International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

Transforming Operations: A ComprehensiveAnalysis of Industry 4.0 Technologies in Operations Management

UNDER THE GUIDANCE OF

DR. Gaurav Gupta

Submitted By PRASHANT KUMAR22042010975

SCHOOL OF BUSINESS GALGOTIAS UNIVERSITY

1. Introduction

In the introductory part of this paper, we provide a brief overview of the research subject matter, research topic, research problem, thesis topic,research questions, and disposition of this paper.

Background 1.1.

Industry 4.0 brings about a major transformation in automotive manufacturing. It is characterized by the use of advanced information analytics, networked machines, and digitalization within organizations. In addition, it is characterized by the integration of internet technologies with forward-looking technologies in the domain of "smart" objects. However, there is no single definition of the term "industry 4.0" in the literature, which restricts theory building and the comparability of research. However, Lasi (2014) argues that industry 4-0 is a "new paradigm shift" in industrial production because of the advanced digitalisation within factories. A paradigm shift is a significant change that occurs when the normal way of thinking or doing something changes to something new and different. In industry 4-0, emerging technologies integrate with each other to bring about a change in manufacturing processes.

Despite the popularity of industry 4.0, research does not provide clear information on how the industry 4.0 transformation occurs or how to navigate it. Compared to other automotive industries like cars and trucks, the bus industry has not undergone much change in terms of transitioning to industry 4.0; however, there are many research-based recommendations that provide knowledge for transitioning to a 4.0 system (e.g., Prinsloo (2019), Ghobakhloo (2018), Wang (2016), and Errasti (2016). However, previous research is not widely accepted in the bus industry due to the unique characteristics of bus manufacturing (i.e. long take-takes, high complexity, big variations, high of empirical studies on a transformation towards 4.0 applicable in the bus industry. This is confirmed by the study by Qin et al. This leads to missing out on potential advantages that have been demonstrated by industry 4.0 research, such as increased productivity, higher quality, improved efficiency, increased flexibility, better energy efficiency and better utilization of production resources.

By focusing on the bus industry, it is important to explore and provide access to the knowledge needed to manage a transformation towards industry 4.0.According to Ghobakhloo (2018), manufacturers need to be prepared to adapt to a possible fourth industrial revolution in order to remain competitive.

In addition, according to Synnes and Welo (2016), one of the keys to sustaining competitiveness in a fast-paced industry is a company's ability to adapt to new technologies. It is also important to provide flexibility in the work environment and

production system in order to maximize capacity utilization.
The reality is that Industry 4.0 requires knowledge in order to achieve competitive advantage (Kotter, 2014). Therefore, knowledge is the key to managing a transformationtowards Industry 4.0. Not only do you need to know about the phenomenon, but you also need to know how to manage the change.
Research has shown that involving and using the knowledge of workers is important forchange management.
A knowledge-based view on the firm offers comprehension of how knowledge is linkedto individuals working within the firm (Grant 1996).
By applying change management and taking a knowledge-based approach to the firm,you create a framework to manage a transformation toward industry 4.
In addition, guidelines are useful for defining and managing a transformation. Therefore, a roadmap is one of the most useful tools for implementing a manufacturingcompany strategy.
Leitão et al., (2013)

1.2. Problematization

In practice, a transition to industry 4.0 changes the automotive manufacturing operations, as new emerging technologies work together to create a complicated manufacturing environment. This necessitates deep knowledge to fully exploit the opportunities that come with industry 4.0: increased flexibility, cost reduction, increased productivity, enhanced quality and reduced delivery time are just a few of the suggested opportunities from Industry 4.0.

Previous paradigm shifts in industrial manufacturing have led to significant transformation in the automotive industry. Research shows that Industry 4.0 will significantly impact existing manufacturing processes (Taylor et al., 2018).

To capitalize on the many opportunities identified by research for manufacturing operations with the implementation of Industry 4.0, consider a transformation towards Industry 4.0 for long-term competitiveness. Previous research and empirical evidence on industry 4.0 does not apply to bus manufacturing due to the significant differences in volume, customer adaptability, large variations and complexity of bus manufacturing compared with other automotive industries (i.e., cars and trucks). Therefore, it is meaningful to focus on the bus industry in order to gain access to the knowledge needed to transition to industry 4.0, although industry 4.0 impacts all aspects of an organization (Taylor et al. 2018, Ghobakhloo, 2018), literature suggests industry 4.0 has significant implications for manufacturing operations (Lu, 2017). Due to previous inadequate research, technologies involved in industry 4.0 need to be further studied in the context of the bus manufacturing operations (pfeiffer, 2017). Therefore, there is a need for increased knowledge within bus manufacturers to manage a transformation into industry 4.0; both technology and change management will play a significant role in this transition.

1.3. Purpose

The purpose of this study is to create and share explicit knowledge about Industry 4.0, by looking at the opportunities and challenges associated with the technologies and concepts that are relevant to bus manufacturing. Adapting a knowledge-driven view of afirm supports understanding how knowledge is interdependent across organizations. A change management model that reflects the knowledge needed to manage a transformation can be created. Furthermore, a comprehensive roadmap with steps to approach and manage a transformation towards Industry 4.0 can help bus manufacturersto begin their transformation journey.

Research questions1.3.1.

Two research questions have been formulated to give clarity to the purpose of this thesis and the answers it aims to provide.

RQ1: *What opportunities and challenges does industry 4.0technologies entail within bus manufacturing operations?*

RQ2: *How would a roadmap for managing a transformation towardsindustry 4.0 look like for bus manufacturing operations?*

This thesis contributes with industry 4.0 knowledge by addressing the research questions:

Identifying opportunities and challenges of high potential technologies in bus manufacturing operations; and

Managing a transformation to industry 4.0; and

Utilizing a well-known change management model, and adapting it for the new industry 4.0, this thesis will provide a framework that bus manufacturers can use. This thesis will answer two critical research questions that will pave the way for future work in industry 4.0 within the bus industry.

Empirical context 1.4.

The Swedish bus maker and the study are working together to undertake the study. In the bus manufacturing industry, there aren't many players, thus the main company's selection was warranted because it runs a full-fledged bus manufacturing operation. allowing the study topics to be examined in the intended setting. Bus manufacture differs greatly from other automotive industries, such cars and trucks, in that it involvesa lot of manual labour, high customer customisation, low volume production, and numerous variations. The bus manufacturer, the core firm, has production locations all throughout the world. Some of these sites specialise in specific production phases, whileothers run a full-fledged bus manufacturing operation.
It is recommended that bus manufacturing processes be divided into seven primary production steps, each of which is typically carried out on a production line with severalspecialised stations. The steps are presented in Table 1.

Table 1. Presents an overview of the production steps for bus manufacturing operations.

1. Pre-manufactured components	A complete bus consists of thousands of components manufactured in-house or outsourced.
2. Chassis	Chassis frame with engine, axles, wheelbase and front floor zones.Welded or bolted together.
3. Powertrain	The powertrain is assembled with other driveline components andelectrical systems.
4. Body structure	Body structural elements are welded or bolted to chassis. Elementscan to a different degree be pre-assembled with body components.
5. Body components	Interior/exterior panels and equipment are mounted to the bus.
6. Exterior finish	Painting of the exterior.
7. Test and verification	Final test of bus functionalities and quality assurance.

Disposition 1.5.

The thesis is structured as presented in Table 2.

Table 2. Disposition of the thesis.

Chapter 1	Describes the background and problematization of the thesis along with its purpose.
Chapter 2	Introduces the reader to a theoretical background where definitions, key concepts and technologies of industry 4.0 from literature are described. Furthermore, knowledge-based theory and change management are presented which leads to thetheoretical framework.
Chapter 3	Describes the methodology of the study and the research process using systematic combining. Further, it explains the data collection, data analysis. Also, delimitations and a discussion on trustworthiness are presented.
Chapter 4	This chapter presents an analysis of empirical data, using the methods described inchapter 3.
Chapter 5	Presents a virtualization case on costs for training using virtual reality vs. traditionaltraining.
Chapter 6	A discussion on the collected data and relating it to theory.
Chapter 7	Presents the conclusion of this thesis and provides answers to the researchquestions.
Chapter 8	Gives limitations of the conducted research, along with potential future research.

2. Theoretical background

The theoretical backdrop offers a theoretical justification for this paper's framework. The industry 4.0 phenomena, with its complex concepts and technologies, is the focus of attention. It also offers a change management methodology linked to the knowledge-based approach for handling the transitionto industry 4.0. The theoretical foundation is finally introduced.

Industry 4.0 2.1.

Drath & Horch (2014) refer to Industry 4.0 as the fourth industrial revolution, which is the idea of using cyber technology in conjunction with physically connected things to facilitate service applications. Despite the fact that this definition may soar in the most transcendental visions, it is frequently revisited because of its futuristic accuracy withoutdelving deeply into its core qualities (Culot et al. 2020). Culot et al. (2020) and Oztemel& Gursev (2020) further suggest that the phrase "industry 4.0" denotes a general digitization of society. Due to the growing use of robots and computerization, which is thought to have an impact on the unemployment rate, operational occupations from the past will be computerised.
With features like robotics-based autonomous solutions, enhanced flexibility, and highcustomizability to satisfy diverse client requirements, emerging technologies centred around manufacturing seek to achieve higher productivity and competitive position (Culot et al. 2020; Oztemel & Gursev 2020).

Industry 4.0 was first presented in a framework of official backing, but there were no established managerial protocols for putting it into practice (Sommer 2015). Industry 4.0is currently a major focus for a large number of businesses, academic institutions, and research facilities. However, most academic experts feel that the phrase "industry 4.0" isnot quite clear (Ghobakhloo 2018). Academic research on industry 4.0, according to Oztemel & Gursev (2020), focuses on comprehending and characterising the idea while attempting to construct systems and business models. On the other hand, the industry concentrates on how industrial machine suits and intelligent products are changing and how this advancement may affect potential clients (Oztemel & Gursev 2020). Manufacturing companies are having trouble comprehending the industry 4.0phenomenon because of the subject's novelty (Ghobakhloo 2018).

Scholars hold varying perspectives regarding the definition of industry 4.0 (Tay et al., 2018), and a clear definition of the term is still lacking (Culot et al., 2020). The conceptof industry 4.0 that has been utilised throughout this thesis is derived from the definitions that are often used in the literature, as shown in Table 3.

Table 3. Industry 4.0 definitions from academia.

Definition	Reference
A new phase in manufacturing through information and communication technology (ICT) driven innovation.	Culot et al. 2020, p. 4
Industry 4.0 is defined as an amalgamation of advanced technologies where the internet is extensively used to support certain technologies such as embedded systems.	Tay et al. 2018, p. 1384
The concept of Industry 4.0 (where 4.0 represents the fourth industrial revolution)arises when the IoT paradigm is merged with the CPSs idea.	Sisinni et al. 2018, p. 4726
...defining Industry 4.0 as a set of initiatives for improving processes, products andservices allowing decentralized decisions based on real-time data acquisition.	Moeuf et al. 2018, p. 1118
Recent advances in manufacturing industry has paved way for a systematical deployment of Cyber-Physical Systems (CPS), within which information from all related perspectives is closely monitored and synchronized between the physical factory floor and the cyber computational space. Moreover, by utilizing advanced information analytics, networked machines will be able to perform more efficiently, collaboratively and resiliently. Such trend is transforming manufacturing industry to the next generation, namely Industry 4.0.	Lee et al. 2015, p. 18

According to Culot et al. (2020), industry 4.0 is made up of a number of "tech ingredients" that are continuously developing into new enabling technologies through mutual combination and convergence rather than a single ground-breaking invention. They go on to say that the technical landscape is incredibly diverse and wide-ranging (Culot et al. 2020). The fourth industrial revolution is being referred to as the applicationof developing technologies in connection with one another, not the technologies themselves, which are not always new. The research notes that it might be challenging todiscern between the ideas and technology that make up industry 4.0 (Culot et al. 2020). As a result, the various industry 4.0 concepts and technologies will be looked at in the following section.

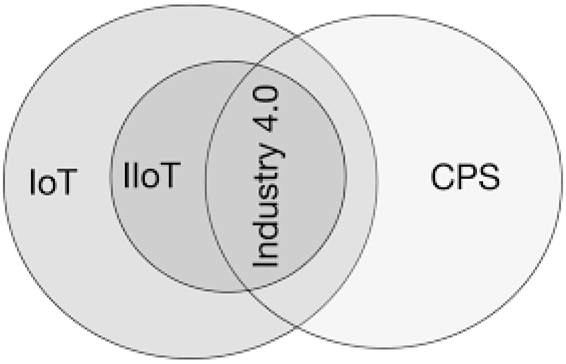
2.1.1 Key concepts within industry 4.0

The term "Internet of Things" (IoT) is frequently used in relation to industry 4.0. "The inter-networking of physical devices, vehicles, buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity that enable theseobjects to collect and exchange data" is how Oztemel & Gursev (2020) define the Internet of Things. (Page 28 of Oztemel & Gursev 2020). Furthermore, Sisinni et al. (2018) provide additional clarification by outlining the strong connection between IIoT (Industrial Internet of Things) and IoT. IIoT refers to automation applications through machine-to-machine and industrial communication technology (Sisinni et al. 2018).

While "things" in the context of IIoT refer to integrated operational technology of machines and control systems, "things" in the context of IoT encompass consumer electronic gadgets (Sisinni et al. 2018).IIoT and industry 4.0 are more closely tied than IoT. "The integration of computing and physical processes which are essential components" is the definition of a Cyber-Physical System (CPS). (Page 15 of Oztemel &

Gursev 2020). Hermann et al. (2016) claim that this integration allows computers to watch over and manage physical processes, and that in a feedback loop, calculations influence physical processes and vice versa. The importance of communication technologies in the IIoT context is further stated by Sisinni et al. (2018), who summariseit in terms of machine-oriented solutions with centralised network administration. Figure1 below illustrates how the various characteristics are related in their study (Sisinni et al.2018).

Figure 1. Illustrates the connection between IoT, IIoT, Industry 4.0 and CPS in a Venn diagram



It is clear from Figure 1 that IIoT and CPS intersect to form industry 4.0. This entails tying information systems and business processes to industrial assets, control systems, and machinery (Sisinni et al. 2018). Numerous scholars (e.g., Oztemel & Gursev 2020; Ghobakhloo 2018; Liao et al. 2017; Hermann et al. 2016; Kagermann et al. 2013) support the claim that IoT and CPS are essential elements of industry 4.0. Industry 4.0 isthe way that production will operate globally, according to study (Tay et al. 2018).
Appendix A.1 provides a summary of recurrent ideas and technological advancementsthat are mentioned in the literature as being a part of the industry 4.0 phenomenon.

2.1.2. Enabling technologies for industry 4.0

Three distinguishing traits of industry 4.0 enabling technology groupings are identifiedby the literature. These clusters align with the characteristics of the most commonly referenced technology. According to Culot et al. (2020), virtualization, real-time information sharing, and autonomy are the enabling technology groupings.

- ***Virtualization***

The term "virtualization" refers to the process of creating a virtual version of the realworld that allows the full value chain, including the factory, machinery,
equipment, goods). This is accomplished by combining virtual or simulation-based models with sensor data collected from the real environment (Ghobakhloo 2018). The term "digital twin" refers to the virtual environment (Ghobakhloo 2018). By optimising manufacturing lines' operation in total isolation without interfering with the physical processes, the digital twin makes enhancements to current processes possible (Gilchrist 2016).Because the production process of the product can be virtually assessed, virtualization technology gives producers the ability to have a complete digital footprintof their products, which increases knowledge (Ghobakhloo 2018). A technique for estimating or determining the output of a simulated system is to test virtual processes orsystems through simulation modelling. Virtual reality (VR) and augmented reality (AR),which are mostly utilised for educational reasons, are other related technologies in this

field. AR is an interactive experience of a real-world setting, while VR is a computer-simulated reality (Oztemel & Gursev 2020). VR can, for instance, give operators the ability to replicate real-world factory floor experiences. The ability to manage information in real-time is crucial for virtualization (Ghobakhloo 2018).

- ***Real-time information sharing***

Real-time capabilities enable the collection and analysis of data in real-time, enabling prompt decision-making at all times (Ghobakhloo 2018). Real-time data integration andanalysis will maximise manufacturing resource utilisation and improve performance (Lu2017). This is because instant access to reports and real-time status updates allow for more control and timely management. Technologies like sensors, big data analytics, andcloud computing are crucial for real-time information access. Thanks to cloud technology, sensor data may be processed and stored in a cloud environment, making information available for use whenever needed. One benefit of real-time analytics, according to Gilchrist (2016), is that it builds a cognitive computer system that may identify or anticipate defects, malfunctions, or irregularities in the system that a human operator might miss.

- ***Autonomy***

According to Culot et al. (2020), autonomy in manufacturing systems refers to the ability of individuals and machines to make decisions on their own and respond to unfamiliar circumstances without outside assistance. Technology that makes autonomy possible is artificial intelligence (Culot et al. 2020). However, changes in organisationalstructure and control systems are also related to autonomy (Hermann et al. 2016).
Additionally, automated guided vehicles (AGV) are discussed as automated transportingsolutions in the context of autonomy (Hermann et al. 2016). Furthermore, autonomy in production is enhanced by robotics.

Culot and colleagues (2020) also identify process integration as a fourth category of enabling technology, defining it as "the influence of interoperability solutions in consolidating product and process data both inside and outside of organisational boundaries." 2020 Culot et al., p. 8. For manufacturers, process integration is a key facilitator of communication between CPS and IoT. Furthermore, industry 4.0 manufacturing depends heavily on both vertical and horizontal system integration. Horizontal integration guarantees the seamless operation of machinery, smart devices,and engineering processes.
Through vertical integration, communication between the horizontally linked shop floor network and systems is made possible, enabling the utilisation of production data for decision-making. Furthermore, Hermann et al. (2016) propose the creation of a technicalassistance technology group that uses electronic equipment to support employees in theirwork. According to Hermann et al. (2016), the jobs are frequently unpleasant, excessively taxing, or dangerous for the employee to perform on their own.

The industry 4.0 concepts are combined by Liu & Xu (2017), as shown in Figure 2. Thepicture depicts a general factory vision of industry 4.0, with multiple smart factories connected by the internet and each physical component of production constituting a "cyber twin." The cyber twin depicted in the illustration is the same as the previously discussed idea of a digital twin.

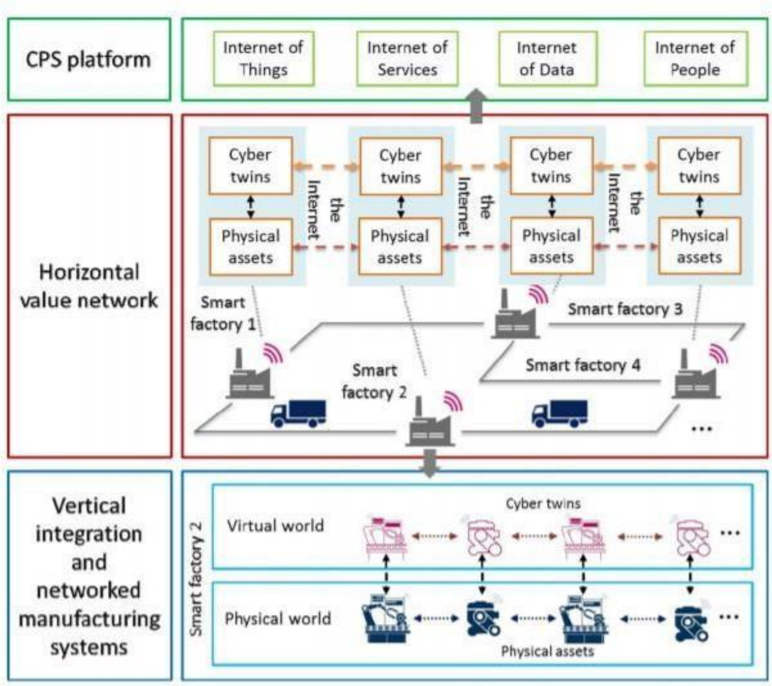


Figure 2. Displays the principle of industry 4.0, by Liu & Xu (2017)

To facilitate optimal decision-making in production across the network, several factoriesare horizontally integrated, i.e., the digital twin and physical assets are integrated.
According to Pfeiffer (2017), there isn't just one industry. 4.0. Which innovations areadopted by which organisations and in which industries relies on the particular conditions determined by variables such as the level of automation, among others.

Production technologies, value chains, and product complexity. As a result, this entails asignificant obligation for both industry and specific companies.
Businesses must recognise where they are now in terms of their processes, procedures, philosophy, strategy, and current technology in relation to the degree of adaptability theyhope to achieve in order to adjust to the ideas of industry 4.0. When it comes to managing change, knowledge is a recurrent building block. A corporation might embarkon a digital transformation journey by following one of several roadmaps.
Still, not every industry or firm can benefit from the same strategy. The intentions, goals, ambitions, finances, and issues facing each business are unique (Gilchrist 2016).The study conducted by Erol et al. (2016) revealed that there is a significant need for assistance to support organisations in developing their industry 4.0 plan and vision. A modern approach to organisational design and strategic management is to adopt a knowledge-based vision of the company (Santoro & Bierly, 2006). This serves as the basis for the road map that is presented in the ensuing sections.

2.2 Knowledge-based view of the firm

As an extension of the resource-based approach, Grant (1996) characterises the knowledge-based view of the company in light of the significance of a firm's knowledgeof industry 4.0. The resource-based paradigm, according to Santoro & Bierly (2006), explains performance discrepancies by pointing out special, priceless, and non-replicable resources and skills. However, the firm's distinctive knowledge base is typically the resource that eventually results in a lasting competitive advantage (Santoro& Bierly 2006). The knowledge-based paradigm calls for a shift in emphasis from finding a multitude of resources to boost competitiveness—both material and immaterial—to having employees place more emphasis on their knowledge (Conner &Prahalad 1996; Foss 1996; Grant 1996; Hoskisson et al. 1999). A knowledge-based view's guiding principles define and provide the framework for theuse of human capital in the organization's regular and structural operations. The knowledge-based view of the firm, which is backed by Grant (1996), Foss (1996), and Conner & Prahalad (1996), conceptualises firms as diverse, knowledge-bearing entities (Hoskisson et al 1997).

In his widely read study, Grant (1996) made a distinction between implicit and explicitknowledge, which are the two main categories. Implicit knowledge, sometimes knownas "knowing how," is abstract information gleaned from certain experiences and circumstances that may include minute aspects of a person's actions in a given setting (Grant 1996).
Explicit knowledge, sometimes defined as "knowing about," is actual knowledge that issimpler to convey, easier to access, and easier to gain in locations where information is kept and made available (Grant 1996). Santoro & Bierly (2006) assert that it is more challenging for people to recognise, comprehend, and integrate tacit knowledge into an organisation. Furthermore, Grant (1996) highlights the value of involving others and themeticulous coordination of distinct specialists who

hold a wide range of knowledge categories.
In the knowledge-based firm, rules and directives exist to facilitate knowledge integration; their source is specialist expertise which is distributed throughout the organization. While analysis of delayering has concentrated upon cost reduction and increasing the speed of decision making, theknowledge-based view suggests to the extent that 'higher-level decisions' are dependent upon immobile 'lower-level' knowledge. Then, according to Grant (1996) hierarchy impoverishes the quality of higher-level decisions.

According to research presented by Kengatharan (2019), knowledge—which is an organization's intellectual capital—correlates favourably with both productivity and a firm's performance. Furthermore, Abreu (2018) asserts the connection between knowledge and competitive intelligence, highlighting the significance of employee knowledge. According to Abreu (2018), an organisation cannot succeed solely on the basis of its acquisition of new technology and productive processes. By modifying the knowledge-based perspective to account for the modern society's demand for adaptability and creativity, it produces well considered solutions for handling the revolutionary shift that will lead to the advent of industry 4.0. Change management willconsequently be covered next because it will have a significant contributing factor.

2.3. Change management

According to Fettig et al. (2018), an organisation must step outside of its comfort zonewhile tackling industry 4.0 in order to foster innovative thinking that results in new business capabilities. According to them, it becomes especially important to manage atransformation (Fettig et al. 2018). But this is also the point at which conventional management approaches have their limitations. Thus, going ahead, Fettig et al. (2018)point out the necessity of a clear strategy for overseeing a shift towards industry 4.0.
Studies, according to Bucy et al. (2016) at McKinsey & Company, indicate that seventypercent of intricate, extensive transformation initiatives fall short of their intended objectives.
Common pitfalls include low or nonexistent cross-functional collaboration, a lack ofaccountability, insufficient managerial support, and a lack of employee engagement

(Bucy et al. 2016). The findings of Agostini & Filippini (2019) appear to indicate that inorder for companies to achieve high levels of industry 4.0 technology application, they must be shaped at all levels. Gupta (2011) asserts that a model is required to alter corporate culture and prepare it for innovation. A methodically constructed framework for innovation is required, one that can be widely adopted in the information-rich knowledge era (Gupta 2011).

There are various approaches to guiding change. This study will modify Kotter's eight- step model, which is a widely used paradigm for managing change (Kotter 1996). When change is required in today's business environment, the processes in this model provide amethodical approach to handling it (Kotter 2014). Kotter's model aligns with the industrial transformation principles due to its flexibility in accommodating organisational structures and capacity to integrate varying reactions to change among theworkers (Small et al. 2016). Furthermore, Kotter's eight steps continue to be a great place for managers to start when implementing change in their organisations, according to Appelbaum et al. (2012). They opine that putting the model into practice should increase the likelihood of success (Appelbaum et al. 2012).

When it was first introduced, Kotter's change management model was an immediate hit, and it isnow regarded as a major reference model in the area (Appelbaum et al. 2012). Since then, the model has been modified (Kotter 2014). Because of the complexity of the issues faced, Kotter contended that the eight-step process as it existed needed to be modified in order to function effectively for ongoing change in organisations (Kotter 2012). Involving as many individuals aspossible—rather than just a core group—was one of the key distinctions between the old and new processes.

"To accelerate, you need more legs to move, more brains to think, and more eyes to see"(Kotter 2014, p. 23). Recall that this is derived from Grant's knowledge-based perspective, according to which each employee's knowledge matters because the company is seen as an institution for integrating information (Grant 1996). Table 4 below presents Kotter's updated eight-step transformation model for reforming an organisation. Coexisting and consistently effective are the phases (Kotter 2012).

Table 4. Presents the eight steps in Kotter's change management model (Kotter 2014).

Step	Description
1.	Establishing a sense of urgency
2.	Forming a powerful guiding coalition
3.	Form a strategic vision and initiatives
4.	Enlist a volunteer army
5.	Enable action by removing barriers
6.	Generating short-term wins
7.	Sustain acceleration
8.	Institute change

Using a model facilitates structure and assurance. A description of the eight stepsin the context of industry 4.0 follows in the theoretical framework.

2.1. Theoretical framework

An authors' assembled definition of industry 4.0 is based on the literary definitionsincluded in Table 3 and the theoretical background explanations. An operational definition of industry 4.0 is suggested by this study:

Industry 4.0 is defined as an amalgamation of advanced technologies where the internet is extensively used to support certain technologies such as embedded systems. It is a general concept for improving manufacturing processes, products and services. Technologies involved are e.g. smart sensors, digital twin, big data analytics, cloud technology, artificial intelligence and robotics. Industry 4.0 arises when the Internet of Things paradigm is merged with the Cyber- Physical System idea and by utilizing advanced information analytics, networked machines will be able to perform more efficiently, collaboratively and resiliently. Allowing decentralized decisions based on real-time data acquisition.

The literature explains how industry 4.0 is causing a paradigm shift that is causing significant change for industrial operations (Ghobakhloo 2018; Lu 2017). Insufficient understanding may lead to an unsuccessful transition towards industry 4.0 management. Change management offers a framework for adapting to change and creating advantageous conditions. The uncertainty surrounding industry 4.0 places a great deal ofpressure on every business to manage a transformation and acquire the necessary skills. The theoretical framework is developed by defining important questions for managing achange, drawing inspiration from Kotter's eight-step model and tailored to industry 4.0. Change management becomes suitable since an industry 4.0 transformation necessitates change and change management adds to an organised method for handling and managing significant change. The roadmap, which is intended for bus makers, will be constructed using this model as the theoretical foundation. Figure 3 presents the framework.

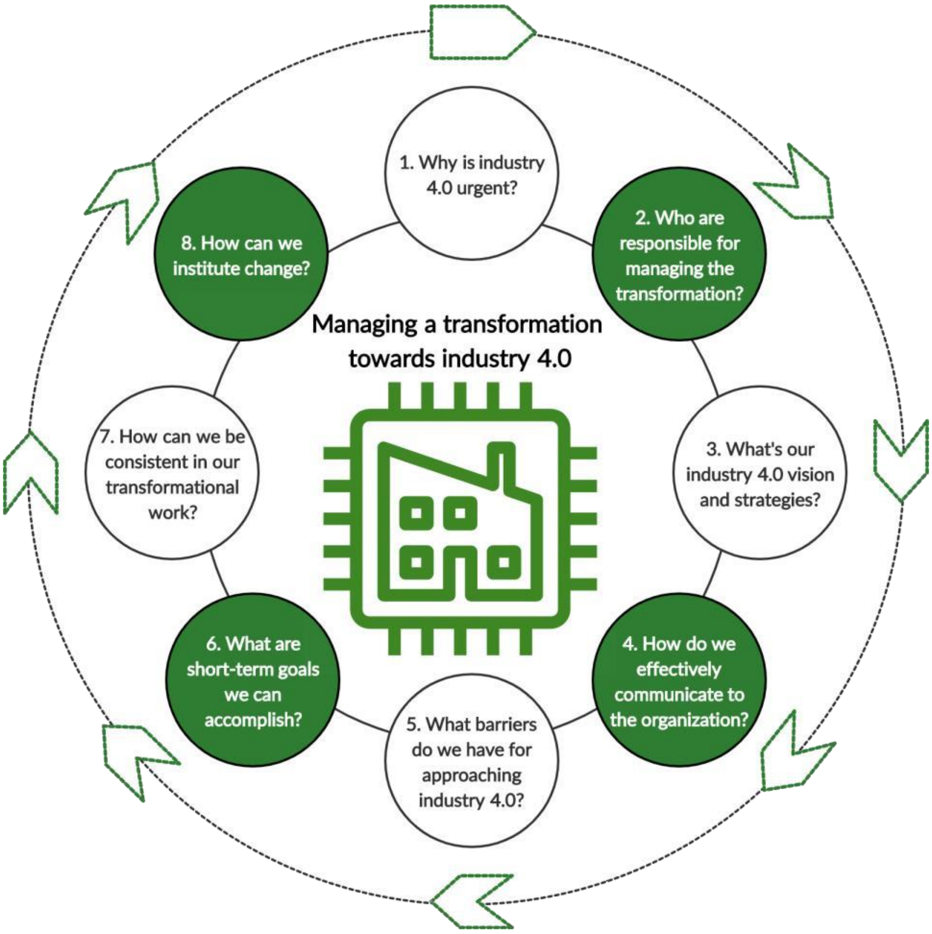


Figure 3. Presents the theoretical framework, inspired by Kotter (2014).

Detailed information for each step of the framework in Figure 3. is described inTable 5.

The knowledge-based perspective of the firm is supported by acknowledging the questions in the theoretical framework. The workforce must be informed about industry 4.0 in order to determine which opportunities are relevant to the company and why it is vital. Additionally, expertise is needed to choose the accountable individuals to start andoversee a change. The knowledge-based perspective also makes a case for including others and getting their buy-in to the entire course of events. Involving employees results in a greater pool of expertise and experience as well as more people supporting the change. If those resisting change take an active role in the change management process, this can also serve as a counterbalance.

Table 5. Describes the eight-step change management framework, inspired by Kotter (2014).

1. Establishing a sense of urgency *Why is industry 4.0urgent?*	Create and maintain a strong sense of urgency among as many people as possible about industry 4.0. People will not change ifthey cannot see the need to do so.
2. Forming a powerful guiding coalition *Who is responsible formanaging the transformation?*	This step entails building the core of the network structure. Assembling a group with enough power to lead the change effort in a transformation towards industry 4.0. This core group needs to have the drive, the intellectual and emotional commitment, the connections, the skills, and the information to make things happen. Also be able to work effectively together as a team.
3. Form a strategic vision and initiatives *What's our industry 4.0vision and strategies?*	Clarify a vision for how a future change towards industry 4.0 will be different from the past. Establish how to make that future a reality through strategic initiatives linked directly to achieving that vision.
4. Enlist a volunteer army *How do we effectively communicate to the organization?*	Communicate the industry 4.0 vision and strategic initiatives to the organization in ways that lead large numbers of people to buy into the whole flow of action. Done well, this process results in many individuals wanting to help.
5. Enable action by removing barriers *What barriers do we have for approachingindustry 4.0?*	Identify and remove obstacles around managing a transformation towards industry 4.0. Such as inefficient processes and hierarchies, which slow or stop change in order to provide the opportunities to generate real impact.
6. Generating short-term wins *What are short-termgoals we can accomplish?*	Create an ongoing flow of strategically relevant wins, both big and small. Ensure that the wins are visible to the entire organization and that they are celebrated, even the small wins. These wins, and their celebration can carry great psychological power and play a crucial role in building and sustaining credibility, leading to respect and more cooperation within the organization.
7. Sustain acceleration *How can we be more consistent in our transformational work?*	Continue the change towards industry 4.0 even though the general human's motivation tends to diminish after a few wins. It is built on the recognition that many wins come from sub- initiatives which by themselves may be neither substantial nor particularly useful in a strategic sense. Larger initiatives will lose steam and support unless related sub-initiatives are also completed successfully.
8. Institute change *How can we institutechange?*	Institutionalize wins and integrate the successful industry 4.0 initiatives. In effect, this helps to implement the changes into the culture of the organization.

3. Research method

The methodology chapter describes the research method used in this study. First, it explains the research process based on the study's problematization. Next, it describes how data collection and analysis has proceeded. It ends with a discussionon research ethics, trustworthiness and delimitations.

The current knowledge gap about the shift to industry 4.0 in bus manufacturing operations is the issue that this thesis seeks to solve. The goal of this thesis is to providespecific knowledge about how bus manufacturing operations may manage the transitionto industry 4.0 by analysing the opportunities and difficulties that industry 4.0 technologies bring to the table. The goal of the thesis serves as the foundation for the research strategy. A qualitative technique was applied to study a case in order to investigate the research questions in this exploratory research, as it applies to deeply explore a topic (Bryman & Bell 2011).
Additionally, abductive reasoning was supported by the systematic combining technique, which helps manage the associated aspects in the research task that arise fromthe interwoven activities in the research process (Dubois & Gadde 2002). By methodically collecting information from many sources, researchers can uncover previously undiscovered details and gain new insights into the relationship between industry 4.0 and bus manufacturing processes, for example (Dubois & Gadde 2002). In order to provide a comprehensive grasp of the intricate real-life background of the bus business, the study centres on a single bus manufacturer. Researching a larger number of examples with the same amount of resources results in more breadth but less depth, according to Easton (1995), who also claims that analysing one case leads to more depth.

3.1. Research process

The methodical merging process involves the concurrent evolution of the theoretical framework, empirical investigation, and case analysis. Accordingly, systematic combining is a path-dependent, non-linear process whose goal is to align theory with reality (Dubois & Gadde 2002). Deep structure is more likely to result from the constant back-and-forth matching and redirection than from linear study (Dubois & Gadde 2014).In hindsight, Figure 4 below depicts the methodical combined research approach that was motivated by Huhtala et al. (2014). It displays how attention changed as a result of our growing comprehension of the phenomenon and adheres to the paradigm developed by Dubois & Gadde (2002).
It began with a proposed area of study to educate the bus sector about industry 4.0. To learn more about the phenomena of industry 4.0 transformation, a comprehensive reviewof the literature was done. Following that, open-ended interviews were conducted with four bus industry professionals at the focus company to understand more about the company, its offerings, and its current state of affairs.

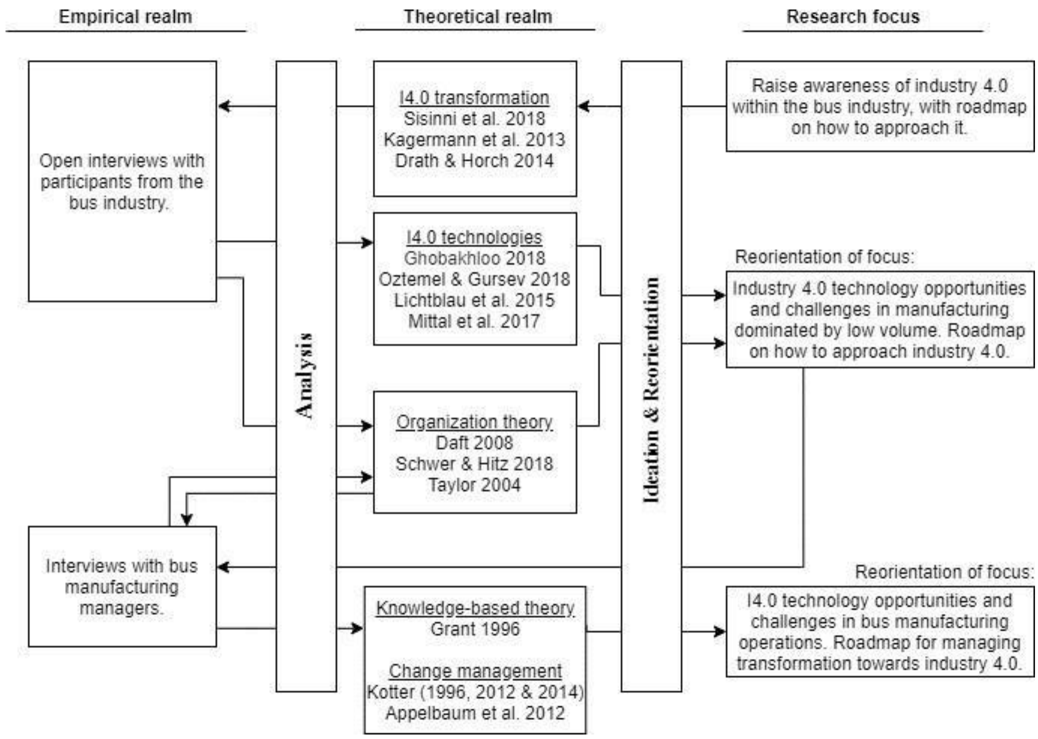


Figure 4. Illustrates the systematic combining research process (2014).

Going back to the theoretical domain once more to comprehend the literature detailing the industry 4.0 revolution, the research was focused on organisation theory and industry 4.0 technologies (e.g. Schwer & Hitz 2018; Daft 2008; Taylor 2004). This resulted fromdiscoveries that the bus sector, with its unique features in contrast to other automotive industries, had not yet determined what it needed. One of the reasons for this was the bus industry's general ignorance of the industry 4.0 phenomenon. In order to produce more broadly applicable results, we therefore shifted the focus to include low volume manufacturing processes.

Five semi-structured interviews with managers of bus production completed the researchprocedure. After comparing the results to the theoretical domain and literature once more, it became clear that a different viewpoint from the researched theories was required to engage in an industry 4.0 transformation because it was challenging to include other low-volume industries, like aircraft manufacturing, because of significant differences between industries. As a result, the research's primary focus was changed again. The bus business, and more especially the bus manufacturing sector, came back into focus now.

Additionally, the roadmap from knowledge-based theory (Grant 1996) and change management (Kotter 2014) to approach industry 4.0 was started by investigating different organisational perspectives. Because of its previous effectiveness in changemanagement and conceptualization of enterprises as diverse, knowledge-bearing organisations, this method to managing transformation was judged to be appropriate.

Data collection3.2.

The data was gathered using qualitative methods. The use of qualitative approaches when the phenomenon is somewhat unknown is supported by Corbin & Strauss (2015).Furthermore, if further research is required to improve understanding since the phenomenon is either poorly or incompletely understood. Additionally, Grey (2017) emphasises that the adoption of techniques and data collection methods in qualitative research tends to be relatively adaptable, which suits the approach's ongoing movementin accordance with systematic combining.

The ability of qualitative data to offer in-depth explanations for complicated problems isone of its strengths (Grey 2017). Emotions, actions, and meaning can all be richly described using qualitative data. The coarse-grained outcroppings of variables and events, which tend to barely skim the surfaces of processes, make this a challenging taskfor quantitative approaches (Langley 1999). Interviews that were semi-structured or unstructured were thought to be appropriate for gathering data.

According to Grey (2017), interviews might be the best method if the goal of the studyis exploratory since they enable the researcher to look for more in-depth answers by asking respondents to elaborate on their answers. The data used in the study was gathered from three bus production facilities: one in Eastern Europe, one in Northern America, and one in Sweden that produced bus chassis.

Sampling 3.2.1.

Purposive sampling was used to choose interview candidates since it is a recommended strategy for qualitative research because it aims to gain understanding of a particular situation (Grey 2017). The most effective use of the resources at hand was made possible by the identification and selection of the information-rich candidates through the use of purposive sampling (Etikan et al. 2016; Patton 2014). This means that the manufacturing managers and operational managers were chosen with great care becauseof their experience in managing transformative change, their position, and their technological know-how in the bus manufacturing industry. Furthermore, it meant choosing applicants according to their geographic location, allowing for in-person interviews. According to Marshall et al. (2013), studies have indicated that data saturation happens after twelve interviews.

As a result, twelve interviews were deemed adequate for gathering enough information for analysis within the allotted time. Sadly, only ten interviews were conducted becauseof the Covid-19 situation. Nonetheless, this was nonetheless deemed acceptable becausesufficient information was gathered during the one-hour interviews. Since poor data collection cannot be made up for by analysis, great care was taken in its acquisition.

Details on the interviews are shown in Table 6.

Table 6. Displays the conducted interviews with the interviewees position and perspective,along with the length of the interview and its respective date.

Interview	Position	Perspective	Length (h:min:sec)	Date	Interview Type
1	Manufacturing Engineering Director	Manufacturing manager	0:59:56	2020-02-24	Face-to-face
2	Industry Vice President	Manufacturing manager	0:55:43	2020-02-25	Face-to-face
3	Global IT Delivery Manager	Manufacturing manager	0:52:18	2020-02-26	Face-to-face
4	Vice President Value Chain	Manufacturing manager	0:42:23	2020-02-26	Face-to-face
5	Industrialization and Engineering Director	Manufacturing manager	0:59:29	2020-03-12	Skype
6	Senior Vice President Europe & South America Manufacturing	Operational manager	1:05:58	2020-03-20	Face-to-face
7	Senior Vice PresidentBus Chassis	Operational manager	1:00:21	2020-03-18	Face-to-face
8	Senior Vice President Global Bus Technology	Operational manager	0:59:15	2020-03-19	Face-to-face
9	Preparation and Development Director	Operational manager	0:55:31	2020-03-23	Skype
10	Digitalization Support Director	Manufacturing manager	0:25:18	2020-03-27	Skype

Interview procedure3.2.2.

Interviews were conducted with respondents from the operational management and manufacturing management business functional domains. While manufacturing management is made up of technical/process managers who oversee certain sections of the bus manufacturing operations, operational management is in charge of organisational and day-to-day operations matters. Because they were thought to provide pertinent material for the study on technical knowledge and transformational work, the two interviewee views were chosen. Interviewing operational management was done with the goal of learning more about their expertise and experience in change management. Inaddition, the goal of the manufacturing management interview was to learn more about the current technologies used in bus manufacturing processes.

Understanding the bus manufacturing process was aided by observations made whiletouring production facilities in Sweden and Eastern Europe. It also produced fresh inquiries that could serve as the basis for interviews.

Questions from the theoretical backdrop and unstructured interviews with employees ofthe target company were used to create an interview guide. Aspects of the interview guide's questions were taken into account based on the interviewee's business field. The interview guide's specifics are provided in Appendices B.1. and B.2. Interviews were conducted in-person wherever feasible since, according to Bryman & Bell (2011), this makes it possible to gather non-verbal information such facial expressions. Additionally,interviews were conducted in either Swedish or English, depending on whatever language the interviewee felt most comfortable in order to elicit rich answers.

The interview arrangement followed Arksey & Knight's (1999) advice, which called fortwo interviewers to be present and for the interviewees to be informed of their duties.

While the other interviewer silently took notes, one conducted the interview. This arrangement had the benefit of allowing the quiet interviewer to pick up on topics of interest that the questioner, whose focus was frequently diverted by group dynamics,may not have noticed. Moreover, having opposing perspectives on the events contributed to the clarification of important themes and research and analytical topics(Arksey & Knight 1999).

Data analysis 3.1.

Because the thematic analysis methodology, as outlined by Braun & Clarke (2006), allows for the unfettered identification of categories and themes within the empirical data, it was selected as the analysis method. Furthermore, because of its relative theoretical independence, theme analysis is adaptable. However, because of its flexibility, which was carefully considered during the process by developing a clear analysing approach, theme analysis can result in inconsistency and a lack of coherence.In order to maintain the exploratory approach, the analysis comprised discovering patterns in the empirical and theoretical findings as well as identifying and developing themes and categories at various levels (Braun & Clarke 2006). The six stages listed inTable 7 by Braun and Clarke (2006) were adhered to in the theme analysis.

Table 7. Describes the six phases used in thematic analysis (Braun & Clarke 2006).

Phase	**Description of the process**
1. Familiarize with the data	Transcribe data, read and re-read the data, note down initial ideas.
2. Generate initial codes	Code interesting features of the data in a systematic fashion across the entire data set, sort data relevant to each code.
3. Search for themes	Sort codes into potential themes, gather all data relevant to eachpotential theme.
4. Review themes	Check that the themes work in relation to the coded extracts andthe entire data set, generating a thematic of the analysis.
5. Define and name themes	Refine the specifics of each theme by generating clear definitions and names for each theme.
6. Produce the report	Select vivid, compelling extract examples, final analysis of selected extracts, and relate the analysis back to the research questions and literature.

The theme analysis did include asking follow-up questions to the respondents to correctany misinterpretations, in addition to the phases listed in Table 7. The audio files from the interviews were played back to ensure that no important information was overlooked. Different categories were highlighted in different colours when codes and themes were being created. During the data analysis coding process, NVivo was utilisedas a software application to facilitate transcription follow-through and organise various category highlights using nodes. The patterns that have evolved from the empirical dataare represented by the nodes. In order to prevent ambiguities, the coding procedure wasfinished as soon as feasible after the interviews before the analytical themes were chosen.

3.1. Research ethics

Ethical issues are present in each research project that collects data from human subjects(Grey 2017). Due to the ethical concerns of this master's thesis—such as the possibility that industry 4.0 will alter the working conditions for manufacturing labor—precautionswere taken. For instance, implementing industry 4.0 technologies may result in layoffs because they demand less human labour in manufacturing operations. All information that could be used to identify the interviewees, including names and positions, has been changed or eliminated in order to protect their anonymity. The focal company's intranet was used to establish contact with the appropriate people.
Therefore, no personal data was gathered in accordance with the General Data Protection Regulation (GDPR). Individuals' fundamental freedoms and rights, includingtheir right to the protection of their personal data, are safeguarded by GDPR. Since therearen't many players in the bus manufacturing business, we decided not to reveal the name of the focus company in order to protect the anonymity of the interviewees.
However, additionally, to win the interviewers' trust by having them confide in us withprivate internal information.

3.2. Trustworthiness

The framework of Lincoln & Guba (1985) criteria—transferability, dependability, confirmability, authenticity, and credibility—was used to achieve trustworthiness in thisthesis. To improve transferability, purposeful sampling was employed along with

thorough descriptions. However, because the study only looked at one bus manufacturing company in-depth, its applicability was restricted. The research procedure was outlined in a step-by-step diagram of the systematic combination processto guarantee reliability. Additionally, it ensured data accuracy, objectivity, and confirmability by emailing the interviewers to ask them to validate our interpretations ofthe empirical findings.
Further ensuring confirmability was the interviewers' thorough understanding of the topic and their reading of it, which allowed them to operate with integrity and lessened confirmation biases. To boost authenticity, direct quotations from the respondents were included in the study alongside the corresponding topics. Additionally, by utilising interviewing strategies that foster rapport and trust, interviewees allowed informants to express themselves and establish their genuineness. According to Grey (2017), establishing trust in the precision of data collection and interpretation is the first step towards establishing credibility. As was previously indicated, this was achieved by methodically merging the empirical data with previously published research on multipleoccasions.
Member checking added even more credibility by having each interviewer perform separate assessments. Additionally, the study ensured that the interview subjects had thenecessary experience and were appropriate for analysis. In order to establish rapport andtrust, introductory questions unrelated to the study were asked at the start of the interview. While transcribing, it's possible that certain crucial elements of social interaction were lost because audio recordings were used.

3.3. Delimitations

Since Industry 4.0 is a widely discussed phenomena that may be applied to many different industrial domains, the study had to be limited in order to achieve its goals within the allotted time. Because the sample size was constrained in terms of time, the interviewee selection process was well thought out. In addition, the Covid-19 situation—which resulted in the cancellation of three interviews—affected data gathering. However, in certain cases, the inability to conduct face-to-face interviews hada negative impact on the interview setting.
This gives rise to criticism about misinterpretation and an inability to read the interviewee's expression (Bryman & Bell 2011). Additionally, neither the study'squantitative analytical ideas for managing a transformation nor its precise implementation plans or the total investment expenditures necessary for an implementation are examined.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 04 | April - 2024 SJIF Rating: 8.448 ISSN: 2582-3930

4. Empirical findings and analysis

This chapter presents an analysis of the empirical data. First, main themes and nodes generated from the thematic analysis method are presented. The second part involves an analysis of the bus manufacturing operations. Third, an analysis of the meaning of industry 4.0 with opportunities and challenges associated with the industry 4.0 technologies is presented. Lastly, the chapter analyses managing a transformation towards industry 4.0 for bus manufacturers adopting the change management model described in the theoretical framework.

Using the thematic analysis approach described in the methodology chapter, this chapter intends to analyze the empirical findings. The three major themes identified together with the nodes and sub-categories are presented in Figure 5.

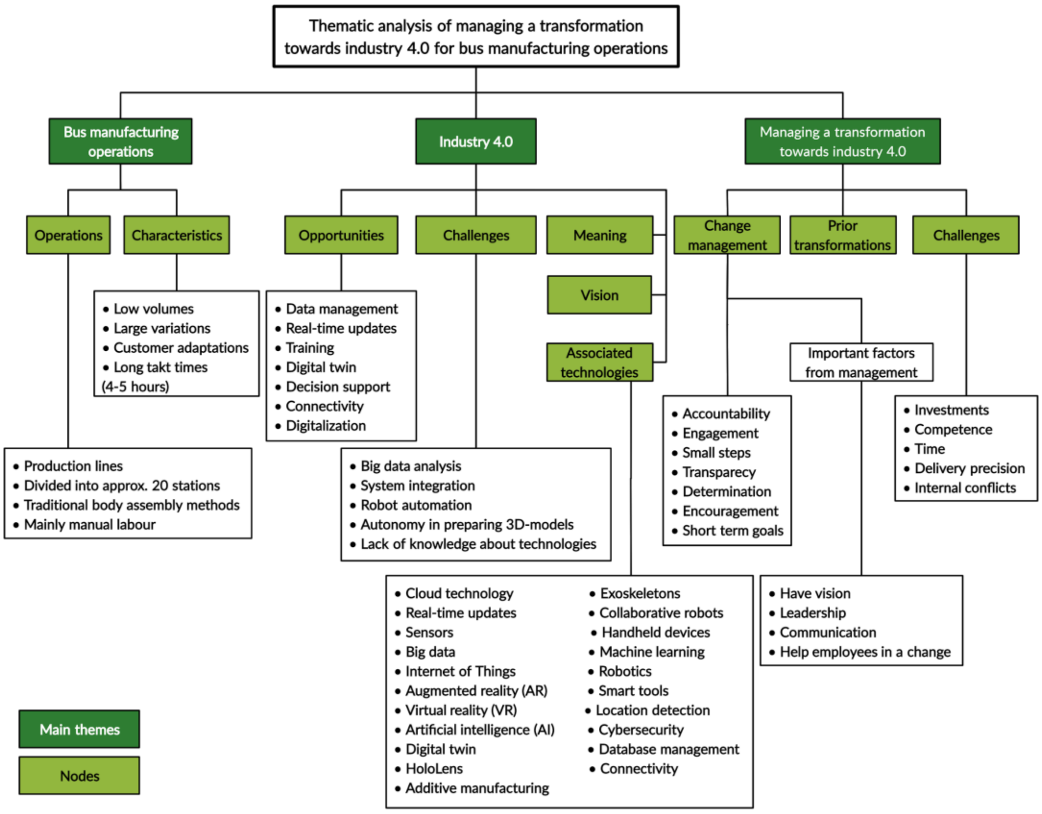


Figure 5. Displays the main themes, generated nodes and sub-categories from the thematicanalysis.

The thematic analysis is broken down into several sub-categories describing the characteristics for the generated nodes based on the empirical findings.

4.1 Bus manufacturing operations

One of the main themes in the empirical data was the existing state of bus manufacturing processes, which was useful for assessing the potential and problems that industry 4.0 technologies bring for bus makers. Interviewees who had positions near the bus manufacturing operations explained how the production process was carried out as workstations where both internal and external vendors provide the material. After that, parts are put together and assembled at different workstations so that the final productcan be produced and then exit the factory.

“We have operations required to produce a bus and the operations are allocated in different stations [...] there are around 20 workstations. The bus progresses throughout the production line and our system is so that the bus that goes in before the bus after, comes out from productionin the same order.” Interviewee 2.

From the interviews, it became apparent that the bus manufacturing operations are very traditional. *“We’re pretty close to the 90’s in actual methods, so there’s no such advanced processes and equipment in the manufacturing itself.” – Interviewee 2.* Unlike other vehicle manufacturers, buses work with craftsmen, *“We have carpenters laying floors, we have painters and we have electricians.” – Interviewee 4.* This could be a part of the explanation for why bus production has long takt times due to the high amount of manual work at each station.

The findings indicate that being a manufacturer using traditional methods, industry 4.0 can be a major transformation for the organization. The reason for the considerable amount of manual work is due to the characteristics of the bus industry. *“Our business is low volume, large mix with customizations.” – Interviewee 7.* This points towards the number of produced and delivered buses are less than in comparison to automotive industries such as cars and trucks. It might also indicate the large variation between manufactured products. One interviewee said that having low volumes with a large mix and customization implies that *“... we almost have to make changes for each order and it takes quite a lot of man- hours to do this.” – Interviewee 9.* The findings indicate that a considerable factor for limitations in bus manufacturing operations is due to the large amount of customization.

“We have a lot of customization [...] and that’s not good, because you change the design to the end [...], buses are very susceptible to changes coming into the very last moments. Every effort is made to keep the customer satisfied, otherwise they go to the competitors.” – Interviewee4.

Due to the extent of customization and large varieties in production, the interviewees agree that having a fully automated production is not reasonable from profit versus investment. However, they believed that there could be certain parts of industry 4.0 that is applicable to bus manufacturing, although it is not clear what those parts are yet. This indicates that there is a need for more knowledge regarding industry 4.0 within bus manufacturing to identify the possible applications.

One interviewee said, *"Our core competence is to take finished components and effectively combine them into new vehicles." – Interviewee 8,* suggesting that assembly is essential in the bus manufacturing process. Much of the competence currently required for operators in production are knowledge from within, and fewer work descriptions. This can be viewed as a necessity to retain a flexible production environment.

"We are not in the car industry where every person on the production line has 30 seconds of work content where you quickly enter. We talk about 4-6 hours of work that every person has to master and you cannot write such clear job descriptions for this." – Interviewee 7.

A shift to industry 4.0 necessitates significant adjustment given the conventional manufacturing process. It was noted by two respondents that industry 4.0 shouldn't be limited to industrial activities. Industry 4.0 would affect the organization's entire end-to-end flow, they said. Thus, a shift to industry 4.0 may result in significant changes to the production process as well as to the entire supply chain, with interviewee 6 predicting that logistics would have the biggest influence. Analysing the prerequisites for successfully managing a transition also requires understanding industry 4.0 and its repercussions.

4.1.1. The meaning of industry 4.0

Regarding the meaning of industry 4.0, there was a big difference between the interviewees. Overall, everyone agrees that industry 4.0 is focused more on involving internet- and database solutions within the manufacturing process, referred to as digitalization. Some interviewees argue that robotics has nothing to do with industry 4.0 and they state that robotics is just an evolution of prior factory setups and that digitalization with focus on connecting devices and gathering data will be the real revolution. No unified meaning of industry 4.0 could be identified from the interviews.

"There are as many definitions as there are people. But very simplified, for me I do not want to be stuck in automation, at least not in mechanical automation. For me it is digital automation that is industry 4.0. […] I think you have to simplify the industry 4.0 concept, for me it is digitalization, data management where we connect our systems giventhat we have so many more sensors that gives us information." – Interviewee 6.

While some interviewees have their own view of industry 4.0, others lack this awareness. *"I know approximately what it is, but I know way too little about it." – Interviewee 8.* When responsible people for bus manufacturing operations express themselves like this, findings indicate the knowledge-gap that exists in order to evaluate industry 4.0 and its implications for the bus manufacturing operations. The many variations of meaning could be explained by that there is no pronounced strategy or goal from higher levels within the organization when it comes to the factory of the future, or industry 4.0. The understanding that does exist, individuals have accumulated through their respective work, searching the internet from self- interest or via attended conferences. For managing a transformation an important factor appears to be to have a defined goal or strategy that can be communicated throughout the company that is engaging the workforce.

"There is no stated goal for implementing Industry 4.0 in the company. We have a stated goal in my department and nobody else in the company does this except us. […] our goal is now to try to build knowledge of Industry 4.0 so that we can see and understand when andhow we can use it." – Interviewee 9.

The absence of having no vision or goal about industry 4.0 could explain the reason for the lack of awareness and knowledge about the subject. Part of building knowledge is examining the technologies involved in industry 4.0 to evaluate whichare applicable to bus manufacturing operations.

Technologies *4.1.2.*

Numerous technologies were identified based on the interviews. After analysis, the technologies were grouped under industry 4.0 enabling technology. Table 8 lists thetechnologies that were discussed in the interviews and are thought to be a part of industry 4.0. Both subjective opinions and literary works serve as the basis for the classification.

Table 8. Presents the complete list of technologies and distinctions mentioned during theinterviews.

Enabling technology group	Technology or distinction associated with industry 4.0	Remark
Virtualization	Augmented reality (AR)	Interviewees: 6 and 7
	Digital twin	Interviewees: 3, 5, 6 and 9
	HoloLens	Interviewee: 10
	Virtual reality (VR)	Interviewees: 4, 5, 6, 7 and 9
Autonomy	Automated guided vehicles (AGV)	Interviewees: 7 and 10
	Artificial intelligence	Interviewees: 3, 4, 5, 6, 9 and 10
	Collaborative robots (COBOTS)	Interviewees: 9 and 10
	Machine learning	Interviewee: 10
	Robotics	Interviewees: 1, 2, 4, 5, 6, 9 and 10
	Smart tools	Interviewees: 5 and 7
	Additive manufacturing	Interviewees: 1, 5, 6, 8 and 9
Real-time information sharing	Big data	Interviewees: 4, 5, 6, 8 and 10
	Cloud technology	Interviewees: 1, 3 and 10
	Data analysis	Interviewees: 1, 3, 4, 5, 6, 7, 8, 9 and 10
	Location detection technology	Interviewee: 8
	Real-time updates	Interviewees: 2, 6 and 7
	Sensors	Interviewees: 1, 3, 4, 5, 6, 9 and 10
Process integration	Cybersecurity	Interviewee: 3
	Database management	Interviewees: 3, 5, 6, 8 and 9
	Internet of Things	Interviewees: 4, 6 and 9
	Connectivity	Interviewees: 1, 5, 8, 9 and 10
Technical assistance	Exoskeleton	Interviewee: 10
	Handheld devices	Interviewees: 1, 3 and 9

Divergent views were expressed by the respondents regarding the technology and how the bus industry was using them. The frequency of technology mentions is correlated with the interviewees' present level of knowledge and comprehension and what immediately came to mind. Robotics, artificial intelligence, sensors, and data analysis were frequently brought up. But as will be shown in the future, the frequency does not account for the possible chance for bus manufacturing operations. Table 8 does not include digitalization because it was cited by three interviewees as an overall notion. It's

also important to notice from Table 8 that none of the two key industry 4.0 concepts—CPS nor IIoT—was brought up in the interviews.
One explanation can be the ambiguity around the notion of industry 4.0 or the organization's ignorance of it. The outcome is a lack of clarity in concepts at work. This poses a challenge: How can one spearhead change when they are unsure of what they areadvocating for? The discussion section goes into more detail about this.

4.1.3. *Opportunities with industry 4.0 technologies*

One benefit of industry 4.0 for the bus sector could be better data management than withcurrent techniques. It is thought to be feasible to gather more data points during the production process as sensors get cheaper and cheaper. Empirical evidence suggests thathaving a structure for the location and handling of data storage becomes essential when handling massive amounts of data inputs. As a result, utilising the data for data analysis is made easier with a solid data management system. In the past, Excel was frequently used to manage data, which necessitated numerous manual transfers. Interviewees state that creating a data management system that permits data autonomy is an obvious way totake advantage of industry 4.0 technology.
"... connect systems and different technologies to avoid excel and manual transfer between the systems, everything has to be moved automatically." - Interviewee 3. This is further explainedby industry 4.0's key feature of data system integration. After that, the systems are connected with one another to provide independent information flow and connection throughout the production process.

By having a functional data management system, this could be analyzed to contribute to another opportunity mentioned in interviews, real-time updates. Real- time updates could contribute to transparency when information is available in real- time for users. One interviewee described it as real-time information allows "*transparency that you can constantly see where the vehicle is in the flow, and that this information is accessible to everyone." - Interviewee 7.* By obtaining the information it could be an opportunity for decision support because data can be analyzed and summarized in real-time, allowing for quicker decisions being made. Decision support can for example be reports or dashboards. One interviewee described it as *"The final step should be a decision dashboard. It is a final document or end-screen where e.g. top management can see daily what the company looks like, or production, factory, sales or operating margin." - Interviewee 3.*

In relation to data management and integrating systems, an opportunity to improve quality assurance arose from the interviews. Technologies enabling the integration of data and real-time updates with continuous quality control through the production line could ease the quality assurance work. *"If we were able to verify quality in a better and easier way at each step of the process, we could reduce the quality assurance at the end." - Interviewee 7*. However, this could be considered to be an opportunity in the long-term since it requires a lot of preliminary work when it comes to implementing the technologies. Moreover, to connect the technologies in order to examine product quality through the production lines.

Digital twin was a technology mentioned by interviewees from both operational and manufacturing managers. Interviewees stated that this technology offers an opportunity to test the quality assurance above in a simulated environment, but it further allows for virtually testing various layouts for machines in the factory before it being implemented physically. This enables examining each station and try different methods without stopping production, and further predict unergonomic movements. Digital twin was described as a necessity to enable the usage of AR and VR in production. One interviewee took the digital twin concept to further include products.

"Imagine if we could have so that when chassis number X will go to customer Y, then digitally we have already put together that vehicle for each station. The operator looks at it via e.g. AR headset and sees how far we have built this vehicle and how things will be assembled, and that it is this variant. But this is based on that you always have a digitalautomated process to build a digital twin for the unique product." - Interviewee 6.

From this, it appears that automation for 3D-figure processing will have a crucial role to make the digital twin solution possible.

Another recognized opportunity was VR and AR for training the operators that will be working in production. Each time new operators are hired, there is a long education time to prepare the operators for their work. Training and education for operators could for example be having a VR-room with all the associated technologies needed for training, e.g. computers, VR-headset and 3D-printed toolssimilar to those used in production.

"It takes 3-4 months if you bring in a new person before you dare to release them and run their own work. Can you then facilitate it with VR or AR techniques to for example educate people, to be able to simulate environments and they wear their glasses on and see that here we will mount this particular piece and it is done in this way. With available work instruction in this then you can shorten that education time. There are definitely great opportunities there." - Interviewee 7.

By enabling VR and AR technologies to enhance the training routines, training time could be more optimized as well as the training plan could be more customizable for each individual employee depending on their needs or prior knowledge. Furthermore, in addition to using virtualization technologies, tool props or 3D- printed tools with attached sensors could be used to create a more realistic environment. In turn, this could lead to a reduction in training time for new employees because it is possible to perform more repetitive activities in comparison to traditional education where one must relate to takt times.

4.1.4. *Challenges with industry 4.0 technologies*

Similar to the identified opportunities, data management was also mentioned as a challenge. *"The big challenge is the data management, and by data management we collect a lot of data, we know we can use it, but how will we use it?"* - *Interviewee 5*. Data management requires collecting data which according to some interviewees is a challenge due to the lack of connectivity between the different systems and devices. One interviewee expanded the view of managing the data systems.

"There is a minor challenge in linking different technologies while the major challenge is to figure out the logic in how to link together every system and every device and secure good quality of data flow." - *Interviewee 3*.

The challenge of linking technologies together was identified in most interviews. It could be easy to implement one technology, but when two or more technologies are intended to communicate, a major challenge arises in having required knowledge about overlapping the system and the technology. Besides, apart from focusing on the systems, it will not be enough to simply collect data from various sensors and later analyze the data. The data needs to be quality-assured and individually managed. *"You need to input data, assure the quality of data and input data on a regular basis. There are not enough people that could do this."* - *Interviewee 3*.

In addition to quality-assuring data, the lack of data preparation is also identified for other technologies. Challenges for virtualization technologies e.g. digital twin, VR and AR were indicated as finding solutions for preparing 3D-models for product components and production units. One interviewee explained it as:

"The tool we have to create VR is too complicated to use as a regular tool. [...] Use for working instructions and training, to prepare this documentation and this reality I don't think the tools are easy enough or that we are fast enough to use it as a regular tool." - *Interviewee 5*.

This challenge could further be attributed to the possibility of implementing the digital twin solution. Moreover, it requires a sustainable structure for enabling data information autonomy. Overall, when implementing new technologies, a major challenge identified in the empirical findings was the lack of knowledge in managing the data and creating an infrastructure between devices. Furthermore, the general lack of knowledge and competences among employees working with new technologies associated with industry 4.0 was mentioned. *"The challenge is that we need to acquire competences and technologies to actually massively manage this, and on top of that, take decisions based on the data." Interviewee 6*.

Employees are mentioned as a challenge when working towards implementing industry 4.0, where workers may show resistance in implementing new technologies. Interviewees mentioned that it is important to involve people and gaintheir interest, which could be related to priorly not addressing the benefits for the workers.

"I don't see interest from production people. Probably because they don't see the benefit from it, that it is more complicated and more thingsto take care of. They see it more as a problem than an opportunity." - Interviewee 5.

Another aspect that was addressed by the interviewees was the lack of financial resources when investing in industry 4.0 technologies. Since every investment needs a business case, one challenge mentioned was how to motivate why investments are necessary.

"There is a challenge in allocating our investment budget. There are always more ambitions than there is money. It is hard to motivate an uncertain investment in robotics and have it compete with a more practical investments e.g. a new ventilation equipment. [...] we need to allocate more money to invest in modern technology in the future." - Interviewee 9.

Money was frequently mentioned by the interviewees as the resource they lack and the reason why they have not transitioned more towards industry 4.0. Since every investment needs a business case, the business case has to be understood and analyzed by the decision-makers as to why it is an important step for the company to take. Required knowledge from decision-makers or analysis of the benefits for a more advanced and "new thinking" investment might be compulsory. Some interviewees did not think that the decision-makers always possess sufficient knowledge compared to the ones actually working closer to the production. *"An operator who possesses a deep knowledge in that area in which the operator work with, should take the decision in that working area." - Interviewee 6.*

The challenge stands clear that knowledge about technologies and managing an implementation towards industry 4.0 is required. Furthermore, by involving more people in the change process, numerous challenges related to the individual workercould be diminished to a certain extent.

4.2. Managing a transformation towards industry 4.0

Here we apply the theoretical framework and combine it with the empirical data in order to emphasize the roadmap for managing a transformation in RQ2.

4.2.1. Change management

The interviewees agree that a transformation towards industry 4.0 is a major change, and for this change management plays an important role.

"One cannot underestimate the need for change management. There are always a lot of people who have invested blood sweat and tears in the old solution that exists and then you come to do it in a completely different way […] it may be perceived as if you reject the old way." - Interviewee 9.

It is noticeable that people with sentiment towards old ways of working questions change. Therefore, it is important to prioritize the change work.

1. Why is industry 4.0 urgent?

According to the interviews, industry 4.0 is urgent due to the many opportunities it entails. Even though some interviewees declared industry 4.0 as a buzzword, it is rather what it stands for that is urgent; introducing internet- and data solutions within the manufacturing process to improve productivity and efficiency.

"The digital transformation has a very high priority. We use an expression very clearly where we talk about 'perform and transform'. We must deliver results today to have the resources to transform us." -Interviewee 6

By becoming more flexible, industry 4.0 could help manufacturers to enable more efficient processes and reduce waste to produce high-quality products at a lower cost. Industry 4.0 could be the way for bus manufacturers to maintain competitiveness in an industry facing change. Thus, it may be the difference between the customer going to the competitor or staying.

2. Who are responsible for managing the transformation?

Responsibility and accountability are two important factors suggested when managing a transformation. The company has no responsible person that works with these topics on a regular basis, which is implied to be required to see any substantial change.

"I think we need to find some persons who have the task to actually follow this area. We have not had this so far, not anyone who has had pronounced time to work on it. It is a bit difficult when having other daily concerns to actually prioritize what does not give any direct payback." - Interviewee 9.

As for whom that person should be, interviewees mention someone that has the drive to pursue change and an interest in the emerging technologies. It is reasonable to believe that the person is from the factory management, or someone who has worked for many years in the production, also CTO could be a suited position. This is because it can be assumed that they have a good understanding and insight into the manufacturing process. Furthermore, the person should have an interest in driving the industry 4.0 transformation.

3. What's our industry 4.0 vision and strategies?

Even though no pronounced company strategy or goal is communicated, interviewees have formed their own perception of a vision. One interviewee's vision is to be able to follow an order through a digital environment where actionsare taken automatically depending on the product being manufactured. Another interviewee said:

"My vision of this is that when we are choosing to start the production of each order, we can use our administrative digital twin to secure that the order is buildable from a material perspective. We can by algorithms secure that the product structure is correct, and we can use machine learning algorithms to predict quality problems on the order. We can check all this before starting the order." - Interviewee 10.

Furthermore, improved manufacturing efficiency, increased product quality, shorter takt times and better material supply was also mentioned. The vision should be comprehensible and easy to understand. Three strategic initiatives for moving towards an industry 4.0 vision includes:

- Build a backbone structure for where and how to store data.
- Establish a cloud solution for company systems.
- Introduce sensors to tools, machines and materials.

What could happen in the event of a transformation towards industry 4.0 is an overflow of data. In large manufacturing companies, data collection would be massive. It will not be possible to manually manage such large volumes of data. Inthe long term, the goal is to have an automated data management system that can control and analyze data using algorithms. Understanding the data infrastructure is important, and therefore to create a backbone structure for where and how to store data. To gather data, sensors were mentioned. Sensors enable the analysis of data by collecting and transferring information to the cloud.

4. How do we effectively communicate to the organization?

Demonstrate that industry 4.0 is important by communicating an established vision. Distribute material and information through intranet and presentations. *"Find the group of crazy innovators in the company. You need to have those promoters, the crazy pushers." - Interviewee 1.* Furthermore, one interviewee made it clear that having someone responsible is important to discuss topics with. It creates alignment, having a direction of where to turn and discuss with those interested andinvolved within the subject.

"*It is very interesting to see or know who in bus manufacturing is the leader in that kind of stuff so I can connect and work with that person. It's a big company, sometimes it is hard to find the right people interested in the same things." - Interviewee 5.*

Internal communication channels, i.e. intranet allows for communication to be spread throughout the company. Moreover, managers need to address that information is available and where to find it.

5. What barriers do we have for approaching industry 4.0?

The characteristics of the bus industry impose challenges when it comes to an industry 4.0 change. *"It is a challenge that we have low series and that it is difficult to gain profitability in automation, and also because we have so many changes." - Interviewee 9.* This inflicts limitations on the technologies suitable to apply in the manufacturing process. For example, having an automated production line using robots might not be plausible due to the low volumes, high complexity and high variations that characterize bus manufacturing. Findings imply that there are no financial incentives for such an implementation. Instead, the focus should be directed towards data management and decision support.

Investments are a barrier because it is what enables a transformation. Without financial support, there is no change. Management will need to have a vision and an understanding that the usual payback time required for business cases most likely will not be satisfied. The investments are for building up and preparing for the manufacturing of the future.

"It is difficult to justify an investment that does not have a clear immediate need that if we do not do this we cannot produce. It is difficult to motivate something like this that we need to invest to learn,

build up a competence around and that could be profitable in the longrun." - Interviewee 9.

Not having sufficient knowledge to manage a transformation is another barrier. This could be handled by allowing responsible persons to have the time and resources to obtain the knowledge necessary. For example, attending conferences, meeting with relevant people having experience within the field or just by offering time for education in the topic. However, this also requires having competence about currentprocesses.

"A prerequisite for becoming successful in the digital transformation is to be really good in your analogue business. If you do not have crystal clear knowing about your processes and all the details about what you do physically, you have not qualified to do the digital journey because it is based on very stable processes and it is not easy to get there." - Interviewee 6.

This implies that before initiating a transformation towards industry 4.0, full control over current processes is suggested to be necessary.

6. What are short-term goals we can accomplish?

Initiating a transformation, one cannot accomplish everything at once. Some parts might not be worthwhile to initiate until others have been completed. *"I think the risk is that when you start you are over-ambitious and start up too much when you can't finish it."* - Interviewee 7. Thus, it becomes important to see the wider picture and start with small initiatives that can be accomplished in the short term. The following are three examples deriving from the interviews:

- Create an internal forum
- Digitize paper documentation
- Map systems used for the manufacturing operations and identify whichinformation relates to each system.

7. How can we be more consistent in our transformational work? Empirical findings suggest that having a mindset with relentless energy focused towards new opportunities and challenges is important to be resolute in actions andto keep going as needed. Accomplishing small wins could have an encouraging effect and keep engagement high. Ongoing progress could for example be displayedduring seminars. Furthermore, determination and seeing that management areengaged and believe in the transformation empower consistent work.

"As a company we must decide that this is what we should do and that this is a priority over other things that are in line and want to get investment and resources [...]. It is a requirement for being able to

make any change at all, that we prioritize that now this is what we needto do." - *Interviewee 7*.

Consistency is advocated as a result of determination. Being determined that industry 4.0 has a future within the bus manufacturing operations, it supports the consistency of the transformational work.

8. How can we institute change?

Interviewees mentioned that one big factor to consider during a change is to involve people in every step in the progress and earn people's trust. "*You need to present 'what is in it for me' not only 'what is in it for the company'. This is very difficult. It is really hard to buy the trust of the workers."* - *Interviewee 1*. Interviewee 7 mentioned that conflicts between different workgroups are usually built-in during change, which could indicate lack of communication or transparency. Another interviewee mentioned the importance of communicating why the change is important, but that the individual perspective should be considered. *"We as humans have basic needs. We want safety, we want clarity, we want 'I should be safe'. It's not motivated to care about the company if not 'I'm' safe."* - *Interviewee 6*. It could be analyzed that the leaders managing the change needs to focus on communicating to the employees why we are doing this change, what the outcome will be and most importantly, why this change will be beneficial for them. Furthermore, institutionalizing wins and encouraging employees could influence the organizational culture to prone support for advocating change and engagement. As mentioned during the interviews, change cannot be successful without involving the employees.

5. Empirical case of virtualization

The chapter presents a case for one of the identified opportunities with industry 4.0 technologies: VR-training. The case compares costs of training in VR versus traditional training for production labor.

One potential found in the empirical data was to use virtualization technology to train labourers in production. Production employees could receive virtual instruction and training in the assembly of various production line stations by using VR technology. Theintroduction of new product variants into production may be made easier with the use ofvirtual training. This is because virtual reality (VR) technology makes it possible for production stations to have virtual models of new product variants in an interactive digital 3D environment. The current kind of training, known as traditional training, entails having a teacher educate employees the various assembly process steps while they work on the production line.
The prepared product is used immediately for the training. To train new labour, the manufacturing currently has to assign experienced production workers. In this instance, a cost analysis was carried out to highlight the possibilities of utilising VR technology toteach new hires the skills necessary to guarantee efficiency and quality when assemblingcomponents.

The computations centre on comprehending a nominal procedure in the chassis assembly manufacturing line, as indicated in table 1. This plant hires 25 new workers per year. Supervisors at the focal company and consultants working in a VR-lab collaborated to identify elements that impact expenses and establish suitable assumptions for the calculation case. The assumptions are oversimplified and may not fully reflect the situation. Regarding the number of training hours required, for instance,it is unclear how VR training compares to traditional training. Approximating the cost of quality defects was likewise challenging, and in this case, approximations were obtained by simplifying the data. The expenses were separated intocost groups, each of which has a detailed explanation in Appendices C.1 through C.6.
Table 9 displays the costs associated with traditional training, whereas Table 10 displaysthe expenditures associated with virtual reality training. The VR case started with the idea of building seven virtual worlds for production facilities.

Table 9. Presents the approximated cost groups related to traditional training.

Cost group	Cost (SEK), rounded	Description	Reference
Variable cost (annual)	1 605 000	Costs for training 25 employees annually,represents mostly salary.	Appendix C.1 Table C.1.
Run-in cost (annual)	2 330 000	Cost for physical training related to introducing new product variants into production.	Appendix C.1 Table C.2.

Table 10. Presents the approximated cost groups related to VR technology education.

Cost group	Cost (SEK), rounded	Description	Reference
Initial costs	1 270 000	Costs required to enable VR training e.g.hardware and creating 3D-environment.	Appendix C.1 Table C.3.
Recurrent costs (annual)	700 000	Costs related to yearly labor cost, including maintenance.	Appendix C.1 Table C.4.
Variable cost (annual)	1 160 000	Costs for training 25 employees annually,represents mostly salary.	Appendix C.1 Table C.5.
Run-in cost (annual)	1 165 000	Cost for virtual training related to introducing new product variants into production.	Appendix C.1 Table C.6.

When comparing VR training to traditional training, there are two types of expendituresinvolved: one-time and ongoing. Traditional training could not pinpoint these expenses.Figure 6 presents a breakdown of the costs when comparing VR training to traditional training.

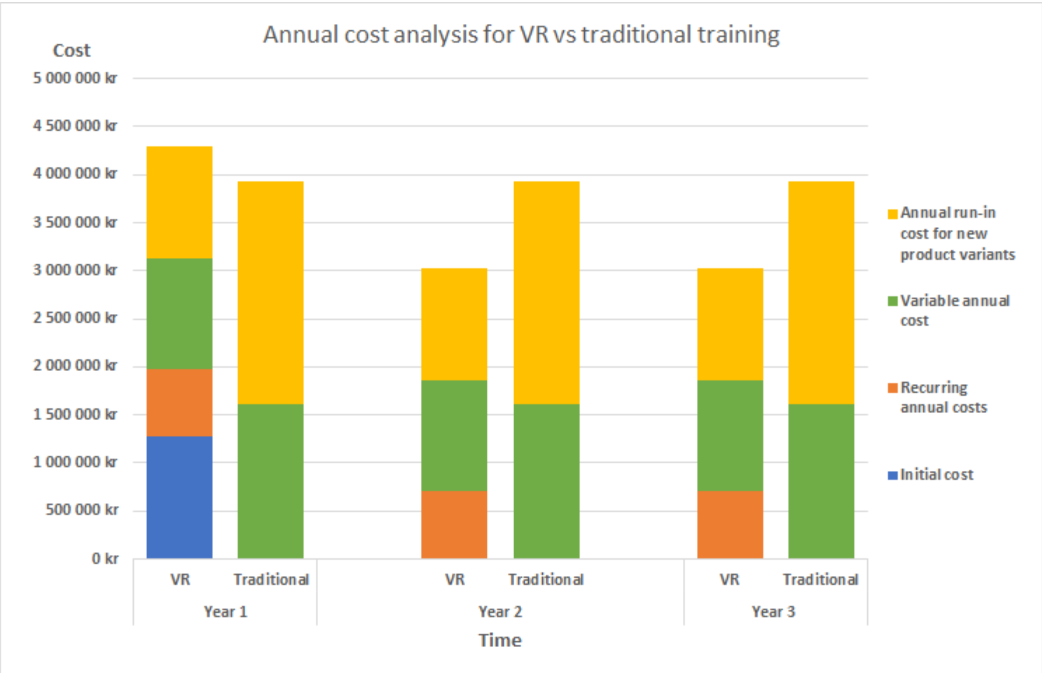


Figure 6. Describes the costs comparing VR training with traditional training for threeupcoming years.

The outcome shows that adding VR training results in two new cost categories: one for initial expenditures and another for ongoing costs. Despite the introduction of two morecost groups, it is predicted that, even with the applicable assumptions and approximations, the total cost of VR training from year 1 to year 3 will be less than that of traditional training. According to the projections, the first year's total cost of VR training will be greater than the year's total cost of traditional training because of initial costs. However, the overall cost of VR training for the years after year one will be about910,000 $ or 23% less than the whole price of conventional training.

As a result, advantages of VR training include reduced training expenses and more effective training because of repetition. However, as VR requires more labour with thevirtual surroundings, the actual cost will increase if the number of production stations increases.

6. Discussion

This chapter will discuss the empirical analysis and relate it to theory. The discussion will elaborate further on the theoretical framework and discuss relevantareas to the research aim and purpose.

6.1. Industry 4.0 for bus manufacturing operations

The interview results suggest that an industry 4.0 change will have a significant impacton the organization's bus manufacturing operations. This is related to Lu's (2017) assertion that manufacturing operations will be significantly impacted by industry 4.0. Nonetheless, respondent number six acknowledged that the biggest shift coming from industry 4.0 will be in logistics. Furthermore, interviewee 7 mentioned that an industry 4.0 transition will impact the entire supply chain and that attention should not be solelyon the production processes. Furthermore, this outcome is consistent with research by Tay et al. (2018), which suggests that industry 4.0 would alter entire enterprises on thewhole.
Additionally, it is consistent with Lu's (2017) literature study, which claims that disruptive changes to business models, supply networks, and business processes are brought about by industry 4.0. Manufacturing operations are receiving a lot of attentionfor several reasons. One reason could be that industry 4.0 has a different focus than academia and industry. According to Oztemel & Gursev (2020), industry interest is directed on intelligent products and machines, whereas academic research is primarily concerned with comprehending and defining the concept of industry 4.0.

According to Sisinni et al. (2018) and Drath & Horch (2014), industry 4.0 is sometimes referred to as the fourth industrial revolution in literature. One conclusion drawn from the investigation was that industry 4.0 will, in some cases, be more of an evolution than a revolution. Since there have been decades of research on robots, robotics was one suchfield. Rather, digital automation—the link between machines and systems that permits information to flow autonomously—was seen as the domain of industry 4.0 revolution. In reference to industry 4.0 technologies suitable for bus manufacturing processes, the results concur with Pfeiffer's (2017) assertion that the industry and the organisation playa significant role in the selection of relevant technologies.
In contrast to other automotive sectors, the bus business is distinguished by its high complexity, large variances, high client adaptation, and low volume. Because of the peculiarities of bus manufacturing, empirical research suggests that the standard application of robotics in the assembly line of bus production may have limited potential. Robotics, however, may find use in upstream operations where variance is smaller and volumes are higher, like component manufacture. Additionally, as shown intwo interviews, collaborative robots may be considered to have some appropriate uses, such as material handling tasks. Robotics could be used to automate some production line stations, but painting is a good example because it is a repetitive task.

The greatest potential benefit of industry 4.0 for bus production is thought to lay in data management and decision support provided by sensors and cloud computing combined with data analysis. We included the whole list of technologies that were brought up in the interviews in Table 8. Numerous technologies align with the concepts of industry 4.0technologies as defined by existing literature. Interviewee 10 brought up AR and said that HoloLens was a suitable way to enable the technology. One noteworthy observationwas the absence of mention of two key industry 4.0 concepts—CPS and IIoT—during the interviews, despite their extensive documentation in the literature (Oztemel & Gursev 2020; Sisinni et al. 2018).
One may claim that the majority of interviewees were able to see technological solutionswhen they understood certain technologies, but they were unable to identify a general differentiation that would characterise their opinions. Furthermore, an explanation for this can be interpreted as a sign of the bus manufacturing industry's general ignorance ofindustry 4.0. This may be the result of the general words related to industry 4.0 not being widely used or discussed within the company or in internal forums. The technology and ideas that are already well-known within the organisation are the main topics of discussion.

Handling a shift towards industry 4.0 was found to require an understanding of the phenomenon known as industry 4.0. This was demonstrated by the investigation, whichfound that previous apathy and a lack of understanding have prevented bus manufacturing processes from utilising industry 4.0 technology to a great extent.
Furthermore, this connects to the second phase of the theoretical framework for managing a transformation, which states that in order to promote change, responsibleparties must possess sufficient information. In summary, empirical research revealedthat a lack of expertise may result from not spending enough time in the field, which may stem from management's lack of a clear vision or objective for industry 4.0.
Having a clear vision and information that links to that explicit knowledge will help people grasp things better. This pertains to Grant's (1996) assertion that explicit knowledge, or "knowing about," is more easily transferable and accessible where data iskept and retrieved, making it more accessible than tacit knowledge. In this case, empirical data appear to support the theoretical framework, which states that the first action should be to establish a feeling of urgency, include others, and decide whether industry 4.0 has a place in the company.

Utilising virtual reality (VR) to teach production labour may have both practical and financial advantages, as demonstrated by the VR-training calculation scenario. Practicalin that it may take less training time for the learners because of their ability to focus on specific regions and repeat tasks. Economical in the sense that, based on our approximations and assumptions, the yearly variable costs for VR-training are lower than those for traditional training since there is less interference in the production environment.
However, the level of sophisticated virtual environment required to make VR-trainingfeasible significantly determines the initial investments required and the quantity of training stations used. It should be noted that the calculation does not provide any concrete proof of whether VR training is more beneficial in the context of bus production.

6.2 Change management

The ambiguity and unpredictability of the industry 4.0 phenomenon make it challengingto decide how to approach a transition. It is still to be determined if the change management model that serves as this study's theoretical foundation would be successfulin leading a transition. The theoretical framework is based on Kotter's eight-step model (Kotter 2014), which has little to no experience with industry 4.0. It might also be debated whether change management is the best strategy for overseeing an industry 4.0 transition. It might be argued that as the industry 4.0 paradigm would require significantorganisational transformation, the activity ought to involve the most extensive divisions of the business.

A broader perspective of the transformation impact, such as how new technologies alterthe company's business model, might be taken into account when managing a transition.Industry 4.0, for instance, can entail altering the business model to one that is more servitized, as seen in Figure 2 with the Internet of Services by Liu & Xu (2017). This is because newly deployed and emerging technologies open up new avenues for service provision.

Alternatively, given the empirical data showed that a business case must be completed before any major investment can be carried out, one may look at the organisational structure to see how choices are made. This is related to the definition of industry 4.0 provided by Moeuf et al. (2018), which calls for decentralised decision- making based on real-time data collection.

Therefore, it can be discussed that in order to benefit from industry 4.0's decision assistance, it must be simpler to make decisions with less hierarchy. As stated by interviewee number six, the decision-maker ought to be the one having in-depth understanding of the subject. However, depending on the size of the organisation, having decisions made by lower hierarchies could lead to decisions that are excessivelyfragmented and disorganised. This may be evaluating data and making inferences abouthow it will impact manufacturing processes for management decision support in the context of Industry 4.0 with real-time data capture.

Ten nodes and three primary themes were found in the thematic analysis's results. Certain components within a node are slightly entangled since it was challenging to classify the factors in certain situations. As an illustration, consider the primary theme ofindustry 4.0: due to interviewees' ignorance of the subject, data management was seen by them as both an opportunity and a challenge. One important component in the changemanagement node was tenacity. The participants also listed accountability, participation,and encouragement as aspects they considered crucial.

However, as it establishes the groundwork for starting the transformation, determinationmay be seen as one of the most crucial elements. One can associate determination with the initial phase

Once the organisation decides that industry 4.0 is a priority for allocating resources andtime, Kotter's model, accountability, and engagement come next. Despite the study's findings that bus manufacturing companies still employ antiquated procedures and havenot adapted quickly, it is reasonable to believe that industry 4.0's advantages will hastenchange.

The management of a shift towards industry 4.0 was shown to require knowledge, as demonstrated by empirical data gathered from manufacturing and operations managers.Yet, the results imply that the organisation has to learn more about the phenomena known as industry 4.0. Furthermore, research shows that a precise definition of industry 4.0 is necessary to increase the effectiveness of change management. Many definitionsfrom the literature exist that may provide guidance; some of these are included in this study. Additionally, the theoretical framework presents a working definition that is extra. Therefore, a precise definition of industry 4.0 could foster understanding amongparties and make it possible to implement the benefits of this technology.

If not, you will encounter obstacles when attempting to grasp something you are unable to adequately explain. It is challenging to involve staff members and get them to contribute to the change if they lack information. Consequently, one of the difficulties ininvolving individuals is information. Changing to a knowledge-based perspective on thecompany may help to clarify the distribution of knowledge inside the company.

However, because interviewees' perceptions of the requisite knowledge varied, it was challenging to determine how to acquire the information based on the data gathered. Onthe day of the interview, seven out of ten respondents said that neither they nor those around them had any understanding about industry 4.0, or that they did know very little. This could be explained by industry 4.0's novelty as a concept. Moreover, the empiricaldata underscored the necessity of comprehending the analogue business prior to commencing the digital transformation for industry 4.0. which could be taken to mean that you lack the maturity to start the industry 4.0 transformation if you have no controlover your current production processes.

6.3. Social sustainability

The social climate among staff members and those engaged in the change process doesshift as a result of the shift to new digital technologies. According to the interviews, it might be difficult to involve people in a change process because they may not want to change or may not trust that change would occur. Grant (1996) and Kotter (2014) bothtouch on the significance of including those outside of the core group in the aspects in order to acquire wide knowledge. People involvement is often complicated by poor communication and a lack of accountability for spearheading the change.

It could be challenging to integrate new technologies if people are not involved. It is necessary to involve and educate those who are resistant to change about the potential advantages of the advancements. Using smarter tools and supporting technologies like exoskeletons and virtual simulations to optimise material flow at workstations is one improvement and opportunity with the shift towards industry 4.0 that was discussed throughout the interviews. Critical circumstances might be replicated and proactively improved by utilising digital twins to analyse the layout of machinery and the movementof material within each station.

6.4. Change management roadmap towards industry 4.0

Although previous research has attempted to offer a road map for approaching industry 4.0 (e.g., Ghobakhloo 2018; Erol et al. 2016), our findings bolster the claim that organisations have distinct criteria for advancement. A roadmap is suggested below, as shown in Figure 7, based on the theory presented in this study and the theoretical framework with findings from actual data. The roadmap includes an explanation of eachphase along with crucial considerations to help bus makers make the transition to industry 4.0.

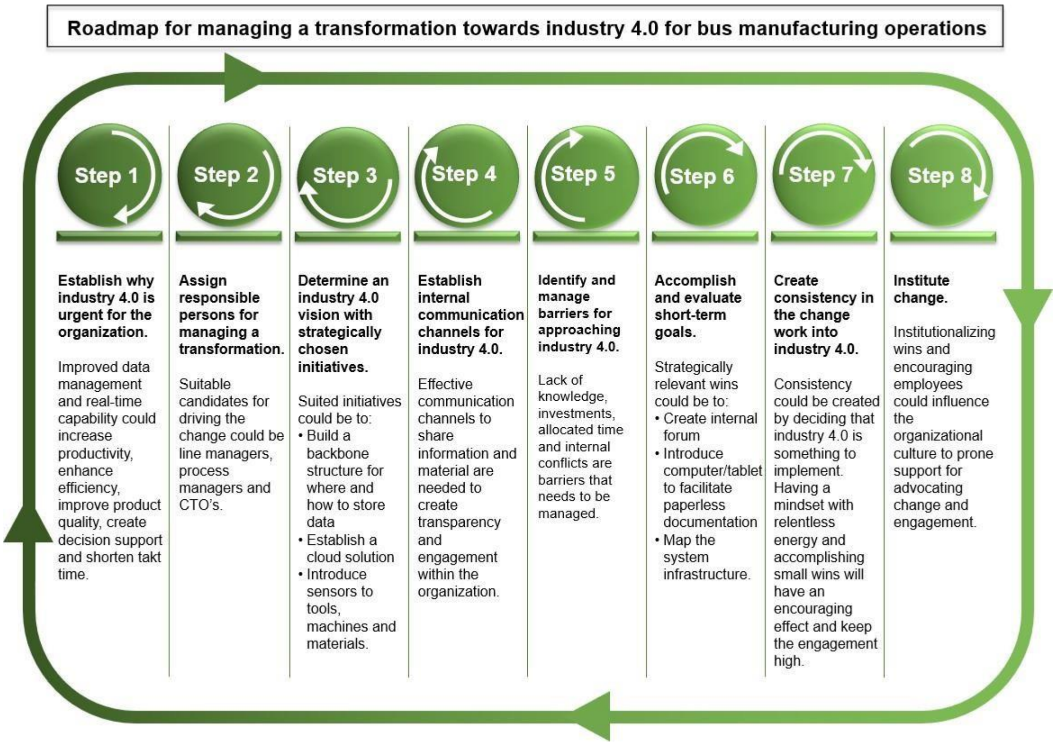


Figure 7. Illustrates a roadmap for managing a transformation towards industry 4.0 for busmanufacturing operations.

Using an iterative methodology, managing a transition requires ongoing change activity.As an example, after achieving a short-term objective, new ones are set and pursued.

One element that unites the plan is knowledge. While it's true that learning about industry 4.0 and its technology in detail is important, even more important is knowinghow to comprehend and connect industry 4.0 to the way things are done now.

Furthermore, to involve staff members, inspiring and energising the individuals withinthe company.

7. Conclusion

This chapter aims to summarize the results of the study and present the conclusions in order to answer the research questions. The chapter is outlined after the two research questions.

The goal of this thesis was to give the bus manufacturing industry clear information regarding the benefits and drawbacks of industry 4.0 technology. In addition, to offer amanagement guide for the shift to industry 4.0. The study has discovered signs that thebus manufacturing industry differs from the automobile industry in implementing industry 4.0. This is supported by the analysis of empirical findings combined with theory from literature.

Research question 1:

What opportunities and challenges does industry 4.0 technologies entail within bus manufacturing operations?

In order to evaluate the opportunities and problems associated with evolving technologies, a portion of this study involved analysing the features of bus manufacturing operations and then relating it to the industry 4.0 phenomenon. Compared to other automotive industries like automobiles and trucks, this study demonstrates that the manufacturing of buses is characterised by low volumes, high complexity, a lot of manual labour, big variability, and a high degree of client adaptation. This in turn influences the technologies that make sense in terms of investments vs benefits for bus manufacturing processes. According to the study, IIoT and CPS systems that combine data management with real-time information sharing anddecision support are appropriate for bus manufacturing operations since information autonomy would reduce production variances and enable complexity. However, the study discovered that because of the peculiarities of bus manufacturing, there is little chance for automation utilising robotics in bus production lines. Robotics,however, can be useful in the component manufacturing industry, where production volumes are larger and product variances are lower. Furthermore, material handling procedures may be a viable application for collaborative robots.

In summary, real-time capabilities and decision support are made possible by opportunities in data management, cloud computing, artificial intelligence, and sensors.It also needs horizontal and vertical integration to provide equipment and systems with connectivity.

Virtualization, which simulates factory layouts or production stations to test modifications in a virtual environment rather than the actual plant, is another opportunity that has been found. It is suggested that doing this will lower expenses and save time in the manufacturing process. Additionally, it is recommended that industrial operations take advantage of virtual environments like VR and AR to train labour, whichcan reduce training times and provide easier, more effective production work. The study's findings indicate that one major difficulty is a lack of awareness about the technologies.

This means partly where to acquire the knowledge but also how to utilize the knowledge, for example for analyzing big data. In concrete, much is about the work of building a structure to get data flowing automatically. System integration and preparing data-files for automation is a challenge due to the large number of different systems used within the organization.

Research question 2:
How would a roadmap for managing a transformation towards industry 4.0 look like for bus manufacturing operations?

The theoretical framework serves as the basis for the roadmap and incorporates key elements for managing a shift towards industry 4.0 based on empirical evidence. As a result, this study offers an eight-step approach that bus makers can use to oversee the shift to industry 4.0. Figure 7 presents the suggested roadmap with the key components.The results also show that a precise definition of industry 4.0 is necessary in order to enhance the effectiveness of change management. The study also supports earlier research showing that due to variances in features, organisations have varying circumstances for implementing Industry 4.0.
Adopting a knowledge-based perspective of the company could also provide significance by incorporating knowledge from throughout the entire enterprise, addingvalue through the engagement and use of all employees.

The theoretical contribution of this work fills a research gap by shedding light on industry 4.0 in the context of bus manufacturing processes. In summary, bus manufacturing processes are thought to have numerous prospects in industry 4.0. Thatbeing said, it is evident that the change is a long-term commitment affecting the entirecompany. The study suggests that determination, accountability, engagement, encouragement, consistency, and taking baby measures to gradually move towards change in the industrial operations are critical characteristics to consider when managing a transformation towards industry 4.0. The research findings offer specific insights into change management and can work as a springboard for bus manufacturing operations totransition to industry 4.0.

8. Limitations and future research

The management of a shift towards industry 4.0 for bus manufacturing operationshas been the main subject of this study. Consequently, the bus sector's study on industry 4.0 is constrained. The study does not account for outward logistics, incoming material or parts, finance, or aftermarket business sectors. Results suggest that industry 4.0 may bring about changes to an organization's whole end-to-end flow. Therefore, to better understand how industry 4.0 affects bus organisations, future research should look at how industry 4.0 could alter the bus industry's supply chain. Logistics was thought to have a lot of potential, and further study in this field may be conducted in the future.

The impact of industry 4.0 on bus manufacturers' sustainability efforts should be furtherinvestigated in future studies, as organisations prioritise sustainability more and more. Examining how industry 4.0 technologies' forecasting or predictive order quantities could improve ecological sustainability could be a further step.

Future research should look into how having a central meaning for industry 4.0 can helpchange management, as the study did not find a consistent or obvious definition for the term. Beyond emphasising knowledge as the most valuable resource inside an organisation, another thing to think about is learning about industry 4.0 from the standpoint of the resource-based philosophy of the company. The firm's resource-based hypothesis may be able to pinpoint more special, inimitable resources that provide bus manufacturers a competitive edge.

To assess the advantages of industry 4.0 and the payback period, investment calculationsare also required.

References

Abreu, P.H.C. (2018). Prospects for the Management of Knowledge in the Context of Industry 4.0. *South American Development Society Journal*, 10, 126.

Agostini, L., & Filippini, R. (2019). Organizational and managerial challenges inthe path toward Industry 4.0. *European Journal of Innovation Management*. Appelbaum, S. H., Habashy, S., Malo, J. L., & Shafiq, H. (2012). Back to the future:revisiting Kotter's 1996 change model. *Journal of Management Development*.

Arksey, H., & Knight, P. T. (1999). *Interviewing for social scientists: An introductory resource with examples*. Sage.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 77–101.

Bryman, A. & Bell, E. (2011). *Business Research Methods*. Ed. 3rd. New York: Oxford University Press.

Bucy, M., Finlayson, A., Kelly, G., & Moye, C. (2016). *The 'how' of transformation.* McKinsey & Company.

Chen, B., Wan, J., Shu, L., Li, P., Mukherjee, M., & Yin, B. (2017). Smart factory of industry 4.0: Key technologies, application case, and challenges. *IEEE Access*, 6, 6505-6519.

Conner, K. R., & Prahalad, C. K. (1996). A resource-based theory of the firm: Knowledge versus opportunism. *Organization science*, 7(5), 477-501.

Corbin, J., & Strauss, A. (2015). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (4rd ed.). Thousand Oaks, CA: Sage.

Culot, G., Nassimbeni, G., Orzes, G., & Sartor, M. (2020). Behind the definition of industry 4.0: Analysis and open questions. *International Journal of Production Economics*, 107617.

Daft, R. (2008) *Organization theory and design*. Ed.10th. Cengage Learning. Datainspektionen (n.d.) *Dataskyddsförordningen.* https://www.datainspektionen.se/lagar--regler/dataskyddsforordningen/ dataskyddsforordningen---fulltext/ [Visited 2020-04-17]

Drath, R. & Horch, A. (2014). Industrie 4.0: hit or hype?. *Industrial ElectronicsMagazine*, 8(2), 56-58.

Dubois, A., & Gadde, L. E. (2002). Systematic combining: an abductive approachto case research. *Journal of business research*, 55(7), 553-560.

Dubois, A., & Gadde, L. E. (2014). "Systematic combining"—A decade later. *Journal of Business Research*, 67(6), 1277-1284.

Dubois, A., & Gadde, L. E. (2017). "Systematic Combining": An approach to caseresearch. *Journal of Global Scholars of Marketing Science*, 27(4), 258-269.

Easton, G. (1995). Case research as a methodology for industrial networks: a realist apologia. *In IMP Conference (11th)* (Vol. 11). IMP.

Erol, S., Schumacher, A. & Sihn, W. (2016) Strategic guidance towards Industry 4.0 – a three-stage process model. *International Conference on CompetitiveManufacturing*. COMA.

Esmaeilian, B., Behdad, S., & Wang, B. (2016). The evolution and future of manufacturing: A review. *Journal of Manufacturing Systems*, 39, 79-100.

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*, 5(1), 1-4.

I

Fettig, K., Gačić, T., Köskal, A., Kühn, A., & Stuber, F. (2018, June). Impact of industry 4.0 on organizational structures. *In 2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)* (pp. 1-8). IEEE.
Foss, N. J. (1996). More critical comments on knowledge-based theories of thefirm. *Organization science*, 7(5), 519-523.
Frankenfield, J. (2020). *Artificial intelligence (AI)*. Investopedia. https://www.investopedia.com/terms/a/artificial-intelligence-ai.asp [Visited2020-03-17].
Ganzarain, J., & Errasti, N. (2016). Three stage maturity model in SME's toward industry 4.0. *Journal of Industrial Engineering and Management (JIEM)*, 9(5), 1119-1128.
Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, 29(6), 910–936.
Gilchrist, A. (2016). *Industry 4.0: the industrial internet of things*. Apress.
Grant, R. M. (1996). Toward a knowledge-based theory of the firm. *Strategic management journal*, 17(S2), 109-122.
Gray, D. E. (2017). *Doing research in the business world*. Sage Publications Limited.
Gupta, P. (2011). Leading innovation change—the Kotter way. *International Journal of Innovation Science*, 3(3), 141-150.
He, H., Maple, C., Watson, T., Tiwari, A., Mehnen, J., Jin, Y., & Gabrys, B. (2016). The security challenges in the IoT enabled cyber-physical systems and opportunities for evolutionary computing & other computational intelligence.*In 2016 IEEE Congress on Evolutionary Computation (CEC)* (pp. 1015- 1021). IEEE.
He, W., & Xu, L. (2015). A state-of-the-art survey of cloud manufacturing. *International Journal of Computer Integrated Manufacturing*, 28(3), 239- 250.
Hermann, M., Pentek, T., & Otto, B. (2016). Design principles for industrie 4.0 scenarios. *In 2016 49th Hawaii international conference on system sciences (HICSS)* (pp. 3928-3937). IEEE.
Hoskisson, R. E., Wan, W. P., Yiu, D., & Hitt, M. A. (1999). Theory and research in strategic management: Swings of a pendulum. *Journal of management*, 25(3), 417-456.
Huhtala, J. P., Mattila, P., Sihvonen, A., & Tikkanen, H. (2014). Barriers to innovation diffusion in industrial networks: A systematic combining approach. *Advances in Business Marketing and Purchasing*, *21*, 61-76.
Kagermann, H., Helbig, J., Hellinger, A., & Wahlster, W. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group.* Forschungsunion.
Kengatharan, N. (2019). A knowledge-based theory of the firm: Nexus of intellectual capital, productivity and firms' performance. *International Journal of Manpower*, 40(6).
Kotter, J. P. (1996). *Leading change*. Harvard Business School Press. Boston Massachusetts.
Kotter, J. P. (2012). Accelerate!. *Harvard business review*, 90(11), 44-52.

II

Kotter, J. P. (2014) *Accelerate*. Harvard business review press. BostonMassachusetts.
Langley, A. (1999). Strategies for theorizing from process data. *Academy ofManagement review*, 24(4), 691-710.
Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0.
Business & information systems engineering, 6(4), 239-242.
Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. *Manufacturing letters*, 3, 18- 23.
Leitão, A., Cunha, P., Valente, F., & Marques, P. (2013). Roadmap for business models definition in manufacturing companies. *Procedia CIRP*, 7, 383-388.
Liao, Y., Deschamps, F., Loures, E. D. F. R., & Ramos, L. F. P. (2017). Past, present and future of Industry 4.0 - A systematic literature review and research agenda proposal. *International journal of production research*, 55(12), 3609-3629.
Lincoln, Y.S. & Guba, E.G. (1985). *Naturalistic Inquiry*. Newbury Park, CA: SagePublications.
Liu, Y., & Xu, X. (2017). Industry 4.0 and cloud manufacturing: A comparative analysis. *Journal of Manufacturing Science and Engineering*, 139(3).
Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, 6, 1-10.
Marshall, B., Cardon, P., Poddar, A., & Fontenot, R. (2013). Does sample size matter in qualitative research?: A review of qualitative interviews in IS research. *Journal of computer information systems*, 54(1), 11-22.
Merriam-Webster. (n.d.). Paradigm shift. In Merriam-Webster.com dictionary. https://www.merriam-webster.com/dictionary/paradigm%20shift [Visited 2020-04-16]
Mittal, S., Khan, M. A., Romero, D., & Wuest, T. (2017). Smart manufacturing: Characteristics, technologies and enabling factors. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*, 233(5), 1342–1361.
Mittelstädt, V., Brauner, P., Blum, M., & Ziefle, M. (2015). On the visual design of erp systems the–role of information complexity, presentation and human factors. *Procedia Manufacturing*, 3, 448-455.
Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S., & Barbaray, R. (2018). The industrial management of SMEs in the era of Industry 4.0. *InternationalJournal of Production Research*, 56(3), 1118-1136.
Moreno-Vozmediano, R., Montero, R. S., & Llorente, I. M. (2012). Key challenges in cloud computing: Enabling the future internet of services. IEEE Internet Computing, 17(4), 18-25.
Oztemel, E., & Gursev, S. (2020). Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, 31(1), 127-182.
Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice.* Sage publications.
Pfeiffer, S. (2017). Industrie 4.0 in the making-discourse patterns and the rise of digital despotism. *The New Digital Workplace: How New Technologies Revolutionise Work*, 21.
Posada, J., Toro, C., Barandiaran, I., Oyarzun, D., Stricker, D., de Amicis, R., ... & Vallarino, I. (2015). Visual computing as a key enabling technology for

III

industrie 4.0 and industrial internet. *IEEE computer graphics and applications*, 35(2), 26-40.
Prinsloo, J., Vosloo, J. C., & Mathews, E. H. (2019). Towards Industry 4.0: A Roadmap for the South African Heavy Industry Sector. *South African Journalof Industrial Engineering*, 30(3), 174-186.
Qin, J., Liu, Y., & Grosvenor, R. (2016). A categorical framework of manufacturing for industry 4.0 and beyond. *Procedia Cirp*, *52*, 173-178.
Radziwon, A., Bilberg, A., Bogers, M., & Madsen, E. S. (2014). The smart factory: exploring adaptive and flexible manufacturing solutions. *Procedia engineering*, 69, 1184-1190.
Rüßmann, M., Lorenz, M., Gerbert, P., Waldner, M., Justus, J., Engel, P., & Harnisch, M. (2015). *Industry 4.0: The future of productivity and growth in manufacturing industries.* Boston Consulting Group, 9(1), 54-89.
Santoro, M. D., & Bierly, P. E. (2006). Facilitators of knowledge transfer in university-industry collaborations: A knowledge-based perspective. *IEEE Transactions on Engineering management*, 53(4), 495-507.
Schwer, K., & Hitz, C. (2018). Designing organizational structure in the age of digitization. *Journal of Eastern European and Central Asian Research (JEECAR)*, 5(1), 11-11.
Sisinni, E., Saifullah, A., Han, S., Jennehag, U., & Gidlund, M. (2018). Industrial Internet of Things: Challenges, Opportunities, and Directions. *IEEE Transactions on Industrial Informatics*, 14(11), 4724–4734.
Small, A., Gist, D., Souza, D., Dalton, J., Magny-Normilus, C., & David, D. (2016). Using Kotter's change model for implementing bedside handoff: a quality improvement project. *Journal of nursing care quality*, 31(4), 304-309.
Sommer, L. (2015), "Industrial revolution – industry 4.0: are German manufacturing SMEs the first victims of this revolution?", *Journal of Industrial Engineering and Management*, Vol. 8 No. 5, pp. 1512-1532.
Synnes, E. L., & Welo, T. (2016). Bridging the gap between high and low-volume production through enhancement of integrative capabilities. *Procedia Manufacturing*, 5, 26-40.
Tay, S. I., Lee, T. C., Hamid, N. Z. A., & Ahmad, A. N. A. (2018). An overview of industry 4.0: Definition, components, and government initiatives. *Journal of Advanced Research in Dynamical and Control Systems*, 10(14), 1379-1387.
Taylor, F. W. (2004). *Scientific management*. Routledge.
Wang, S., Wan, J., Li, D., & Zhang, C. (2016). Implementing smart factory of industrie 4.0: an outlook. *International Journal of Distributed Sensor Networks*, 12(1), 3159805.
Xu, X. (2012). From cloud computing to cloud manufacturing. *Robotics and computer-integrated manufacturing*, 28(1), 75-86.
Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of things for smart cities. *IEEE Internet of Things journal*, 1(1), 22-32.
Zuehlke, D. (2009). SmartFactory–A Vision becomes Reality. *IFAC Proceedings Volumes*,42(4), 31-39

IV

PLAG REPORT


PREPOSTSEO

Date:Thu, Apr 18, 2024Word Count:19425

Exclude Url: No Rocords Found 71

97% Unique Content
3% Plagiarized Content
0% Paraphrased Pla

Content Checked For Plagiarism: