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Navigating through uncertainties: coordinating digital transformation in international manufacturing networks

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Abstract

Purpose – Coordination of digital transformation within globally dispersed factories belonging to international manufacturing networks (IMNs) is essential for competitiveness. This paper explores how digital transformation necessitates changes in the coordination of IMNs.

Design/methodology/approach – A case study is conducted with three Swedish manufacturing companies, thus adding to the limited empirical research covering the examined research field. Data analysis uses the technology-organization-environment (TOE) framework.

Findings – The results highlight 15 digital transformation attributes linked by intermediate themes to 13 changes in the coordination of IMNs and provide concrete industry examples. Four major themes emerged as significant in the coordination of IMNs: increased speed of technology development and rollout, amplified emphasis on a global mindset, increased need to adapt the organizational structures to enable collaboration and a higher degree of uncertainty.

Originality/value – Although coordination of IMNs is acknowledged as directly related to competitive advantage, the ways digital transformation necessitates changes in the coordination of IMNs have been missing in contemporary research. This research decreases this omission.

Keywords Global production, Smart production, Digitalization, Digital technologies, TOE framework, Manufacturing networks, Collaboration, Operations management

Paper type Research paper

Quick value overview

Interesting because – This paper explores the largely unexamined area of coordinating digital transformation within international manufacturing networks (IMNs). It highlights how digital transformation's complexity and uncertainty impact entire networks rather than just factories. Effective coordination is crucial for IMNs to gain competitive advantages, but digital transformation adds complexity by requiring adjustments across operations, culture, and structures. Despite its significance, the coordination of digital transformation is underexplored, underscoring the need to understand how it reshapes IMN coordination.

Theoretical value – The study highlights four key themes: the increased speed of technology development and rollout, amplified emphasis on a global mindset, increased need to adapt organizational structures to enable collaboration and a higher degree of uncertainty.

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The themes link 15 digital transformation attributes with 13 changes in the coordination of IMNs. The findings demonstrate the challenge of balancing speed and standardization in digitalization efforts and the need for cross-functional collaboration and adaptions to the organizational structure.

Practical value – Managers can use the identified digital transformation attributes to understand complexities that affect the coordination of IMNs and tailor actions accordingly. This includes evaluating current coordination strategies to ensure alignment with the demands of digital transformation by considering technology, organizational, and environmental perspectives. The study emphasizes synchronizing activities across IMNs and suggests managers focus on addressing heightened uncertainty, directing efforts toward enhancing adaptability and coordination.

1. Introduction

Coordination is essential in various settings, particularly in global operations, where it is notoriously complex (Ferdows, 2018). However, effective coordination is crucial for obtaining specific benefits, especially within international manufacturing networks (IMNs). In these networks, coordination helps synchronize factories globally, enabling competitive advantages. The coordination of knowledge, information, and best practices is linked to the growth of IMNs and the enhancement of production capacity (Cheng *et al.*, 2016; Norouzilame, 2018). Coordination also supports the operational gains and strategic goals of IMNs, as it facilitates the linkage of factories through physical and non-physical flows (Cheng *et al.*, 2015; Rudberg and West, 2008). Coordination's importance in IMNs is clear, as access to technological resources and related knowledge is the primary reason for forming these networks (Vereecke *et al.*, 2006).

As IMNs undergo digital transformation, coordination is also required. Current research indicates a consensus that digital transformation impacts seemingly every aspect of the manufacturing industry, including its operations, culture, strategies, processes, and organizational structures (Gong and Ribiere, 2021; Warner and Wäger, 2019). Manufacturing companies have undergone significant transformations such as Lean in the past and continue to tackle the challenges of diffusing and coordinating traditional production development across IMNs. However, digital transformation differs due to the rapid pace of change driven by digital technologies. This speed makes outcomes harder to predict and creates interdependencies involving many organizationally dispersed stakeholders (Loonam *et al.*, 2018; Smith and Beretta, 2021). Evidence shows digital transformation's success is closely linked to its coordination within IMNs; both elements must be designed together to be mutually beneficial (Deflorin *et al.*, 2021).

Both coordination and digital transformation in IMNs are complicated, and the manufacturing industry lacks established best practices for managing them together. Researchers agree that coordination is adapted to the context where it is used. In the IMNs, it serves to reap the benefits of belonging to the IMN (Sayem *et al.*, 2018). However, determining the right level of coordination remains a significant industry challenge, especially when a high level of coordination is necessary (Kiely *et al.*, 2022).

While the coordination of IMNs has generally been studied from a product and process development perspective, the coordination of digital transformation remains largely unexplored. Insights are provided concerning coordinating specific digital technologies, e.g. Deflorin *et al.* (2021), but the intricate details of digital transformation are not fully understood (Demeter *et al.*, 2021). Digital transformation represents a fundamental change in IMNs that goes beyond implementing digital technologies (Siachou *et al.*, 2021), adding layers of complexity and uncertainty due to the need for coordination. Coordination is crucial, as digital transformation affects the entire IMN, not just individual factories (Deflorin *et al.*, 2021). Yet, the ways in which digital transformation compels IMNs to adapt their coordination remain unexplored. Therefore, the purpose of this paper is to explore how digital transformation necessitates changes in the coordination of IMNs.

The technology-organization-environment (TOE) framework has been used to analyze the data, and this paper offers three main contributions. First, it identifies 15 digital transformation attributes that necessitate 13 changes in the coordination of IMNs, along with four intermediate themes linking these. Second, it provides concrete industry examples from practitioners coordinating digital transformation in the IMNs. Third, this paper contributes to the limited research on coordinating digital transformation in IMNs, offering a foundation for evaluating if global manufacturing companies need to adapt their coordination strategies.

2. Theoretical framework

2.1 Coordination of IMNs

Shi and Gregory (1998) describe IMNs as a matrix with interconnected factories spread across the globe. Ferdows (1997) identifies six factory roles, asserting that factories can enhance their production and product or process development capabilities, allowing them to progress to more advanced roles. The lead factory is at the top of this hierarchy, which is a central hub for global product and process knowledge.

The coordination within IMNs is inherently interdependent, as factories influence one another and must be managed cohesively. Innovation, knowledge, information, and best practices are coordinated, particularly in developing and adapting products, processes, and production (Badasjane, 2023). Previous work on IMN coordination often relies on the dimensions proposed by Martinez and Jarillo (1989, 1991), that is, (1) structural and formal, and (2) informal and subtle. *Formal* coordination includes management-designed plans and structures that guide how factories collaborate to extract the benefits of belonging to an IMN (Deflorin *et al.*, 2021). It encompasses organizational structure, formalization, standardization, and decision-making, creating a structure for coordination activities across the IMN (Sayem *et al.*, 2018). The formal coordination dimension emphasizes collaboration across functional and geographical boundaries and is supported by clear plans for interactions among factories, top management, and shared processes (Granlund *et al.*, 2019; Norouzilame, 2018). As such, it benefits operational performance by attaining knowledge and information across the IMN (Cheng *et al.*, 2021). However, not all factories within an IMN share the same role in knowledge dissemination (Vereecke *et al.*, 2006). They can be positioned on a spectrum, with some primarily receiving knowledge and others predominantly responsible for sending it (Szász *et al.*, 2019).

The *informal* coordination of IMNs takes on many forms, all aimed at expanding factory knowledge and sharing resources and expertise (Badasjane, 2023) enabled by cross-departmental relationships, temporary or permanent teams, task forces, and integrative departments (Martinez and Jarillo, 1989). Joint innovation is also included, which can establish global competence groups representing a united experience and insight of factories (Rudberg and West, 2008). In fact, a collaborative environment promotes the integration of factories (Arellano *et al.*, 2021).

Informal coordination includes communication throughout the IMNs, containing personal contacts among managers, meetings, and conferences, which supplement the formal coordination channels (Martinez and Jarillo, 1989). Active participation in development activities across IMNs has been shown to facilitate standardization across factories by providing insight and understanding of factories' needs (Granlund *et al.*, 2019). Participation has thus been vital for developing technology, products, and processes and acquiring knowledge on updates and improvements (Rudberg and West, 2008; Shi and Gregory, 1998). However, adding digital transformation into the IMN might alter the preconditions of coordination.

2.2 Applying an IMN perspective to digital transformation

Introducing digital transformation into IMNs comes with prerequisites, largely due to the interdependent nature of IMNs, which discourages focusing only on individual factories (Arellano *et al.*, 2021). Managing this complexity requires acquiring managerial capabilities to balance local and network levels while developing standards for technology and processes to prevent implementation and integration complications (Horváth and Szabó, 2019). However, because digital transformation comes without best practices, integrating new technologies demands both time-consuming development and simultaneous learning, particularly given the variability in legacy systems across factories. This variability can hinder smooth technology transfers between factories and complicate digital transformation efforts within IMNs, as different production setups across factories exacerbate the challenges (Ahlskog *et al.*, 2023). In fact, best practices, like advanced manufacturing technologies, may not be equally effective for all factory roles. Implementing such technologies in higher-level factories, like lead factories, can impact differentiation performance, yet lower-level roles may instead be impacted negatively (Demeter *et al.*, 2017).

Digital transformation is an overarching concept encompassing factories' digitalization via digital technologies (Horváth and Szabó, 2019). It can be broken down into three phases: digitization, digitalization and digital transformation, all triggered by the introduction of digital technologies. During digitization, information is converted from analog to digital (Verhoef *et al.*, 2021). Digitalization involves exploring new technologies at the operational level, while digital transformation emphasizes achievements at the strategic level (Gong and Ribiere, 2021). Digital transformation, therefore, represents a fundamental shift powered by digital technologies and the strategic use of key resources and capabilities aimed at dramatically improving the company and redefining its value to stakeholders (Gong and Ribiere, 2021). Since digital transformation involves strategic, company-wide changes, it affects various levels of the organization, including structures, resources, and capabilities (Verhoef *et al.*, 2021).

The traditional ways of working with production system development have shifted due to digital transformation, necessitating the inclusion of new knowledge domains and increasing system complexity (Ahlskog *et al.*, 2023). Therefore, digital transformation cannot be viewed solely from a technological perspective. Suggested adaptations of organizational structures comprise two levels: a global unit(s) responsible for overseeing digital transformation and coordinating technological and organizational innovations and local units with hands-on digitalization activities (Smith and Beretta, 2021). New interfaces should link these two levels where formal and informal coordination affect their effectiveness, highlighting the need for tools that foster collaboration (Kiely *et al.*, 2022). Because manufacturing companies tend to be hierarchical and formalized, it is essential to establish roles that remove the functional silos and promote collaboration (Imran *et al.*, 2021). Such roles include boundary spanners between levels of the IMN and operational-oriented IT functions that are fluent between levels (Badasjane *et al.*, 2023).

Previous research also points out the need for formalization at both levels of the new organizational structures of the IMN, precisely defining their roles, responsibilities, and expectations while leaving room for future adjustments, depending on the unexpected needs of the IMN concerning digital transformation (Badasjane *et al.*, 2022). Consequently, new competencies are also needed in leadership positions, such as spreading awareness, endorsing collaborations, driving digital transformation and coordinating knowledge, and emphasizing adaptability or flexibility (Imran *et al.*, 2021). Nevertheless, digital transformation lacks answers, uniform solutions, rules, and outcomes that manufacturing companies can easily apply (Kane *et al.*, 2019).

2.3 Digital transformation within the TOE framework

The context of a company influences the adoption and implementation of technological innovation. To explain how this influence occurs, the technology-organization-environment (TOE) framework, an organization-level theory stemming from Tornatzky and Fleischer (1990), can be used. This framework has been used extensively in many contexts and has shown its applicability across various research domains due to its explanatory power (Baker, 2012). For instance, it has been applied in online retailing utilization in digital transformation (Xuan Cu, 2022) and digital transformation of small- and medium-sized enterprises (Qi *et al.*, 2023). Additionally, the TOE framework is highly adaptable, allowing for examining different factors within the three contexts, as each technology or context produces a unique set of characteristics (Baker, 2012).

The *technological* context consists of technologies relevant to a company, including processes and equipment (Tornatzky and Fleischer, 1990). A company's existing technologies are important in the adoption process because they limit the scope and pace of technological change a company can undertake (Baker, 2012). In this paper, the technology possibilities outside a company are seen in the environmental context, as these technologies need to be identified in the market and selected.

Notably, implementing technology can disrupt a company's functions. While some implementations are barely noticeable and have the lowest risk, others can create a moderate change and conform to existing technology. Technology can, however, significantly change companies and require them to make rapid and decisive adoption decisions (Ettlie *et al.*, 1984). As such, the adopted technology can dramatically alter the company and the industry (Baker, 2012). The *organizational* context includes a company's characteristics and resources; these factors deal with the degree of formalization, managerial structure, and employee interfaces (Tornatzky and Fleischer, 1990). Here, the adoption of technology is enforced by roles such as gatekeepers, champions, or boundary spanners, as well as roles or cross-functional teams that serve as interfaces (formally or informally) (Baker, 2012). In this context, other factors can include communication processes and top management's creation of a supportive culture (Tushman and Nadler, 1986), which involves forming executive teams to formalize a vision (Baker, 2012). Last, the *environmental* context deals with, for instance, the size and structure of the industry, its competitors, and regulations. This context brings up a company's current phase and whether that company is growing and maturing, which affects the introduction of novel technologies (Tornatzky and Fleischer, 1990).

Even though this framework has been used to examine the digital transformation of companies, to the best of our knowledge, it has not been used to study the digital transformation of IMNs. Leveraging the TOE framework could offer a novel perspective in understanding the unique dynamics and nuances of digital transformation in IMNs. It could, in turn, contribute to unraveling how the digital transformation necessitates changes in the coordination of IMNs.

3. Research design

A case study was performed to accommodate the purpose of this paper, i.e. to explore how digital transformation necessitates changes in the coordination of IMNs. Motivated by limited access to empirical research covering the examined area of research (Horváth and Szabó, 2019), the empirical data collection approach was deemed appropriate to understand the intricacies present in IMNs, thus taking advantage of the strengths of analyzing qualitative data to illuminate the context, understand latent or underlying subjects, and expose complexities (Miles and Huberman, 1994). Because digital transformation and its coordination in IMNs are context-bound and multifaceted, the case study approach was deemed suitable, as it allows for obtaining new and creative insight valuable for practitioners (Voss *et al.*, 2002). This approach has its limitations in generalizability compared with other methods. Yet, due to the limited explanations of the examined research area in a real-life setting, the case study method was most suitable to begin filling the identified research gap and providing necessary depth rather than broader reach, which would be possible by, for instance, a survey (Yin, 2018).

Three manufacturing companies located in Sweden (referred to as companies A, B, and C) were selected based on multiple criteria:

(1) They had to operate an IMN, which includes its coordination;

(2) The companies should actively work with digital transformation in their IMNs and

(3) The companies took steps toward coordinating the digital transformation in the IMNs.

Hence, the criteria implied that the digital transformation should not be confined to one specific factory (local level). The selected companies should have a team at the global level (centralized function, outside of a factory) responsible for the coordination of digital transformation in the entire IMN. As such, in line with Patton (2002), the case companies were selected based on the richness of the available examples of the studied phenomenon and served as a reasonably common representation of the industry.

Company A is a heavy vehicle manufacturing company operating in 180 countries and employing 15,000 people. This company had established a global team that was mandated to define and coordinate the digital transformation throughout the IMN and local teams at each of their 14 factories, which possessed the operational responsibility for digitalization.

Company B is an automotive manufacturing company operating in 33 countries with 30,000 employees. Their digital transformation approach included global and local initiatives and incorporated technology roadmaps. The participants in this study were connected to supporting digital transformation on global and local levels.

Company C is a manufacturing company spread out in 43 countries with 43,000 employees. This company established a global support function focusing on the standardization of digitalization technology in their IMN and worked closely with a lead factory in the IMN in their development endeavors. Where the global function had the overall digital transformation vision, its execution relied heavily on this lead factory.

3.1 Data collection

Data collection was conducted between December 2019 and September 2023 and included 37 interviews, documents, two workshops, feedback loops with each company, and informal discussions with key personnel. The interview respondents were speaking from strategic and operational perspectives and were located in different factories or global organizations (see Table 1). Noteworthy, data saturation was achieved more quickly at Company C, requiring fewer interviews due to its clear structure and active participants. The internal structure, with a dedicated department and global function overseeing digital transformation, allowed for targeted interviews. Additionally, Company C's workshop participants were more vocal, resulting in a stronger focus on insights from this company. Despite fewer interviews, the insights were sufficient and consistent with findings from the other case companies, validated by a feedback loop. Saunders *et al.* (2018) explain that saturation occurs when no new insights emerge.

The interviews were approximately 45–90 min and focused on the following areas: (1) how the companies generally work with production and technology development in their IMNs and coordinate their efforts. This focus was required to understand the companies' preconditions and (2) how they work with digital transformation in the IMNs, including ways of working and coordination. Emphasis was on establishing the attributes of digital transformation that force companies to adapt their usual manner of conducting production and technology development and its coordination (e.g. additional necessary coordination, how it is now performed and why in this new way, examples of what is now coordinated). Relevant documents, including

Table 1. Representation of interviewees from Company A-C

Company	No. of interviews	Job description of interviewees
A	16	Manufacturing technology development manager, global manufacturing engineering manager, global quality and data management manager, specialist and local team leader (2), global logistics director, process and IT director, process and IT (2), digitalization strategy manager, HR, maintenance specialist, virtual manufacturing specialist and director of sustainability
B	16	Global R&D, manufacturing engineering (2), program office manager, technology transformation manager, manufacturing engineering development manager, manufacturing technology specialist (2), global manufacturing technology manager (3), technology process manager, VP digitalization and IT, VP manufacturing technologies, technology development and testing manager, digital and IT manager
C	5	Reliability and digital transformation manager, program office manager, technology transformation manager, technical lead manufacturing IT and regional director of IT

Source(s): Authors' own work

organizational charts, functional and role descriptions, digitalization roadmaps, vision statements, etc., were collected during the interviews.

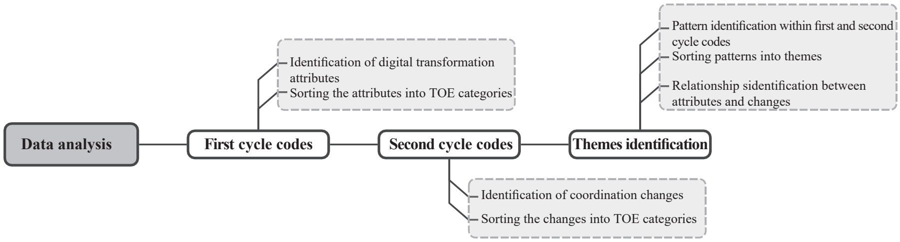
The interview data was complemented by two workshops, wherein company representatives could interact with each other and the authors. The workshops were online, each lasting 180 minutes, and managed by the authors. The first workshop focused on company presentations of experienced digital transformation challenges, in which the companies included their approach and work practices according to the guidelines provided in advance. This workshop provided insight into company preconditions and work with digital transformation. The second workshop deepened the focus on the coordination of their IMNs in connection to production and technology development in general and in connection to digital transformation.

Additionally, the data-collection phase was concluded by feedback loops to each company (three with Company A, one each with companies B and C). The intent was to present the findings to validate their accuracy, provide room for discussion, and collect information about recent company changes.

3.2 Data analysis

The data analysis consisted of multiple iterative steps involving collecting empirical data and theory. The latter consisted of a literature review and categorization to identify key findings from previous research to arrive at research gaps, case selection criteria, and provide guidance for empirical data collection design (i.e. design of workshops, interview focus, and interview questions). The collected empirical data were documented in a case study protocol to provide a chronological overview and enable data filtering (Yin, 2018). The authors reread the transcribed interview and workshop data multiple times to keep updated with its content and gain familiarity. Notably, the collection occurred iteratively to enrich already collected data, e.g. by designing a workshop to fill in data gaps (Miles and Huberman, 1994). Thereafter, the data analysis was performed, as represented in Figure 1.

The data analysis was performed in multiple steps, first to fulfill each segment of the purpose and then to identify the relationships. The first step of the data analysis consisted of extrapolating the attributes of digital transformation and sorting the attributes into the first cycle codes. The deductive first cycle codes stemmed from the TOE framework, i.e. the



Source(s): Authors' own work

Figure 1. Data analysis procedure

technological, organizational, and environmental context (Baker, 2012). As such, the TOE framework provided focus and guidance for data analysis. Likewise, the same process was recreated but focused on coordinating digital transformation, which became the second cycle codes. The coordination codes were sorted into the TOE framework categories. Until now, the first and second cycle codes were analyzed separately. The codes were not strictly confined to the TOE categories; however, no new codes emerged from the data analysis.

In the last step, patterns within the first and second cycle codes were identified. Pattern identification was focused on revealing relationships and interconnections between the digital transformation attributes and the changes they necessitated in the IMN coordination. The identified patterns could then be sorted into themes that represented an intermediate between the two cycle codes, i.e. the attributes and the changes they necessitated in coordinating IMNs.

Last, the analysis was reviewed, which included relabeling, removal of overlaps, and removal of codes that did not correspond to the study's purpose. This process was enabled by repeated discussions between the authors, scrutinizing the content of the overall analysis, codes, patterns, and themes to ensure coherence and validity.

4. Empirical findings

This section presents the empirical findings within the TOE framework, concluding with a summation of the case study findings.

4.1 Technological context

Across the case companies, the prioritization of speed over perfection during digital technology development was highlighted as a common attribute of digital transformation. The objective is to accelerate digitalization activities by choosing solutions that are sufficient but may not reach perfection, as explained: *"The only thing we do know is that changes will arise, no matter if the solution is perfect or good enough, certain solutions need to be in place to enable the continuation of work. Then it is better to have a good enough solution that can be rolled out globally"* (Company C). Hence, emphasizing speed in development activities to enable the swift rollout of solutions is crucial for establishing global standards. The rationale behind this lies in avoiding potential bottlenecks in future development trajectories based on already set standards in the IMNs. Thus, heightened emphasis has been placed on standardization, rapid deployment, and dissemination of digitalization solutions. Therefore, coordination must be adapted to reflect the focus on speed and provide a proficient infrastructure that enables the global standard solutions' rollout.

There is an agreement in the case companies that digitalization technologies require a myriad of competencies spread out in the IMNs, which raises the demand for cohesive collaboration, specifically coordination and intensified collaboration between the technology or process development functions and IT. By doing this, the inherent competencies present in the IMNs can be leveraged, though it requires a joint effort to harness the competencies present in factories and overcome the difficulties of digital transformation, as explained: *"We are developing and learning at the same time as we're implementing, and this is what we need to learn to live with during this transformation"* (Company A). Co-development initiatives are perceived as pivotal in expediting the implementation and widespread adoption of new digitalization solutions, which demand coordination.

Digital transformation enforces a change in mindset, from focusing on what is best for the factory to what is needed in the IMN. This adjustment in mindset poses certain demands on IMNs, as factories are used to performing development activities suited for the factory alone: *"We are not used to this; it is a cultural challenge because the factories want to do as they please"* (Company C). Moreover, as only local digitalization initiatives do not drive the digital transformation in IMNs, the case companies perceive establishing a global-level infrastructure to facilitate coordination across operational domains as necessary. The emphasis on speed should harmonize with standardization and efficient global deployment to synchronize the accelerated advancement throughout the IMNs. Traditional developmental efforts have primarily addressed local issues, effectively preventing or constraining the widespread adoption of solutions. However, the strengths of factories certainly have their upsides: *"It may look a bit depressive and negative, but the strong drive in factories has de facto always pushed the company forward. But this culture is not helpful when we enter the digitalization era as it demands a more standardized approach"* (Company C).

There is, however, a paradox in balancing identified local needs and digitalization opportunities with possibly slowing local progress waiting for, e.g. a global IT solution. The digital transformation thus creates a need to develop global solution standards even before local factory needs have been expressed. This demands that the global tier have the structure and roles to understand factory prerequisites and foresee future needs. There is also a need to combine competencies from different areas, such as production and IT. Additionally, the paradox stresses the need to synchronize and coordinate digitalization activities across IMN.

The distributed nature of an IMN, along with the ongoing digitalization activities across factories, underscores the stronger global pressures to coordinate and capitalize on ongoing activities benefiting the entire IMNs. This contrasts with previous transformation approaches (e.g. the ERP transitions), which are mainly top-down initiatives, thus highlighting the increased need to coordinate local digitalization activities in the IMNs.

4.2 Organizational context

Managing digital transformation poses several changes to the organizational structures and requires a strong global commitment to leverage the unique strengths of belonging to an IMN. As indicated in the previous section, a global focus on coordinating initiatives in the IMNs is imperative. The case companies aim to utilize these strengths to drive global benefits and synchronization, thus emphasizing the need for global unity to amplify results.

Another attribute of digital transformation addresses the organizational structure in IMNs and specifically how the production development function is arranged to conform to the digital transformation. The case companies have created an organizational structure around digital transformation, thus reflecting the necessity to adapt to evolving technological landscapes, as explained: *"The challenge is to break free from old roles and ways of working and breaking down functional barriers"* (Company B). The pressures to capitalize on ongoing but widespread digitalization activities in the IMNs have also led to the need for a global production development and coordination tier. This tier ensures that digital transformation efforts are consistently coordinated across the IMN of two case companies, addressing previous weaknesses in the global structure.

The global tier also requires funding. Several implications have risen by addressing the cost concerns and appointing a factory as the lead for digitalization, as explained: *"This is a huge difference in how we work"* (Company C). This major difference includes distinct coordination of activities across the IMN and a dedicated budget thereof. Notably, successful coordination in these two case companies is specifically attributed to the infusion of global funding.

The accelerated speed of digital transformation demands IMNs to reevaluate and adapt their ways of working with digital technology development. Specifically, adapting the organizational structures to enable coordination between various functions scattered throughout the IMNs is necessary to optimize the speed and efficiency of digitalization activities. Digital transformation requires organizations in the IMNs to strategically adapt their ways of collaborating to align with the rapid pace of technological change. Central to this adaptation is the emphasis on early-stage and cross-functional collaboration, as explained: *"We need to work cross-functionally and in whole other ways, especially in the early phases of development"* (Company B). Coordination is, thus, needed between new functions created to accommodate digital transformation and existing ones.

Specifically, the existing organizational structures are deemed insufficient during digital transformation due to the difficulty of foreseeing developmental needs. For instance, the need for close collaboration between the factory and IT departments becomes apparent when the factory development personnel lack the expertise to envision an IT solution to propel development. Relying on existing organizational structures is inadequate, and openness in adjusting organizational structures and ways of working is needed. The case companies agree that the organizational structure must be adapted to facilitate coordination between personnel with appropriate expertise and to capture emergent development needs across the IMNs to provide the necessary support.

4.3 Environmental context

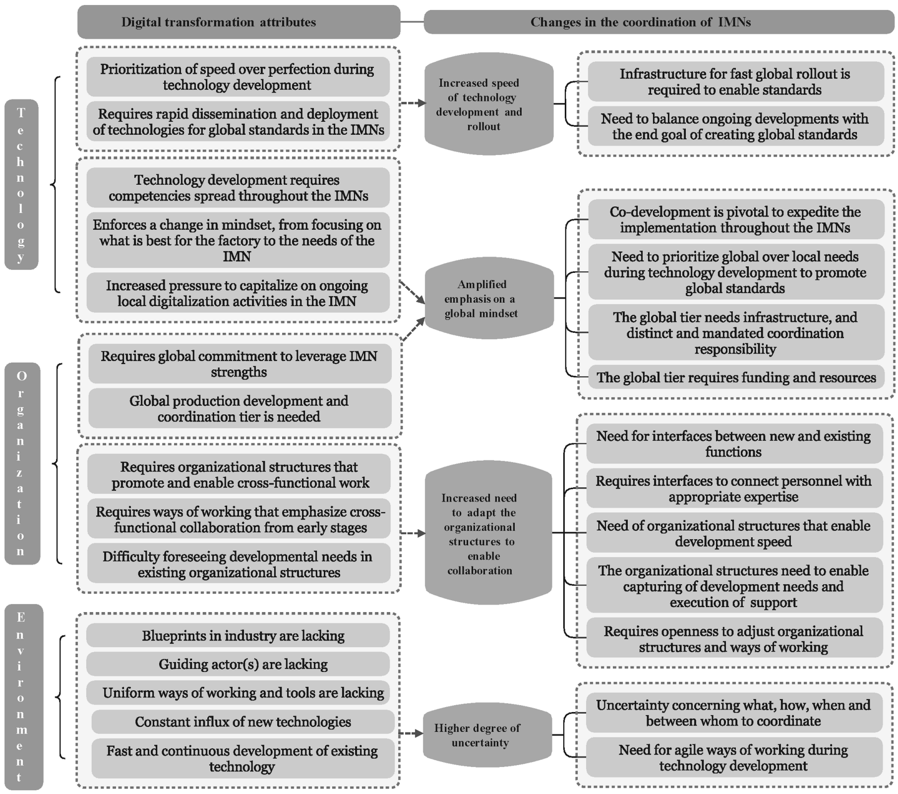
Examining digital transformation within IMNs reveals a landscape fraught with uncertainties, particularly in the absence of predefined blueprints for execution. Coordination emerges as a key factor and plays a crucial role in digital transformation at all levels of the IMNs. However, the inherent difficulties with digital transformation stem from its elusive nature, which requires coordination beyond what IMNs are traditionally used to. Specifically, adding uncertainty concerning how coordination should look like to conform to digital transformation. One case company identifies the attributes of digital transformation to three specific factors: *"We have the speed, the uncertainty, and continual changes. Each step we take changes the preconditions, and you have to pause and reflect before taking any more steps forward"* (Company B).

Because of the lack of a guiding actor or universally applicable ways of working and tools for digital transformation, this vacuum is attributed as a distinct challenge compared with previous transformations, e.g. Lean. Hence, the uncertainties and difficulties with digital transformation can be traced back to the challenges in achieving a united organizational front aligned with a uniform vision and goals. As such, digital transformation confronts IMNs with uncharted terrain requiring a strategic roadmap for effective navigation, as exemplified by two case companies: *"We don't have a template, and therefore, we need to coordinate it a bit differently"* (Company A) and *"It is undeniably difficult to paint a clear picture because we can't predict how it should look like"* (Company B). The lack of precedent in the manufacturing industry underscores the uniqueness of the challenges posed by digital transformation, as does the absence of established best practices. No company has completed the transformation that could serve as a guiding actor or role model and weed through the coordination uncertainties when handling digital transformation in IMNs. Therefore, the coordination uncertainty cannot be resolved by looking outward from the IMNs.

The constant influx of new and niche digitalization technologies also adds difficulties in handling digital transformation in the IMNs. Consequently, it affects the coordination within IMNs, balancing the act of time-consuming investigations while maintaining the clear direction of creating global standard solutions for the IMN. However, remaining in the state-of-the-art stage comes with difficulties: *"It is difficult to change directions when a solution pops up which is theoretically better, but you cannot investigate both of them. And the solutions are not mature."* (Company A). The rapid speed and continual development of existing digital technologies require that IMN factories relieve dependence on rigid plans and usual ways of working with technology development. Specifically appointed is an agile way of working during technology development. Yet this standpoint has already affected the coordination of the IMNs: *"If we don't know where we are heading, then it's even more difficult to coordinate the initiatives coming in"* (Company B).

4.4 Summary of results

Figure 2 summarizes the findings of how the digital transformation necessitates changes in the coordination of IMNs. To this end, using the three categories of the TOE framework, digital transformation attributes are identified and the changes they necessitate in the coordination of IMNs.



Source(s): Authors' own work

Figure 2. Summary of case study findings

5. Discussion

This study's results and analysis using the TOE framework reveal how digital transformation necessitates changes in the coordination of IMNs. It is shown that digital transformation attributes escalate the need for coordination of IMNs as the pressure to synchronize within the IMN intensifies. However, the case companies demonstrate that the nature of how coordination is affected seems to be interlocked with one dominant aspect, i.e. uncertainty. Uncertainty stems from the environmental context and permeates the contexts of technology and organization. This finding indicates that coordination of an IMN is ordinarily demanding and that complexity intensifies when adding digital transformation.

5.1 Increased speed of technology development and rollout

In line with Baker (2012) and Ettlie *et al.* (1984), the case companies demonstrated how technology dramatically alters the IMNs. Digital technologies can thus be characterized as significantly changing companies, and coordination has been affected in two main ways due to the digital transformation attributes within this theme. Foremost, structures for the fast global rollout are required to enable standard solutions benefitting the IMNs, which can be linked to the formal plans and structures needed in the IMNs (Deflorin *et al.*, 2021). Likewise, standardization has been raised in previous research within this context, pointing out the formalization of roles, responsibilities, and expectations as possible coping mechanisms to resolve the imminent challenges with the coordination of digital transformation in IMNs (Badasjane *et al.*, 2022).

Hence, the main objective seems to revolve around creating global standard solutions, which require formal coordination covering organizational structure, formalization, and standardization (Sayem *et al.*, 2018). Moreover, as more focus is placed on creating standards, previous research has demonstrated that standardization can be facilitated by active participation in development activities, thus raising awareness of factories' needs across the IMNs (Granlund *et al.*, 2019). Standardization is a common reoccurring difficulty within IMNs and is brought into focus within the research domain. However, this study finds digital transformation attributes that amplify the need to resolve coordination issues, which may otherwise hinder the coordination of digital transformation in the IMNs.

Instead of following traditional methods that aim to find a perfect solution tailored to each factory, the focus seems to have shifted to using global standard solutions to prevent technological challenges in IMNs. This shift can be questioned, especially given the findings of Demeter *et al.* (2017), which suggest that best practices, e.g. advanced manufacturing technology, are not equally suited for all factory roles. Lower-lever factories, in particular, may experience a negative impact. Addressing this issue may require fostering a global mindset, emphasizing the importance of balancing standardized solutions with the specific needs of individual factories.

5.2 Amplified emphasis on a global mindset

Although a global mindset is crucial for standardization in IMNs, it represents a broader effect of digital transformation on coordination within these networks. While individual factories may possess development power, their initiatives should evolve into global standards that benefit the entire network. This global perspective has long been a guiding principle (Rudberg and West, 2008) and is now amplified by the pressures of digital transformation. The drive to capitalize on the widespread digitalization efforts contrasts with the typical top-down approach, where factories receive standardized implementation initiatives. However, it is important to recognize that not all factories have the same role or the broader network perspective necessary to align their development efforts to develop global IMN standards (Vereecke *et al.*, 2006). The factories are now expected to collaborate more closely, share knowledge, and contribute to overall digitalization, regardless of their position within the IMN during digital transformation.

This intensifies the involvement of factories in knowledge exchange (Cheng *et al.*, 2021; Szász *et al.*, 2019), making their contributions to the IMN's digital transformation more crucial.

Another issue is that digital technology development requires specific competencies that are not neatly gathered in one function of the IMN; rather, they are spread out through the multiple levels of the IMN, e.g. specific factories and global production development. However, co-development involves gathering skilled personnel, which must be coordinated on an IMN level. This expands the complexity of coordination to include another level that is new to the case companies but is required to expedite the implementation of digitalization solutions in the IMN. Ahlskog *et al*. (2023) note that system complexity is increased when dealing with digital transformation and requires the inclusion of new knowledge domains.

Altogether, these attributes result in needed alterations to the organizational structures of the IMNs, requiring global commitment to leverage IMN strengths. Hence, realizing the organizational structure alterations depends on top management's commitment to harness the potential present in the IMN and the advantages the adaptations can bring about for coordination purposes. Similarly, Tushman and Nadler (1986) and Baker (2012) propose a supportive top management culture and executive teams.

A specific alteration noted in the case companies is the introduction of a global tier of production development. This global tier is deemed crucial for coordinating digital transformation throughout the IMNs. It must possess distinct and mandated coordination responsibilities to properly execute its overview role and infrastructure for coordination execution. Hence, the findings coalign with previous research that point out the importance of attaining skills on the management level and endorse collaboration in the IMN (Imran *et al.*, 2021). Last, the global tier should also possess global funding and resources that affect its success and the extent of its coordination.

5.3 Increased need to adapt the organizational structures to enable collaboration

The most prominent attribute of digital transformation is the increased need to adapt the organizational structures to enable collaboration within the IMNs. This adaptation involves liberating from traditional structures, dismantling organizational silos and moving away from rigid plans. Instead, digital transformation drives the need for organizational structures to be adapted to promote and enable cross-functional work, allowing them to respond effectively to changes in work methodologies, specifically emphasizing early and cross-functional collaborations in the IMNs. As such, there is a pressing need to reevaluate and extend the formal coordination (Badasjane, 2023).

Therefore, it is essential to coordinate digitalization efforts within IMNs by aligning existing and newly established functions. This requires collaboration structures that connect personnel with the right expertise. Past studies highlight boundary spanners and cross-functional teams as vital organizational structures for coordinating digital transformation in IMNs (Badasjane *et al*., 2023). Hence, the degree of formalization (Tornatzky and Fleischer, 1990) requires questioning. Indeed, the need for adaptation can conflict with the formalization required to coordinate IMNs, leading to a greater reliance on informal coordination based on immediate needs. Generally, as informal coordination is more fickle and based on personal contacts and supplements formal coordination (Deflorin *et al*., 2021; Martinez and Jarillo, 1989), the findings leaning toward informal coordination coincide with expressed needed flexibility prompted by the case companies.

Nevertheless, the prioritization of speed raises the need for organizational structures that enable IMNs to meet this digital transformation attribute. It is essential to remove functional silos and promote collaboration during digital transformation (Imran *et al.*, 2021); however, linking the levels of the IMN requires tools that enable collaboration (Kiely *et al*., 2022). This study further confirms the precedent of adapting the existing organizational structures, as the existing ones are insufficient during digital transformation. Logic prevails that if the organizational structures are adapted, coordination must be shaped to correspond to the changes. One such alteration is the requirement of closeness to IT expertise during technology development, which can be upfilled by coordinating roles such as boundary spanners or operational IT functional units (Badasjane *et al.*, 2023). These kinds of alterations are needed to capture the present development needs in the IMNs and to execute support, especially as a response to the difficulty of foreseeing needs within the existing organizational structures.

5.4 Higher degree of uncertainty

The major attribute of digital transformation is the lack of blueprints and precedents of how it should be performed, and there are no guiding actors that could aid the manufacturing industry that has already paved the way and could provide validated methodology and tools. Kane *et al.* (2019) point out the lack of uniform solutions, rules, and outcomes accompanying digital transformation, and the case study findings highlight the coordination uncertainty brought about by their absence. This adds uncertainty to the coordination of the IMNs involving what to coordinate, how the coordination should be performed, when it is most beneficial to coordinate, and between whom. Parallels can also be drawn to the changes in organizational structures to benefit the coordination of digital transformation and the resulting new interfaces and functions that add uncertainty to coordination with the existing structures. The case companies pose many relevant questions, although they still operate within a mature and sizable industry (Tushman and Nadler, 1986). They agree on the struggle to predict how digital transformation will inevitably alter the landscape and, consequently, the coordination of the IMNs. Thus, the uncertainty needs internal resolution.

Last, the speed of change has been pointed out in previous research as a major uniqueness of digital transformation (Loonam *et al.*, 2018; Smith and Beretta, 2021). This study highlights how the ongoing introduction of new technologies and rapid changes to existing ones impacts the coordination of IMNs. This often necessitates greater reliance on informal coordination, especially when technology development is conducted more agile than companies are accustomed to.

5.5 Theoretical and managerial implications

This study contributes to the increasing body of work covering digital transformation. Contemporary research concurs that digital transformation shakes the manufacturing industry by affecting many aspects, such as culture, strategy and processes and is therefore associated with uncertainties and complexities (Gong and Ribiere, 2021; Warner and Wäger, 2019). This paper contributes to lessening the uncertainties by bringing them up to the surface. Specifically, the findings have implications for theory in two main ways.

First, digital transformation is examined within the context of IMNs, which in and of itself requires coordination, and previous research highlights the need to adapt coordination to the context in which it is performed (Sayem *et al.*, 2018). Thus, this study contributes to the global production domain by focusing on the IMN view, extending the prior factory-focused research covering digital transformation. Yet, the manners in which coordination is affected and what needs to be adapted for manufacturing companies to coordinate digital transformation in their IMNs has been largely unexplored. This paper decreases this omission by using the TOE framework to identify (1) the digital transformation attributes, (2) the changes the attributes have on the coordination of IMNs, and (3) intermediate themes between the attributes and changes.

The second contribution to theory is the content of the four identified themes. Each theme is thoroughly described and highlighted by empirical data from three case companies providing concrete examples from the manufacturing industry that add to current research. Hence, by adopting a qualitative case study approach, this paper answers the call to focus on applied research needed in the manufacturing sector (Bosman *et al.*, 2020) and provides evidence and concrete industry examples that broadcast the experience of practitioners dealing with digital transformation and its coordination in the IMNs.

Concretely, the findings illustrate how the case companies are confronted with balancing the speed and standardization of digitalization activities in their IMNs. This involves the challenge of simultaneously developing technology for both factory and IMN needs while striving to establish standardized best practices throughout the IMN. The study underscores the difficulty in balancing this conflict. Digital transformation demands a shift in mindset from local factory-centric development to a global IMN perspective. The findings also pinpoint the need for cross-functional collaboration and the elimination of silos for dealing with the rapid pace of technology influx caused by digital transformation, consequently reevaluating the existing organizational structures for efficient coordination in the IMNs. Lastly, this study highlights the fundamental challenge of digital transformation—the absence of established blueprints or guiding actors for the manufacturing industry. This confirms previous research pressing the need to alter the organizational structures during digital transformation (Imran *et al.*, 2021; Verhoef *et al.*, 2021) and gives concrete reasoning for the alterations.

This paper also provides insight and implications for managers dealing with digital transformation and having a coordinating role in their IMNs. The identified digital transformation attributes in IMNs can enable global managers to unravel the intricacies of digital transformation within an already complicated context of IMNs and global operations. By understanding the attributes of digital transformation, corresponding actions can be formed to fit the new circumstances.

Moreover, the attributes, as seen in Figure 2, can be a basis for evaluating the current coordination of the IMN and whether it corresponds with the needs posed by the digital transformation. To this point, the coordination of digital transformation can be examined from technology, organizational, and environmental perspectives to evaluate possible adaptations to the coordination. Lastly, this study pinpoints that digital transformation attributes escalate the need for coordination due to the pressures to synchronize activities in the IMNs. At the same time, the findings point to uncertainty as the dominant aspect currently faced by the manufacturing industry, which is a difficult challenge to overcome and is a valuable input for global managers on where to place effort.

6. Conclusions

The paper's contribution is the identification of 15 digital transformation attributes linked by four intermediate themes and 13 necessary changes in the coordination of IMNs. The TOE framework provides a conceptual understanding of how digital transformation attributes affect the coordination of IMNs. Manufacturing companies need to manage the increased speed of technology development and rollout, the amplified emphasis on a global mindset, the increased need to adapt the organizational structures to enable collaboration, and a higher degree of uncertainty.

While digital transformation has been investigated from multiple perspectives in previous literature, covering aspects such as the organizational structure (Horváth and Szabó, 2019), this study is the first attempt to provide an understanding of how digital transformation attributes specifically necessitate changes in the coordination of IMNs.

A few studies have explored the coordination of digital transformation in IMNs (Badasjane *et al.*, 2022; Deflorin *et al.*, 2021). Focusing on coordination is essential, as it is vital to an IMN's success (Cheng *et al.*, 2016; Norouzilame, 2018). This study shows how the manufacturing industry is currently adapting to the coordination of digital transformation in IMNs and the uncertainties that need managing. A last contribution is the identification of four intermediate themes that were not previously discussed in this context.

6.1 Limitations and future research paths

This study has limitations, primarily those inherent to the case study approach, such as the limited reach that a survey could have avoided. Future work could measure the impact of digital transformation attributes on IMN coordination. Although this case study examined three companies from different industries, the focus was not on comparing them but on creating a narrative and strengthening the findings' generalizability. More research is needed to compare how multiple companies handle uncertainties caused by digital transformation attributes. This calls for research exploring how global manufacturing companies can adjust coordination to meet digital transformation demands efficiently.

Future research could also investigate how digital transformation and technologies can be tailored to diverse factory roles within IMNs. It could explore the negative impacts of standardized solutions on lower-level factories and examine strategies to balance global standards with individual factory needs. Additionally, future research could analyze how different factory roles influence contributions to digital transformation, offering insights into fostering a global mindset that accommodates varying technological readiness across IMNs.

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