International Journal of Manufacturing Research

ISSN online: 1750-0605 - ISSN print: 1750-0591
https://www.inderscience.com/ijmr

Approaching digital transformation in the manufacturing industry - challenges and differing views

Mats Ahlskog, Anna Granlund, Viktorija Badasjane, Jessica Bruch, Barrett Sauter

DOI: 10.1504/IJMR.2024.10057606

Article History:

Received:	11 November 2022
Last revised:	31 March 2023
Accepted:	27 April 2023
Published online:	20 December 2023

Approaching digital transformation in the manufacturing industry – challenges and differing views

Mats Ahlskog*, Anna Granlund, Viktorija Badasjane, Jessica Bruch and Barrett Sauter

Division of Product Realisation,
School of Innovation, Design and Engineering,
Mälardalen University,
Sweden
Email: mats.ahlskog@mdu.se
*Corresponding author

Abstract: In order to support manufacturing companies in their digital transformation, challenges and views of the term 'digital transformation' need to be identified since digital transformation is considered a source of competitive advantages. Therefore, this paper aims to explore the challenges and differing views of digital transformation in the manufacturing industry. A case study was conducted in collaboration with four Swedish manufacturing companies. The results were then mapped into categories of three dimensions (people, process and technology), indicating that digital transformation can have different meanings within a company. We conclude that the term 'digitalisation' is more frequently used in the manufacturing industry than 'digital transformation' and identified challenges relate to lack of best practice for digital transformation, degree of standardisation and therefore affects the workload and limits the possibilities of transferring technical solutions between factories. Our findings are relevant to operations managers and other interested in digital transformation.

[Submitted 11 November 2022; Accepted 27 April 2023]

Keywords: production system development; smart production; digitalisation; manufacturing industry; Industry 4.0; knowledge; new competences; degree of standardisation; way of working; organisational structure.

Reference to this paper should be made as follows: Ahlskog, M., Granlund, A., Badasjane, V., Bruch, J. and Sauter, B. (2023) 'Approaching digital transformation in the manufacturing industry – challenges and differing views', *Int. J. Manufacturing Research*, Vol. 18, No. 4, pp.415–433.

Biographical notes: Mats Ahlskog is employed as a Researcher at Mälardalen University, Sweden. He earned his PhD degree in Innovation and Design from Mälardalen University in 2017. His research interest is connected to smart production as well as strategies for digital transformation and his research is carried out in close collaboration with industry. His previous research has focused on the fuzzy front end of manufacturing technology development and knowledge integration. His current research interests include strategies for digital transformation and approaches for creation of smart production in manufacturing industry.

Anna Granlund is an Associate Professor at the division of Product Realisation at Mälardalen University in Sweden. She earned her PhD in Innovation and Design from Mälardalen University in 2014. Her research interest is connected to production and technology development and her research is carried out in close collaboration with industry. Her previous research has focused on strategies for automation development from both technical and organisational perspectives as well as different aspects of supplier relations. Her current research interests include the coordination of digital transformation in international manufacturing networks and data driven production planning in manufacturing industry.

Viktorija Badasjane is a doctoral student in Innovation and Design at the School of Innovation, Design and Engineering at Mälardalen University. She holds a BSc in Nursing and an MSc in Product and Process Development from Mälardalen University. Her main research interests are global production, digital transformation, and their combination. Specifically, the research interest surrounds international manufacturing networks (IMNs), and their global coordination of digital transformation, including the necessary adaptations to the organisational structures. Her research is facilitated by collaboration with the manufacturing companies within the KODIT research project.

Jessica Bruch is a Professor in Production Systems at Mälardalen University, Sweden. She holds an MSc in Industrial Engineering and a PhD in Innovation and Design. She is particularly interested in digitalisation as an enabler of production innovation and sustainable industry. Her of topics include digital production innovation, integration of digital technologies, digital transformation and green design of production equipment. Her research work involves close collaboration with leading industrial companies.

Barrett Sauter is a doctoral student in Innovation and Design at the School of Innovation, Design and Engineering at Mälardalen University. She holds an MSc in Product and Process Development from Mälardalen University. Her research focuses on integrating augmented and virtual reality technologies into manufacturing organisations, specifically digital strategies, organisational factors, and work procedures. Her research is facilitated by collaboration with the manufacturing companies within the KODIT research project.

This paper is a revised and expanded version of a paper entitled ‘Differing views of the meaning of digital transformation in manufacturing industry’ presented at the 10th Swedish Production Symposium, Skövde, Sweden, 26–29 April 2022.

1 Introduction

When Industry 4.0 was launched in 2011 by the German government, the meaning of the term ‘Industry 4.0’ was more blurry than concrete (Ghobakhloo, 2018; Hermann et al., 2016). However, since 2011, its meaning has become more concrete, and many researchers have proposed key design principles and technology trends (Ghobakhloo, 2018) related to the Industry 4.0 concept (Castelo-Branco et al., 2019). For example, Castelo-Branco et al. (2019) described Industry 4.0 as ‘a concept that represents the adoption by industrial companies of techniques and processes allowed by digitalisation, cloud computing, the internet of things and big data to gain competitive advantages in

domestic and global markets'. Furthermore, Ustundag and Cevikcan (2017) proposed that the transformation to Industry 4.0 is based on eight foundational technology advances: adaptive robotics, data analytics and artificial intelligence (big data analytics), simulation, embedded systems, communication and networking (e.g., industrial Internet), cloud systems, additive manufacturing and virtualisation technologies. In the literature, the terms 'Industry 4.0', 'smart manufacturing' and 'smart factory' are often used interchangeably (Mittal et al., 2018).

From one perspective, these terms describe an ideal future state, such as a smart factory or a factory of the future, that will create competitive advantages for manufacturing companies. This ideal future state can be achieved with the implementation and usage of digital technologies that enable digital transformation (De Carolis et al., 2017). De Carolis et al. (2017) described digital technologies as the core drivers of manufacturing transformation. Meanwhile, Vial (2019) highlighted the ambiguous meaning of digital technologies and argued that many authors use the term 'digital technologies' without explicit clarification. What can be considered digital technology will not be covered in this paper. However, digital technologies, including systems, hardware and software necessary for digital transformation, are considered enablers of the development of a smart factory.

Another research stream that is closely related to and may overlap with Industry 4.0 is the concept of 'digital transformation'. In recent years, it has gained increasing interest from both researchers and practitioners, resulting in independent research in emerging areas (Chinotaikul and Vinayavekhin, 2020). Focus areas in the field of digital transformation range from value creation (Babar and Yu, 2019; Vial, 2019), business strategy and models (Babar and Yu, 2019; Drieschner et al., 2019; Schallmo et al., 2017), maturity models and characteristics (Babar and Yu, 2019; Sjödin et al., 2018), digital technologies (Schallmo et al., 2017; Vial, 2019), process innovation capabilities (Chirumalla, 2021; Sjödin et al., 2018) and organisational aspects (Bordeleau and Felden, 2019; Vial, 2019), among others. In this research field, there is currently no commonly accepted definition of the term, and the terms 'digitisation', 'digitalisation' and 'digital transformation' are often used interchangeably (Bloomberg, 2018; Gong and Ribiere, 2021; Schallmo et al., 2017). Similar to the term 'Industry 4.0', the meaning of 'digital transformation' is not well defined. According to Aguiar et al. (2019) and Gong and Ribiere (2021), researchers and practitioners have yet to achieve consensus regarding the meaning of digital transformation and its implementation, thus requiring further research. These differing views have caused problems for both researchers and practitioners in relation to the development of smart factories. Due to this lack of consensus, it has been quite challenging to define intra- and inter-organisational communication as well as the description of a future wanted state, such as smart factories. In order to support manufacturing companies in their digital transformation challenges and views of the term 'digital transformation' need to be identified. Therefore, this paper aims to explore the challenges and differing views of digital transformation in the manufacturing industry.

A case study was conducted in collaboration with four Swedish manufacturing companies. In particular, this paper aims to contribute to discussions related to differing views of digital transformation by comparing various perspectives between the literature and manufacturing companies. Furthermore, the challenges to this process were identified and then mapped into categories of three dimensions: people, technology and process (Liker and Morgan, 2006).

The results of this study offer three novel contributions. First, our results show that the term 'digitalisation' is more frequently used in the manufacturing industry than 'digital transformation'. Second, our results show that in large global manufacturing companies, global standardisation vs. local deviations of technologies is a major challenge, which is a consequence of different production setups at various factories. Our results indicated that the balance between global standardisation vs. local adoption at different factories increases the workload and limits the possibilities of transferring solutions between factories. Finally, our results show that there is a lack of best practice for digital transformation and learning takes place during integration of technologies; therefore it is challenging to incorporate an end-to-end perspective.

The remainder of the paper is outlined as follows. First, the theoretical framework is outlined, followed by a description of the research methodology. Thereafter, the empirical findings are presented, starting with differing views of digital transformation, followed by key challenges from an industrial perspective. Next, we discuss the implications of our findings and provide specific recommendations for management practice. Finally, we conclude with a discussion of the research limitations and future research directions.

2 Theoretical framework

This section starts by introducing the terms digitisation, digitalisation, digital transformation, and Industry 4,0, followed by an overview of differing views of digital transformation and related digital transformation challenges.

2.1 Digitisation vs. digitalisation vs. digital transformation vs. Industry 4.0

In the literature, many authors have discussed the differences and meanings of 'digitisation', 'digitalisation' and 'digital transformation', as well as their interrelationships (Bloomberg, 2018; Gong and Ribiere, 2021). These three terms are associated with the use of digital technologies, and it is commonly accepted that the meaning of 'digitisation' is to convert analogue to digital information (Bloomberg, 2018). However, when it comes to 'digitalisation', this term is often used interchangeably in the literature with both 'digitisation' and 'digital transformation' (Bloomberg, 2018). According to Bloomberg (2018), the term 'digitalisation' does not have a single clear definition. Gong and Ribiere (2021) argued that while 'digitalisation' is mainly focused on work at the operational level, 'digital transformation' emphasises the results at the strategic level. Further, Stark (2020) concluded that there could be a need for several definitions of the term, depending on the type of change. For instance, digital transformation projects can range from small scale (e.g., single technology integration) to large projects (e.g., several technologies to be integrated). In the literature, the term is often described as a digital technology-enabled change process that creates value. This description has many similarities to those presented in the Industry 4.0 literature. For example, according to Calabrese et al. (2020), 'Industry 4.0' refers to a transformation enabled by a series of technologies providing new and improved approaches to value creation, proposition and capture (e.g., enhanced productivity, better quality products and working conditions, sustainability, development of innovative capabilities and new revenue models (Calabrese et al., 2020). Furthermore, Trotta and Garengo (2018) stated

that 'Industry 4.0' could be defined as the integration of technologies (i.e. big data analytics, cloud services, 3D printing, cyber security, autonomous robots, internet of things, augmented reality, simulation and horizontal and vertical integration), which allows the transformation of organisations to operate, along with changes in business models and manufacturing processes. Thus, the core of Industry 4.0 is the integration of digital technologies, and the term 'smart manufacturing' is often used to describe this. Aside from 'smart manufacturing', 'smart factory' is generally used as a synonym for Industry 4.0, with no link to any specific government plan, but with the goal of increasing the connectivity of production (Trotta and Garengo, 2018). According to Romero et al. (2020), smart factories are flexible cyber-physical production factories that provide personalised services and products to customers and employ functions based on the use of big data. From a theoretical perspective, the main enabler of digital transformation is the use and integration of digital technologies. The end goal of this transformation is to create value that creates competitive advantages.

2.2 Challenges and differing views of digital transformation

In recent years, several literature reviews have been conducted to explore the meanings of the term 'digital transformation' (Babar and Yu, 2019; Chinotaikul and Vinayavekhin, 2020; Schallmo et al., 2017; Vial, 2019). For instance, Vial (2019) reviewed 282 articles and found 28 sources that provided 23 unique definitions. Chinotaikul and Vinayavekhin (2020) explored digital transformation and found it to be a young but rapidly growing field in business and management research. They reviewed 456 journal articles and found that the most common keywords used by authors in this field were 'digital transformation', 'Industry 4.0', 'digitalisation' and 'innovation'. Babar and Yu (2019) reviewed 36 journal articles and identified eight concrete characteristics of digital transformation (i.e., business strategy and models, enterprise agility, customer centricity, rapid cycles of product and solution delivery, multi-speed organisations, data-driven decision making, social and organisational aspects, business process automation). Schallmo et al. (2017) pointed out that there is currently no commonly accepted definition for the term 'digital transformation' and proposed their own definition. The most recent work exploring the many definitions of the term was conducted by Gong and Ribiere (2021), who analysed 134 definitions and proposed a unified definition.

As there are many definitions of 'digital transformation', this has been studied based on various conceptualisations and key challenges belonging to a broad spectrum of perspectives. The many definitions and descriptions of the term in the literature show that various aspects are transformed, such as people, culture, mindset, talent development and leadership, business models, organisational structure, and so on (Badasjane et al., 2022; Gong and Ribiere, 2021; Schallmo et al., 2017; Vial, 2019).

Like the various definitions of digital transformation, challenges related to digital transformation have also been identified and categorised in different ways. For example, Sjödin et al. (2018) classified challenges into three categories: people, technology, and process when identifying and categorising challenges. Furthermore, Abdallah et al. (2021) used four main categories: skills gap, adoption of new technologies, change management process, innovation policies and procedures. In this paper digital transformation challenges from the literature are mapped into the three dimensions: people, technology, and process (see Table 1).

Table 1 Challenges with digital transformation

Challenges related to	*Author (s)*										
	Abdallah et al. (2021)	*Albukhitan (2020)*	*Badasjane et al. (2022)*	*Brunetti et al. (2020)*	*Calabrese et al. (2020)*	*Chirumalla (2021)*	*Favoretto et al. (2022)*	*Khin and Kee (2022)*	*Pessot et al. (2021)*	*Shahi and Sinha (2020)*	*Sjödin et al. (2018)*
People											
Lack of knowledge and skills	x	x	x	x	x	x	x	x	x		
Culture and mindset						x		x		x	
Commitment		x	x				x		x		
Resistance to change	x	x			x						
Lack of understanding of benefits		x	x								x
Technology											
Adaption or technology complexity	x			x	x			x			x
Legacy system and infrastructure	x			x			x			x	
Cybersecurity		x			x						
Rapid development											x
Data management					x	x	x			x	x
Lack of standardisation					x						
Process											
Lack of roadmap, strategy and vision	x		x						x	x	x
Limited budget and funding		x			x			x		x	
Adapting traditional routines and work processes			x			x					x
Value creation			x		x		x				
Lack of cross-functional work										x	x
Inflexible company structure	x	x	x								

In the people dimension, challenges related to resistance to change, lack of digital skills, and lack of resources are frequently described (Abdallah et al., 2021; Khin and Kee, 2022). Abdallah et al. (2021) discuss that there is an apparent skill gap between the digital skills possessed by manufacturing organisations and what is needed for the digital transformation. Digital transformation is a change process that affects employees' work environment and Albukhitan (2020) describes that many people resist change to their work environment since it affects their comfort zone. This is in line with Khin and Kee (2022), who found that finding the right people to handle digital transformation, lack of knowledge, and workers fear of unemployment are challenges to be considered. Badasjane et al. (2022) studied coordination of digital transformation in factory networks and found that limited resources are used, lack of management support, and organisational structures are not adapted for digital transformation.

In the technology dimension, challenges related to adaption of technologies, legacy system, and cybersecurity are some of the most frequently described challenges (Albukhitan, 2020; Calabrese et al., 2020). Digital transformation requires integration of new or adapted digital technologies and the IT architecture connecting things together is critical. Shahi and Sinha (2020) found that lack of digital infrastructure is one of the major hurdles in the path of the transformation process. Favoretto et al. (2022) also found that shortcomings in IT architecture, scalability, lack of standards and reference architecture are challenges that manufacturing companies experience. Cybersecurity is of high importance when integrating new technologies or changing the IT architecture. Cybersecurity is a major concern for any digital transformation project since the operation network and systems will be exposed to the internet (Albukhitan, 2020).

Commonly described challenges in the process dimension are related to adaption of routines and work processes, budget restrictions, and lack of strategy and roadmap (Pessot et al., 2021; Shahi and Sinha, 2020). Sjödin et al. (2018) identified challenges when implementing a smart factory concept and found that a lack of common understanding and vision amongst employees, technological complexity, and difficulties in adapting traditional routines and work processes to digital transformation are the top three challenges. Also, Chirumalla (2021) found there is a lack of standardised practices for change when integrating new technologies and digital transformation is a matter of cost. Lack of financial resources to implement digital technologies is a challenge for many manufacturing companies (Favoretto et al., 2022). Calabrese et al. (2020) describe that the high costs to carry out an Industry's 4.0 transformation are often cited as an impeding barrier and Shahi and Sinha (2020) identified that teams are working silos and the lack of collaborative efforts from all functions of the organisation as one of the challenges in digital transformation projects.

3 Research method

This section starts by describing the research design and study context, followed by data collection and analysis.

3.1 Research design and company selection

As the aim of the paper is to explore the challenges and differing views of digital transformation in the manufacturing industry, a case study was conducted. This method was chosen because it can help obtain a detailed understanding of the phenomenon being studied (Karlsson, 2009; Yin, 2009). Furthermore, it can provide the opportunity to use different techniques for data collection and sourcing, thus supporting the ability to gather a rich set of data from observation, interviews, documents, etc. (Voss et al., 2002).

This study is a part of a larger research project conducted in collaboration with four manufacturing companies located in Sweden (labelled companies A, B, C and D and described below respectively). All manufacturing companies are spread globally through international manufacturing networks. Further, they have both local (at the production site) and global (centralised and not belonging to production sites) support functions. All companies applied the concept of core plants: dedicated production sites serving as centres of excellence, have a central role in knowledge creation and must ensure that the

latest knowledge is diffused throughout the organisation's production network (Bruch et al., 2020).

Company A is a manufacturing company within the automotive industry and has 30,000 employees located in 33 countries. The participants in this study worked at both global and local support functions in different areas connected to digital transformation. Company A has an organisational structure that is linked to global and local initiatives, and roadmaps for technology development have been created per technology area. Recent digitalisation initiatives in the company involve the introduction of IIoT platforms, Big Data and Edge computing as well the introduction of co-bots and autonomous transports.

Company B is a manufacturing company within the manufacturing industry and has over 43,000 employees located in more than 40 countries. The participants in this study worked at both global and local support functions, with a focus on digital transformation. Company B is working towards its vision of a future factory and focuses on the standardisation of technologies in general and information technology (IT) infrastructure in particular. Recent initiatives include the introduction of shop floor LAN. The standardisation of technologies is performed at the global level.

Company C is a manufacturing company within the heavy vehicle industry and has approximately 15,000 employees located in 180 countries. The participants in this study worked at both the global and local levels but were all part of the company's initiative for its digital transformation. The company has developed a vision of a future factory and has defined high-level digital technologies to be implemented. To achieve this vision, it introduced teams working on digital transformation to all production sites. These teams are often responsible for pilots where new technology is developed and tested. Recent initiatives involve AR/VR and AI for quality control, co-bots and IIoT platforms.

Company D is a manufacturing company within the transportation industry, with over 74,000 employees located in 70 countries. The participants in this study work at a production site, which is a core plant responsible for the industrialisation of new products. The production site has limited resources in terms of working with digital transformation, but is linked to the global support function dealing with IT concerns. Recent digitalisation initiatives in the company involve the work towards a paperless factory with a focus on using screens and other digital devices for all types of information.

Table 2 Job title of project participants

Company	*Job title*
A	Global R&D, manufacturing engineering, programme office manager, technology transformation manager, manager manufacturing engineering development.
B	Manager reliability and future factory, manager process and manufacturing development, technical lead manufacturing it, director regional it and central services
C	Manager manufacturing technology development, director management systems and data analysis, director process and IT operations, IT local and regional manager, director production preparation process
D	Head of industrialisation and manufacturing engineering, production and logistic developer

To understand how the participating companies approach digital transformation and identify challenges and differing views, this study used various data collection techniques

described in the following section. In Table 2, the job titles of the project participants are described.

3.2 Data collection and analysis

First, a theoretical framework was developed for this study. The main search string used in the SCOPUS and IEEE databases was 'digital transformation and literature review' to rapidly cover the state-of-the-art in the area of digital transformation and to identify definitions/descriptions of the term. Even though SCOPUS is a multidisciplinary database, it is necessary to include IEEE to cover another spectrum of areas, such as aerospace, computer science and robotics. Another filtration parameter was that only publications later than 2017 were reviewed.

Table 3 Summary of the data collection process implemented in the study'

Workshop (WS) topic	*Length/no. of*
WS1: Company presentation and digital transformation challenges	180 min
Survey	17 responses
WS2: Presentation and discussion of survey results	180 min
WS:3 Challenges workshop	180 min

Data collection started by assessing how the four case companies presented their approach to and work practices concerning digital transformation, followed by describing the main challenges involved. This was done during a workshop (see Table 3, WS1) where each case company presented prepared materials from given guidelines. In the second step, a survey was designed with a focus on the term 'digital transformation'. The survey aimed to identify how companies view digital transformation and the project participants. The results from two questions in the survey (Q1: 'What is digital transformation to you? Describe your view of what digital transformation implies in a production context or your company context' and Q2: 'Has your company defined the term digital transformation?' (Yes/No). Based on the literature review and the survey data, a cross-comparison of the differing views of digital transformation was performed. The survey results were compiled, presented and discussed with the participants at the following workshop (WS2). Then, a final workshop (WS3) was conducted, focusing on the challenges faced by the participants whilst coordinating digital transformation in international manufacturing networks. This workshop included both joint presentations and discussions per case company. All workshops were performed digitally, managed by the authors, and attended by the project participants listed in Table 2.

Drawing upon prior studies on digital transformation, a systems view was applied in this paper involving the three basic dimensions of people technology and process (Liker and Morgan, 2006). The people dimension refers to individuals and groups representing different knowledge and organisational functions at a company who interact and collaborate to perform digital transformation activities (Ahlskog et al., 2017; Sannö and Ahlskog, 2019). This dimension thus refers to various aspects, such as the availability of competencies, the organisation and management of digital transformation and the norms and culture that affect how the process is carried out. The technology dimension refers to the digital technologies to be implemented in a production system and those used after the transformation. Examples of technology include the integration and use of IT, AI,

IIoT, cloud computing and so on (Gong and Ribiere, 2021; Oztemel and Gursev, 2020). The process dimension refers to the way a company performs digital transformation. This dimension involves the actions, activities, routines, work processes, project models and well-founded decisions that result in the integration and usage of digital technologies in a production system (Vial, 2019).

To draw transparent conclusions, final data analysis was an iterative process between collected empirical data and theory. The data analysis began by analysing each case company separately, thus compiling a case study history based on the data collected. Data analysis was performed according to Miles and Huberman's (1994) interactive model of data collection, data display, data condensation and conclusions. The final analysis of the data was performed in the following steps:

1 The literature reviewed was stored and categorised and, based on the digital transformation challenge identified, the key findings from the literature were derived and stored in a spreadsheet.

2 During the case study, data were documented and coded in a case study database. A case study protocol was also used for filtering the data and arranging occurrences in chronological order (Yin, 2009).

3 The qualitative data were analysed with the aim of identifying unique patterns for each case company, and key findings from the literature were compared with the empirical data collected (Eisenhardt and Graebner, 2007). To facilitate the analysis, empirical driven categories were used for the three dimensions (Miles and Huberman, 1994).

4 Empirical findings

The results from the first workshop showed that all companies approached digital transformation by using different organisational designs and ways of working. The key challenges for all companies were the lack of best practices for performing digital transformation, organisational knowledge and knowledge development related to work processes and technologies (Abdallah et al., 2021). Consequently, technology selection and the degree of technology standardisation have become major challenges. The results from the survey questions showed that frequent keywords were used, such as 'digitalisation', 'data-driven decision', 'a future state', 'customer value', 'way of working', 'a journey' and 'use of digital technologies', amongst others. The answers showed a scattered picture of what digital transformation implies and what it is perceived to be. Only three respondents described the concept from a bigger perspective by emphasising that the usage of new digital technology will require new competences and ways of working as well as a changed organisational structure that supports digital transformation in this value creation process.

Moreover, the answers also showed that the case companies have not defined the term digital transformation and only company C answered that their company defined the term 'digital transformation'. In particular, they described that they had spent a great deal of time focusing on communication and the creation of a common language. For example, they stated that the term 'Industry 4.0' has existed for a long time without a clear meaning and that everybody has their opinion of its meaning (Hermann et al., 2016).

Therefore, company C tried to avoid using the term 'Industry 4.0' in the creation of a common language and during communication when starting a global initiative within the company on how to develop and create a smart factory. Based on the discussions, it was quite clear that the mixed answers at the other three companies depended on how each participant viewed the term 'digital transformation' and on the lack of company description.

Table 4 Digital transformation challenges identified by the company employees

Dimension	*Categories*	*Challenge (experienced by companies A, B, C and D)*
People	Knowledge and new competence	• Manage old and new technologies with different maturity levels (A, B and C)
		• Knowledge development around digitalisation and technologies (A, B and C)
		• Management commitment (A)
		• Increased system complexity (B)
		• Use competences in the best way (C)
	Organisation	• Involve all functions needed (A, C)
		• Prioritisation and utilisation of resources in all projects (C and D)
		• Understanding the organisational structures needed (A)
		• Utilisation of local innovation capability (A)
		• Employees' fear of losing their jobs (A)
		• Different knowledge levels in the organisation (B)
		• Lack of resources for digital transformation (D)
	Culture and mindset	• Cultural differences at each production site (B and C)
		• Strong entrepreneurship at each production site (B)
		• Acceptance of a new way of working (B)
		• Change to an innovative and agile way of working (C)
Technology	Implementation	• Legacy systems (A, B and D)
		• Different production setups at various production sites (B and C)
		• Utilisation of digital technology in the best way (A)
		• Dependency on secure connectivity (B)
	Degree of standardisation	• Global standardisation vs. local deviations (A, B and D)
		• High-speed technology development in the market (B and C)
		• Regional differences (C and D)
		• Time constraints for development of standard solutions (B)
		• Differing maturity levels amongst technologies (C)
	Security	• Achieve cybersecurity (B)
	Data	• Become more data driven (A)
		• Make use of big data (B)

Table 4 Digital transformation challenges identified by the company employees (continued)

Dimension	*Categories*	*Challenge (experienced by companies A, B, C and D)*
Process	Time	• Time constraints to develop standard solutions (B)
		• Concurrent development and learning during implementation (B)
		• Accelerate speed in implementation – from pilot to scaleup (C)
	Factory network	• Balance global standardisation vs. local adaption (A, B and D)
		• Cultural differences in the factory network (B, C and D)
		• The role of a core plant in digital transformation (A)
		• Production sites of different sizes and capabilities (C)
	Work process	• Creation of cross-functional project teams, including IT (A, C and D)
		• Coordination and integration of different initiatives with one another (A and D)
		• Lack of best practices in conducting the digital transformation (B and C)
		• Prioritisation of development initiatives and activities (C and D)
		• Inclusion of local innovation capability (A)
		• Production sites focus on what impacts the business (C)
		• Incorporation of end-to-end perspective (C)
		• Difficulties in changing the course of large initiatives (C)
	Knowledge	• Knowledge around digitalisation at all levels in the organisation (A, B)
		• Knowledge sharing internal and externally (C)

Furthermore, the results from the discussions showed that the term ‘digitalisation’ was used more frequently in all companies. Several questions were addressed as final discussion points during the workshop. For the question, ‘Why is digital transformation important and what is the most challenging part?’, the group had to agree upon one single aspect for each question. The answers from the group showed that digital transformation is about survival and increased competitiveness and that lack of knowledge is a major challenge. From the workshops, a broad spectrum of challenges was presented by the company employees. All the challenges identified from the three workshops are listed in Table 4. The challenges are categorised and divided in the dimensions of people, technology and process. The letters in parentheses represent the case company that experienced a specific challenge.

4.1 Challenges related to the people dimension

The three main categories in the people dimension are knowledge and new competence, organisation and culture and mindset (Shahi and Sinha, 2020; Khin and Kee, 2022). The

results showed that all companies had a vision of creating smart factories, even though different words for this were used (e.g., 'factory of the future'). To achieve this, all companies recently made adaptations or organisational changes that were most often related to the decentralisation of the IT function and the integration of the IT function closer to production. In some cases, these changes were still being established when it came to ways of working and defining responsibilities between functions. Frequent challenges mentioned and discussed by the employees were knowledge and new competences. For example, company A highlighted the need to develop knowledge in the area of data analytics so that it can become more data driven. In general, the organisational knowledge of all companies had to be developed to enable them to manage old and new digital technologies and promote the utilisation of new technologies in the best possible ways (Calabrese et al., 2020).

In the category of culture and mindset (Shahi and Sinha, 2020), the challenge with strong entrepreneurship could be seen as a challenge or enabler. In particular, strong entrepreneurship at different production sites enables digital transformation through the development of a company's own technical solutions whilst forming a company perspective. However, such strong entrepreneurship makes it challenging to develop standardised solutions for industrial networks. Both company B and company C employees stated that cultural differences at each production site posed challenges to implementing ways of working and creating a mutual understanding of the vision of a smart factory.

4.2 Challenges related to the technology dimension

The four identified categories in the technology dimension are implementation, degree of standardisation, security and data (Albukhitan, 2020; Favoretto et al., 2022). The identified challenges are closely linked to one another, as the legacy system is unique for each factory in the network (i.e., different sizes, designs and production capacities). Consequently, this affects the degree of standardisation (i.e., how to manage global standardisation vs. local deviations). Specifically, company B employees focused on developing standardised solutions for IT infrastructure, whilst those in company D described their challenges with the enterprise resource planning system. Employees from both companies also stated that the rapid development of technologies in the market caused challenges in the identification and selection of technologies. As with all implementations of digital technologies in a production system, company B employees pointed out that cybersecurity (i.e., how to protect hardware, software and data assets) is a major challenge (Albukhitan, 2020).

4.3 Challenges in the process dimension

The three main categories in the process dimension are time, factory network, work process and knowledge sharing. All manufacturing companies see digital transformation towards a smart factory as an important and necessary step. company C employees described this digital transformation as an endless journey facing the challenge of combining transformation and performance from a resource perspective (Sjödin et al., 2018). They also shared that there was no best practice in implementing this transformation. In a similar vein, company D employees indicated that development occurred whilst they were learning and implementing. Another challenge was raised by

company A personnel, who had trouble integrating different initiatives and understanding what role a core plant should have in digital transformation (Bruch et al., 2020). Company D employees described a similar challenge related to coordinating global and local digital transformation initiatives. These intertwined challenges are essentially due to the lack of best practices in ways of working and the difficulties of managing different initiatives whilst simultaneously developing technical solutions to some degree of standardisation. The combination of these challenges affects how fast digital solutions are implemented, and the challenges are exacerbated when resources must balance daily work with digital transformation activities. Company C employees described the challenge of going from pilot tests to implementation and scaleup, sharing that they often got stuck when in the scaleup phase. Another challenge raised by employees in all three companies dealt with the importance of cross-functional teams and the difficulties of including various functions in projects (Shahi and Sinha, 2020). A final challenge that steams from this situation is how to share knowledge of best practices of ways of working and successful digital transformation cases.

5 Discussion and conclusions

Existing research has studied digital transformation challenges from different perspectives, while research from a manufacturing network perspective is still limited (Badasjane et al., 2022). Therefore, this paper aimed to explore the challenges and differing views on digital transformation in the manufacturing industry. Our findings are particularly relevant in light of the growing managerial and theoretical interest in understanding related challenges from an operations perspective. The findings are relevant to digitalisation, operations and plant managers, as well as other practitioners interested in digital transformation and the development of smart factories. Many of the identified challenges interact with each other over the three dimensions (people, process and technology). Furthermore, the findings showed that digital transformation and the creation of a future wanted state, such as a smart factory enabling increased competitiveness, is an important matter for all companies. Digital transformation is a new mode of production system development towards the creation of smart factories (Sjödin et al., 2018). Thus, previous ways of working and organising for production system development no longer apply as digital transformation requires new knowledge domains to be included in the work and increased system complexity. The lack of best practice for digital transformation causes that learning take place during integration of technologies and the different factories legacy systems limit possibilities of transferring bookshelf solutions between factories. As a consequence, the workload and development time increases when local adaptions are needed.

5.1 Differing views of digital transformation between the literature and the manufacturing industry

From the reviewed literature, it can be concluded that the term ‘digital transformation’ can be viewed and defined in different ways and has a long way to go until it can be well defined (Gong and Ribiere, 2021; Vial, 2019). Furthermore, the empirical findings show a scattered picture of what this term implies and how it is viewed in the manufacturing industry. One conclusion is that the term ‘digitalisation’ is more frequently used in the

manufacturing industry than in the field of digital transformation. In the literature, the terms 'digitalisation' and 'digital transformation' are often used interchangeably, as they are interconnected (Gong and Ribiere, 2021; Schallmo et al., 2017). However, in the current paper, digital transformation is seen from a bigger picture, including organisational changes, ways of working and knowledge development with the end goal of value creation, whilst digitalisation is seen as the implementation and usage of digital technologies for value creation. Without defining these two terms, they should be kept separately at a conceptual level. At a high level, 'digital transformation' is a change process in which value is created. In this process, different parts of a company are transformed into a new state. The differing views and definitions of this term in the literature make it challenging research-wise; therefore, have we avoided adding another definition to the many already existing ones. From a managerial and industrial perspective, the most important part is to have a common language for internal communication—one that enables the organisational understanding of what digital transformation implies. In this case, a shared vision of the end goal and a common language for communication are needed. As highlighted by a company C employee:

> We have worked a lot with communication and have tried to create a common language. The meaning of Industry 4.0 is fuzzy, and everybody has their own opinion; therefore, we have tried to avoid the term Industry 4.0 in the description of our future digital transformation journey. (Manager, manufacturing technology development, company C)

This quote indicates that the research community has yet to clarify the meaning of 'Industry 4.0' since its introduction in 2011 and that the term is still understood as having different meanings. In a similar vein, the differing views on digital transformation in both the industry and literature seem to follow the pattern shown in the use of the term 'Industry 4.0'.

5.2 Challenges with digital transformation

Most of the identified digital transformation challenges (Table 4) have already been identified and discussed in previous research. For example, in the literature, challenges related to lack of knowledge and skills are frequently discussed (Pessot et al., 2021; Chirumalla, 2021) and our findings shows that knowledge development around digital transformation is a major challenge as well as lack of best practices. All manufacturing companies approached digital transformation in different ways and considered it a critical part of their overall success, especially their increased competitiveness (Sjödin et al., 2018). The challenge with a lack of best practice for digital transformation is that it causes learning to take place during integration of technologies. This challenge has not been discussed in prior research and the challenge to incorporate an end-to-end perspective in the work process is a consequence of lack of best practice for digital transformation.

When it comes to technology and process challenges, legacy systems, and cybersecurity were identified as major challenges (Albukhitan, 2020; Shahi and Sinha, 2020). Our findings showed that in large global manufacturing companies' global standardisation vs. local deviations of technologies is a major challenge, which is a consequence of different production setups and legacy system at various production sites. This is related to Badasjane et al. (2022) who found the difficulties of balancing the

trade-off between local factory ownership and global overview as a challenge during digital transformation.

The balance between global standardisation vs. local adoption at different production sites increased the workload for the resources involved and limited the possibilities of transferring bookshelf solutions between production sites. Looking from a coordination perspective the category factory network is the set of challenge that contrast most from prior research (see Table 4). Other challenges related to coordination of digital transformation can also be found in the other categories such as utilisation of local innovation capability, coordination and integration of different initiatives, etc.

This research aims to contribute to the literature on digital transformation by exploring theoretical understandings and conducting empirical analyses of the challenges and differing views related to the concept. The contributions of this research are summarised as follows:

- The discovery that the term 'digitalisation' is more frequently used in the manufacturing industry than 'digital transformation'.
- In large global manufacturing companies, global standardisation vs. local deviations of technologies is a major challenge as a consequence of different production setups at different factories.
- The balance between global standardisation and local adoption at different production sites increases the workload and limits the possibilities of transferring bookshelf solutions between factories.
- Since there is a lack of best practice for digital transformation learning takes place during integration of technologies and it is challenging to incorporate an end-to-end perspective.

6 Limitations and suggestions for future research

An important limitation of this study is worth mentioning: this study was conducted at four manufacturing companies with limited data samples from each company related to the participants' views and definitions of digital transformation. Thus, the actual view of the term 'digital transformation' in all manufacturing companies is not covered. The empirical findings only indicate how the term is perceived by certain participants and not by organisations. Accordingly, it is important to be careful when generalising the findings to other manufacturing companies working in different contexts.

Based on the identified digital transformation challenges, a topic for further research is how to manage global standardisation vs. local technology adoption at factories. Often there are different production arrangements at different production sites, which increase the complexity regarding the degree of standardised solutions and transfer of solutions. More time and resources are needed to adapt solutions for each factory and limits the possibilities of transferring technical solutions between factories.

More research is also needed when it comes to better understanding best practices for digital transformation in the manufacturing industry. As the empirical findings show, learning takes place during integration of technologies and therefore one path for further studies is to investigate lessons learned from digital transformation projects considered successful. Therefore, future research should consider the following:

- how to manage global standardisation vs. local technology adaptation at factories
- investigate lessons learned of digital transformation projects considered successful.

References

Abdallah, Y.O., Shehab, E. and Al-Ashaab, A. (2021) 'Digital transformation challenges in the manufacturing industry', *Product Management & Development*, Vol. 19, No. 1, pp.9–14.

Aguiar, T., Gomes, S.B., Cunha, P.R.d. and Silva, M.M.d. (2019) 'Digital transformation capability maturity model framework', Paper presented at the *2019 IEEE 23rd International Enterprise Distributed Object Computing Conference (EDOC)*.

Ahlskog, M., Bruch, J., and Jackson, M. (2017) 'Knowledge integration in manufacturing technology development', *Journal of Manufacturing Technology Management*, Vol. 28, No. 8, pp.1035–1054.

Albukhitan, S. (2020) 'Developing digital transformation strategy for manufacturing', *Procedia Computer Science*, Vol. 170, pp.664–671.

Babar, Z., and Yu, E. (2019) 'Digital transformation – implications for enterprise modeling and analysis', Paper presented at the *2019 IEEE 23rd International Enterprise Distributed Object Computing Workshop (EDOCW)*.

Badasjane, V., Granlund, A., Ahlskog, M., and Bruch, J. (2022) 'Coordination of digital transformation in international manufacturing networks – challenges and coping mechanisms from an organizational perspective', *Sustainability*, Vol. 14, No. 4, pp.1–21.

Bloomberg, J. (2018) 'Digitization, digitalization, and digital transformation: confuse them at your peril', *Forbes* [online] https://www.forbes.com/sites/jasonbloomberg/2018/04/29/digitization-digitalization-and-digital-transformation-confuse-them-at-your-peril/?sh=29255f2f2c7f (accessed April 2021).

Bordeleau, F-È. and Felden, C. (2019) 'Digitally transforming organisations: a review of change models of Industry 4.0', *Proceedings of the 27th European Conference on Information Systems (ECIS)*, Stockholm & Uppsala, Sweden, 8–14 June, ISBN 978-1-7336325-0-8 Research Papers.

Bruch, J., Rösiö, C., Granlund, A. and Johansson, P. E. (2020) 'Managing the core plant role-key prerequisites from an operations perspective', *International Journal of Manufacturing Research*, Vol. 15, No. 1, pp.90–106.

Brunetti, F., Matt, D.T., Bonfanti, A., De Longhi, A., Pedrini, G., and Orzes, G. (2020) 'Digital transformation challenges: strategies emerging from a multi-stakeholder approach', *The TQM Journal*, Vol. 32, No. 4, pp.697–724.

Calabrese, A., Dora, M., Levialdi Ghiron, N. and Tiburzi, L. (2020) 'Industry's 4.0 transformation process: how to start, where to aim, what to be aware of', *Production Planning & Contro*l, Vol. 33, No. 5, pp.1–21.

Castelo-Branco, I., Cruz-Jesus, F. and Oliveira, T. (2019) 'Assessing Industry 4.0 readiness in manufacturing: evidence for the European Union', *Computers in Industry*, Vol. 107, pp.22–32.

Chinotaikul, P. and Vinayavekhin, S. (2020) 'Digital transformation in business and management research: bibliometric and co-word network analysis', Paper presented at the *2020 1st International Conference on Big Data Analytics and Practices (IBDAP)*, pp.1–5.

Chirumalla, K. (2021) 'Building digitally-enabled process innovation in the process industries: a dynamic capabilities approach', *Technovation*, Vol. 105, No. 102256, pp.1–24.

De Carolis, A., Macchi, M., Negri, E., and Terzi, S. (2017) 'A maturity model for assessing the digital readiness of manufacturing companies', Paper presented at the *IFIP International Conference on Advances in Production Management Systems*.

Drieschner, C., Passalidis, I., Kienegger, H., and Krcmar, H. (2019) 'Business model transformation initiated by the digital transformation: a review of learning concepts', Paper presented at the *2019 IEEE Global Engineering Education Conference (EDUCON)*.

Eisenhardt, K.M. and Graebner, M.E. (2007) 'Theory building from cases: opportunities and challenges', *Academy of Management Journal*, Vol. 50, No. 1, pp.25–32.

Favoretto, C., Mendes, G.H.d.S., Filho, M.G., Gouvea de Oliveira, M., and Ganga, G.M.D. (2022) 'Digital transformation of business model in manufacturing companies: challenges and research agenda', *Journal of Business & Industrial Marketing*, Vol. 37, No. 4, pp.748–767.

Ghobakhloo, M. (2018) 'The future of manufacturing industry: a strategic roadmap toward Industry 4.0', *Journal of Manufacturing Technology Management,* Vol. 29, No. 6, pp.910–936.

Gong, C. and Ribiere, V. (2021) 'Developing a unified definition of digital transformation', *Technovation*, Vol. 102, No. 102217, pp.1–17.

Hermann, M., Pentek, T., and Otto, B. (2016) Design principles for Industrie 4.0 scenarios', Paper presented at the *2016 49th Hawaii International Conference on System Sciences (HICSS)*.

Karlsson, C. (2009) *Researching Operations Management*, Routledge, New York, NY.

Khin, S. and Kee, D.M.H. (2022) 'Factors influencing Industry 4.0 adoption', *Journal of Manufacturing Technology Management*, Vol. 33, No. 3, pp.448–467.

Liker, J.K. and Morgan, J. M. (2006) 'The Toyota way in services: the case of lean product development', *Academy of Management Perspectives*, Vol. 20, No. 2, pp.5–20.

Miles, M.B. and Huberman, A.M. (1994) *Qualitative Data Analysis: An Expanded Sourcebook*, SAGE, Thousand Oaks, CA.

Mittal, S., Khan, M.A., Romero, D. and Wuest, T. (2018) 'A critical review of smart manufacturing & Industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs)', *Journal of Manufacturing Systems*, Vol. 49, pp.194–214.

Oztemel, E. and Gursev, S. (2020) 'Literature review of Industry 4.0 and related technologies', *Journal of Intelligent manufacturing*, Vol. 31, No. 1, pp.127–182.

Pessot, E., Zangiacomi, A., Battistella, C., Rocchi, V., Sala, A., and Sacco, M. (2021) 'What matters in implementing the factory of the future: Insights from a survey in European manufacturing regions', *Journal of Manufacturing Technology Management*, Vol. 32, No. 3, pp.795–819.

Romero, M., Guédria, W., Panetto, H., and Barafort, B. (2020) 'Towards a characterisation of smart systems: a systematic literature review', *Computers in Industry*, Vol. 120, No. 103224, pp.1–17.

Sannö, A. and Ahlskog, M. (2019) 'Integrating knowledge for manufacturing technology development', *International Journal of Product Development*, Vol. 23, No. 1, pp.65–83.

Schallmo, D., Williams, C.A. and Boardman, L. (2017) 'Digital transformation of business models-best practice, enablers, and roadmap', *International Journal of Innovation Management*, Vol. 21, No. 8, pp.1–17.

Shahi, C. and Sinha, M. (2020) 'Digital transformation: challenges faced by organizations and their potential solutions', *International Journal of Innovation Science*, Vol. 13, No. 1, pp.17–33.

Sjödin, D.R., Parida, V., Leksell, M. and Petrovic, A. (2018) 'Smart factory implementation and process innovation: a preliminary maturity model for leveraging digitalization in manufacturing moving to smart factories presents specific challenges that can be addressed through a structured approach focused on people, processes, and technologies', *Research-Technology Management*, Vol. 61, No. 5, pp.22–31.

Stark, J. (2020) *Select Digital Technology. In Digital Transformation of Industry*, Springer [online] https://link.springer.com/chapter/10.1007/978-3-030-41001-8_12 (accessed January 2021).

Trotta, D. and Garengo, P. (2018) 'Industry 4.0 key research topics: a bibliometric review', Paper presented at the *2018 7th International Conference on Industrial Technology and Management (ICITM)*.

Ustundag, A. and Cevikcan, E. (2017) *Industry 4.0: Managing the Digital Transformation*, Springer [online] https://link.springer.com/content/pdf/10.1007/978-3-319-57870-5.pdf (accessed February 2019).

Vial, G. (2019) 'Understanding digital transformation: a review and a research agenda', *The Journal of Strategic Information Systems*, Vol. 28, No. 2, pp.118–144.

Voss, C., Tsikriktsis, N. and Frohlich, M. (2002) 'Case research in operations management', *International Journal of Operations & Production Management*, Vol. 22, No. 2, pp.195–219.

Yin, R.K. (2009) *Case Study Research: Design and Methods*, SAGE, London, UK.