectives. For example, new WoW or working methods.*

(a) What strategies have your company used to reach the current state of digitalization? For example, what operational strategies are used to implement changes towards a digital transformation?
If they are lacking in capabilities →
   i. How do you think your company could implement new operational strategies to increase the capabilities that you are lacking in?

(b) If you had any previous lacking capabilities, how did your company implement new operational strategies to improve your lacking capabilities in the beginning?
If they are lacking in technologies →
   i. How do you think your company could implement new operational strategies to increase the digital technologies that you are lacking in?

(c) If you had any lacking technologies, how did your company implement new operational strategies to improve your lacking technologies in the beginning?
If the organizational culture or structure are seen as obstacles →
   i. How do you think your company could implement new operational strategies to improve the organizational culture, but also structure, in order to support the digital transformation?

(d) If you have had previous organizational structure or cultural struggles, how did your company implement operational strategies to improve the organizational culture, but also structure, in order to support the digital transformation?

8. **Sum-up:**
   (a) To summarize the interview
      i. Is there anything else that you would like to include that we have not mentioned?
      ii. Do you know any company that we could interview related to our project?
      If yes → Do you have contact information of anyone from that company?
      iii. Can we contact you for follow-up questions?
      If yes → What is your email address?
   (b) Thanks!
      i. *We would like to thank you for participating in this interview and hope that we can use the received information to come up with useful conclusions in our project report.*

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