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# THE PROCESS OF ACTUALIZATION OF DIGITAL TECHNOLOGIES AFFORDANCES IN ORGANIZATIONS

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KAUNO TECHNOLOGIJOS UNIVERSITETAS

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# SKAITMENINIŲ TECHNOLOGIJŲ NULEMTŲ ĮGALINIMŲ AKTUALIZAVIMO PROCESAS ORGANIZACIJOSE

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## LIST OF ABBREVIATIONS AND DEFINITIONS

**Abbreviations:**

EMS – European Manufacturing Survey
PLS-SEM – Partial least squares structural equation modeling
PLS-MGA – Partial Least squares multigroup analysis
RBV– Resource-based view
NACE C – Nomenclature of Economic Activities (Manufacturing)

**Definitions:**

**Digitalization –** a business transformation through the implementation of digital tools to optimize the organization's operations.

**Digital capabilities –** the high-level skills required to utilize advanced technologies.

**Digital transformation –** refers to the combined effect of various digital advancements that give rise to novel entities, frameworks, methodologies, and principles that modify, supplant, or supplement the current norms and regulations in institutions, networks, sectors, or domains.

**Digital technologies –** tools which allow the generation, accessing, gathering, manipulating, presenting, or communicating of information expressed in binary form.

**Process** – series of steps that are executed in a particular order to achieve a specific outcome or result.

**Affordance –** the action potential offered by digital technology that occurs in the relationship between a digital technology with certain characteristics and a goal-oriented person.

**Actualization of affordances –** the realization of the action potential offered by digital technologies.

**Augmentation affordance –** enabling and enhancing human performance in the execution of various tasks (Raisch and Krakowski, 2021).

**Connect affordance –** utilizing wireless communication networks in an organizational context to facilitate the exchange of data and information between individuals and digital devices (Lenka et al., 2017).

**Analytic affordance** – gathering data from the operations of the organization and surroundings and utilizing software tools to convert it into beneficial knowledge and company guidelines (Lenka et al., 2017).

**Automation affordance –** enabling an operation or system to function independently (Raisch and Krakowski, 2021).

# INTRODUCTION

## Situation

In recent decades, digital technologies have become inseparable from our lives, influencing how we communicate, work, and interact with our environment. The rapid advancement and widespread adoption of these technologies have presented a myriad of opportunities and challenges for individuals, organizations, industries, and societies alike. Organizations must quickly adapt to an ever-evolving landscape where new digital technologies are continually emerging (Kraus et al., 2022; Konopik et al., 2022; Vial, 2019). Central to this transformation is digitalization. The success of an organization today hinges on its understanding of the processes and drivers of the digitalized environment and its ability to address the impacts of digital technologies (Yang et al., 2021; Martinez-Caro et al., 2020). Organizations harness digital technologies to boost efficiency, spur innovation, enhance customization, and forge competitive advantages (Lin and Lin, 2023; Clauss et al., 2021; Bharadwaj et al., 2013).

While digital transformation opens new avenues of opportunity, it simultaneously poses novel challenges for organizations. Digital technologies have a profound impact on an organization's business strategy (Tsou and Chen, 2022; Zaki, 2019; Hess et al., 2016; Bharadwaj et al., 2013). They also reshape organizational culture, redefine employee roles, and transform company structures (Lanzolla et al., 2020; Grover et al., 2022; Martinez-Caro et al., 2020; Singh et al., 2020). The COVID-19 pandemic has only hastened these digitalization-related organizational shifts (Nagel, 2020; Soto-Acosta, 2020; Kudyba, 2020). Simply integrating various digital technologies into an organization is not sufficient. What is paramount is how these organizations utilize and evolve these technologies (Denner et al., 2018). As posited by Volkoff and Strong (2013) and Zammuto et al. (2007), the initiation of digital technologies triggers a set of "digital technologies' affordances"—such as the capability to visualize entire work processes, enhanced communication, data analysis, and simulation. An "affordance" is described as the action potential provided by a digital technology (Majchrzak and Markus, 2012). The process of actualizing these digital technologies' affordances is crucial for an organization's success and efficient resource use. This actualization translates the potential benefits of digital technologies into tangible results. Given that companies operate with finite resources, prioritizing which digital technologies affordance to actualize first, second, or third is of great importance. Through the experience of actualizing multiple digital technologies' affordances, organizations gather insights that can guide the integration and optimization of new digital technologies' affordances in the future (Strong et al., 2014).

## Complication

**The main theories that delve into the development of digital technologies within organizations are the Resource-Based View (RBV) theory and the**

**Affordances theory.** Barney (1991) and Wernerfelt (1984) established the foundational concepts of the RBV theory. This theory emphasizes the capabilities and resources that give companies a technological edge (Prahalad and Hamel, 1990; Conner and Prahalad, 1996). The Affordances theory has its roots in ecological psychology. Gibson (1979) introduced this theory as a framework for understanding the behavior of animals in their environments. The term "affordance" was originated by Gibson (1979), transforming the verb "to afford" into a noun, capturing the essence of offering an opportunity. Norman (1988) was the pioneering scholar who applied the Affordances theory to describe human-technology interactions. A significant contribution to the evolution of the Affordances theory came from Zammuto et al. (2007). They approached the theory of affordances from the angle of the mutual relationship between information technology and organizations (Zammuto et al., 2007). According to Strauss and Hoppen (2019), the Affordances theory has been employed to explore the relationship between users—viewed as the "animal"—and technological artifacts, perceived as the "object".

Affordances of digital technologies received attention from scholars from the resource-based view and affordances theory. However, critical, overlooked areas exist. The main streams of research on affordances are clustered into two streams: a) affordances resulting from the adoption of digital technologies and b) actualization of digital technologies' affordances.

Researchers in the first stream have delved into the affordances that arise from digital technologies. Volkoff and Strong (2013) as well as Strong et al. (2014) noted that the emerging affordances from digital technologies can be categorized as individual, organizational, and process-level affordances. They emphasized how these levels of affordances are interconnected and intertwined. Similarly, Chatterjee et al. (2015) explored individual, organizational, and process affordances that stem from digital technologies. Vyas et al. (2017) also examined affordances of digital technologies, categorizing them as single-user, organizational (or workgroup), and societal. Furthermore, some scholars have focused on the affordances resulting from the utilization of specific digital technologies within organizations. For instance, Du et al. (2019) discussed the affordances arising from blockchain technology, while Gunter and Braga (2018) highlighted those emerging from mobile app usage. On the other hand, a segment of researchers investigated the affordances resulting from the deployment of various digital technologies in an organization. As an example, Øvrelid and Kempton (2019) identified the following affordances from digital technologies usage: resource integrating affordances (such as accessing, booking, and silent reporting), visibility affordances (like monitoring and individualizing), process flow affordances (including progressing and synchronizing). Additionally, scholars like Bobsin et al. (2019), Markus and Silver (2008), Zammuto et al. (2007), Vitari and Pigni (2014), Herterich et al. (2016), and Stendal et al. (2016) delved into the affordances derived from simultaneously using multiple digital technologies within an organization. Central to their investigations was the relationship between digital technology and human users. Most of the studies referenced here employed a qualitative approach. There is a notable gap in this research stream when it comes to quantitative analyses of affordances of digital technologies.

Researchers in the second stream have studied the actualization of digital technologies' affordances. Ostern and Rosemann (2021) delved into the processual affordances model, but their description of the actualization phenomena was predominantly theoretical. Moreover, they did not explore the actualization of multiple affordances. Chatterjee et al. (2020) examined how information technology affordances are actualized to foster organizational innovation. Dremel et al. (2020) analyzed the actualization of big data analytics affordances, particularly focusing on the actualization of analytic affordance. Strong et al. (2014) addressed the actualization of various digital technologies' affordances and sought to uncover relationships between multiple IT technologies' affordances. However, their analysis was limited to a single-case qualitative study of one company. Anderson and Robey (2017) explored the potency of affordances and aimed to elucidate the actualization of technology affordances using a qualitative research lens. Yet, their analysis was constrained to a single public sector organization. In summary, there is a noticeable gap in comprehensive research regarding the actualization of multiple digital technologies' affordances. Qualitative studies on this topic often either generalize the actualization of a single affordance or focus solely on certain aspects of this phenomenon. The conclusions drawn from these narrow qualitative studies are not universally applicable across different industries (Volkoff and Strong, 2017). To gain a comprehensive understanding of the actualization of multiple digital technologies' affordances, it is imperative to craft a process model addressing this. Furthermore, researchers need to emphasize the complementarity of affordances in discussions about the actualization of numerous digital technologies' affordances. There is also a need to place a greater focus on analyzing the speed at which multiple digital technologies' affordances are actualized (Volkoff and Strong, 2017).

Still, several areas remain under-researched:

- The process of actualization of multiple digital technologies' affordances in organizations is not extensively analyzed.
- The complementarity of multiple digital technologies' affordances is under-researched.
- The speed of the process of actualization of multiple digital technologies' affordances in organizations is under-researched.

Arguments:

- while companies adopt different digital technologies, they cannot be adopted at once because the organization has limited resources (Barney and Clark, 2007).

- qualitative research (i.e., case studies) dominates the research on digital technologies' affordances, and quantitative research may bring new insights.

- companies have their own rules and digitalization strategies, they adopt different digital technologies step by step.

**Research problem:**

How are the affordances of multiple digital technologies actualized and complement each other in the process of actualization in organizations?

**The object of research:**

Actualization of digital technologies' affordances in organizations and complementarities between digital technologies' affordances in this process.

**The aim of the research:**

To determine the process of actualization of digital technologies' affordances and the complementarities between digital technologies' affordances in organizations.

**The objectives of the research:**

1) To develop a structured overview of digital technologies' affordances through a comprehensive literature review.

2) To ground the process model of the actualization of digital technologies' affordances in organizations.

3) To create and ground the quantitative research methodology allowing empirically to verify the process model of the actualization of digital technologies' affordances in organizations.

4) To empirically test the process model of actualization of digital technologies' affordances and to reveal how digital technologies' affordances complement each other in the process of actualization in organizations.

**Methods**

The philosophical foundation of this study is rooted in positivism and pragmatism. The research utilizes data from the European Manufacturing Survey, chosen specifically because it showcases the use of various digital technologies within organizations. Additionally, this survey offers insights into the affordances that arise from the adoption of digital technologies by European manufacturers. Given their extensive use of digital technology and their inclination towards innovation, manufacturing businesses were the primary focus of this study. The research encompasses manufacturing organizations (N=798) in Central and Eastern European countries, specifically Lithuania, Slovenia, Croatia, Slovakia, and Austria.

For the quantitative research, various methods were employed to test the process model of the actualization of digital technologies' affordances in organizations. The Partial Least Squares Structural Equation Modeling (PLS-SEM) method was applied to assess the strength of path coefficients and to determine their statistical significance among the constructs of the process model.

To robustly examine the sequence in which digital technologies' affordances are actualized in organizations, the study employed the determination of sequence frequencies determination using a process mining analysis tool, supplemented by the chi-square test. Furthermore, the Mann-Whitney U test was utilized to evaluate the statistical significance of differences in speed and other selected criteria during the actualization process across various potential sequences. PLS-SEM multigroup analysis was conducted to check differences in path coefficients in the process model of actualizing digital technologies affordances. The quantitative research evaluated constructs such as augmentation, connect, analytic, and automation affordance, drawing on multi-item digital technologies.

**Theoretical significance**

- This research uncovers the universal affordances of digital technologies within organizations and elucidates how they complement one another during actualization. The present study significantly advances both the affordances and resource-based view theories by addressing a notable gap in the literature concerning the complementarities of multiple digital technologies' affordances in their actualization process.
- This study clearly defines the process of actualizing the multiple digital technologies' affordances within organizations. The results indicate that the sequence of actualizing various digital technologies' affordances is as follows: 1) augmentation affordance, 2) connect affordance, 3) analytic affordance, and 4) automation affordance. This delineation of the actualization process of multiple digital technologies' affordances enhances both the theory of affordances and the resource-based view theory. In past research, the affordances of different digital technologies were often studied separately, with scholars typically focusing on the actualization process of just one digital technology affordance within an organization.
- This study, focusing on manufacturing companies, has significantly enriched the theory of affordances. Up until now, the process of actualizing the affordances of multiple digital technologies within manufacturing companies remained under-researched. Earlier scholars predominantly examined isolated cases within the manufacturing sector. In contrast, this research scrutinized 798 manufacturing companies across various countries, extensively covering all sectors listed under the NACE classification.
- This study delved into the duration of the actualization process of digital technologies' affordances within organizations. It disclosed the average duration for each possible sequence in the actualization of these affordances. These findings notably enhance both the theory of affordances and the resource-based view. Up to now, scholars have not addressed the duration aspect of the actualization process of affordances of digital technologies.
- The study sheds light on the development of digital technologies within organizations. While extensive research has been conducted on possible roadmaps for digital transformation, these prior studies have not embraced the perspective of digital technologies affordances.

**Practical significance**

- It was created, and grounded methodology allows researchers to check the process of actualization of digital technologies' affordances more robustly. This methodology is versatile.

- This empirical study provided insights into how companies should manage digital technologies' affordances within their enterprises and leverage their complementarities to maximize business value.
- It was determined empirically that the sequence of actualization of digital technologies' affordances where companies follow augmentation affordance → connect affordance → analytic affordance → automation affordance is the most manifested compared with all other possible sequences of actualization of digital technologies' affordances. The empirical research results analysis also showed that the prevalence of this digital technologies' affordances actualization sequence (augmentation affordance → connect affordance → analytic affordance → automation affordance) is statistically significant.
- The empirical research results analysis revealed that companies actualizing digital technologies' affordances in the sequence of augmentation affordance → connect affordance → analytic affordance → automation affordance tend to actualize these affordances on average 2.8 years faster than companies pursuing any other sequence. This result is statistically significant. Companies opting for this specific sequence can thus secure a competitive edge.
- The empirical research results analysis showed that the process model of the actualization of digital technologies affordances (augmentation affordance → connect affordance → analytic affordance → automation affordance) is stable under different conditions (the size of the company; sector; the company's age; incorporated major technical improvements/introduced new products; R&D development).

**Structure of the dissertation**

This dissertation begins with the first chapter titled, "Theoretical Justification of the Process of Actualization of Digital Technologies' Affordances in Organizations." This chapter elucidates the rationale behind the chosen theoretical approach and delves into the main definitions, the typology of affordances, and the unique affordances that emerge from the incorporation of digital technologies in organizations. The chapter concludes by presenting a process model for the actualization of these affordances and explaining the complementarities between them.

The second chapter, "Methodology of the Research on the Process Model of Actualization of Digital Technologies' Affordances in Organizations", outlines the research philosophy and approach adopted in this dissertation. Moreover, it details the methods employed in the quantitative study of the aforementioned process model.

The third chapter, titled "Empirical Research on the Process Model of Actualization of Digital Technologies' Affordances in Organizations", presents descriptive statistics on the affordances of digital technologies within manufacturing companies. This chapter also analyzes and tests the process model of actualization of digital technologies' affordances for these firms. Furthermore, it offers a robustness analysis of this process model. The chapter concludes by comparing the dominant sequence of actualization with all other potential sequences.

The discussion chapter opens with the theoretical implications of this dissertation, followed by managerial implications, research limitations, and directions for future studies.

To conclude the dissertation, a summary of the findings from both theoretical and empirical research is provided.

# 1. THEORETICAL JUSTIFICATION OF THE PROCESS OF ACTUALIZATION OF DIGITAL TECHNOLOGIES' AFFORDANCES IN ORGANIZATIONS

This part of the thesis centers on the theoretical foundations that elucidate the affordances of digital technologies in organizations. It begins by selecting the theoretical approach for the analysis of research questions. This is followed by an overview of the definitions of digital technologies and affordance. Subsequently, the typology of affordances is presented. The section concludes with the process model of the actualization of digital technologies' affordances in organizations.

## 1.1. Choice of the theoretical approach to research question analysis

This section discusses the selection of the primary theory used in this dissertation. Typically, researchers employ basic theories such as the resource-based view theory and the affordances theory to analyze organizational digital technologies' affordances. These theories focus extensively on the developmental processes of digital technologies within organizations.

The resource-based view theory posits that enhanced long-term company performance is anchored in efficiency. This theory provides a lens through which researchers can examine the relationship between information systems, company strategy, and performance. Wade and Hulland (2004) suggest that this approach lays a solid foundation for determining the strategic value of information system resources. The resource-based perspective, emphasizing a firm's internal resources, presents a unique viewpoint on competitive advantage (Barney and Clark, 1997). Barney (1991) contends that possessing resources that are valuable, rare, unique, and irreplaceable can provide an organization with a sustainable competitive advantage. His insights have been influential, and many subsequent studies have underscored the importance of internal resources in shaping a firm's strategic approach and performance (see Table 1).

**Table 1.** Main theories for exploring digital technologies development in organizations

| | **Resource-based theory** | **Affordances theory** |
|---|---|---|
| The main object | Capabilities/ resources that constitute technology advantage | Digital technologies affordances |
| The main topics | Strategic resources<br>Competitive advantage<br>Dynamic capabilities | What affordances emerge<br>The actualization of affordances<br>Effects on the organization |
| Key contributors | Wernerfelt (1984), Barney (1991), Barney and Clark (1997), Teece et al. (1997), Conner and Prahalad (1996), Wade and Hulland (2004) | Gibson (1979), Strong (2014), Markus and Silver (2008), Zammuto et al. (2007), Leonardi et al. (2011), Leonardi et al. (2013) |

The resource-based view (RBV) theory, however, has faced criticism. Priem and Butler (2001a; 2001b) contend that the theory is tautological, arguing that the criteria for VRIN (Valuable, Rare, Imperfectly Imitable, and Non-substitutable) resources are too ambiguous and subjective. They assert that the theory's inherently circular reasoning makes it difficult to refute or empirically validate. Additionally, Gibbert (2006a; 2006b) suggests that the RBV's emphasis on resource uniqueness — stemming from resource heterogeneity and volatility — compromises its generalizability.

The theory of Affordances, originally introduced by James J. Gibson (1979) in the realm of ecological psychology, has become a foundational construct across multiple disciplines since its inception. Gibson (1979) devised the theory to describe the actionable properties between an actor and the environment. He posited that affordances are the opportunities for action that an environment offers to an organism. This perspective marked a significant shift from prior cognitive theories, highlighting the interaction between entities and their surroundings. Over the years, the Affordances theory has been extensively adapted and expanded beyond its original ecological context. Notably, Norman (1988) popularized the term in Human-Computer Interaction (HCI) to refer to the perceived and actual properties of an object that determine its possible uses. He underscored the importance of perceived affordances in design, advocating that designers focus on enhancing user-technology interactions by making these affordances explicit.

The theory of affordances serves as an apt theoretical framework for understanding the potential of digital technologies. This is attributed to its emphasis on the relationship between users and technology, considering not just the technological properties but also how these features can be perceived, engaged with, and utilized by users (Strong et al., 2014; Leonardi et al., 2011; Leonardi et al., 2013; Bobsin et al., 2019). It offers a dynamic and user-centric lens for grasping the potential of digital technologies, balancing the perspectives of both the technology and its users. This allows for a comprehensive understanding of how digital technologies are used and how they can be optimized to better meet user needs. Owing to its versatility, the theory of affordances is applicable to a diverse array of digital technologies, ranging from basic user interfaces to intricate virtual environments. Its adaptability makes it invaluable for analyzing and understanding a broad spectrum of technologies (Strong et al., 2014; Volkoff and Strong, 2013; Zammuto et al., 2007).

However, the theory of affordances does face challenges. A key point of contention is the interpretation of affordances. Some researchers advocate for the intrinsic, objective reality of affordances, aligning with Gibson's perspective. In contrast, others believe that affordances emerge from the interaction between an individual and an object, as proposed by Norman. This divide has led to conceptual ambiguities and inconsistencies in the literature (Gaver, 1991; McGrenere and Ho, 2000). Additionally, a recurring critique is the absence of a definitive methodological approach to studying affordances. Although many studies employ qualitative and ethnographic methods, there's a call for a structured, empirical framework to measure and analyze affordances (Volkoff and Strong, 2017). Notwithstanding these issues, the theory of affordances yields valuable insights across various fields. It has influenced the design of user-friendly interfaces and deepened our understanding of human-technology interactions.

The theory of affordances has been selected as the primary theoretical framework for this dissertation due to its comprehensive focus on digital technologies, ranging from the basic to the advanced. It is not constrained to a limited set of digital tools. Moreover, the affordances theory adeptly elucidates and aids in comprehending the full potential of digital technologies.

### 1.2. Analysis of the definitions of digital technologies and digital capabilities

This section is provided definitions of the concept of digital technologies and discusses the main digital technologies in the enterprise. Also, this section provides the definitions of the concept of digital capabilities.

Various authors suggest similar definitions of digital technologies with little difference (see Table 2). Bharadwaj et al. (2013) define digital technologies just mentioning different digital technologies from information to connectivity.

**Table 2.** Definitions of digital technologies

| Authors | Definition |
|---|---|
| Bharadwaj et al. (2013, p. 471) | "Digital technologies are combinations of information, computing, communication, and connectivity technologies." |
| Arkhipova and Bozzoli (2018, p. 122) | "Digital technologies are mobile technology, big data, cloud computing, internet of things, and artificial intelligence." |
| Urbinati et al. (2020, p. 148) | "Digital technologies constitute big data, internet of things, idea and knowledge management systems, cloud computing, product lifecycle management systems, systems of rapid prototyping." |
| Nambisan (2017, p. 1031) | "Digital technologies manifest in the realm of entrepreneurship in the form of three distinct but related elements – digital artefacts, digital platforms, and digital infrastructure." |

Arkhipova and Bozzoli (2018) and Urbinati et al. (2020) follow a similar path as Bharadwaj et al. (2013) by merely mentioning digital technologies in their definitions. Nambisan (2017), on the other hand, suggests a slightly different definition of digital technologies, emphasizing aspects such as digital artifacts, digital platforms, and digital infrastructure.

Upon analyzing various definitions of digital technologies provided by scholars (see Table 2), it is evident that these definitions do not align with Suddaby's (2010) criteria for a robust definition. According to Suddaby (2010), an effective definition should capture the essential properties and attributes of the concept or phenomenon under examination. Moreover, a well-constructed definition should avoid tautology or circular reasoning, which manifests when researchers include elements intrinsic to the concept within their definition. At its core, a solid definition should be parsimonious, accurately representing the core attributes of the examined phenomenon or concept. Bharadwaj et al. (2013) presented a definition of digital technologies that lists various examples of such technologies but does not clarify the inherent properties and characteristics that define the concept. Additionally, Bharadwaj et al. (2013) do not delineate the essential traits of digital technologies as comprehensively as needed. Arkhipova and Bozzoli (2018), Urbinati et al. (2020), and Nambisan (2017) offer definitions of digital technologies that encounter similar issues as those presented by Bharadwaj et al. (2013).

Digital technologies can generally be categorized into several groups (Frank et al., 2019; Lasi, 2014) including:

- Information Technologies: This category encompasses technology primarily utilized for processing and distributing information, such as databases, cloud computing, big data analytics, and artificial intelligence.
- Communication Technologies: This group includes technological applications like social media platforms, messaging applications, video conferencing tools, and collaborative software, all of which enhance communication and collaboration.
- Operational Technologies: This category incorporates devices related to the Internet of Things (IoT), robotics, and automation software that assist or automate operational processes.

In reviewing the literature, it becomes apparent that while authors propose somewhat similar definitions of digital technologies, these definitions often lack clarity and comprehensibility. For the purposes of this dissertation, I will draw upon the definitions proposed by various scholars who have written extensively on digital technologies. Consequently, I put forth the following definition: *Digital technologies are tools which allow the generation, accessing, gathering, manipulating, presenting, or communicating of information expressed in binary form.*

### *The definition of digital capabilities*

The concept of digital technologies is closely related to that of digital capabilities. This section provides definitions of the digital capabilities concept (see Table 3). For instance, Sjödin et al. (2016) suggest that digital capabilities pertain to the abilities to use advanced technologies. Annarelli et al. (2021) state that digital capabilities stem from digital properties and extend to networks.

**Table 3.** Definitions of digital capabilities

| Authors | Definition |
|---|---|
| Sjödin et al. (2016) | Advanced technological capabilities, related products, and data analytics employed by a company facilitate service and product development and delivery, generating exceptional value. |
| Annarelli et al. (2021) | The capacity to harness digital properties and organizational resources, coupled with the utilization of electronic networks, promotes innovation in products, services, and processes. |

| Authors | Definition |
|---|---|
| Daniel et al. (2014), Peppard and Ward, (2004) | Digital capabilities reflect an organization's deliberate application of advancements in communication and information technology and its proficiency in harnessing, mobilizing, and employing the organization's resources effectively. |
| Yoo et al. (2012) | Digital capabilities are employed across an organization to bolster its various functions, relying on digital technologies. |
| Kohli and Grover (2008) | Digital capabilities emerge from the interplay of technology with complementary resources, including process redesign, training, and motivational structures. |

There is no single, straightforward term for the definition of digital capabilities. In summary, drawing from various scholars, this dissertation defines digital capabilities as *the high-level skills required to utilize advanced technologies*.

### 1.3. Analysis of the definitions: "affordance" and "actualization of affordances"

This section provides definitions of the concept of "affordance", the theoretical model describing how an affordance is formed, and the definition of the "actualization of affordances".

James Gibson introduced the concept of affordance in 1979 in his book. Over time, the term "affordances" has been interpreted differently across various streams of literature, yet its connection with the socio-cultural context has persisted. The term underwent a notable evolution when Donald Norman (1988) applied it to the realm of human-computer interaction (see Table 4). Furthermore, within the fields of management and business, Majchrzak and Markus (2012) and Strong et al. (2014) articulated definitions of affordances in relation to the use of digital technologies. Additionally, Markus and Silver (2008), Vyas et al. (2017), and other scholars have expanded upon the definitions proposed by Majchrzak and Markus (2012) and Strong et al. (2014).

**Table 4.** Definitions of affordance

| Authors | Definition |
|---|---|
| Gibson (1979, p. 127) | "The affordances of the environment are what it offers the animal, what it provides or furnishes, either good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment." |
| Norman (1988, p. 9) | "The term affordance refers to the relationship between a physical object and a person (or for that matter, any interacting agent, whether animal or human, or even machines and robots)." |
| Nambisan et al. (2019, p. 3) | "Action potential or possibilities offered by an object (e.g., digital technology) in relation to a specific user (or use context) in innovation and entrepreneurship – for example, digital affordances, spatial affordances, institutional affordances, social affordances." |

| Authors | Definition |
|---|---|
| Strong et al. (2014, p. 69) | "The potential for behaviors associated with achieving an immediate concrete outcome and arising from the relation between an artifact and a goal-oriented actor or actors." |
| Markus and Silver (2008, p. 622) | "Affordances are defined as the possibilities for goal-oriented action afforded to specified user groups by technical objects." |
| Maier and Fadel (2007, p. 1) | "An affordance is what one system provides to another system." |
| Vyas et al. (2017, p. 118) | "The one-to-one relationship between a user and an artefact." |
| Brown and Blessing (2005, p. 3) | "Context dependent action or manipulation possibilities from the point of view of a particular actor." |
| Majchrzak and Markus (2012, p. 832) | "An action potential, that is, to what an individual or organization with a particular purpose can do with a technology or information system." |

Strong et al. (2014) proposed a model for analyzing affordance resulting from the implementation of digital technology. According to Strong et al. (2014), digital technology affordance is a product of the interaction between the technology itself and the actors involved in achieving their goals. This model is illustrated in Figure 1.

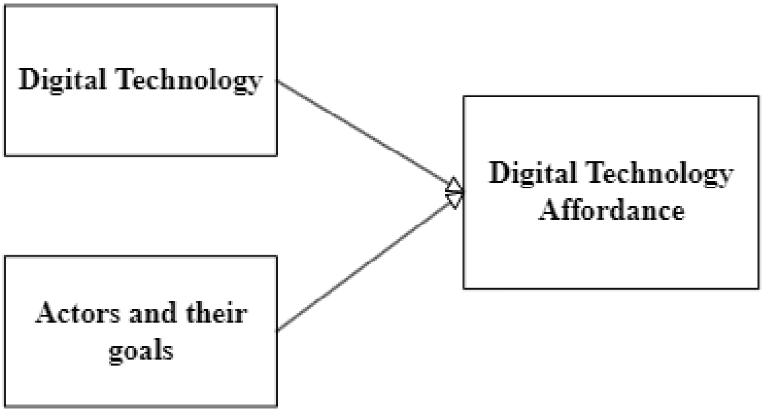



**Figure 1.** Formation of the digital technology affordance
(Based on Strong et al., 2014)

Drawing on the insights from various scholars, this dissertation defines 'affordance' *as the action potential offered by digital technology that occurs in the relationship between a digital technology with certain characteristics and a goal-oriented person.*

### *Definition of the Actualization of Affordances*

When scholars analyze the definition of affordance in the context of digital technologies, they often focus on the actualization of affordances, as the two concepts are closely related. This section provides the most prevalent definitions of the concept of affordance actualization (see Table 5). According to Strong et al. (2014), actualization refers to the use of digital technologies to achieve a specific goal by leveraging one or more affordances. In contrast, Dremel et al. (2020) offer a slightly different definition, emphasizing the value derived from digital technologies.

**Table 5.** Definitions of the actualization of affordances

| **Authors** | **Definition** |
|---|---|
| Strong et al. (2014, p. 70) | "The actions taken by actors as they take advantage of one or more affordances through their use of the technology to achieve immediate concrete outcomes in support of organizational goals." |
| Dremel et al. (2020) | The realization of digital technology's value. |
| Bernhard et al. (2013, p. 7) | "The actualization of a possibility for goal-oriented action afforded by an object for a user." |
| Chan et al. (2019) | Actualization is the process of realizing the potential that is offered by digital technology affordances. |

Few scholars specifically define the "actualization of affordances"; most merely mention the phenomenon without providing a clear definition. Commonly, when discussing this topic, scholars reference the definition proposed by Strong et al. (2014). In summary, based on contributions from various scholars, this dissertation defines the actualization of affordances as *the realization of the action potential offered by digital technologies.*

## 1.4. Typology of digital technologies' affordances

This thesis draws on the definition of typology as proposed by Doty and Glick (1994, p. 232), who assert that a "typology refers to conceptually derived interrelated sets of ideal types." Research on the types of digital technologies' affordances can be broadly categorized into two main streams (see Figure 2): 1. The first group of researchers focuses on affordances at various levels: individual (e.g., Leonardi, 2013; Majchrzak and Markus, 2013; Vyas et al., 2017), organizational (e.g., Strong et al., 2014; Leonardi, 2013; Vyas et al., 2017), and community (e.g., Tim et al., 2018; Vaast et al., 2017; Vyas et al., 2017). 2. The second stream of researchers (e.g., Du et al., 2019; Markus and Silver, 2008; Zammuto et al., 2007; Herterich et al., 2016; Hartson, 2003; Volkoff and Strong, 2013; Chatterjee et al., 2015; Raich and Krakowski, 2021; Kaptelinin and Nardi, 2012; Osch and Mendelson, 2011; Lenka et al., 2017) delve into affordances stemming from the adoption of digital technologies.

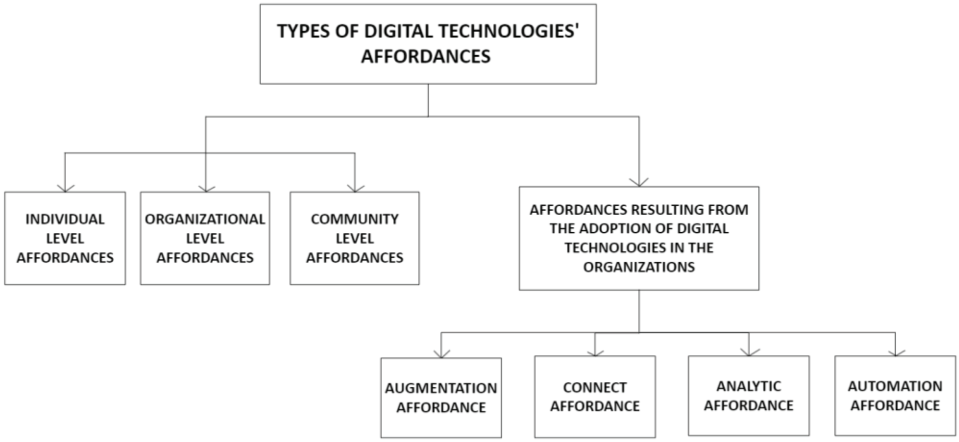



**Figure 2.** Types of digital technologies' affordances

The following sections discuss the types of digital technologies' affordances in more detail.

### 1.4.1. Individual, organizational, and community-level affordances

Leonardi (2013) suggests distinctions between individualized affordance, collective affordance, and shared affordance:

*Individualized Affordance:* This pertains to the unique capabilities or uses that specific technologies offer individual employees. For instance, a particular software feature might enable employees to execute their tasks more efficiently or optimize their workflow.

*Collective Affordance:* This is the way technologies facilitate actions at the group or organizational level. Such features could bolster collaboration, communication, or information dissemination among a team or throughout the organization. The influence of collective affordance can be profound, often serving as a catalyst for organizational change by reshaping work dynamics and information trajectories within a company.

*Shared Affordance:* This encompasses technological features utilized by various individuals within an organization, exerting analogous impacts on their respective tasks. Since this affordance aids similar actions or results for diverse individuals, it is deemed "shared." It can be instrumental in formulating organizational norms or practices, given its role in standardizing employees' technological interactions.

Majchrzak and Markus (2012) elaborate on affordances at both individual and organizational levels. They contend that when discussing digital technologies, the concept of affordance relates to the potential for action. This refers to the spectrum of activities that an individual or organization with a specific intent can undertake using technology. They emphasize that the capabilities and objectives of one individual or organization might determine different uses for technology compared to another individual or entity with the same technology.

Strong et al. (2014), when discussing organization-level affordances, highlight the following:

1) recording and preserving electronic information pertaining to individuals receiving medical care,

2) retrieving patient information and its use at any time and from any place,

3) coordinating patient care in various locations, institutions, and suppliers of services,

4) standardizing of information, procedures, and duties,

5) monitoring of the organization's activities,

6) mutual substituting of health care specialists,

7) integrating comprehensive data into the process of making informed choices,

8) transferring tasks from one role to another.

Vyas et al. (2017) delineate three levels of digital technology affordances: single-user, organizational, and societal levels. The single-user affordance pertains to the potential actions or functionalities that a technology provides to an individual user. This focuses on how the user adopts and adapts to the technology in various contexts, continually shaping and reshaping specific digital technologies' affordances. The organizational and societal level affordances pertain to the "one-to-many" or "many-to-many" relationships between the artifact(s) or technology and the broader organizational and societal contexts.

Vyas et al. (2017) also highlight the following specific characteristics of an organization's affordances:

1) Affordance as "use": Here, emphasis is placed on practice rather than the attributes or features of the technology.

2) Affordance as an "episode": This perspective on technology affordance refers to specific instances of user interaction with technology. It suggests that organizational capabilities evolve gradually and often emerge over time. Such episodes can be recurring, yielding consistent benefits, but changes in technology or conditions can alter those benefits.

3) Affordance is governed by four conditions: interpretive, power, technological, and cultural.

The study by Chan et al. (2019) seeks to extend the categorization of affordances at the individual, collective, and shared levels beyond the perspective of singular participants. Chan et al. (2019) propose expanding the concept of individual-level affordance beyond the technological potential perceived by an individual, to include the affordance perceived by a social actor, be it an individual or an organization, through technology. They define collective-level affordance as the potential arising when a group of social actors uses an artifact in a shared manner, albeit through varied approaches. Furthermore, Chan et al. (2019) suggest a refined understanding of shared-level affordance, suggesting it pertains to a potential collectively perceived and employed by a group of social actors. Notably, a social actor can function both as an individual and as an entity, such as a company.

### 1.4.2. Affordances resulting from the adoption of digital technologies in the organizations

Based on an analysis of the scientific literature, the following universal affordances, resulting from the adoption of digital technologies in organizations, have been identified (see Table 6):

- Augmentation affordance,
- Connect affordance,
- Analytic affordance,
- Automation affordance.

It is important to note that different researchers may use different terms or synonyms to describe the same digital technologies' affordances. However, the essence and meaning of these affordances remain consistent.

**Table 6.** Affordances resulting from the adoption of digital technologies in the organizations

| Digital technologies' affordances | Authors | Digital Technologies | Sub level affordances |
|---|---|---|---|
| *Augmentation affordance* | Du et al. (2019), Øvrelid and Kempton (2019), Markus and Silver (2008), Zammuto et al. (2007), Herterich et al. (2016), Hartson (2003), Volkoff and Strong (2013), Chatterjee et al. (2015), Raich and Krakowski (2021), Vyas et al. (2006), Kaptelinin and Nardi (2012), Osch and Mendelson (2011) | Enterprise resource planning, warehouse management system, real-time quality control system, mobile apps for managing various processes | 1) resource integrating affordances (accessing, booking, silent reporting),<br>2) process flow affordances (progressing, synchronizing),<br>3) affordance of managing, optimizing, and integrating product operations,<br>4) standardizing and integrating affordances,<br>5) process management affordance,<br>6) instrumental affordance. |
| *Connect affordance* | Gunter and Braga (2018), Conole and Dyke (2004), Bobsin et al. (2019), Vitari and Pigni (2014), Zammuto et al. (2007), Herterich et al. (2016), Hartson (2003), Volkoff and Strong (2013), Chatterjee et al. (2015), Lenka et al. (2017), Vyas et al. (2006) | Mobile apps, information and communication technologies, Internet of Things (IoT), industrial internet, cloud services | 1) mobility affordance,<br>2) communication and collaboration affordance,<br>3) coordination affordance,<br>4) mass collaboration affordance,<br>5) networking affordance,<br>6) affordance of access to resources and accountability,<br>7) monitoring and controlling industrial products remotely affordance. |

| Digital technologies' affordances | Authors | Digital Technologies | Sub level affordances |
|---|---|---|---|
| *Analytic affordance* | Dremel et al. (2020), Vitari and Pigni (2014), Volkoff and Strong (2013), Chatterjee et al. (2015), Zammuto et al. (2007), Raich and Krakowski (2021), Lenka et al. (2017), Kaptelinin and Nardi (2012) | Data flow analysis software, Visualization software, API, Forecasting software, and Simulation software. | 1) analysis affordance,<br>2) sensing affordance,<br>3) affordance of visualizing entire work processes,<br>4) future prediction affordance,<br>5) monitoring organizational operations affordance. |
| *Automation affordance* | Raich and Krakowski (2021), Zammuto et al. (2007), Frohm et al., (2008), Davenport and Kirby, (2016), Lindebaum et al., (2018),<br>Russell and Norvig (2009) | Industrial robots, RPA technology, additive manufacturing (3D printing, etc.), automatic machine tools for working parts, automatic assembly machines, automatic inspection systems | 1) affordance of automation of simple manufacturing processes,<br>2) affordance of additive manufacturing (3D printing) solutions. |

While scholars discuss various digital technologies' affordances, the following four are most observed in organizations: augmentation, connect, analytic, and automation. Each of these digital technologies' affordances have sub-level affordances. Although these four digital technologies' affordances (augmentation, connect, analytic, and automation) have been studied, there has not been enough focus on their actualization. Therefore, the subsequent section will delve into the process of actualizing the digital technologies' affordances.

In summary, the typology of digital technologies' affordances can be categorized into two groups: 1) individual, organizational, and community-level affordances, and 2) affordances that emerge from the adoption of digital technologies within an organization.

## 1.5. The process model of actualization of digital technologies' affordances in organizations

### 1.5.1. Augmentation affordance

In the last century, much of the work in organizations was manual. Information systems and computers were only beginning to emerge. Over time, these systems and computers evolved, and the Internet became a powerful and essential tool. A plethora of digital tools has since been developed to enhance business efficiency. Companies began adopting various digital tools, such as software for fabrication planning and management, logistics management, real-time quality control systems, and handheld devices for process management. The affordances offered by these technologies may be fully actualized or only partially so. Scholars from two prominent theories, the resource-based view and the affordances theory, outline how and why organizations integrate these digital technologies into their operations. In the resource-based view theory, this process is referred to as IT capability (Bharadwaj, 2000). In contrast, in the affordances theory, it is termed augmentation affordance (Raisch and Krakowski, 2021).

***Existence and Perception of Augmentation Affordance***

To better understand augmentation affordance, it is essential to delve into two theories: the resource-based view and affordances. Both theories discuss augmentation affordance, though the resource-based view uniquely refers to this process as IT capability.

According to the resource-based view (RBV) theory, scholars argue that companies should develop their information technology (IT) capability to gain a competitive advantage. Bharadwaj (2000) emphasizes that IT capability encompasses the use of IT-based resources alongside other resources and capabilities to enhance their overall value. Duliba et al. (2001) maintain that an organization's IT capabilities are pivotal in determining the benefits derived from IT investments. Grover and Malhotra (1999) define IT capability as the technological capacity used to obtain, process, and transmit information, aiming to facilitate more efficient decision-making compared to competitive benchmarks. In discussions on IT capability, scholars identify three primary dimensions: technological, human, and organizational (see Table 7).

**Table 7.** Main dimensions of IT capability

| | **Technological level** | **Human-level** | **Organizational level** |
|---|---|---|---|
| *Dimensions* | Technology base,<br>IT infrastructure,<br>External IT linkages,<br>IT applications. | Competent IT human resources,<br>Effective management of IT resources,<br>The management of human resources within the IT domain. | IT enterprises partnerships,<br>IT business operations integration,<br>IT-enabled resources,<br>Complementary organizational resources. |
| *Key authors:* Ross et al. (1996), Bharadwaj et al. (1999), Bharadwaj et al. (2000), Melville et al. (2004), Sanders and Premus (2005), Chen et al. (2014), DeGroote and Marx, (2013), Sabherwal and Jeyaraj (2015) | | | |

Some scholars, such as Curley (2007) and Pintaric and Bronzin (2013), have analyzed IT capability dimensions from a different perspective. This view focuses on the maturity of IT capability. In his research on IT management, Curley (2007) delineates and categorizes four distinct stages of IT Capability maturity: IT budget management, IT capability management, IT value management, and IT business management. Pintaric and Bronzin (2013) posit that the realization of IT Capability relies on five distinct maturity levels. The initial stage is termed “Unmanaged”. The subsequent stage is labeled as the “Technology Supplier” level. The third level is known as the "Technical Expert". The fourth tier is the "Strategic Business Partner", while the fifth is termed "Strategic Core Competencies".

Drawing from the affordances theory, scholars such as Raisch and Krakowski (2021) and Amershi et al. (2014) discuss how companies begin to implement various digital technologies (like ERP, warehouse management systems, real-time quality control systems, mobile apps for managing different processes) in their operations. The process is termed differently in this theory compared to the resource-based view. The initial step in implementing various digital technologies in this context is termed "augmentation affordance". Scholars offer varied definitions for augmentation affordance. Jain et al. (2021) describe augmentation as leveraging computers to amplify human capabilities. Ras et al. (2017) view augmentation affordance as the shift from manual operations to IT systems and software that facilitate swifter, more precise, and more efficient management of organizational processes. Jain et al. (2021) defined augmentation affordance in a narrower sense, emphasizing the value creation of digital technologies in the nexus between individuals and these technologies. Raisch and Krakowski (2021) perceive *augmentation affordance* as enabling and enhancing human performance in the execution of various tasks. Among these definitions, Raisch and Krakowski (2017) provide the most precise definition of augmentation affordance, which aligns well with Suddaby's (2010) criteria for a comprehensive definition. Hence, this definition will be adopted in this dissertation.

Raich and Krakowski (2021) emphasize that companies should prioritize augmentation to achieve optimal results. Despite the inherent limitations of machines and software, we are entering an era where the relationship between humans and software is increasingly significant. Implementing augmented processes requires continuous human involvement and experimentation.

According to scholars such as Ras et al. (2017), Raisch and Krakowski (2021), Daugherty and Wilson (2018), and Langley and Simon (1995), the primary dimensions of augmentation affordance are as follows:

- to enhance the utility function or attain a solution that is in close proximity to the optimal outcome,
- to enhance production and service control,
- to optimize production activities planning and scheduling,
- to enhance mitigation of human errors based on real-time control,
- to optimize the administration of products logistics.

Despite the benefits of augmentation affordance, authors also point out potential drawbacks. They stress that implementing unilateral augmentation could lead to a new digital divide. This may cause social tensions between individuals equipped with the necessary resources and capabilities to enhance their technological capacities and those without such resources (Brynjolfsson and McAfee, 2014; Brynjolfsson and Mitchell, 2017; Norris, 2001).

***Actualization of Augmentation affordance***

Actualization of the augmentation affordance immediately gives specific results and outcomes. Gagnon (2023), Raisch and Krakowski (2021), Schryen (2013), and Volkoff and Strong (2013) argue that the realization of augmentation affordance yields tangible consequences and achievements:

- recording data related to the execution of operations,
- doing all the work through one system,
- real-time access to a wide range of functions, global and historical information,
- uniforming procedures and records,
- combining processes and information,
- utilization of real-time data to regulate processes and outcomes in an organization's operation,
- enhanced production and service control,
- enhanced planning and scheduling,
- simpler management of products logistics,
- improved the quality of after-sale services and assistance.

Volkoff and Strong (2013) highlight the significance of correctly utilizing the enterprise resource planning (ERP) system in their analysis of augmentation affordance actualization. They argue that an ERP system should be configured with a shared database and standardized procedures. Furthermore, it should be used consistently, avoiding any deviations from established practices.

### 1.5.2. Connect affordance

The rapid advancement of digital technologies that facilitate information sharing and integrate diverse systems wirelessly presents new business opportunities. In manufacturing, these cutting-edge technologies link various devices and artifacts, enabling real-time information exchange between different systems, suppliers, and users. Connectivity solutions like the Internet of Things (IoT), the Industrial Internet, and cloud services are increasingly prevalent in companies. The affordances of these technologies can be either fully actualized or only partially so. According to affordance theory, this process is termed connect affordance (Lenka et al., 2017).

***Existence and Perception of Connect Affordance***

To gain a deeper understanding of connect affordance, it is essential to examine connectivity technologies such as the Internet of Things (IoT), the Industrial Internet, and cloud services that companies employ. Scholars of affordance theory also identify these particular digital technologies as crucial for achieving "connect affordance".

Chen (2017) posits that the Internet of Things facilitates the integration and interconnection of complex physical machinery, equipment, individuals, and resources, all made possible through networked sensors and software designed for industrial production and operations. Frank et al. (2019) argue that the IoT seamlessly integrates sensors and computing within a wireless internet framework. The advancements on the Internet enable communication among various objects, with smart sensors capable of identifying any object and incorporating it into a broader network. Boyes et al. (2018) offer their interpretation of the Industrial Internet of Things, describing it as a network of intelligent objects and digital assets.

Chen (2017) describes the Industrial Internet as a pivotal toolbox for digital enterprise transformation and a vital implementation tool for the Internet of Things (IoT). It is frequently associated with other concepts and technologies such as IoT, Industry 4.0, Big Data, and Machine Learning. For the Industrial Internet to function effectively, certain conditions are imperative, such as a tailored environment within a factory and ensuring a reliable internet connection.

Cloud services represent the networked, on-demand utilization of a shared pool of configurable server computers. These services allow information to be digitally stored and accessed from anywhere via a web interface. Cloud services simplify the connection of various devices since they can share data and collaborate without being co-located (Grozev and Buyya, 2014; Yu et al., 2015; Bello et al., 2021).

Such digital technologies introduce substantial actionable potential within organizations. This potential can either be harnessed or left untapped. When capitalized upon, it manifests as a potent actualized connect affordance. Scholars offer varied definitions of connect affordance. Zammuto et al. (2007) posit that realizing connect affordance relies on the effective integration of both technological and organizational attributes, which promote the open dissemination, acquisition, retention, updating, and retrieval of knowledge within an organizational milieu. Lenka et al. (2017) define *connect affordance* as utilizing wireless communication networks in an organizational context to facilitate the exchange of data and information between individuals and digital devices. This definition by Lenka et al. (2017) will be adopted in this dissertation due to its precision and its alignment with Suddaby's (2010) criteria for quality definitions.

Main dimensions of connect affordance according to scholars (Agiwall et al., 2021; Lenka et al., 2017; Conole and Dyke, 2004):

- wirelessly transmit information and signals to the cloud,
- facilitate networked features utilizing interconnected resources,
- interchange of goods and procedure data between vendors and consumers,
- facilitate the transmission of digital pictures, timetables for work, and work instructions to the respective workstations,
- utilize electronic devices to program and manage equipment and infrastructure,
- facilitate consultations with fellow engineers in a more streamlined manner,
- collaborate on a project or share your work with others by digital tools,
- facilitate remote communication and data exchange with clients.

While connect affordance offers numerous benefits, such as enhanced collaboration, communication, and data sharing, it also comes with potential downsides. Scholars have identified several of these potential negative aspects. Increased connectivity often leads to greater data sharing, posing substantial privacy challenges. Additionally, heightened connectivity may bombard users with incessant messages, updates, or notifications, creating feelings of being overwhelmed and distracted. Excessive dependence on connectivity can also erode a user's autonomy and independence. The features embedded within connectivity technologies can sometimes increase system complexity, making it particularly challenging for novice users (Avram, 2014; Rahim et al., 2021). While these are potential drawbacks, many can be mitigated through the careful and effective use of connectivity technologies.

***Actualization of Connect Affordance***

Actualization of the connect affordance immediately gives specific results and outcomes. Braga and Gunter (2018) analyze the use of the Internet and mobile apps and their interrelationships in an organization. Under this analysis, they state actualization of connect affordance gives these concrete outcomes and results:

- opportunity for immediate access to different systems and the form of databases,
- opportunity to monitor and track events, work emails, different resources, and the overall quality issues within a company,
- opportunity for individuals to remain engaged in their work with the help of constant connectivity and up-to-date information,
- opportunity to access and exchange documents, sketches, and data on various organizational activities,
- facilitate the dissemination of documents in real-time on the shop floor.

Also, they emphasize that workers who observe the potential of connect affordance try to actualize this potential to concrete results.

According to Vitturi et al. (2019) and Conole and Dyke (2004), actualization of connect affordance offers these outcomes:

- faster collaboration with colleagues that improves work,
- allowed for different ways of talking to each other,
- built virtual communities and methods of exchanging information,
- better exchange of data with suppliers/customers.

Volkoff and Strong (2013) identify the following outcomes from the actualization of connect affordance: enhanced ease of consulting with other engineers, increased speed and simplicity in sharing work, and heightened ability for constructive client communication.

### 1.5.3. Analytic affordance

The use of analytics is becoming increasingly important in contemporary business. Analytics can be defined as the process of deriving valuable insights from vast amounts of data to identify recurring patterns, thereby facilitating more informed decision-making. Data analysis, also referred to as analytic affordance (Chen, 2017; Lenka et al., 2017), is gaining momentum and is becoming essential for modern manufacturing processes because of the industry's immense potential.

*Existence and Perception of Analytic affordance*

In the context of the 4th Industrial Revolution, analytic is one of the most essential aspects. George et al. (2014) denote that analytic can be used in many ways in organizations, for example:

- collecting data from production equipment,
- collecting data from industrial robots,
- collecting data from information systems,
- improving management systems.

The term "big data" refers to the extensive volume of data gathered from various sources, including systems and objects like sensor readings (Porter and Heppelmann, 2015). George et al. (2014) define "big data" as data derived from an ever-increasing variety of sources, encompassing online actions and material. Big data is widely viewed as a central driver for the 4th Industrial Revolution and is anticipated to be a fundamental source of sustainable competitive advantage across various industries in the foreseeable future, owing to analytical tools such as data mining and machine learning. The significance of big data lies in its ability to generate information, which is essential for creating digital twins of factories. Analytics offers a distinct advantage by delivering advanced forecasting capabilities, allowing for the identification of potential production-impacting events before they occur. Integrating big data with analytics holds the promise of enabling self-organization in manufacturing facilities and enhancing decision-making across all aspects of a manufacturing enterprise (Lenka et al., 2017; Ahuett-Garza and Kurfess, 2018; Wang et al., 2020).

Wang et al. (2020), Porter and Heppelmann (2015), and Watson (2014) distinguish these key big data technologies:

- Application programming interface (an essential tool that allows different software applications to communicate and share data),
- Data Lake (a huge database that lets you store all organized and unstructured data at any scale),
- Data flow analysis (a technique used to understand the flow of data in a program, system, or application),
- Web analytics (the procedure for gathering, evaluating, reporting, and measuring web data in order to comprehend and improve web usage),
- Mobile device analysis (the process of extracting, analyzing, and interpreting data from mobile devices such as smartphones, tablets, and smartwatches),
- Social media analysis (the process of collecting data from social media platforms and analyzing that data to make business decisions),
- Forecasting analytics (the utilization of past data to forecast forthcoming results),
- Rules-based system (a system that uses rules as a form of knowledge representation to infer information or make decisions),
- Visualization program (a tool or system that allows for the graphical representation of large and complex datasets).

At present, a significant amount of data is generated daily throughout the entire production cycle, spanning machinery, manufacturing, logistics, marketing, and user input. In traditional production environments, this data was often either unavailable or inaccessible, making it difficult for analysts with standard tools to analyze given the vastness of the data. To address the current trends and challenges faced by the industry, new data analysis methods and frameworks, including mathematical modelling, intelligent machine learning, and association and clustering techniques, are emerging. The use of digital technology in data analysis allows for the extraction of essential information vital for informed decision-making within production processes. This method promotes a transition in the control of production systems from a reactive to a proactive decision-making paradigm (Lenka et al., 2017; George, 2014; Wang et al., 2020).

The immense volume of data emanating from various systems and intelligent devices brings about both opportunities and challenges, especially with data overload. As a result, companies see vast potential in analytic tools, which can be actualized into robust analytic affordances. Volkoff and Strong (2013) describe analytic affordance as the potential actions or insights directly related to analysis or logical reasoning. On the other hand, Lenka et al. (2017) define *analytic affordance* as the affordance to gather data from the operations of the organization and surroundings and utilize software tools to convert it into beneficial knowledge and company guidelines. This definition by Lenka et al. (2017) aligns with the criteria for a suitable definition as outlined by Suddaby (2010). Thus, it will be adopted in this dissertation.

Main dimensions of analytic affordance according to scholars (Lenka et al., 2017; Raisch and Krakowski, 2021; Volkoff and Strong, 2013):

- to establish correlations between distinct client profiles and several diverse components utilizing the company’s customer information;
- to perform predictive customer insight by logically processing data;
- to perform value visualization by modelling scenarios;
- to monitor the activities of the organization on the display boards;
- to make decisions using cross-functional, global information;
- to compare multiple iterations of model testing;
- to analyze and evaluate the results of solvers to improve design methods.

Despite the positive aspects of analytic affordance, some scholars highlight the potential drawbacks of this phenomenon. Analytic affordance often involves tools or features for data analysis. While these can provide valuable insights, they might lead individuals to overly depend on data, overlooking other types of knowledge or understanding. Additionally, tools that facilitate analytical actions can be biased in their design or use. Data can also be misinterpreted or manipulated to affirm pre-existing biases (O'Neil, 2013; Crawford and Schultz, 2014).

***Actualization of Analytic Affordance***

Actualization of the analytic affordance immediately gives specific results and outcomes. Volkoff and Strong (2013) and Tim et al. (2020) posit that the actualization of analytic affordance yields tangible consequences and achievements:

- utilizing comprehensive, worldwide data to make informed decisions,
- conducting multiple rounds of model testing,
- scrutinizing and assessing the solver outcomes to enhance the design methodologies,
- enabling data visualization on display boards.

Lenka et al. (2017) and Dremel et al. (2020) analyze the process of actualization of analytic affordance to distinguish these main results and outcomes of actualization:

- conducting predictive customer analysis through systematic data processing,
- developing preparedness for future events through predictive modelling,
- generating value visualization utilizing situation simulation.

### 1.5.4. Automation affordance

Automation replacement is becoming a trend in different business organizations, from the financial sector to manufacturing companies. Companies are entering a phase where digital and automated devices perform simple and routine production, operational management, and control functions. Automated processes are being implemented by organizations to replace human actions that are daily routine and time-consuming, thereby enhancing precision and effectiveness. Such digital technologies as industrial robots, 3D printing-based solutions, and various software for automation participate in implementing automation. The actualization of automation affordance is vital to competitiveness in the current market because all companies try to optimize their resources. Complex and unpredictable economic conditions further accelerate automation processes.

***Existence and Perception of Automation affordance***

Automation is widely understood to be a process that uses little to no human labor, a preset sequence of procedures, and specialized equipment and gadgets to perform and control industrial processes (Gupta and Arora, 2009). Also, Gupta and Arora (2009) state that automation is a step beyond mechanization when people are operators of machines that help them get the job done. The most apparent aspect of automation is industrial robotics. Contemporary automated procedures are commonly governed by computer algorithms that oversee advancement and regulate the order of occurrences until the procedure is finalized by responding to sensors and actuators. The computer's decisions ensure that the process is completed precisely and swiftly.

Butt (2020) investigates the topic of automation, focusing on autonomous robots. According to him, autonomous robots have a certain level of self-sufficiency and autonomy. An autonomous robot perceives its environment, makes decisions based on what it sees or has been taught to perceive, and then moves or manipulates in that environment. These choice-based tasks in mobility programs, for example, include but are not limited to the main stages to begin moving, pausing, and avoiding obstacles. Butt (2020) contends that autonomous robots have made substantial advances, namely artificial intelligence, navigation, cost reduction, sensors, responsiveness, regulatory reform, and public policy. Robots are significant in many industries, including medicine, transportation, aviation, and construction. The number and quality of multi-purpose industrial robots have expanded dramatically, leading to complex robot development.

Scholars classify automation into three to five levels. Milgram et al. (1995) identify five stages of automation:

- Manual teleoperation (all instances in which the human operator is compelled to persistently stay within the oversight cycle without any foreseeable end),
- Telepresence (a master-slave control system in which the human operator initiates all operations of the master arm),
- Director/Agent Control (a basic form of oversight supervision, where an individual assumes the role of an administrator and the machine, which holds limited cognitive ability, acts as their representative),
- Supervisory Control (describes several choices in which the human operator can assume various supervisory roles),
- Autonomous Robotics (the system operates without remote control, and the human is not involved in its operation).

According to Ruff et al. (2002), there are three distinct phases of automation: manual control, consent management, and exception management. In the manual control phase, the automation remains inactive without operator intervention. In the consent management phase, automation suggests possible actions, but their execution relies on the explicit consent of the operator. In the exception management phase, automation operates independently, not requiring explicit operator approval. It can only be overridden by specific commands from the operator.

Scholars (Gupta and Arora, 2009; Butt, 2020; Frohm et al., 2008) distinguish these digital technologies as necessary for automation:

- automated machinery utilized for the manipulation and refinement of functional components,
- automated construction equipment,
- manufacturing robots,
- automated manipulation of substances and components.,
- automated archiving and retrieval systems,
- automated assessment systems,
- computer systems that facilitate the computerized transformation of concepts into components,
- computerized scheduling and making choices system for supporting the fabrication,
- additive production (3D printing, etc.).

The exploration of the digital technologies mentioned earlier underscores the importance of additive manufacturing in enabling automation affordance. Over the past three decades, Additive Manufacturing (AM) technologies have become a dominant form of production. These technologies represent one of the most significant advances in automation, boasting considerable potential and promising prospects for the future. In additive manufacturing, a three-dimensional (3D) computer-aided design (CAD) model is used to fabricate parts by successively adding materials in a layer-by-layer manner. This process allows for the creation of complex geometries that are otherwise impossible with conventional manufacturing methods. Additive manufacturing streamlines the production of custom designs and prototypes. The 4th Industrial Revolution is often attributed to the rise of additive manufacturing due to its advantages over traditional production methods (Beyca et al., 2017; Pereira et al., 2019; Savolainen and Collan, 2020).

The following factors should be considered when deciding whether to automate a new or existing facility, according to Gupta and Arora (2009):

- the type of product produced,
- the amount and speed of production needed,
- the specific phase of the production process,
- the proficiency level of the labor force,
- the deployment of automated systems may raise concerns regarding their reliability, and associated costs.

The allure of immediate cost reductions has propelled organizations to prioritize automation (Davenport and Kirby, 2016). Lindebaum et al. (2018) note that organizations often become entrenched in their automated operations due to the narrow scope of automation. This confinement is typically limited to specific activities within well-understood domains and is dictated by formal norms that narrow the choices for companies and penalize deviations. Implementing automation into organizations can reduce costs, streamline processes, and provide higher levels of rationality and consistency in managing information. As Raisch and Krakowski (2021) point out, harnessing automation technology facilitates the cost-effective design and production of customized products.

So based on various scholars, automation gets in different forms in organizations. You can use the potential of automation or not. At this moment, we deal with the concept of automation affordance. Automation affordance is understood as using electronic devices, equipment, and robots to replace simple and monotonous human labor in the organization (Frohm et al., 2008). Automation is a process by which machines take over a human task (Raisch and Krakowski, 2021). Raisch and Krakowski (2021) define *automation affordance* as enabling an operation or system to function independently. This definition of automation affordance is compatible with Suddaby's (2010) good definition criteria. Therefore, it will be used in this dissertation.

Main dimensions of automation affordance according to scholars (Frohm et al., 2008; Raisch and Krakowski, 2021; Russell and Norvig, 2009; Gupta and Arora, 2009):

- automate well-organized daily duties,
- enhance the selected utility function,

- implement 3D printing-based solutions,
- use industrial robots to automate basic manufacturing operations,
- reduce manufacturing expenses to increase productivity,
- lessen workpiece damage brought on by manual manipulation of parts,
- increase worker safety, particularly in hazardous environments and working situations.

Diverse academic perspectives exist regarding the affordances and potential drawbacks of automation. According to Brynjolfsson and McAfee (2014), the availability of automation can significantly reduce employment opportunities. Furthermore, managers who rely on machines to perform tasks may inadvertently cause a decrease in the skill level required for specific jobs, thereby contributing to a rise in unemployment rates and social inequality. Gupta and Arora (2009) have raised inquiries about significant social concerns regarding the affordance of automation in their research. One area of concern pertains to the effects of automation on the labor market, specifically about employment and unemployment. Gupta and Arora (2009) present a contrasting perspective to the viewpoints of Brynjolfsson and McAfee (2014) by asserting that automation engenders increased employment. Gupta and Arora (2009) assert that the initial implementation of automation instigated widespread apprehension. The notion that computerized systems would result in unemployment, as was observed with mechanization in earlier centuries, was a concern among workers. The prevalence of redundancy in contemporary society has facilitated increased employment opportunities within the information sector, which typically offers more lucrative compensation. A curious consequence of this transformation is that unskilled labor is reimbursed at a high rate in many developed nations due to a reduced labor pool, resulting in challenges related to supply and demand.

***Actualization of Automation affordance***

Actualization of the automation affordance immediately gives specific results and outcomes. Mistry et al. (2020), Bravo et al. (2016), and Merchant (2000) distinguish these significant results of the actualization of automation affordance:

- heightened quality of goods,
- reduced delay in delivery,
- improved employee satisfaction,
- enhanced client happiness,
- lowered expenditures,
- greater efficiency enabled by industrial robots,
- greater adaptability (agility),
- heightened goods producibility.

According to Chen et al. (2021), Villani et al. (2018), and Gupta and Arora (2009), the actualization of automation affordance offers these concrete outcomes and results:

- heightened productivity,
- decreasing manufacturing costs,

- alleviation of human fatigue,
- minimized floor space requirements,
- decreased maintenance demands,
- improved working conditions for employees,
- efficient control of the production process,
- enhanced product quality,
- enhanced working without human intervention.

### 1.5.5. Process vs. variance model theory

This section will utilize the works of Payne et al. (2017), Tsohou et al. (2008), Langley (1999), Gelman (2005), Van de Ven and Engleman (2004), Poole et al. (2000), and other scholars to explain process and variance models.

The classification of research models for organizational processes can be broadly categorized into two distinct groups: *process models* and *variance models* (see Figure 3).

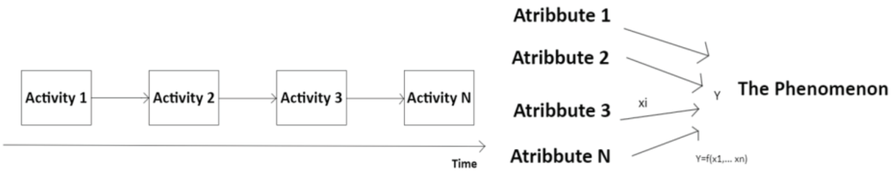



**Figure 3.** Process model vs. variance model

Payne et al. (2017) and Toshou et al. (2008) assert that variance models explain the associations between a dependent variable and one or multiple independent variables. The researchers assert that a process model attempts to elucidate a result's manifestation by discerning antecedent occurrences. Within organizational and procedural contexts, a conspicuous differentiation exists between the models. Furthermore, each model encompasses distinct methodologies and is grounded on diverse assumptions. Langley (1999) concurs with the ideas proposed by Payne et al. (2017) and Tsohou et al. (2008) regarding process and variance models. According to Langley's (1999) assertion, process theories elucidate the chronological progression of events that culminate in a particular outcome. The process data predominantly comprises narratives detailing the sequence of events, individuals involved, temporal aspects, activities, and decision-making processes over time. The data analysis process necessitates using tools to conceptualize events and identify their patterns, as stated by Langley (1999). The process model, as posited by Van de Ven and Huber (1990), is primarily concerned with comprehending the evolution of phenomena and the underlying reasons for such evolution. The variance model elucidates phenomena about the associations between independent and dependent variables, as posited by Gelman (2005) and Langley (1999).

The process and variance models are distinct approaches that pose distinct inquiries in empirical investigation (see Table 8). Research utilizing the process model prompts inquiry into how a problem arises, progresses, expands, or concludes throughout a given period. Nevertheless, research utilizing the variance model prompts an inquiry into the underlying assumptions or ramifications of the matter under consideration (Langley, 1999; Tsohou et al., 2008; Payne et al., 2017).

**Table 8.** Assumptions of process and variance models

| | Process theory-based model | Variance theory-based model |
|---|---|---|
| *The main characteristics* | • Process theories explain occurrences in terms of their sequence,<br>• Recognizing patterns in events,<br>• Causation is the succession of essential conditions,<br>• The temporal sequence and duration of events hold significance in determining the ultimate outcome. | • Explanations of phenomena using relationships between dependent and independent factors,<br>• Effects on various phenomena,<br>• Explains why something happens,<br>• Justifications that can be generalized across a wide range of circumstances. |
| *Key Contributors* | Langley (1999), Van de Ven and Huber (1990), Glabbeek (2001), Tsohou et al. (2008), Payne et al. (2017) | Mohr (1982), Landis and Koch (1977), Poole et al. (2000), Van de Ven and Engleman (2004), Gelman (2005), Tsohou et al. (2008), Payne et al. (2017) |

Using process and variance models is applicable in addressing diverse research inquiries. Van de Ven and Engleman (2004), Tsohou et al. (2008), and Payne et al. (2017) have suggested that process models are suitable for investigating the development and progression of change over time, while variation models are appropriate for examining the underlying assumptions or outcomes of the process. Nevertheless, many scholars utilize variational models to address inquiries under the first classification.

The differentiation between change and development is based on various scholars' perspectives, including Langley (1999), Tsohou (2008), Payne et al. (2017), Van de Ven and Engleman (2004), Mohr (1982), Van de Ven and Huber (1990), Markus and Robey (1988), and Gelman (2005), who have adopted process and variation approaches.

Typically, the process model lacks generalizability without contextual information, yet its findings may be extrapolated to broader contexts. According to Markus and Robey (1988) and Mohr (1982), when utilizing a process model, the anticipated outcomes are inferred based on the understanding of the process rather than solely on the degree of predictor variables. The utilization of the process model confers several advantages to scholars:

- The utilization of this approach facilitates the acquisition of knowledge about the process, ultimately enabling the identification of patterns that can be verified in alternative settings, and the subsequent derivation of overarching conclusions.

- This methodology allows the transition from a mere description of outcomes to a comprehensive elucidation of their underlying causes. Process model predictions are more precise in reflecting actual events in organizations than traditional variation model outcome predictions, which contrasts with dispersion models.
- This methodology facilitates comprehension of the development and execution of diverse instruments and frameworks and their evaluation of effects (Tsohou, 2008; Van de Ven and Engleman, 2004; Markus and Robey, 1988).

The variation model is characterized by a propensity for ongoing development and alteration, whereas the process model emphasizes the human element in the process of change and development. The variability model offers the benefit of generating non-contextual generalizations that facilitate prediction. Nevertheless, the variation model presents certain drawbacks. The model's efficacy in analyzing various processes, particularly social processes, is limited due to its excessively rigid assumptions, as noted by Tsohou (2008), Gelman (2005), Psyne et al. (2017), and Van de Ven and Engleman (2004).

The coexistence of the process and variation models does not present a contradiction in examining the selected phenomenon. The mutual reinforcement between them has been demonstrated by several researchers (Van de Ven and Engleman, 2004; Tsohou, 2008; Langley, 1999; Markus and Robey, 1988). The researcher employs a variation model to elucidate the causal mechanism underlying the impact of an independent variable on a dependent variable. This approach entails tracing the sequence of events that lead to the observed effect, thereby illuminating the underlying process that mediates the relationship between the two variables. Variation research questions can serve as a complementary source of information to process research. In analyzing the progression of events that result in notable alterations within an organization, such as implementing novel digital technologies, it can be advantageous to ascertain the determinants that dictate their distinct pattern. This approach has been advocated by scholars such as Tsohou et al. (2008) and Gelman (2005) in their respective works.

In the research of this dissertation, a process model was chosen as a more appropriate tool to show the actualization of digital technologies affordances, the sequence in which it takes place, and the interrelationships and complementarities between different digital technologies affordances.

### 1.5.6. The process model of actualization of digital technologies' affordances

The existence of affordances does not necessarily ensure outcomes as they pertain to the potential for performance rather than concrete actions or outcomes. In order to translate potential into tangible results, members of an organization must undertake purposeful actions aimed at utilizing technology to attain a desired outcome. This process is commonly referred to as affordances actualization, as highlighted in the works of Burton-Jones and Volkoff (2017) and Strong et al. (2014). The process model for actualizing digital technologies' affordances in organizations was established through a comprehensive analysis of the scientific literature, as depicted in Figure 4. The model presented herein outlines a process for actualizing affordances offered by digital technologies. This process is underpinned by six hypotheses, which are elaborated upon in the subsequent sections.

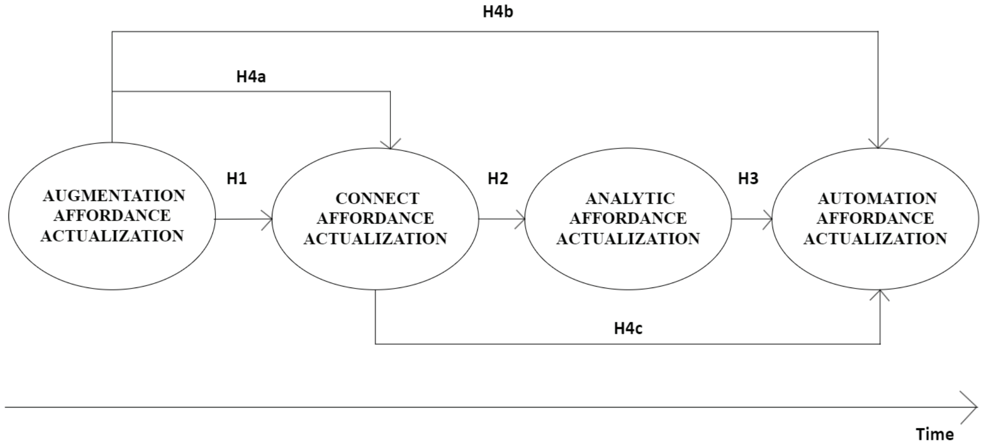



**Figure 4.** The process model of the actualization of digital technologies' affordances in organizations

### *Complementarity-related hypotheses*

Firstly, it is assumed that the actualization of augmentation affordance affects the actualization of connect affordance in organizations. The concept of augmentation affordance in technology and human-computer interaction pertains to the technological capability of expanding or improving human abilities to execute a given task effectively. While connect affordance pertains to the technological capacity to enable connections and interactions among users (Raisch and Krakowski, 2021; Lenka et al., 2017; Vilkas et al., 2022). The reason augmentation affordance has a direct positive effect on connect affordance can be attributed to several arguments: 1) enhanced capabilities: as technology augments human abilities, people are better equipped to engage with others, share information, and collaborate more effectively. This enhanced capacity can directly improve the quality of user connections and interactions. 2) Increased accessibility: augmented technologies often make it easier for users to access and utilize the tools necessary for connecting with others, such as communication platforms, social media, and collaboration software. 3) Improved communication: actualization of augmentation affordances can also enhance communication, enabling users to express themselves more effectively, understand each other better, and collaborate more efficiently (Gagnon, 2023; Norman, 1999; Bodker, 1991; Gaver, 1991; Zammuto, 2007). For example, if you have strong actualized augmentation affordance, it will be easier to actualize a connect affordance. This assumption is built by the findings of previous studies (Volkoff and Strong 2013; Strong et al. 2014), which confirmed the positive links between augmentation and connect affordances outcomes. When organizations have a lot of different digital technologies and software, the natural demand to connect these technologies to one network arises, and data sharing between various systems becomes essential. Experience gained in actualizing augmentation affordance can be successfully used to connect affordance (Volkoff and Strong, 2013; Strong et al., 2014; Dremel et al., 2020). Therefore, the hypothesis is that:

*H1: Actualization of augmentation affordance has a direct positive effect on the actualization of connect affordance.*

Secondly, it is assumed that the actualization of connect affordance affects the actualization of analytic affordance in organizations. The concepts of affordance and analytic affordance are essential in the field of human-computer interaction, specifically in the context of wireless communication networks that facilitate the exchange of data and information within organizations, as well as in data analysis and visualization. Connect affordance refers to facilitating meaningful connections between digital technologies in the organization. On the other hand, analytic affordance pertains to the system's capacity to support users in extracting insights, identifying patterns, and making data-driven decisions (Lenka et al., 2017; Vilkas et al., 2022). The reason why the actualization of connect affordance has a direct positive effect on the actualization of analytic affordance can be attributed to several arguments. Strong actualized connect affordance equips users with a valuable resource that helps them better understand their data, identify trends, and make informed decisions. By leveraging this resource, users can gain a competitive advantage in their respective domains, ultimately contributing to enhanced analytic affordance. Actualization of connect affordance can act as a complementary resource to other components of a data analysis system, such as visualization tools and machine learning algorithms. By synergistically combining these resources, users can derive more excellent value from their data and improve their analytic affordance (Lenka et al., 2017; Tim et al., 2020; Conole and Dyke, 2004). Volkoff and Strong (2013) emphasize possible connections between connect and analytic affordances. When organizations connect different digital technologies and systems, it generates data. In this situation, it analytical tools are needed. Experience gained in the process of actualization of connect affordance can be used to actualize analytic affordance successfully. Examining connect and analytic affordance through the lenses of affordances theory can justify the direct positive effect of the actualization of connect affordance on the actualization of analytic affordance. Actualization of connect affordance facilitates actionable insights and reduces cognitive load, thereby improving the actualization of analytic affordance from an affordances theory perspective. Therefore, the hypothesis is that:

*H2: Actualization of connect affordance has a direct positive effect on the actualization of analytic affordance.*

Thirdly, it is assumed that the actualization of analytic affordance affects the actualization of automation affordance in organizations. The relationship between analytic and automation affordance is one of the crucial aspects of human-computer interaction, particularly in actualizing digital technologies affordances. Analytic affordance refers to a system's capacity to support users in extracting insights, identifying patterns, and making data-driven decisions, while automation affordance pertains to a system's ability to execute tasks autonomously, reducing the need for human intervention (Lenka et al., 2017; Raisch and Krakowski, 2021; Vilkas et al., 2022).

The reason why the actualization of analytic affordance has a direct positive effect on the actualization of automation affordance can be attributed to several arguments. Within the realm of information systems, analytic affordance facilitates users in making well-informed decisions by utilizing insights from data analysis. As users become more adept at making data-driven decisions, the scope for automation affordance increases, as automation systems can be designed to execute those decisions more efficiently and accurately (Davenport, 2013; Brynjolfsson & McAfee, 2014). The actualization of analytic affordance is a resource that complements the actualization of automation affordance, as it allows organizations to identify patterns and insights that can be leveraged to optimize and streamline processes. This complementarity means that firms with actualized solid analytic affordance can effectively utilize their actualization of automation affordance, thus reinforcing the positive relationship between the two affordances. As organizations leverage analytic affordance to identify patterns and derive insights, they are better equipped to adapt to changing environments and improve their processes continuously. This adaptability and continuous improvement make it possible to develop further and refine automation affordance, leading to more efficient and effective automated systems. Actualization of analytic affordance allows organizations to analyze large volumes of data, identify trends, and uncover hidden patterns. This analysis can reveal inefficiencies and bottlenecks in existing processes, pinpointing areas where automation can be introduced to improve performance. In contemporary organizations, especially manufacturing, optimizing multiple processes leads to greater automation of different business processes, both simple routines and more complex ones (Volkoff and Strong, 2013; Raisch and Krakowski, 2021). Therefore, the hypothesis is that:

*H3: Actualization of analytic affordance has a direct positive effect on the actualization of automation affordance.*

The process model of actualization posits that the relationships between various digital technologies' affordances result in significant outcomes that impact an organization's overall performance, both directly and indirectly. Some indirect effects and complementarities are present in the actualization of various affordances of digital technologies. The actualization of augmentation affordance exhibits a favorable indirect impact on the actualization of analytic affordance as well as automation affordance. The actualization of connect affordance exhibits a favorable indirect impact on the actualization of automation affordance. The indirect effects present in the process model of actualization of digital technologies' affordances can be attributed to various arguments. The indirect effect of the actualization of augmentation affordance on the actualization of analytic affordance (via actualization of connect affordance) can be described as a sequential relationship between these three affordances, where the stronger actualization of one affordance leads to the stronger actualization of the next affordance. The strong actualized augmentation affordance leads to an enhanced actualization of connect affordance. As the actualization of augmentation affordance supports users in their tasks, they become more capable of connecting and sharing relevant data. As the actualization of connect affordance improves, the actualization of augmentation affordance indirectly enhances the actualization of analytic affordance by providing more diverse and accurate data from various sources. With improved collaboration and information sharing, organizations can access a broader range of data points and perspectives, contributing to a more robust data analysis process. It enables the organization to derive more accurate and actionable insights, thus improving analytic affordance. This indirect effect ultimately contributes to a more robust actualization of analytic affordance (Lenka et al., 2017; Zammuto et al., 2007; Raisch and Krakowski, 2021).

The facilitation of the indirect relationship between the actualization of connect and automation affordances is enabled by the actualization of analytic affordance. The stronger actualization of connect affordance leads to an enhanced actualization of analytic affordance, which leads to enhanced actualization of automation affordance. Actualization of connect affordance is critical for harnessing the full potential for the actualization of automation affordance. Better connected systems help to work for digital technologies more autonomously and adapt to changing conditions. The indirect relationship between the actualization of connect and automation affordances is complex and multifaceted. While actualizing both affordances contributes to system efficiency and adaptability, they also influence each other in various ways (Leonardi, 2011).

As technology advances, the relationships between actualizing various digital technologies' affordances become increasingly relevant to optimize system performance, efficiency, and adaptability. The indirect relationship between the actualization of augmentation and automation affordances, mediated by the actualization of connect and analytic affordances, is important. Actualization of augmentation affordance is essential for empowering users to harness the full potential of digital technologies in various domains. Actualization of augmentation affordance via the actualization of connect affordance and via the actualization of analytic affordance positively and indirectly affect the actualization of automation affordance (Raisch and Krakowski, 2021). Therefore, the hypotheses of indirect effects are these:

*H4a: Actualization of augmentation affordance has an indirect positive effect on the actualization of analytic affordance.*

*H4b: Actualization of augmentation affordance has an indirect positive effect on the actualization of automation affordance.*

*H4c: Actualization of connect affordance has an indirect positive effect on the actualization of automation affordance.*

***Process/pattern-related hypothesis***

Initially, companies start by introducing simple digital technologies to their activities. Organizations initiate to utilize digital technologies, such as Enterprise Resource Planning (ERP) systems, essential software for warehouse management, production control systems that operate in near real-time, and various other technological tools. This first step is the actualization of augmentation affordance (Barney and Clark, 2007; Ras et al., 2017). Companies reach a stage where they have many different digital systems, but these systems need more cooperation and information sharing in real-time. Then there is a need to deploy digital technologies (such as the Industrial Internet, a system for exchanging product and process information with suppliers and customers, and digital solutions that provide drawings and other important information to the workplace in real-time) that help connect a variety of different information technologies wirelessly in the organization. This second step is called the actualization of connect affordance (Lenka et al., 2017; Volkoff and Strong, 2013, Tams et al., 2014).

When organizations use different related and connected digital technologies in their activities, there is a growing natural demand for analytic tools. Because companies want to know how efficient different activities and processes are, what generates the most significant revenues, where the most significant gaps in processes are, how to improve activities, and how to reduce time costs in production. Also, nowadays, many information and production systems and sensors of products collect a large amount of valuable data. So, they start to use different analytical tools (for example, Microsoft Power BI and others). This third step is actualizing analytic affordance (Lenka et al., 2017; Zammuto et al., 2007; Dremel et al., 2020). After the third step, organizations have much valuable information, which can help make decisions. These decisions lead to automation in organizations with the help of digital technologies. Organizations can automate from simple things to complex tasks. This final step is the actualization of automation affordance (Raisch and Krakowski, 2021).

The cumulative effect of actualizing augmentation, connect, analytic, and automation affordances is a slew of synergistic benefits rooted in the intertwined complementarities of these affordances. Realizing these affordances empowers stakeholders to achieve a spectrum of results within organizations. These include streamlining the adoption of varied digital technologies, optimal allocation of finite organizational resources, enhancing process efficiency, and unlocking the full potential of digital technologies (Barney and Clark, 2007; Zammuto et al., 2007). The hypothesis supporting the process model is:

*H5: The affordances of digital technologies are actualized in this sequence: augmentation, connect, analytic, and automation.*

***Speed-related hypothesis***

Companies that follow this sequence of affordances – 1) augmentation, 2) connect, 3) analytic, and 4) automation – are on average faster in actualizing digital technologies affordances than companies that follow other sequences because this approach corresponds to the natural development of technology adoption and implementation.

Each stage in this sequence builds on the previous one, allowing for a smoother and more efficient transition. In the actualization stage of augmentation affordance, organizations focus on enhancing human capabilities through digital technologies. Companies that start with augmentation are often more successful because they initially focus on supporting and improving existing processes and employee productivity. It allows them to understand better the potential of digital technologies and how they can be effectively integrated into their operations. Once companies have experienced the benefits of augmentation, they connect different systems and data sources. This stage involves integrating various technologies to enable seamless communication and data exchange. By connecting different systems, companies can create more efficient and faster workflows, reduce redundancies, and improve decision-making. After establishing a connected ecosystem, companies can start leveraging the power of data analytics. This stage entails utilizing sophisticated analytical tools and methodologies to derive observations from the interconnected systems' copious amounts of data generated. Companies can use these insights to optimize and make their operations faster. Also, these insights help to identify new business opportunities and make more informed decisions. Finally, companies can focus on automating processes and tasks using digital technologies. Automation allows for significant efficiency improvements and cost savings by reducing the need for manual intervention. At this stage, companies have already built a strong foundation with the previous affordances, enabling them better and faster actualize automation affordance (Barney and Clark, 2007; Raisch and Krakowski, 2021; Ras et al., 2017; Zammuto et al., 2007; Lenka et al., 2017; Tan et al., 2015). Therefore, the hypothesis is this:

*H6: Companies that actualize digital technologies' affordances following the Augmentation affordance->Connect affordance->Analytic affordance->Automation affordance sequence are, on average, faster in actualizing digital technologies' affordances than companies following all other possible actualization sequences.*

## 2. METHODOLOGY OF THE RESEARCH ON THE PROCESS MODEL OF ACTUALIZATION OF DIGITAL TECHNOLOGIES' AFFORDANCES IN ORGANIZATIONS

This part of the thesis is built around the research methodology. The section starts with the research philosophy and approach. An overview of the methodology of the quantitative study follows this. Survey design, sample, data collection, operationalization of the constructs and data analysis methods are described. The section concludes with a description of the measurement model.

### 2.1. Research philosophy and approach

Scientific assumptions and concepts underpin several research philosophies (Park et al., 2020). The philosophy of research can be defined as what the researcher views to be truth, reality, and knowledge. The research philosophy outlines the principles and beliefs influencing research data gathering and analysis (Gemma, 2018). Positivism, realism, interpretivism, and pragmatism are the major research philosophies.

Positivism is based on a deductive model of science that relies on hypothesis testing and experimentation in operationalizing variables and measures. In this case, the results of hypothesis testing are used to inform and improve science. The findings of the research based on the philosophy of positivism are used to supplement the theory, thus completing the circular process (analysis of the theory → hypothesis → operationalization of variables → research → addition of new knowledge to the theory) (Park et al., 2020).

Realism asserts that reality exists independently of human consciousness, assigns causal powers to human causes and social structures, and rejects relativism in social and scientific discourse (Yeung, 1997). Realists think reality exists outside the researcher's control (Gemma, 2018).

Interpretivism is in opposition to positivism. Interpretivism arose from the development of Kant's ideas and the subjectivity of values. Interpretivism argues that knowledge is subjective and based on people's experiences and beliefs. Because it is difficult for researchers to distance themselves from their values and beliefs, so this will affect the material they collect or analyze (Gemma, 2018).

The philosophy of pragmatism is concerned with both knowledge and values. Pragmatism links measures and ends with requirements, which must be validated based on factual rather than theoretical conditions. Induction and ongoing study in pragmatism apply to solve problems (Emison, 2004). Pragmatism is a valuable paradigm for qualitative research on organizational processes. Pragmatism is founded upon several fundamental principles, including prioritizing knowledge that can be put into practical use, recognizing knowledge and action, and committing to inquiry as an experiential process (Kelly and Cordeiro, 2020).

Positivism and pragmatism are chosen as the philosophical ground of this research. These philosophical paradigms are chosen because they will best answer the problematic questions raised in this dissertation.

## 2.2. Quantitative study of the process model of actualization of digital technologies' affordances in organizations

**Survey design.** This quantitative study is based on 2018–2019 European manufacturing survey data. It is a total of 22-question survey instruments with 310 items. The chosen targeted population for the research is 10,949 manufacturing companies in Central and Eastern European countries (Lithuania, Slovenia, Croatia, Slovakia, and Austria). Company size (small, medium, big) and company sector under Nace C were selected as representative criteria because they are essential demographic criteria in manufacturing companies' research (Grafström and Schelin, 2014). A sample (N=798) was collected from targeted population using a survey method. The margin error of the sample was 3% when the confidence level was 95%. It shows that the collected sample well represents the population (Thornton and Thornton, 2004; Kosar et al., 2018). These five countries (Lithuania, Slovenia, Croatia, Slovakia, and Austria) were selected as homogeneous countries for the research. One of the main selection criteria was the geographic location: these countries are in Central and Eastern Europe and are part of the European Union. They are relatively close to each other, which makes it easier to compare and analyze data. Central and Eastern European countries have historical strengths in manufacturing. Austria has a highly developed digital economy with solid manufacturing companies, while Lithuania's manufacturing companies are rapidly developing their digital infrastructure. The manufacturing industry in Slovenia has a strong background in developing various digital technologies solutions. In contrast, Croatia and Slovakia have grown adoption of digital technologies in manufacturing companies. Central and Eastern European countries have strong trade ties due to proximity and shared history. It means that manufacturing companies operate in similar supply chains or markets, and it ensures some level of homogeneity in their operations and challenges. Manufacturing companies were chosen for the research because of several reasons:

- High level of digital technologies adoption: manufacturing businesses frequently adopt new technologies early, especially those that can increase production and efficiency. As a result, they offer a valuable context for examining the affordances of digital technology.
- Complex operations: manufacturing processes sometimes entail several different steps. This complexity offers a rich context for examining the affordances of digital technologies.
- Large data sets: manufacturing businesses produce a lot of data, which can be used to study how digital technologies have impacted various operations.
- Wide range of technology: The Internet of Things (IoT), robotics, automation, and data analytics are just a few examples of the diverse digital technologies used by manufacturing organizations. This variety offers the chance to examine the benefits offered by various technologies and how they affect the manufacturing processes.
- Economic impact: manufacturing is a crucial industry for many countries and a significant driver of economic expansion and development.

Overall, manufacturing companies provide a rich and diverse environment for analyzing digital technologies affordances. Their early adoption of new technologies, complex operations, large data sets, and economic impact make them an ideal research object for understanding digital technologies affordances.

The data from the European manufacturing survey was chosen because this study has dedicated question blocks for digital technology analysis in organizations (see Annex 1). The questions sought to find out what digital technologies were used in the organization when they were introduced and at what level the affordances of digital technologies have been actualized in the organization. These digital technologies were surveyed in EMS: additive manufacturing (3D printing technologies), manufacturing robots, digital platforms for sharing data, digital solutions that offer all needed information on the workplace, mobile and wireless devices, real-time manufacturing monitoring systems, software for manufacturing organizing and time management, automated systems of internal logistics, virtual reality, and computer simulation, display boards in production.

Another part of this questionnaire is dedicated to the demographic questions of an organization. The questions pertain to the determination of the industry and primary product line manufactured at the factory and the identification of the characteristics that most accurately depict the primary product or product line within the organization. The questionnaire inquires about the business models the organization provides to its customers and requests information such as the annual turnover, number of employees, year of factory establishment, investment in equipment and machinery, and return on sales.

The last part of this questionnaire regarding organizational concepts is currently used in factories, cooperating with other companies, data security in an organization, about R&D (Research and Development).

The data from the European manufacturing survey was used to test a process model that hypothesizes how the affordances of digital technologies are actualized.

**Sample**. Population – NACE C – manufacturing (10,949 companies). Sample size is 798 companies. Type of survey: telephone and online. Respondents – CEO, technicians, or manufacturing managers. Defined target sample stratification by sector: 1) Food and beverages; 2) Textiles; 3) Engineering; 4) Wood and furniture, 5) Chemical, 6) Other. Defined by geographical region: 1) Lithuania (199 cases), 2) Slovenia (127 cases), 3) Croatia (105 cases), 4) Slovakia (114 cases), 5) Austria (253 cases). Defined by Size (employees): 1) up to 49, 3) 50–249, 4) 250+.

**Data collection.** The data was gathered in 2018–2019 from the European Manufacturing Survey (EMS). An international network of research organizations, EMS, gathers data in its member nations. The data collection process makes use of a standardized questionnaire. The questionnaire is written in English and then translated into each nation's national language. The questionnaire was pre-tested in each participating nation, and any problems were fixed. Because each manufacturing site within a business unit may display varied performance capabilities, the data were gathered on distinct manufacturing sites (Schroeder et al., 2011). The information was gathered using a survey administered over the phone and online.

The author of this dissertation is a member of the Lithuanian team in the European Manufacturing Survey and participated in the survey, data collection, and data processing in Lithuania. Data for the other countries selected for the study (Austria, Slovakia, Slovenia, and Croatia) were obtained from the countries' teams that carried out the study.

**Operationalization of the constructs.** The following items (see Table 9) to measure digital technologies affordances (augmentation, connect, analytic, and automation) in organizations were developed and chosen according to Marcon et al. (2022), Blichfeldt and Faullant (2021), Von Haartman et al. (2020), Lalic et al. (2020), Palcic et al. (2015), Armbruster et al. (2005), scholars who worked and wrote about digital technologies based on European manufacturing survey data.

The measuring items for the augmentation, connect, analytic, and automation affordances were also influenced by academics who wrote about these affordances. The academics who have written about augmentation affordance include Raisch and Krakowski (2021), Ras et al. (2017), Daugherty and Wilson (2018), and Langley and Simon (1995). Their work impacted the choice of measuring items for augmentation affordance. The researchers focused on different digital technologies, from software for production planning to automated systems for internal logistics, which are essential for augmentation affordance.

**Table 9.** Operationalization of process model constructs

| **Authors** | **Constructs** | **Measurement items (Yes/No)** | **Year of implementation** | **Extent of actualized potential (low; medium; high)** |
|---|---|---|---|---|
| Raich and Krakowski, (2021); (Ras et al., 2017); Jain et al. (2021); (Amershi et al., 2014); (Holzinger, 2016); Daugherty and Wilson, (2018); Langley and Simon, (1995); | *Augmentation affordance* | Use of software for production planning and scheduling | X | X |
| | | Use of real-time production control system | X | X |
| | | Use of systems for automation and management of internal logistics | X | X |

| Authors | Constructs | Measurement items (Yes/No) | Year of implementation | Extent of actualized potential (low; medium; high) |
|---|---|---|---|---|
| Lenka et al., (2017); Vitturi et al. (2019); Zammuto et al. (2007); Conole and Dyke, (2004); | *Connect affordance* | Use of programming and controlling facilities and machinery | X | X |
| | | Use of digital solutions to provide documents directly on the shop floor | X | X |
| | | Use of exchange of product/process data with suppliers/customers | X | X |
| Lenka et al., (2017); Tim et al. (2020), Raisch and Krakowski, (2021); Volkoff and Strong (2013) | *Analytic affordance* | Use of virtual reality or simulation for product design or product development | X | X |
| | | Use of display boards in production | X | X |
| Frohm et al., (2008); Raisch and Krakowski, (2021); Davenport and Kirby, (2016); Lindebaum et al., (2018); Russell and Norvig (2009) | *Automation affordance* | Use of industrial robots for manufacturing processes | X | X |
| | | Use of industrial robots for handling processes | X | X |
| | | Use of 3D printing technologies | X | X |

Lenka et al. (2017), Vitturi et al. (2019), Zammuto et al. (2007), and Conole and Dyke (2004), who have written on connect affordance, had an impact on the selection of measurement items for connect affordance. These researchers focused on digital technologies that are the background for connect affordance, from mobile and wireless devices to digital platforms for sharing product and process data.

Lenka et al. (2017), Tim et al. (2020), Raisch and Krakowski (2021), and Volkoff and Strong (2013), who have written on analytic affordance, had an impact on the selection of assessment items for analytic affordance. These scholars underlined the importance of using virtual reality, computer simulation, and display boards in production for monitoring purposes for analytic affordance.

Frohm et al. (2008), Raisch and Krakowski (2021), Lindebaum et al. (2018), and Russell and Norvig (2009), who have written about automation affordance, had an impact on the selection of measurement items for automation affordance. These scholars underlined the importance of industrial robots and additive manufacturing (3D printing technologies) for automation affordance.

Notably, the historical component of digital technology implementation is a crucial factor in assessing the evolution of its affordances. The categorization of digital technology's potential (low, medium, high) is employed to ascertain the degree of actualization of the affordances of digital technologies.

**Data analysis methods.** Different methods were used in quantitative research to test the process model for the actualization of the affordances of digital technologies in organizations.

One of the most useful cutting-edge statistical analysis methods in the social sciences in recent decades is structural equation modeling (SEM). Although there are other SEM methods, the covariance-based approach SEM (CB-SEM) has been the most extensively utilized since the late 1970s. In the years after, the PLS-SEM method has grown in popularity across various social science disciplines. It examines the goals of covariance-based SEM (CB-SEM) and partial least squares SEM (PLS-SEM) (Hair et al., 2017).

Consider the differences in their characteristics and goals when determining whether to use PLS-SEM or CB-SEM (Hair, Sarstedt, Ringle, et al., 2012; Henseler et al., 2014). When CB-SEM cannot be used because the theory needs to be developed, PLS-SEM should be considered. It is critical if the primary goal of using structural modeling is to forecast the target model and explain the constructs (Rigdon, 2012; Rigdon et al., 2014). One of the significant conceptual distinctions between PLS-SEM and CB-SEM is how each method addresses the model's latent variables. CB-SEM treats the constructs as common factors that explain the covariance of the linked measures. These typical factor estimations' assessment indicators are neither known nor required for the assessment model parameters (Rigdon, 2012).

In this study, regression analysis was conducted using Partial Least Squares Structural Equation Modelling (PLS-SEM) (Hair et al., 2017). Compared to other methods like covariance-based structural equation modeling (CB-SEM), PLS-SEM is preferable. PLS-SEM, an approach well-suited for exploratory research, is advantageous because the predicted relationship between the constructs in the previously presented process model primarily draws from qualitative case studies or less detailed models. Since the European manufacturing survey questionnaire was not explicitly tailored for the specified study issue, PLS-SEM is more apt for this research than CB-SEM. Hair et al. (2019) suggest that PLS-SEM is more likely to produce accurate results. It also facilitates the analysis of non-normal data and small sample data sets (Hair et al., 2011; Hair et al., 2012). Importantly, PLS-SEM can manage single-item constructs and both reflective and formative measurement methods with ease, making it versatile for various research contexts. The superior parameter estimation efficiency of PLS-SEM boosts its effectiveness. Compared to CB-SEM, PLS-SEM possesses greater statistical power. With this heightened statistical power, PLS-SEM is more apt to recognize a significant relationship in the population as such (Thiele et al., 2015). The PLS-SEM analysis facilitated the reliable evaluation of complementarity-related hypotheses (H1, H2, H3, H4a, H4b, H4c). For these hypotheses (H1, H2, H3, H4a, H4b, H4c) to be accepted, all relationships must be positive and statistically significant. Otherwise, if even one relationship is negative or statistically insignificant, the complementarity-related hypotheses are rejected (see Table 10).

The determination of sequence frequencies, supplemented with the chi-square test, was employed to robustly examine the sequence of actualization of digital technologies' affordances as posited in the process pattern hypothesis (H5).

Process mining analysis was employed to determine sequence frequencies. Initially, the data was prepared for the process mining method. Out of 798 companies, only 153 were deemed suitable for analysis, as they had all four actualized digital technology affordances: augmentation, connection, analytics, and automation. The remaining companies were excluded due to their fewer actualized digital technologies' affordances. Given the specific nature of process mining, it is imperative that the companies under investigation have all the digital technologies' affordances actualized.

Process mining encompasses a range of data-driven methods that leverage both business process management and machine learning to analyze and improve business processes. By examining event data from information systems, process mining contrasts the actual process flow with how the information systems are intended to operate, pinpointing discrepancies. Thus, process mining bridges the gap between traditional model-based and data-driven approaches in business process management. While data-driven methods tend to be process-independent, conventional model-based techniques can miss critical hidden evidence. These limitations are addressed by process mining, which draws on event data to refine entire business processes (Zerbino et al., 2021; Van der Aalst, 2016).

The method of process mining analysis uses longitudinal data, i.e., the temporal ordering of digital technologies' affordances actualization. The method consists of two stages: discovering a complete set of sequence alternatives and analyzing their characteristics. During the first stage, available data on digital technologies' affordances actualization is used to identify numerous potential sequences. To develop a set of available sequences, at least a ranking of the actualization of digital technologies' affordances of a consistent group of companies is necessary. The data comprising the year of introducing each digital technologies' affordance enrich the analysis. It is best to present data at the start and end of each introduction to digital technologies' affordance. Thanks to EMS data, generating a complete set of sequences alternatives and their manifestation frequencies in the sample is possible. Process mining algorithms (Van der Aalst, 2016; Zerbino et al., 2021) allow mining all possible digital technologies' actualization sequences and characteristics. Depending on the availability of the input data, the second stage reveals the characteristics of each actualization sequence. No further meaningful analysis could be implemented in case ranking data is unavailable. It is feasible to determine the average time it takes for a digital technologies' affordance to actualize (that is, from the first to the last) given the data at the beginning of the introduction of each affordance. Finally, it is possible to determine the starting-end duration of each sequence and the duration of actualization of each affordance using the dates of the beginning and finish of the actualization of digital technologies' affordances. The process mining method has its strengths and weaknesses. The longitudinal data on affordances actualization is challenging to collect. The "beginning" and the "end" could be difficult to identify. On the contrary, the method can reveal a complete set of potential sequences and their characteristics.

The results of determining sequence frequencies must conform to the order of the actualization sequence of digital technologies' affordances to accept the hypothesis (H5). The sequence (augmentation affordance → connect affordance → analytic affordance → automation affordance) should be most manifested compared with all other possible digital technologies' affordances actualization sequences. Otherwise, the hypothesis (H5) is rejected if the result does not conform to the sequence.

The chi-square test was employed to check the significance of determining sequence frequency results. The utilization of this test proves to be highly valuable in situations where there is a need to assess the conformity of observed data to a predetermined distribution. It is also applicable in cases where an anticipated distribution has been derived from either a theoretical model or historical data. The null hypothesis for the chi-square test posits that there is no significant difference between the observed frequencies and the expected frequencies. The alternative hypothesis posits that there exists a statistically significant disparity between the frequencies observed and those expected, thereby suggesting a departure from the predetermined distribution or model. The chi-square statistic is computed by summing the squared differences between observed and expected frequencies, which are then divided by the expected frequency for each category (Pearson, 1900; Cochran, 1952).

The prevalence of the sequence (augmentation affordance → connect affordance → analytic affordance → automation affordance), which is most common, was compared to the second most prevalent sequence. Each was compared with equal probabilities of 0.5. If the difference in prevalence between the first and second sequences were statistically significant, then the differences in prevalence between the first sequence and the third, fourth, and all other subsequent sequences would also be statistically significant, based on the logic of the chi-square test. For H5 to be accepted, the prevalence of the sequence (augmentation affordance → connect affordance → analytic affordance → automation affordance) must be statistically significant compared to the second and all other sequences. Otherwise, hypothesis H5 is rejected.

Speed-related hypothesis (H6) was tested with sequences speed determination and the Mann-Whitney U test. Process mining analysis provided speed data of all possible sequences of actualization of digital technologies' affordances. The most manifested sequence (augmentation affordance → connect affordance → analytic affordance → automation affordance) speed was compared with all other possible sequences of actualization of digital technologies' affordances. Because all other sequences of actualization of digital technologies' affordances were manifested in small samples, they were combined into one variable for comparison. The speed differences were compared between the dominant sequence and all other possible sequences of actualization of digital technologies' affordances. To check the significance of speed differences between the dominant sequence and all other possible actualization sequences of digital technologies' affordances, the Mann-Whitney U Test was employed, which is a nonparametric statistical test used to compare two independent groups. Unlike parametric tests like the Student's t-test, the Mann-Whitney U technique does not require data distribution assumptions. It makes it especially useful for assessing data that does not follow a normal distribution or when the sample size is insufficient to discern the underlying distribution correctly. The Mann-Whitney U method tests the null hypothesis that two independent groups have equal medians. Alternatively, the likelihood of an observation being more critical in one population than another is equal to 0.5 (King and Eckersley, 2019; Ramachandran and Tsokos, 2020; Mann and Whitney, 1947).

There are some advantages to using the Mann-Whitney U Method. Because the test does not make any assumptions about the distribution, it is more robust than parametric tests when the underlying distribution is unknown or non-normal. This approach is also less dependent on outliers. The Mann-Whitney U technique uses ranks instead of raw values. Data outliers less impact it. Finally, this technique is appropriate for ordinal data. The test can be applied to ordinal, continuous, or interval data, allowing it to be used in various research contexts (Nachar, 2008; MacFarland et al., 2016). Mann-Whitney U test allows to reliably check the speed-related hypothesis (H6).

For H6 to be accepted, the sequence of the process of actualization of digital technologies' affordances (augmentation affordance → connect affordance → analytic affordance → automation affordance) should be, on average, faster compared with all other possible digital technologies' affordances actualization sequences. This speed difference should be statistically significant. Otherwise, the hypothesis (H6) is rejected (see Table 10). Also, the hypothesis (H6) is rejected if the speed difference between the dominant sequence and all other possible digital technologies' affordances actualization sequences is not statistically significant.

In summary, Table 10 provides the main criteria for acceptance or rejection of research hypotheses.

**Table 10.** Criteria for acceptance/rejection of hypotheses

| Hypotheses | Methods for hypotheses testing | Result for acceptance | Result for rejection |
|---|---|---|---|
| H1, H2, H3, H4a, H4b, H4c | PLS-SEM | All relationships are positive and statistically significant. | At least one relationship is negative or statistically insignificant. |
| H5 | 1) The determination of sequence frequencies (process mining analysis)<br>2) Chi-square test | 1) Conform to the order of the actualization sequence of digital technologies' affordances.<br>2) The sequence is the most manifested compared with all other possible digital technologies' affordances actualization sequences.<br>3) The prevalence of the sequence (augmentation affordance → connect affordance → analytic affordance → automation affordance) is statistically significant compared to the second and all other sequences. | 1) Does not conform to the order of the actualization sequence of digital technologies' affordances.<br>2) The sequence is not the most manifested compared with all other possible digital technologies' affordances actualization sequences.<br>3) The prevalence of the sequence (augmentation affordance → connect affordance → analytic affordance → automation affordance) is not statistically significant compared to the second and all other sequences. |
| H6 | 1) Speed determination (process mining analysis)<br>2) Mann-Whitney U test. | 1) The sequence of the process of actualization of digital technologies' affordances (augmentation affordance → connect affordance → analytic affordance → automation affordance) is on average faster compared with all other possible digital technologies' affordances actualization sequences.<br>2) This speed difference between the dominant sequence and all other possible digital technologies' affordances actualization sequences is statistically significant. | 1) The sequence of the process of actualization of digital technologies' affordances (augmentation affordance → connect affordance → analytic affordance → automation affordance) is not on average faster compared with all other possible digital technologies' affordances actualization sequences.<br>2) The speed difference between the dominant sequence and all other possible digital technologies' affordances actualization sequences is not statistically significant. |

Also, partial least squares multigroup analysis (PLS-MGA) was used to check path coefficient differences of the process model of actualization of digital technologies' affordances (Hair et al., 2017). PLS-MGA analysis aimed to check whether the process model of actualizing digital technologies' affordances is stable or not under different criteria (country, size of the company, sector, the company's age; incorporated significant technical improvements/introduced new products;

R&D development). The Mann-Whitney U test was used for the comparative analysis under selected criteria (financial characteristics, the extent of actualized potential of digital technologies affordances) between the dominant sequence and all other possible sequences of actualization of digital technologies' affordances.

**Measurement model (Confirmatory factor analysis).** Researchers must consider two main categories of measurement specification when creating constructs: reflecting and formative measurement models. The reflecting measurement paradigm is based on traditional test theory and has a rich social science history. This theory states that the measures' items represent the effects (or manifestations) of the underlying notion. As a result, the construct and its measure's items are the sources of the causal relationship.

In contrast, formative measurement models presuppose that the assessed variables combine linearly to generate a construct. Consequently, academics sometimes refer to this measuring approach as a formative index. Unlike reflective items, formative items cannot be substituted. Deleting even one indicator can reduce the content validity of the measurement model. It is a crucial feature (Cenfetelli and Bassellier, 2009; Winklhofer 2001). As a result, each formative construct measure corresponds to a particular component of the construct domain. The meaning of the concept is ultimately determined by how the measured components are combined (Hair et al., 2017). Because the constructs in the process model of actualization of digital technologies' affordances are formative, this study will employ a formative measurement model. In the process model of actualization, digital technologies' affordances are created and defined by users of those technologies. This aspect of the formative model is present.

These criteria are used to evaluate the formative measurement model: indicator collinearity (VIF), indicator outer weights, and weight statistical significance (see Table 11). The collinearity should not exceed the threshold of 3 (Hair et al., 2017; Mason and Perreault, 1991; Becker et al., 2015). According to Kock (2015), a VIF larger than 3.3 is a sign of pathological collinearity, and that a model might be tainted by common method bias. Therefore, a comprehensive collinearity test's results are regarded as free of common method bias if all VIFs are equal to or below 3.3. The analysis showed that all VIF values of the constructs of the process model of actualization of digital technologies' affordances are acceptable and free of common method bias.

The values of outer weights in the formative measurement model are less important than in the reflective measurement model. However, it is very important statistical significance of these outer weights (Hair et al., 2019; Hair et al., 2017).

The weights of constructs items should have a P-value $< 0.05$ (Chin, 1998; Hair et al., 2017). The analysis showed that all P-values are acceptable, and the outer weights of the construct items are significant.

**Table 11.** Formative measurement model

| Construct | Item | VIF | Outer weights | p-value |
|---|---|---|---|---|
| Augmentation affordance | Use of software for production planning and scheduling | 1.141 | 0.69 | p<0.05 |
| | Use of real-time production control system | 1.199 | 0.394 | p<0.05 |
| | Use of systems for automation and management of internal logistics | 1.175 | 0.233 | 0.001 |
| Connect affordance | Use of programming and controlling facilities and machinery | 1.115 | 0.293 | p<0.05 |
| | Use of digital solutions to provide documents directly on the shop floor | 1.131 | 0.583 | p<0.05 |
| | Use of exchange of product/process data with suppliers/customers | 1.082 | 0.521 | p<0.05 |
| Analytic affordance | Use of virtual reality or simulation for product design or product development | 1.031 | 0.533 | p<0.05 |
| | Use of display boards in production | 1.031 | 0.759 | p<0.05 |
| Automation affordance | Use of industrial robots for manufacturing processes | 1.211 | 0.291 | 0.015 |
| | Use of industrial robots for handling processes | 1.193 | 0.375 | 0.001 |
| | Use of 3D printing technologies | 1.083 | 0.694 | p<0.05 |

In summary, the formative measurement model analysis results showed that all measurement model parameters are acceptable and significant.

## 3. EMPIRICAL RESEARCH ON THE PROCESS MODEL OF ACTUALIZATION OF DIGITAL TECHNOLOGIES' AFFORDANCES IN ORGANIZATIONS

This part of the thesis is built around the findings of empirical research. The section starts with the descriptive statistics of the quantitative research. After it is presented, the process model of actualizing digital technologies' affordances is analyzed. Next the robustness analysis of the process model of actualization of digital technologies' affordances is presented. The section closes with a comparative analysis between the dominant sequence and all other possible sequences of actualization of digital technologies' affordances.

### 3.1. Descriptive statistics of the digital technologies' affordances in the manufacturing companies

The sample statistics are discussed in the first section of the descriptive analysis to give context to the data set. Subsequently, the possession of digital technologies' affordances is analyzed. After, the extent of the actualized potential of digital technologies' affordances and associations between digital technologies' affordances are analyzed. Ultimately, the determination of the start year of actualization of digital technologies' affordances is provided.

#### 3.1.1. Sample statistics

Data from 798 European manufacturers are included in the dataset. According to Table 12, Austrian companies comprise the largest country-specific group of enterprises, accounting for 31.7% of the dataset. In contrast, Croatian companies comprise the smallest country-specific group, representing 13.2%.

**Table 12.** Number of datasets by country

| Country title | Number of cases | Percent |
|---|---|---|
| Austria | 253 | 31.7% |
| Lithuania | 199 | 24.9% |
| Slovenia | 127 | 15.9% |
| Slovakia | 114 | 14.3% |
| Croatia | 105 | 13.2% |
| Total number: | 798 | 100% |

Table 13 shows the size of the surveyed companies in terms of the number of employees. According to respondents' responses, small enterprises comprise most companies, 42.4%.

**Table 13.** Company size and number of employees

| Company size | Number of employees in 2017 | |
|---|---|---|
| | **Frequency** | **Percent** |
| Small enterprise (Up to 49 employees) | 338 | 42.4% |
| Medium enterprise (50–249 employees) | 333 | 41.7% |
| Big enterprise (250 and more employees) | 123 | 15.4% |
| Other (Companies which did not provide data about the number of employees) | 4 | 0.5% |

The medium enterprise is very near with 41.7%. The smallest percentage among respondents' responses is 15.4% for large businesses (250 employees or more). Four businesses (0.5%) did not offer information on the number of employees.

The distribution of manufacturing companies is displayed in Table 14. The biggest industry group represented in the survey is engineering manufacture, with 52.5%. The smallest industry group represented in the survey is other manufacturing, with 3.3%.

**Table 14.** Distribution of companies by sub-sectors

| Industry type of manufacturing | Frequency of companies | Percent |
|---|---|---|
| Manufacture of engineering | 419 | 52.5% |
| Manufacture of wood and furniture | 135 | 16.9% |
| Manufacture of food and beverages | 85 | 10.7% |
| Manufacture of chemical | 68 | 8.5% |
| Manufacture of textiles | 65 | 8.1% |
| Other manufacture | 26 | 3.3% |
| Total | 798 | 100% |

The questionnaire asked which digital technologies companies use in their activities. The most popular digital technologies used in manufacturing companies are these (see Table 15): software for manufacturing organizing and time management (59.8%), display boards to monitor work processes and the status of ongoing work in production (44.9%), digital tools to deliver sketches, plans, timetables, or instructions for job tasks directly to the workplace (44.5%), the digital platforms for sharing product and process data with suppliers and customers (41.7%).

**Table 15.** Digital technologies usage level in manufacturing companies

| Digital technologies in manufacturing companies | Manufacturing companies which use specific digital technology (percentage) |
|---|---|
| Software for manufacturing organizing and time management | 59.8% |
| Display boards to monitor work processes and the status of ongoing work in production | 44.9% |
| Digital tools to deliver sketches, plans, timetables, or instructions for jobs tasks directly to the workplace | 44.5% |
| Digital platforms for sharing product and process data with suppliers and customers | 41.7% |
| Real-time manufacturing monitoring system | 33.7% |
| Wireless and mobile devices to manage machinery and facilities | 33.5% |
| Automated systems of internal logistics | 26.8% |
| Manufacturing robots for production operations | 26.7% |
| Virtual reality or computer simulation in the context of product design, creation, and testing | 24.6% |
| Manufacturing robots for handle tasks and procedures | 23.6% |
| Additive manufacturing (3D printing technologies) for production | 17.1% |

Some digital technologies are less used by manufacturing companies. For example, additive manufacturing (3D printing technologies) is used by only 17.1% of all companies.

### 3.1.2. Possession of digital technologies' affordances by country

When analyzing which digital technologies' affordances are most prevalent among manufacturing companies in Central and Eastern Europe (see Table 16), results indicate that the augmentation and connect affordances are predominant. 68.8% of these companies incorporate both the augmentation and connect affordances into their activities. The analytic and automation affordances are less common: 54.9% of companies have the analytic affordance, while 42.5% have the automation affordance.

**Table 16.** Number of manufacturing companies possessing digital technologies' affordances

| Digital technologies' affordances | % companies possessing |
|---|---|
| Augmentation affordance | 68.8 |
| Connect affordance | 68.8 |
| Analytic affordance | 54.9 |
| Automation affordance | 42.5 |

When analysing the possession of digital technologies' affordances by manufacturing companies in different research countries, distinct variations become evident (see Table 17). For instance, in Austria, 77.5% of manufacturing companies have actualized the augmentation affordance, the highest percentage among all countries. Similarly, 71.4% of manufacturing companies in Croatia have adopted the augmentation affordance. Conversely, Lithuania has the lowest percentage, with 58.8% of companies actualizing the augmentation affordance.

**Table 17.** The possession of digital technologies' affordances in manufacturing companies (Different Countries)

| Digital technologies' affordances | Country name | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Lithuania | | Slovenia | | Croatia | | Slovakia | | Austria | |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % |
| Augmentation affordance | 117 | 58.8 | 87 | 68.5 | 75 | 71.4 | 74 | 64.9 | 196 | 77.5 |
| Connect affordance | 121 | 60.8 | 91 | 71.7 | 64 | 61 | 79 | 69.3 | 194 | 76.7 |
| Analytic affordance | 110 | 55.3 | 82 | 64.6 | 51 | 48.6 | 59 | 51.8 | 136 | 53.8 |
| Automation affordance | 49 | 24.6 | 76 | 59.8 | 52 | 49.5 | 44 | 38.6 | 118 | 46.6 |

Note: (Freq.)- Frequency

The actualization of the connect affordance shows similar trends. Austria leads with 76.7% of its companies having actualized the connect affordance. Slovenia follows closely with 71.7%. Croatia and Lithuania have the lowest percentages, with 61% and 60.8%, respectively. When considering the analytic affordance, Slovenia tops the list with 64.6% of its companies having actualized this affordance. Lithuania and Austria follow with 55.3% and 53.8%, respectively. Croatia has the fewest at 48.6%.

Regarding the automation affordance, there are more pronounced differences between the countries. In Slovenia, 59.8% of companies have actualized the automation affordance. In contrast, Lithuania has only 24.6% of its companies having done so.

Delving deeper into the data country by country, Lithuania stands out in its possession of these digital technologies' affordances. The connect affordance is actualized by 60.8% of companies, while the augmentation affordance stands at 58.8%. The least actualized in Lithuania is the automation affordance, with only 24.6% of companies adopting it. In Slovenia, manufacturing companies predominantly actualize the connect affordance, as it is evident in 71.7% of firms. The percentages for augmentation, analytic, and automation affordances – 68.5%, 64.6%, and 59.8% respectively – in Slovenian manufacturing companies show a close range of adoption. Generally, there are not significant differences in the adoption of various digital technologies' affordances among these countries (Croatia, Slovakia, Austria). In Croatia, the primary affordance among manufacturing companies is the augmentation affordance, actualized by 71.4%.

In Croatia, fewer manufacturing companies possess the automation affordance (49.5%) and the analytic affordance (48.6%). In Slovakia, the connect affordance is predominant, as evident in 69.3% of manufacturing companies. Yet, a substantial 64.9% of Croatian companies also have the augmentation affordance. The least actualized in Slovakia is the automation affordance, with only 38.6% of companies adopting it. Austrian manufacturing companies predominantly possess the augmentation affordance (77.5%) and the connect affordance (76.7%). However, only 53.8% of Austrian manufacturing companies have the analytic affordance. The automation affordance is the least prevalent in Austria, with only 46.6% of companies adopting it – though this is still nearly double the percentage in Lithuania, where only 24.6% of companies possess the automation affordance.

### 3.1.3. Possession of digital technologies' affordances by industry and employees' number

When analyzing the possession of digital technologies' affordances across different manufacturing sub-sectors, we observe notable differences. According to the survey results (see Table 18), the chemical industry boasts the highest percentage of companies with augmentation affordance at 75%. In the engineering industry, as many as 72.1% of companies utilize augmentation affordance in their operations. In contrast, the 'other manufacturing' sub-sector has the fewest enterprises employing augmentation affordance, with only 57.7% doing so.

**Table 18.** The possession of digital technologies' affordances by industry

| **Industry** | **Digital technologies' affordances** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Augmentation** | | **Connect** | | **Analytic** | | **Automation** | |
| | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** | **Freq.** | **%** |
| Food and beverages | 56 | 65.9 | 63 | 74.1 | 49 | 57.6 | 40 | 47.1 |
| Textiles | 42 | 64.6 | 47 | 72.3 | 38 | 58.5 | 24 | 36.9 |
| Wood and furniture | 83 | 61.5 | 89 | 65.9 | 65 | 48.1 | 49 | 36.3 |
| Chemical | 51 | 75 | 46 | 67.6 | 40 | 58.8 | 30 | 44.1 |
| Engineering | 302 | 72.1 | 291 | 69.5 | 232 | 55.4 | 188 | 44.9 |
| Other | 15 | 57.7 | 13 | 50 | 14 | 53.8 | 8 | 30.8 |

Note: (Freq.)- Frequency

When examining the possession of connect affordance in manufacturing companies by industry, it has been found that the food and beverages industry leads with 74.1%, followed by the textiles industry at 72.3%. The 'other manufacturing' sub-sector has the fewest companies employing the connect affordance, standing at just 50%. For analytic affordance, the chemical industry leads at 58.8%, closely followed by the textiles industry at 58.5%. Other sectors, such as food and beverages (57.6%) and engineering (55.4%), also have a significant number of companies utilizing the analytic affordance. Notably, the wood and furniture industry has the lowest representation in this category. Finally, regarding the possession of automation affordance by industry, the food and beverages sector is at the forefront with 47.1%. The engineering industry is close behind at 44.9%. Again, the 'other manufacturing' sub-sector has the fewest companies using automation affordance, at just 30.8%.

Analyzing the possession of digital technologies' affordances in enterprises, the primary focus is on the following categories: small enterprises (up to 49 employees), medium enterprises (50–249 employees), and large enterprises (250 or more employees) (see Table 19).

**Table 19.** The possession of digital technologies' affordances by the number of employees

| **Possession of affordances** | **Number of employees** | | | | | |
|---|---|---|---|---|---|---|
| | **Small enterprise (Up to 49 employees)** | | **Medium enterprise (50–249 employees)** | | **Big enterprise (250 and more employees)** | |
| | **Frequency** | **%** | **Frequency** | **%** | **Frequency** | **%** |
| Augmentation affordance | 176 | 52.1 | 256 | 76.9 | 114 | 92.7 |
| Connect affordance | 192 | 56.8 | 244 | 73.3 | 110 | 89.4 |
| Analytic affordance | 148 | 43.8 | 193 | 58 | 95 | 77.2 |
| Automation affordance | 99 | 29.3 | 157 | 47.1 | 81 | 65.9 |

In small enterprises, the possession of connect affordance (56.8%) and augmentation affordance (52.1%) is dominant. The analytic affordance is present in 43.8% of these companies. Automation affordance is less common in small enterprises, with only 29.3% of them possessing it. In medium enterprises, the predominant affordances are augmentation (76.9%) and connect (73.3%). Analytic affordance is less common in this group, with 58% of these companies having it. Automation affordance is the least common, possessed by just 47.1% of medium enterprises. In large enterprises, the dominant affordances are augmentation (92.7%) and connect (89.4%). The possession of analytic affordance is slightly lower at 77.2%. While automation affordance is the least common among the three, its presence in large enterprises, at 65.9%, is significantly higher compared to small and medium enterprises.

### 3.1.4. The extent of the actualized potential of digital technologies' affordances

The analysis examining the extent of actualization of digital technologies' affordances revealed that companies vary in their levels of actualizing these affordances (see Table 20). The data showed that 31.3% of all companies are at a low level of actualization for the augmentation affordance. In contrast, 22.7% are at a medium level, and only 9.4% have achieved a high level of actualization for this affordance.

For the connect affordance, the analysis indicated that 33.6% of all companies are at a low level of actualization. Meanwhile, 21.8% are at a medium level, and 7.4% have reached a high level of actualization.

**Table 20.** The extent of the actualized potential of digital technologies' affordances in companies

| **Digital technologies' affordances** | **The extent of the actualized potential of digital technologies' affordances** | | |
|---|---|---|---|
| | **Low level (% of all companies)** | **Medium level (% of all companies)** | **High level (% of all companies)** |
| *Augmentation affordance* | 31.3 | 22.7 | 9.4 |
| *Connect affordance* | 33.6 | 21.8 | 7.4 |
| *Analytic affordance* | 26.3 | 17.4 | 8.4 |
| *Automation affordance* | 27.5 | 11.5 | 1.7 |

The analysis regarding the actualized potential of the analytic affordance revealed that 26.3% of all companies are at a low level of actualization for this affordance. Meanwhile, 17.4% are at a medium level, and only 8.4% have achieved a high level of actualization. For the automation affordance, 27.5% of all companies are at a low level of actualization, 11.5% are at a medium level, and a mere 1.7% have reached a high level of actualization.

Furthermore, when evaluating the extent of actualized potential of digital technologies' affordances across companies, it becomes evident that a significant majority fall within the low or medium levels of actualization. Fewer than 10% of companies have achieved a high level of actualization for digital technologies' affordances.

### 3.1.5. Associations between digital technologies' affordances

The study examined the correlations among the affordances of digital technologies that constitute the process model of actualization. This was done to assess the complementarity and accumulation between the model constructs. Positive correlations between the actualizations of the affordances would suggest complementarity and accumulation. Conversely, negative correlations between the actualizations of the digital technologies' affordances would indicate a lack of accumulation and complementarity. The analysis (refer to Table 21) has revealed that all relationships between the actualizations of digital technologies' affordances are positive and statistically significant ($p<0.01$). The most robust correlation, at **0.487, was observed between the actualizations of augmentation and connect affordances.

**Table 21.** Correlations between actualization of digital technologies' affordances

| **Digital technologies' affordances** | **Mean** | **SD** | *Augmentation affordance actualization* | *Connect affordance actualization* | *Analytic affordance actualization* | *Automation affordance actualization* |
|---|---|---|---|---|---|---|
| *Augmentation affordance actualization* | 0.688 | 0.464 | | | | |
| *Connect affordance actualization* | 0.688 | 0.464 | 0.487** | | | |
| *Analytic affordance actualization* | 0.549 | 0.498 | 0.394** | 0.361** | | |
| *Automation affordance actualization* | 0.425 | 0.495 | 0.318** | 0.288** | 0.343** | |

Note: ** p< 0.01

The weakest relationship, **0.288, was observed between connect affordance and automation affordance actualization. Furthermore, there is a positive relationship of **0.394 between augmentation affordance and analytic affordance actualization. The relationship between augmentation affordance and automation affordance actualization stands at **0.318. Connect affordance and analytic affordance actualization share a positive relationship of **0.361, indicating they complement each other. The relationship between analytic affordance and automation affordance actualization is also positive at **0.343. As all correlations regarding the actualization of digital technologies' affordances are positive, it signifies the complementarity and accumulation of all affordances.

### 3.1.6. The determination of the start year of actualization of digital technologies' affordances

The start year for the actualization of digital technologies' affordances has been identified across 798 companies. Outliers have been subsequently removed from the analysis. The results reveal that, initially, companies began the actualization of the augmentation affordance in 2009 (see Figure 5). During this phase, organizations concentrated on enhancing human capabilities and refining existing processes with the aid of digital technologies. This marked the onset of their journey towards digital transformation, offering immediate benefits and enabling companies to acquaint themselves with the potential of digital innovations. Upon realizing the advantages of augmentation, companies embarked on the actualization of the connect affordance in 2010. This phase centered on integrating various systems and data sources, fostering streamlined communication and data sharing. As the merits of digital technologies in bolstering human capabilities became evident, firms moved to interlink systems, aiming to enhance workflows and bolster decision-making. Once a cohesive digital ecosystem was established, the actualization of the analytic affordance commenced towards the close of 2011. This period was characterized by the adoption of cutting-edge data analytics tools and strategies, purposefully designed to draw insights from the extensive data produced by the connected infrastructure. With a robust foundation in place, organizations were poised to leverage data analytics, fine-tuning their operations and pinpointing areas for improvement.

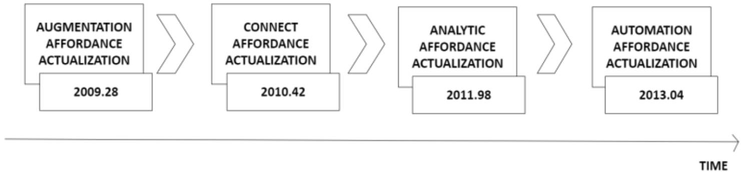



**Figure 5.** The start year of actualization of digital technologies' affordances

In the fourth phase, organizations began the actualization of the automation affordance in 2013. With the foundational elements of augmentation, connect, and analytic already established, companies embraced digital technologies to automate processes that had previously been manual. This involved the deployment of robots and other automation tools to handle repetitive tasks, thereby enhancing operational efficiency and reducing costs.

### 3.2. Analysis and testing of the process model of actualization of digital technologies' affordances in manufacturing companies

This section presents the results of testing the process model of digital technology affordances' actualization. It includes an evaluation of the complementarity of these affordances and the identification of their actualization sequence. The research then compares the speed differences between the dominant sequence and all other potential sequences for actualizing these affordances. A robustness analysis based on selected criteria follows. Finally, it compares the dominant path and all other potential paths using selected financial and other criteria.

#### 3.2.1. Evaluation of digital technologies' affordances complementarity using structural modeling

PLS-SEM analysis (Hair et al., 2017; Hair et al., 2012) was employed to test direct relationships between digital technologies' affordances formulated in hypotheses (H1, H2, H3). PLS-SEM analysis showed enough strength of path coefficients and their statistical significance among digital technologies affordances in the process model of actualization (see Table 22). The direct relationship between the actualization of augmentation affordance and connect affordance is positive and strong at 0.49**. The direct relationship between connect and analytic affordances actualization also is positive 0.36**. The direct relationship between analytic affordance and automation actualization is positive and strong at 0.34**. The data analysis showed that all direct paths hypotheses are supported.

**Table 22.** Path coefficients (direct effects)

| Hyp. | Paths | O | M | STDEV | O/ STDEV | P | Support for hyp. |
|---|---|---|---|---|---|---|---|
| *H1* | Augmentation affordance actualization → Connect affordance actualization | 0.49 | 0.492 | 0.029 | 16.893 | p<0.01 | Yes |
| *H2* | Connect affordance actualization → Analytic affordance actualization | 0.36 | 0.363 | 0.036 | 9.963 | p<0.01 | Yes |
| *H3* | Analytic affordance actualization → Automation affordance actualization | 0.34 | 0.349 | 0.039 | 8.736 | p<0.01 | Yes |

Note: (Hyp.)-hypothesis; (O)-original sample; (M)-sample mean; (STEDV)-standard deviation; (O/STEDV)- T Statistics; (P)- P value.; ** p< 0.01

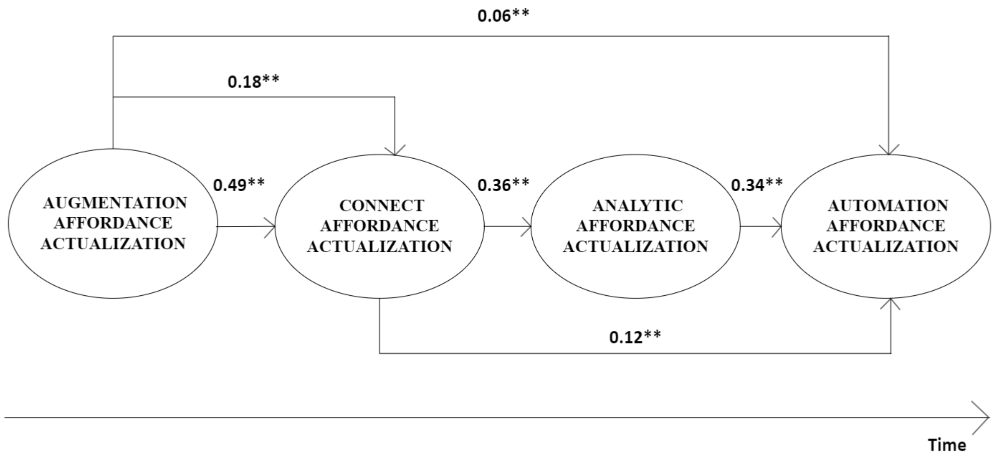
Also, PLS-SEM analysis (Hair et al., 2017; Hair et al., 2012) was employed to test hypotheses (H4a, H4b, H4c) related to indirect relationships. PLS-SEM analysis showed that all indirect relationships among digital technologies affordances in the actualization process model are also positive and significant (see Table 23). For example, the indirect relationship between the actualization of augmentation affordance and analytic affordance is 0.18**, and between the actualization of augmentation affordance and automation affordance, the relationship is 0.06**. The indirect relationship between the actualization of connect affordance and automation affordance is also positive and significant, 0.12**. All indirect paths hypotheses are supported.

**Table 23.** Path coefficients (indirect effects)

| Hyp. | Paths | O | M | STDEV | O/ STDEV | P | Support for hyp. |
|---|---|---|---|---|---|---|---|
| *H4a* | Augmentation affordance actualization → Connect affordance actualization → Analytic affordance actualization | 0.18 | 0.179 | 0.023 | 7.595 | p<0.01 | Yes |
| *H4b* | Augmentation affordance actualization → Connect affordance actualization → Analytic affordance actualization → Automation affordance actualization | 0.06 | 0.063 | 0.012 | 5.193 | p<0.01 | Yes |
| *H4c* | Connect affordance actualization → Analytic affordance actualization → Automation affordance actualization | 0.12 | 0.127 | 0.021 | 6.024 | p<0.01 | Yes |

Note: (Hyp.)-hypothesis; (O)-original sample; (M)-sample mean; (STEDV)-standard deviation; (O/STEDV)- T Statistics; (P)- P value.; ** p< 0.01

The PLS-SEM model with direct and direct path coefficients is provided in Figure 6.




Note: ** p< 0.01

**Figure 6.** The PLS-SEM model

These results confirm complementarities between different digital technologies' affordances and hypotheses (H1, H2, H3, H4a, H4b, H4c) that affordances affect each other.

### 3.2.2. Identification of the sequence of actualization of digital technologies' affordances

Determining sequence frequencies with a process mining tool (Zerbino et al., 2021; Van der Aalst, 2016) was employed to identify the sequence of actualization of digital technologies' affordances and test the hypothesis (H5).

The European manufacturing survey is unique because it has a question that measures the introduction year of digital technologies in an organization. These digital technologies constitute automation, connect, analytic, and augmentation affordances.

The data regarding the year of the introduction of digital technologies was used to determine sequence frequencies in the process of actualizing digital technologies' affordances. Such data reveals a temporal dimension of the actualization of digital technologies' affordances and could be employed for a process mining analysis. 645 out of 798 organizations were eliminated from process mining analysis because they introduced fewer than four affordances. Thus, 153 organizations constituted the adequate sample. Further, the data was processed using fuzzy miner – a process mining-related algorithm (Tax et al., 2016). The algorithm resulted in the complete set of sequences alternatives (see Table 24) constituted by 23 possible digital technologies' affordances actualization variants.

**Table 24.** The sequence frequencies of actualization of digital technologies' affordances (N=153)

| No. | Sequence | | | | % of organizations | No of organizations |
|---|---|---|---|---|---|---|
| **1** | **Augmentation** | **Connect** | **Analytic** | **Automation** | **18.3** | **28** |
| **2** | **Augmentation** | **Connect** | **Automation** | **Analytic** | **9.8** | **15** |
| **3** | **Analytic** | **Augmentation** | **Connect** | **Automation** | **9.15** | **14** |
| **4** | **Augmentation** | **Analytic** | **Automation** | **Connect** | **8.5** | **13** |
| **5** | **Augmentation** | **Automation** | **Connect** | **Analytic** | **6.4** | **10** |
| 6 | Analytic | Automation | Connect | Augmentation | 5.23 | 8 |
| 7 | Analytic | Automation | Augmentation | Connect | 5.23 | 8 |
| 8 | Automation | Augmentation | Connect | Analytic | 5.23 | 8 |
| 9 | Automation | Augmentation | Analytic | Connect | 4.58 | 7 |
| 10 | Automation | Connect | Analytic | Augmentation | 3.92 | 6 |
| 11 | Augmentation | Analytic | Connect | Automation | 3.27 | 5 |
| 12 | Automation | Connect | Augmentation | Analytic | 2.61 | 4 |
| 13 | Automation | Analytic | Augmentation | Connect | 2.61 | 4 |
| 14 | Analytic | Connect | Automation | Augmentation | 1.96 | 3 |
| 15 | Connect | Augmentation | Automation | Analytic | 1.96 | 3 |
| 16 | Connect | Augmentation | Analytic | Automation | 1.96 | 3 |
| 17 | Connect | Analytic | Augmentation | Automation | 1.96 | 3 |
| 18 | Automation | Analytic | Connect | Augmentation | 1.96 | 3 |
| 19 | Analytic | Connect | Augmentation | Automation | 1.31 | 2 |
| 20 | Connect | Automation | Augmentation | Analytic | 1.31 | 2 |
| 21 | Augmentation | Automation | Analytic | Connect | 1.31 | 2 |
| 22 | Connect | Automation | Analytic | Augmentation | 0.65 | 1 |
| 23 | Analytic | Augmentation | Automation | Connect | 0.65 | 1 |

The most prevalent variant employed by 18.3% of the companies comprises Augmentation → Connect → Analytic → Automation affordance actualization sequence. The first five patterns are manifested among 52.15% of sample organizations. The data also reveals that the augmentation affordance, in the beginning, characterizes four of these five patterns. It was tested whether the proportion of companies in the sample of 43 companies following hypothesized pathway (Augmentation affordance → Connect affordance → Analytic affordance → Automation affordance) and second pathway (Augmentation affordance → Connect affordance → Automation affordance → Analytic affordance) occur with equal probabilities of 0.5. Using a chi-square test (Pearson, 1900; Cochran, 1952) with 1 degree of freedom, we found that the sequences occur with non-equal probabilities ($\chi2(1) = 3.930$, Asymptotic $p<0.05$). This result means that the Augmentation → Connect → Analytic → Automation affordance actualization sequence is significantly more prevalent than other sequences.

In summary, the process mining analysis revealed a complete set of sequences of digital technologies' actualization alternatives. Augmentation → Connect → Analytic → Automation affordance actualization sequence is manifested significantly more extensively than other sequences of actualization of digital technologies' affordances. This result confirmed hypothesis (H5).

affordance, their digital technologies' affordance actualization process is, on average, 2.8 years faster than all other possible actualization sequences.

Companies with large-scale digitalization programs introducing many digital technologies at once, sometimes it could have consequential effects on the speed of comparison of actualization sequences. Therefore, additionally, the Mann-Whitney U test (King and Eckersley, 2019; Ramachandran and Tsokos, 2020; Mann and Whitney, 1947) (see Table 26) was used to determine whether companies that follow the first sequence (n=28) actualize digital technologies' affordances on average faster than companies that follow any other of the 22 identified sequences (n=125). The Mann-Whitney U test helped to check the significance of speed differences; it was conducted as the data were non-normally distributed. The null hypothesis was that there was no difference in digital technologies' affordances actualization duration between the two groups, while the alternative hypothesis was that there was a significant difference.

**Table 26.** Independent Samples Mann-Whitney U test of the speed of the process of actualization of digital technologies' affordances

| **Null hypothesis** | **Dominant sequence (Augmentation affordance → Connect affordance → Analytic affordance → Automation affordance) (Mean Rank)** | **All other possible sequences (Mean Rank)** | **Sig.[a,b]** | **Decision** |
|---|---|---|---|---|
| The distribution of speed of the process of actualization of digital technologies' is the same across different digital technologies affordances actualization sequences | 53.93 | 82.17 | 0.002* | Reject the null hypothesis |

Notice: *p<0,05

Using the Mann-Whitney U test, a significant difference between the two groups was found. Thus, the mean digital technologies' actualization duration in the companies following the Augmentation affordance → Connect affordance → Connect affordance → Automation affordance sequence was significantly shorter than following all other possible sequences. It conforms to hypothesis (H6).

### 3.2.4. The summary of the hypotheses testing results

The PLS-SEM analysis (Hair et al., 2017; Hair et al., 2012) validated the complementarity-related hypotheses (H1, H2, H3, H4a, H4b, H4c) (see Table 27). This analysis revealed that there are positive and significant direct effects between digital technologies' affordances, namely augmentation, connect, analytic, and automation. Furthermore, the PLS-SEM analysis indicated that the indirect effects among augmentation, connect, analytic, and automation affordances are also positive and significant.

**Table 27.** The results of testing the hypotheses

| Hypotheses | Method of Testing | Result (Accepted/ Rejected) |
|---|---|---|
| H1: Actualization of augmentation affordance has a direct positive effect on the actualization of connect affordance. | PLS-SEM analysis (Path coefficients analysis) | Accepted |
| H2: Actualization of connect affordance has a direct positive effect on the actualization of analytic affordance. | PLS-SEM analysis (Path coefficients analysis) | Accepted |
| H3: Actualization of analytic affordance has a direct positive effect on the actualization automation affordance. | PLS-SEM analysis (Path coefficients analysis) | Accepted |
| H4a: Actualization of augmentation affordance has an indirect positive effect on the actualization of analytic affordance. | PLS-SEM analysis (Path coefficients analysis) | Accepted |
| H4b: Actualization of augmentation affordance has an indirect positive effect on the actualization of automation affordance. | PLS-SEM analysis (Path coefficients analysis) | Accepted |
| H4c: Actualization of connect affordance has an indirect positive effect on the actualization of automation affordance. | PLS-SEM analysis (Path coefficients analysis) | Accepted |
| H5: The affordances of digital technologies are actualized in this sequence: augmentation, connect, analytic, automation. | 1) The determination of sequence frequencies (The process mining analysis)<br>2) Chi-square test | Accepted |
| H6: Companies that actualize digital technologies' affordances following the Augmentation affordance->Connect affordance->Analytic affordance->Automation affordance sequence are on average faster in actualizing digital technologies' affordances than companies following all other possible actualization sequences. | 1) The sequences speed determination (The process mining analysis)<br>2) The Mann-Whitney U test | Accepted |

Meanwhile, determining sequence frequencies and the Chi-square test (Pearson, 1900; Cochran, 1952) confirmed the process pattern-related hypothesis (H5). The process mining analysis (Zerbino et al., 2021; Van der Aalst, 2016) results revealed that the most manifested sequence of actualization of digital technologies' affordances is the same as in the hypothesis (H5). The chi-square test confirmed that this result is significant.

The sequences speed determination (process mining analysis) and the Mann-Whitney U test (Ramachandran and Tsokos, 2020; Mann and Whitney, 1947) confirmed the speed-related hypothesis (H6). The process mining analysis results revealed that such sequence Augmentation affordance → Connect affordance → Analytic affordance → Automation affordance is, on average, a faster sequence of actualization of digital technologies' affordances than all other possible actualization sequences. The Mann-Whitney U test showed that this speed difference between such sequence Augmentation affordance → Connect affordance → Analytic affordance → Automation affordance and all other possible sequences is significant.

### 3.3. Robustness analysis of the digital technologies' affordances actualization process model

The PLS-MGA analysis (Hair et al., 2017) was conducted to examine the differences in path coefficients of the process model of actualization of digital technologies' affordances based on several criteria: country, company size, sector, company age, incorporation of major technical improvements/introduction of new products, and R&D development. Calculations were performed using 2,000 bootstrap samples with a significance level set at 5%. A p-value of less than 0.05 indicates significant differences.

Initially, a multigroup analysis (Hair et al., 2017) was carried out to evaluate the process model of actualization of digital technologies' affordances according to country. The countries analyzed included Austria, Croatia, Lithuania, Slovakia, and Slovenia. The comparison began with the path coefficients of Austria and Croatia in the model for actualizing digital technologies' affordances. The results revealed only one significant difference between Austria's and Croatia's path coefficients (see Table 28), specifically from the connect affordance to the analytic affordance actualization, which was -0.385 (0.005*).

Comparisons were also made between the path coefficients of the process model of actualization of digital technologies' affordances in Austria and Lithuania. The analysis indicated that all path coefficient differences regarding digital technologies' actualization between Austria and Lithuania were insignificant. When comparing Austria and Slovakia, only the path coefficient difference from augmentation affordance to connect affordance actualization, at -0.199 (0.015*), was significant. In the case of Austria and Slovenia, significant path coefficient differences were observed from augmentation affordance to connect affordance actualization at -0.206 (0.01*), and from connect affordance to analytic affordance actualization at -0.284 (0.013*). Analyzing Croatia versus Lithuania, significant path coefficient differences were noted from augmentation affordance to connect affordance actualization at 0.253 (0.014*) and from connect affordance to analytic affordance actualization at 0.263 (0.026*). In the comparison between Croatia and Slovakia, only one significant path coefficient difference was found, from connect affordance to analytic affordance actualization, at 0.27 (0.035*). Lastly, the comparison between Croatia and Slovenia revealed just one significant path coefficient difference, from analytic affordance to automation affordance actualization, at -0.259 (0.036*).

**Table 28.** Path coefficient differences in the countries

| | Augmentation affordance actualization → Connect affordance actualization | Connect affordance actualization → Analytic affordance actualization | Analytic affordance actualization → Automation affordance actualization |
|---|---|---|---|
| **Path Coefficient differences (Austria vs. Croatia), p-Value** | -0.138 (0.106) | -0.385 **(0.005*)** | 0.073 (0.554) |
| **Path Coefficient differences (Austria vs. Lithuania), p-Value** | 0.115 (0.214) | -0.122 (0.289) | 0.11 (0.327) |
| **Path Coefficient differences (Austria vs. Slovakia), p-Value** | -0.199 **(0.015*)** | -0.115 (0.384) | -0.128 (0.302) |
| **Path Coefficient differences (Austria vs. Slovenia), p-Value** | -0.206 **(0.01*)** | -0.284 **(0.013*)** | -0.185 (0.062) |
| **Path Coefficient differences (Croatia vs. Lithuania), p-Value** | 0.253 **(0.014*)** | 0.263 **(0.026*)** | 0.036 (0.756) |
| **Path Coefficient differences (Croatia vs. Slovakia), p-Value** | -0.061 (0.496) | 0.27 **(0.035*)** | -0.201 (0.169) |
| **Path Coefficient differences (Croatia vs. Slovenia), p-Value** | -0.068 (0.433) | 0.101 (0.342) | -0.259 **(0.036*)** |
| **Path Coefficient differences (Lithuania vs. Slovakia), p-Value** | -0.314 **(0.001*)** | 0.007 (0.982) | -0.238 (0.091) |
| **Path Coefficient differences (Lithuania vs. Slovenia), p-Value** | -0.321 **(0.001*)** | -0.163 (0.157) | -0.295 (0.012) |
| **Path Coefficient differences (Slovakia vs. Slovenia), p-Value** | -0.007 (0.936) | -0.17 (0.193) | -0.057 (0.664) |

Note: * $p < 0.05$

The comparison of path coefficients between Lithuania and Slovakia revealed only one significant difference: from augmentation affordance to connect affordance actualization, at -0.314 (0.001*). A comparison between Lithuania's and Slovenia's path coefficients indicated a significant difference from augmentation affordance to connect affordance actualization, at -0.321 (0.001*). In the comparison between Slovakia and Slovenia, all path coefficient differences related to the actualization of digital technologies' affordances were found to be insignificant.

In summary, when considering path coefficient differences across Austria, Croatia, Lithuania, Slovakia, and Slovenia, 69.70% of the differences are not significant. Only 30.30% of path coefficient differences are deemed significant. This suggests that the process model of the actualization of digital technologies' affordances remains stable across countries.

Secondly, a multigroup analysis (Hair et al., 2017) was conducted to examine the process model of the actualization of digital technologies' affordances based on company size. This variable is divided into three groups: small enterprises (up to 49 employees), medium enterprises (50–249 employees), and big enterprises (250 employees and more). The comparison began with big and medium enterprises (see Table 29). The analysis revealed that only one path coefficient difference – from augmentation affordance to connect affordance actualization, at 0.187 (0.023*) is significant between big and medium enterprises.

Additionally, the path coefficients for big and small enterprises in the process model of actualization of digital technologies' affordances were compared. The analysis revealed that the path coefficient difference between the analytic affordance and the automation affordance actualization 0.226 (0.024*) is significant when comparing big and small enterprises. When comparing medium and small enterprises, all path coefficient differences were found to be insignificant.

**Table 29.** Path coefficient differences under the size of the companies

| | Augmentation affordance actualization → Connect affordance actualization | Connect affordance actualization → Analytic affordance actualization | Analytic affordance actualization → Automation affordance actualization |
|---|---|---|---|
| **Path Coefficient differences (Big enterprises vs. Medium enterprises), p-Value** | 0.187 **(0.023*)** | 0.106 (0.344) | 0.186 (0.053) |
| **Path Coefficient differences (Big enterprises vs. Small enterprises), p-Value** | 0.12 (0.138) | -0.024 (0.832) | 0.226 **(0.024*)** |
| **Path Coefficient differences (Medium enterprises vs. Small enterprises), p-Value** | -0.067 (0.347) | -0.13 (0.138) | 0.039 (0.658) |

Note: * $p< 0.05$

In summary, among all the path coefficient differences between big, medium, and small enterprises, a substantial 77.80% are insignificant, with only 22.20% being significant. The process model of actualization of digital technologies' affordances remains stable irrespective of company size.

Thirdly, a multigroup analysis (Hair et. al., 2017) was conducted to examine the process model of the actualization of digital technologies' affordances based on sector criteria. This variable is categorized into six groups: chemical, engineering, food and beverages, textiles, wood and furniture, and others. The analysis began with a comparison between the chemical and engineering sectors (see Table 30). The examination of path coefficient differences between the chemical and engineering sectors, the chemical vs. food and beverages sectors, and chemical vs. textiles revealed no significant differences. However, a single significant difference was noted between the path coefficients of the chemical and wood and furniture sectors, specifically from the augmentation affordance to the connect affordance actualization, which was 0.274 (0.028*).

The comparison of path coefficient differences between the engineering and food and beverages sectors revealed that all path coefficients are insignificant. In the analysis comparing the engineering and textiles sectors, only one significant difference emerged in the path coefficients — from the analytic affordance to the automation affordance actualization, which was 0.309 (0.046*). The comparison between the engineering and wood and furniture sectors found that all path coefficients were insignificant. Analyzing the process model of actualization of digital technologies' affordances, only one significant path coefficient difference was identified between the food and beverages and textiles sectors, specifically from the analytic affordance to the automation affordance actualization, which was 0.41 (0.026*). Lastly, the analysis of path coefficient differences between sectors showed that in the comparison of the food and beverages and wood and furniture sectors, only one significant difference exists, from the connect affordance to the analytic affordance actualization, at 0.281 (0.048*).

In calculating the path coefficients for various sectors, some limitations were encountered. Multigroup analysis revealed that it was not feasible to calculate the differences for the 'other' sector category when compared to the chemical, engineering, food and beverages, textiles, and wood and furniture sectors. The primary issue was the small sample size of the “other” sector (26 companies) in relation to the other sectors. Additionally, calculating path coefficient differences between the textiles and wood and furniture sectors proved challenging due to significant collinearity and zero variance. In summary, when evaluating all path coefficient differences among the chemical, engineering, food and beverages, textiles, and wood and furniture sectors, 85.20% of the path coefficient differences were found to be insignificant, while only 14.80% were significant. Thus, the process model of actualization of digital technologies' affordances remains consistent across sectors.

**Table 30.** Path coefficient differences under the sector

| | Augmentation affordance actualization → Connect affordance actualization | Connect affordance actualization → Analytic affordance actualization | Analytic affordance actualization →Automation affordance actualization |
|---|---|---|---|
| **Path Coefficient differences (Chemical vs. Engineering), p-Value** | 0.13 (0.183) | 0.09 (0.435) | -0.019 (0.68) |
| **Path Coefficient differences (Chemical vs. Food and beverages), p-Value** | 0.056 (0.62) | -0.032 (0.891) | -0.12 (0.773) |
| **Path Coefficient differences (Chemical vs. Textiles), p-Value** | 0.118 (0.346) | 0.284 (0.283) | 0.29 (0.286) |
| **Path Coefficient differences (Chemical vs. Wood and furniture), p-Value** | 0.274 **(0.028*)** | 0.249 (0.149) | -0.097 (0.889) |
| **Path Coefficient differences (Engineering vs. Food and beverages), p-Value** | -0.074 (0.402) | -0.121 (0.244) | -0.101 (0.378) |
| **Path Coefficient differences (Engineering vs. Textiles), p-Value** | -0.012 (0.877) | 0.195 (0.5) | 0.309 **(0.046*)** |
| **Path Coefficient differences (Engineering vs. Wood and Furniture), p-Value** | 0.144 (0.112) | 0.159 (0.196) | -0.078 (0.44) |
| **Path Coefficient differences (Food and beverages vs. Textiles), p-Value** | 0.062 (0.618) | 0.316 (0.198) | 0.41 **(0.026*)** |
| **Path Coefficient differences (Food and beverages vs. Wood and Furniture), p-Value** | 0.218 (0.062) | 0.281 **(0.048*)** | 0.023 (0.856) |

Note: * $p < 0.05$

Fourthly, a multigroup analysis (Hair et al., 2017) was conducted to examine the process model of actualization of digital technologies' affordances based on the company's age criteria (see Table 31). This variable is divided into four groups: 0–10 years, 10–20 years, 20–30 years, and more than 30 years. In summary, the comparison of path coefficients across all age groups revealed no significant differences. The process model of actualization of digital technologies' affordances remains consistent irrespective of the company's age.

**Table 31.** Path coefficient differences under the age of the company

| | Augmentation affordance actualization → Connect affordance actualization | Connect affordance actualization → Analytic affordance actualization | Analytic affordance actualization → Automation affordance actualization |
|---|---|---|---|
| **Path Coefficient differences (0–10 years vs. 10–20 years), p-Value** | 0.056 (0.588) | 0.003 (0.961) | 0.11 (0.378) |
| **Path Coefficient differences (0–10 years vs. 20–30 years), p-Value** | 0.044 (0.635) | 0.127 (0.291) | 0.175 (0.160) |
| **Path Coefficient differences (0–10 years vs. More than 30 years), p-Value** | 0.119 (0.214) | 0.191 (0.137) | 0.107 (0.370) |
| **Path Coefficient differences (10–20 years vs. 20–30 years), p-Value** | -0.012 (0.896) | 0.124 (0.209) | 0,065 (0.529) |
| **Path Coefficient differences (10–20 years vs. More than 30 years), p-Value** | 0.063 (0.454) | 0.188 (0.073) | -0.004 (0.973) |
| **Path Coefficient differences (20–30 years vs. More than 30 years), p-Value** | 0.075 (0.301) | 0.064 (0.507) | -0.069 (0.478) |

Note: * $p < 0.05$

Fifthly, a multigroup analysis (Hair et al., 2017) was conducted to examine the process model of actualization of digital technologies' affordances based on whether companies had incorporated major technical improvements or introduced new products in recent years. The companies were categorized into two groups: those that had introduced major technical improvements or new products in the past several years, and those that had not. The comparison revealed that all path coefficient differences between these two groups were insignificant (see Table 32).

**Table 32.** Path coefficient differences regarding incorporated major technical improvements/introduced new products during the past several years in the company

| | Augmentation affordance actualization → Connect affordance actualization | Connect affordance actualization → Analytic affordance actualization | Analytic affordance actualization → Automation affordance actualization |
|---|---|---|---|
| **Path Coefficient differences (Incorporated major technical improvements / introduced new products vs. Not incorporated major technical improvements/ introduced new products), p - Value** | -0.026 (0.690) | -0.046 (0.603) | -0.069 (0.457) |

Note: * $p < 0.05$

In summary, whether companies introduced major technical improvements or new products in recent years is inconsequential to the model. The process model of actualization of digital technologies' affordances remains consistent irrespective of the introduction of major technical improvements or new products.

A multigroup analysis (Hair et al., 2017) was conducted to examine the process model of actualization of digital technologies' affordances based on whether companies engage in research and development (R&D). Companies were categorized into two groups: those that undertake R&D activities and those that do not. The analysis of path coefficient differences between companies that engage in R&D and those that do not revealed that the differences in path coefficients from the augmentation affordance to connect affordance actualization -0.049 (0.422) and from connect affordance to analytic affordance actualization -0.005 (0.947) are insignificant (see Table 33). However, the path coefficient difference from analytic affordance to automation affordance actualization -0.165 (0.03*) is significant.

**Table 33.** Path coefficient differences under the companies which perform research and development (R&D) and do not perform (R&D)

| | Augmentation affordance actualization → Connect affordance actualization | Connect affordance actualization → Analytic affordance actualization | Analytic affordance actualization → Automation affordance actualization |
|---|---|---|---|
| **Path Coefficient differences (Companies which perform R&D vs. Companies which do not perform R&D), p-Value** | -0.049 (0.422) | -0.005 (0.947) | -0.165 **(0.03*)** |

Note: * p< 0.05

In summary, from calculating all path coefficient differences between companies that perform R&D and those that do not perform R&D, it can be stated that there are more insignificant differences than significant differences. The process model of actualization of digital technologies affordances is stable regardless of the performing research and development (R&D).

PLS-MGA analysis (Hair et al., 2017) checked all path coefficient differences of the process model of actualization of digital technologies affordances under these criteria: countries, size of the company, sector; the age of the company; incorporated major technical improvements/introduced new products; R&D development. The multi-group analysis showed that the majority path coefficient differences are insignificant. The process model of actualization of digital technologies affordances is stable under different criteria.

### 3.4. Comparative analysis of the dominant sequence vs. all other sequences in the actualization of digital technologies' affordances

These criteria were selected for the comparative analysis of the dominant sequence versus all other possible sequences of actualization of digital technologies' affordances in manufacturing organizations:

- financial characteristics,
- the extent of the actualized potential of digital technologies' affordances (augmentation, connect, analytic, automation).

The normality test indicated that the sample data are not normally distributed, as shown in Table 34. It means that the T-test cannot be used in this situation to compare the means between the most dominant sequence of actualizing digital technologies' affordances and all other possible sequences in the organizations.

**Table 34.** Tests of normality

| Dependent variable | Independent variables | Shapiro-Wilk | Q-Q plot |
|---|---|---|---|
| | **Criteria** | **Result** | **Result** |
| Sequences (most dominant and all other possible sequences of the process of actualization of digital technologies' affordances) | Financial characteristics (Sales Growth, Productivity Growth, Profitability, Sales per Employee 2015, Sales per Employee 2017) | Not normally distributed (significance values below 0.05) | Not normally distributed |
| | The extent of the actualized potential of digital technologies' affordances (augmentation, connect, analytic, automation). | Not normally distributed (significance values below 0.05) | Not normally distributed |

Instead of the T-test, the Mann-Whitney U test (Ramachandran and Tsokos, 2020; Mann and Whitney, 1947) was chosen — a non-parametric test — for comparing financial characteristics and the extent of actualized potential of digital technologies' affordances. Additionally, the Mann-Whitney U test is less sensitive to outliers compared to the T-test.

#### 3.4.1. Comparative analysis of financial characteristics across different sequences of digital technologies' affordances actualization

The differences in the means of financial characteristics were analyzed using the Independent Samples Mann-Whitney U test (Ramachandran and Tsokos, 2020; Mann and Whitney, 1947) (see Table 35). The test revealed that the mean rank value of sales growth (2015–2017) for the dominant sequence of actualization of digital technologies' affordances is higher at 75.45, compared to the mean rank value of 62.85 for all other possible sequences of actualization. Additionally, the test indicated that the mean rank value of productivity growth (2015–2017) is 70.89 in the dominant sequence, in contrast to the mean rank value of 62.56 for all other sequences.

**Table 35.** Independent Samples Mann-Whitney U test of financial characteristics

| Null hypothesis | Dominant sequence (Mean Rank) | All other possible sequences (Mean Rank) | Sig.[a,b] | Decision |
|---|---|---|---|---|
| The distribution of Sales growth % (2015–2017) is the same across different digital technologies' affordances actualization sequences | 75.45 | 62.85 | 0.150 | Retain the null hypothesis |
| The distribution of Productivity growth % (2015–2017) is the same across different digital technologies' affordances actualization sequences | 70.89 | 62.56 | 0.334 | Retain the null hypothesis |
| The distribution of Profitability is the same across different digital technologies' affordances actualization sequences | 73.82 | 77.1 | 0.688 | Retain the null hypothesis |
| The distribution of Sales per Employee in 2015 is the same across different digital technologies' affordances actualization sequences | 56.77 | 66.10 | 0.283 | Retain the null hypothesis |
| The distribution of Sales per Employee in 2017 is the same across different digital technologies' affordances actualization sequences | 59.82 | 71.05 | 0.201 | Retain the null hypothesis |

Notice: *$p<0.05$

However, the test showed that the mean rank value for profitability is lower, at 73.82, in the dominant sequence of digital technologies' affordances actualization when compared to the mean rank value of 77.71 for all other potential sequences.

The test indicated that the mean rank value for sales per employee in 2015 was lower in the dominant sequence of actualization of digital technologies' affordances, standing at 56.77, compared to the mean rank value of 66.10 for all other possible sequences. Similarly, for sales per employee in 2017, the dominant sequence had a mean rank value of 59.82, whereas all other possible sequences had a value of 71.05.

This test revealed that the mean differences in financial characteristics such as sales growth % (2015–2017), productivity growth % (2015–2017), profitability, sales per employee (2015), and sales per employee (2017) between the dominant sequence and all other possible sequences of digital technologies' affordances are not significant. The Mann-Whitney U test (Ramachandran and Tsokos, 2020; Mann and Whitney, 1947) led to the retention of all null hypotheses.

### 3.4.2. Comparative analysis of the extent of actualized potential in different sequences of digital technologies' affordances

The differences in mean values regarding the extent of the actualized potential of digital technologies' affordances were examined using the independent samples Mann-Whitney U test (Ramachandran and Tsokos, 2020; Mann and Whitney, 1947) (see Table 36). The results indicated that the actualized potential of the augmentation affordance has a higher mean rank of 75.29 in the dominant sequence of actualization compared to a mean rank of 72.50 in all other possible sequences. Conversely, the mean rank for the actualized potential of the connect affordance is slightly lower, at 69.20, in the dominant sequence compared to 75.68 in all other sequences.

Additionally, the Mann-Whitney test revealed that the mean rank for the actualized potential of the analytic affordance is marginally lower at 73.48 in the dominant sequence compared to 74.73 in all other possible sequences. In contrast, for the automation affordance, the dominant sequence has a significantly lower mean rank of 54.78 compared to 76.69 in all other sequences.

The results from the independent samples Mann-Whitney U test (Ramachandran and Tsokos, 2020; Mann and Whitney, 1947) indicate that the differences in mean values regarding the extent of the actualized potential for digital technologies' affordances (namely, augmentation, connect, and analytic) are insignificant between the dominant sequence and all other possible sequences. Therefore, the null hypotheses are retained. Only the mean differences in the extent of the actualized potential for the automation affordance are significant between the dominant path sequence and other possible sequences. For this affordance, the null hypothesis is rejected.

**Table 36.** Independent Samples Mann-Whitney U test of the extent of the actualized potential of digital technologies' affordances

| **Null hypothesis** | **Dominant sequence (Mean Rank)** | **All other possible sequences (Mean Rank)** | **Sig.[a,b]** | **Decision** |
|---|---|---|---|---|
| The distribution of the extent of actualized potential of augmentation affordance is the same across different digital technologies' affordances actualization sequences | 75.29 | 72.50 | 0.758 | Retain the null hypothesis |
| The distribution of the extent of actualized potential of connect affordance is the same across different digital technologies' affordances actualization sequences | 69.20 | 75.68 | 0.461 | Retain the null hypothesis |

| Null hypothesis | Dominant sequence (Mean Rank) | All other possible sequences (Mean Rank) | Sig.[a,b] | Decision |
|---|---|---|---|---|
| The distribution of the extent of actualized potential of analytic affordance is the same across different digital technologies' affordances actualization sequences | 73.48 | 74.73 | 0.887 | Retain the null hypothesis |
| The distribution of the extent of actualized potential of automation affordance is the same across different digital technologies' affordances actualization sequences | 54.78 | 76.59 | 0.011* | Reject the null hypothesis |

Notice: *p<0.05

In summary, the comparative analysis indicates that there are differences in financial characteristics between the dominant sequence and all other possible sequences of digital technologies' affordance actualization. However, these differences are not statistically significant. While there are variances in the extent of the actualized potential of digital technologies' affordances between the dominant sequence and all other possible sequences, most of these differences are not significant. Notably, the actualized potential of the automation affordance is significantly higher in all other possible sequences compared to the dominant path.

# 4. DISCUSSION

## 4.1. Theoretical implications

This study makes several significant contributions to the theory. Firstly, this study theoretically grounds the existence of universal affordances of digital technologies within organizations and examines how they interplay during the actualization process. The research found that when multiple digital technologies' affordances — specifically, augmentation, analytic, automation, and connect — are actualized, they tend to complement each other. This enriches both the affordances and resource-based view theories. Up until now, there was a notable absence of comprehensive studies and articles discussing how various digital technologies' affordances synergize during the actualization process (Volkoff and Strong, 2017). Raisch and Krakowski (2021) touched upon the complementarity between augmentation and automation affordances in their work. Likewise, Zammuto et al. (2007) delved into several digital technologies' affordances, such as visualization of entire work processes, flexible product and service creation, large-scale online collaboration, and simulated reality, but their exploration of the synergies between these affordances was somewhat limited. Lenka et al. (2017) discussed digitalization capabilities — including intelligence, connect, and analytic capabilities — and their value addition to organizations. While they mentioned potential interfaces and relationships between varying digitalization capabilities, their perspective seemed fragmented and did not encompass all possible interactions. Strong and Volkoff (2013) took a closer look at basic and advanced affordances, examining their interrelationships. Yet, their analysis, based on only a few company cases, captured merely a fraction of the possible interactions. In contrast, this dissertation delves deeply into all potential synergies among various digital technologies' affordances. For the first time, it provides an in-depth exploration of the interactions among the four universal digital technologies' affordances — augmentation, analytic, automation and connect — during their actualization process.

Secondly, it precisely delineates the process of actualization of multiple digital technologies' affordances within organizations. The research indicates that the actualization process follows a sequence: 1) augmentation affordance, 2) connect affordance, 3) analytic affordance, and 4) automation affordance. By defining this process, the study enriches both the affordances theory and the resource-based view theory. Until now, research largely tackled these affordances individually. Many scholars, such as Volkoff and Strong (2017), often focused solely on one digital technology affordance. For instance, Chatterjee et al. (2020) explored the actualization of information technology affordance in the context of organizational innovation, limiting their study to a single digital technology affordance. Similarly, Dremel et al. (2020) addressed the actualization of big data analytics affordances but concentrated exclusively on the analytic affordance. While Strong et al. (2014) discussed the actualization of various digital technologies' affordances, their examination of the relationships between multiple IT technologies affordances was restricted to a qualitative analysis of a single company. A noticeable gap exists in research concerning the actualization of multiple digital technologies affordances in organizations, and this study fills that void, offering the process model for the actualization of digital technologies' affordances.

Thirdly, this study offers insights into how multiple digital technologies' affordances are actualized within manufacturing companies, thereby enriching the affordances theory. Up to this point, there has been limited research on the process of actualization of multiple digital technologies' affordances specifically within the manufacturing sector. While Lenka et al. (2017) did explore digitalization capabilities in manufacturing companies, their study was based on a sample of just four firms: those in heavy machinery, telecommunications infrastructure, machine tools, and renewable packing material. Similarly, Volkoff and Strong (2013) conducted research on digital technologies' affordances, focusing on case studies from only two manufacturing companies. The limited sample sizes in these studies hinder the ability to generalize their findings across the manufacturing industry. Moreover, the scope of the manufacturing companies analyzed in the works of Lenka et al. (2017) and Strong and Volkoff (2013) was quite restricted, covering only a few sectors within the manufacturing industry. In contrast, this study encompasses a sample of 798 manufacturing companies from various countries, providing a comprehensive view across all manufacturing sectors as per the NACE classification. Such broad coverage facilitates the generalization of the study's findings on the actualization of digital technologies' affordances across the manufacturing industry.

Fourthly, this study delves into the duration of the actualization process of digital technologies' affordances within organizations, detailing the average duration for each possible sequence. Such findings substantially enrich both the affordances and resource-based view theories. Historically within the affordances theory domain, while studies have been conducted on the actualization process of digital technologies' affordances (Volkoff and Strong, 2017; Strong and Volkoff, 2013; Ostern and Rosemann, 2021), the duration of these actualization processes has largely been overlooked. Similarly, in the resource-based view realm, although scholars such as Szalavetz (2019) have discussed the development of fabrication, technological, innovative, and research and creation capabilities, and Wu et al. (2022) have touched upon the evolution of internal and external digitalization capabilities, the duration of these capability developments remains unaddressed. Furthermore, since these studies predominantly rely on qualitative methods, their findings are not readily generalizable across organizations. In contrast, Lu et al. (2022) employed a quantitative approach to study the evolution of operational and digitalization capabilities but did not probe into the associated durations. This thesis, however, not only investigates the duration of the actualization process for multiple digital technologies affordances but also offers average durations for each sequence. The employed quantitative methodology facilitates the generalization of findings related to the duration of the actualization process of digital technologies' affordances.

Finally, this study enriches the research landscape surrounding digital transformation by providing fresh insights into the development of digital technologies within organizations. While a plethora of research exists on potential roadmaps for digital transformation (Zaouia and Souissi, 2020; Issa et al., 2018; Schallmo et al., 2017), these prior studies have not adopted the perspective of digital technologies' affordances. In contrast to other digital transformation research, this dissertation boasts several advantages: a substantial sample size of 798 manufacturing companies from five countries (Lithuania, Slovakia, Slovenia, Croatia, Austria) facilitates data generalization, and the process mining analysis ensures a comprehensive examination of all potential roadmaps for the actualization of digital technologies' affordances.

### 4.2. Managerial implications

The process model for the actualization of digital technologies' affordances, delineated as Augmentation → Connect → Analytic → Automation, holds profound significance for managers and organizations alike. By comprehending this sequence, managers can judiciously implement digital technologies, enhancing organizational performance, fostering innovation, and securing a competitive advantage in the market. This sequence is invaluable to organizations as it furnishes a systematic methodology for harnessing the full potential of digital technologies. Below is a breakdown of why each phase is vital and its potential benefits to organizations.

In the actualization phase of the augmentation affordance, organizations concentrate on amplifying the individual through the deployment of digital technologies, thereby bolstering, and broadening their capabilities. This affordance can boost productivity, refine decision-making processes, and foster collaboration. Furthermore, it can aid in the development of new products and services, potentially leading to an enriched customer experience. This stage serves as the bedrock for the actualization of subsequent affordances.

During the actualization phase of the connect affordance, the emphasis is on forging connections and networks among individuals, processes, and technology. This paves the way for seamless communication and collaboration, both internally and externally. Enhanced communication fuels innovation by facilitating knowledge sharing and idea exchange. Improved connectivity can also lead to cost savings, heightened operational efficiency, and a more transparent and controlled environment. Properly actualizing the connect affordance sets the groundwork for the subsequent actualization of the analytic affordance.

During the actualization phase of the analytic affordance, analytics assist organizations in deciphering the vast data produced by digital technologies. By leveraging advanced analytics and big data technologies, organizations can extract valuable insights and make informed, data-driven decisions. This capacity allows them to discern patterns, anticipate outcomes, and refine processes, all of which enhance competitiveness. A robustly actualized analytic affordance lays the groundwork for the subsequent actualization of the automation affordance.

In the actualization phase of the automation affordance, organizations capitalize on the collective knowledge derived from the previous actualization of the augmentation, connect, and analytic affordances. Digital technologies facilitate the automation of routine tasks and processes, which in turn bolsters organizational efficiency and curtails costs.

Companies that follow the sequence of actualizing digital technologies' affordances — starting with augmentation affordance, then connect affordance, followed by analytic affordance, and finally automation affordance — actualize these affordances faster on average 2.8 years than companies pursuing any other sequence. Empirical testing showed that this result is statistically significant. Those organizations that adhere to this specific order of actualization can secure a competitive edge.

This study illustrates how enterprises should handle digital technologies' affordances and leverage their synergies to maximize value with constrained resources.

### 4.3. Research limitations and directions for the future

Examining the process of actualization of digital technologies' affordances in organizations presents a complex challenge with several potential limitations. This discussion outlines these research constraints:

- The concept of digital technologies' affordances is inherently subjective. It hinges on the user's perception and interpretation. Consequently, pinning down a clear, universally accepted definition of digital technologies' affordances is challenging.
- The actualization of digital technologies' affordances is a multifaceted process influenced by numerous factors, including individual cognitive abilities, motivation, social context, and cultural norms. The intricate nature of this process complicates efforts to isolate and evaluate specific components.
- Quantitative research on the actualization of digital technologies' affordances relies on self-reported evaluations. These are susceptible to biases such as the desire to present oneself favorably, potential inaccuracies in recalling events, and over or underestimating one's skills and technology use. Moreover, quantitative research can sometimes oversimplify complex phenomena by breaking them down into distinct variables and relationships, potentially overlooking the nuanced interplay of cognitive, social, and cultural aspects.
- The European Manufacturing Survey collects data on financial performance over a constrained timeframe, limited to specific years. It does not gather annual financial metrics. Given that the process of actualization of digital technologies' affordances can span several years, sometimes even up to a decade, for certain organizations, analyzing the relationship between actualization and financial performance could not show statistically significant results without access to comprehensive longitudinal financial data.

It can highlight several directions for future research:

Future research could focus on how individual differences, such as users' prior knowledge, cognitive abilities, motivation, cultural norms, and social factors, influence the process of actualization of digital technologies' affordances in manufacturing companies. It could help clarify how better to adapt the design and implementation of digital technologies to address different users' needs and preferences in manufacturing companies.

In the long term, it would be useful to re-examine the process of actualization of digital technologies' affordances, as novel digital technologies are constantly appearing that either complement existing digital technologies' affordances or enable the resulting of novel digital technologies' affordances.

The quantitative research approach could be used to investigate the process of actualization of digital technologies' affordances in other regions of Europe or the world.

## CONCLUSIONS

The theoretical and empirical results of this study on the process of actualization of digital technologies affordances in organizations led to the following findings:

1. The thesis has reviewed scholarly literature on digital technologies' affordances. An analysis of scientific literature revealed that the universal digital technologies' affordances relevant to many organizations are augmentation, analytic, automation, and connect. Proposed definitions of these universal digital technologies' affordances are conceptualized in the following way. Augmentation affordance is understood as enabling and enhancing human performance in the execution of various tasks. Analytic affordance is understood as gathering data from the operations of the organization and surroundings and utilizing software tools to convert it into beneficial knowledge and company guidelines. Automation affordance is understood as enabling an operation or system to function independently. Connect affordance is understood as utilizing wireless communication networks in an organizational context to facilitate the exchange of data and information between individuals and digital devices.
2. Based on the scientific literature analysis, the process model of actualization of multiple digital technologies' affordances in organizations was theoretically grounded. In this process model, firstly, augmentation affordance is actualized. Secondly, connect affordance is actualized. Thirdly, analytic affordance is actualized. In the end, automation affordance is actualized. The relationships between multiple digital technologies' affordances are represented in this process model. The importance of complementarities between different affordances in the process of actualization is theoretically grounded. This process model allows for the study of possible sequences of actualization of multiple digital technologies' affordances rather than just separate single digital technologies' affordance actualization. The sequence of this process model leads to faster actualization of multiple digital technologies' affordances. The proposed process model of actualization of multiple digital technologies' affordances contributes to the affordances and resource-based view theories.
3. The methodology for empirically verifying the process model of the actualization of multiple digital technologies' affordances within organizations was developed and substantiated. Quantitative research allowed to check the reliability of the process model of actualization of multiple digital technologies' affordances in organizations. This methodology provided a comprehensive approach to studying the sequences of actualization of multiple digital technologies' affordances and made sequence analysis more robust. The methodology created and substantiated in this study is versatile. This study's methodology allows other researchers to examine sequences related to the actualization of multiple digital technologies' affordances.
4. The thesis has performed empirical testing of the process of actualization of multiple digital technologies' affordances in organizations:

4.1. The PLS-SEM analysis revealed that the complementarities between multiple digital technologies' affordances lead to a more effective and smooth realization of the full potential of digital technologies within organizations. This indicates that multiple digital technologies' affordances significantly enhance one another during the actualization process.

4.2. Sequence frequency analysis confirmed that manufacturing organizations predominantly follow a specific process model for the actualization of digital technologies' affordances. The sequence, beginning with the actualization of augmentation affordance and followed by the actualization of connect, analytic, and automation affordances, emerged as the most prevalent. A chi-square test further validated that this sequence is statistically more significant than other potential sequences. This sequence is the structured way organizations can actualize digital technologies' affordances.

4.3. The sequences speed determination and Mann-Whitney U test confirmed that the differences in the actualization speed of digital technologies' affordances between the most dominant sequence and all other possible sequences are statistically significant. Companies that actualize digital technologies' affordances following the augmentation affordance → connect affordance → analytic affordance → automation affordance sequence are, on average 2.8 years faster in actualizing digital technologies' affordances than companies following all other possible actualization sequences. This digital technologies' affordances actualization sequence where companies follow augmentation affordance → connect affordance → analytic affordance → automation affordance sequence saves time for organizations.

4.4. The robustness analysis showed that the process model of the actualization of digital technologies' affordances (augmentation affordance → connect affordance → analytic affordance → automation affordance) is stable. The robustness analysis of the process model of actualization of digital technologies' affordances showed that most path coefficient differences under criteria (country; the size of the company; sector; the company's age; incorporated major technical improvements/introduced new products; R&D development) are statistically insignificant. The process model of the actualization of digital technologies' affordances (augmentation affordance → connect affordance → analytic affordance → automation affordance) could be used in different conditions.

## SANTRAUKA

### Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesas organizacijose

### Situacija

Pastaraisiais dešimtmečiais skaitmeninės technologijos tapo neatsiejamos nuo mūsų gyvenimo ir daro įtaką mūsų bendravimui, darbui ir sąveikai su aplinka. Sparti šių technologijų pažanga ir platus jų pritaikymas suteikė daugybę galimybių ir iššūkių tiek asmenims, tiek organizacijoms, pramonės šakoms ir visuomenėms. Organizacijos turi greitai prisitaikyti prie nuolat besikeičiančio kraštovaizdžio, kuriame nuolat atsiranda naujų skaitmeninių technologijų (Kraus ir kt., 2022; Konopik ir kt., 2022; Vial, 2019). Pagrindinis šios transformacijos veiksnys yra skaitmeninimas. Organizacijos sėkmė šiandien priklauso nuo to, kaip ji supranta skaitmenizuotos aplinkos procesus ir varomąsias jėgas bei geba spręsti skaitmeninių technologijų poveikio problemas (Yang ir kt., 2021; Martinez-Caro ir kt., 2020). Organizacijos pasitelkia skaitmenines technologijas, kad padidintų efektyvumą, paskatintų inovacijas, padidintų produktų ir paslaugų pritaikymą pagal vartotojo poreikius ir sukurtų konkurencinį pranašumą (Lin ir Lin, 2023; Clauss ir kt., 2021; Bharadwaj ir kt., 2013).

Skaitmeninė transformacija atveria naujas galimybes, tačiau kartu kelia organizacijoms naujų iššūkių. Skaitmeninės technologijos daro didelį poveikį organizacijos verslo strategijai (Tsou ir Chen, 2022; Zaki, 2019; Hess ir kt., 2016; Bharadwaj ir kt., 2013). Jos taip pat keičia organizacijos kultūrą, iš naujo apibrėžia darbuotojų vaidmenis ir transformuoja įmonės struktūras (Lanzolla ir kt., 2020; Grover ir kt., 2022; Martinez-Caro ir kt., 2020; Singh ir kt., 2020). COVID-19 pandemija tik paspartino šiuos su skaitmeninimu susijusius organizacinius pokyčius (Nagel, 2020; Soto-Acosta, 2020; Kudyba, 2020). Vien integruoti įvairių skaitmeninių technologijų į organizaciją nepakanka. Svarbiausia yra tai, kaip šios organizacijos naudoja ir plėtoja šias technologijas (Denner ir kt., 2018). Kaip teigia Volkoff ir Strong (2013) bei Zammuto ir kiti (2007), skaitmeninių technologijų naudojimas aktyvuoja „skaitmeninių technologijų nulemtų įgalinimų rinkinį“, pavyzdžiui, galimybę vizualizuoti ištisus darbo procesus, geresnį bendravimą, duomenų analizę ir modeliavimą. „Įgalinimas“ apibūdinamas kaip skaitmeninės technologijos suteikiamas veikimo potencialas (Majchrzak ir Markus, 2012). Šių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesas yra labai svarbus organizacijos sėkmei ir veiksmingam išteklių naudojimui. Šis aktualizavimas potencialią skaitmeninių technologijų naudą paverčia apčiuopiamais rezultatais. Atsižvelgiant į tai, kad įmonės veikia su ribotais ištekliais, labai svarbu nustatyti prioritetus, kuriuos skaitmeninių technologijų nulemtus įgalinimus aktualizuoti pirmiausia, antroje eilėje ar trečioje eilėje. Įgydamos patirties aktualizuojant kelis skaitmeninių technologijų nulemtus įgalinimus, organizacijos sukaupia įžvalgų, kuriomis gali vadovautis ateityje integruodamos ir optimizuodamos naujus skaitmeninių technologijų nulemtus įgalinimus (Strong ir kt., 2014).

**Problema**

Pagrindinės teorijos, nagrinėjančios skaitmeninių technologijų vystymąsi organizacijose, yra ištekliais pagrįsto požiūrio (RBV) teorija ir įgalinimų teorija. Barney (1991) ir Wernerfelt (1984) sukūrė pagrindines RBV teorijos koncepcijas. Šioje teorijoje pabrėžiami gebėjimai ir ištekliai, suteikiantys įmonėms technologinį pranašumą (Prahalad ir Hamel, 1990; Conner ir Prahalad, 1996). Įgalinimų teorijos šaknys glūdi ekologinėje psichologijoje. Gibsonas (1979) pristatė šią teoriją kaip sistemą, padedančią suprasti gyvūnų elgesį jų aplinkoje. Terminą „įgalinimas" sukūrė Gibsonas (1979), veiksmažodį „įgalinti" paversdamas daiktavardžiu, atspindinčiu galimybės suteikimo esmę. Normanas (1988) buvo pirmasis mokslininkas, kuris pritaikė įgalinimų teoriją žmonių ir technologijų sąveikai apibūdinti. Prie įgalinimų teorijos evoliucijos reikšmingai prisidėjo Zammuto ir kiti (Zammuto ir kt., 2007). Jie į įgalinimų teoriją pažvelgė iš informacinių technologijų ir organizacijų tarpusavio santykių pozicijos (Zammuto ir kt., 2007). Pasak Strauss ir Hoppen (2019), įgalinimų teorija buvo taikoma siekiant ištirti naudotojų, į kuriuos žiūrima kaip į „gyvūnus", ir technologinių artefaktų, suvokiamų kaip „objektai", santykius.

Skaitmeninių technologijų nulemti įgalinimai susilaukė mokslininkų, atstovaujančių ištekliais pagrįstam požiūriui ir įgalinimų teorijoms, dėmesio. Tačiau dar yra kritinių neištirtų sričių. Pagrindinės įgalinimų tyrimų kryptys yra suskirstytos į du srautus: a) įgalinimus, atsirandančius dėl skaitmeninių technologijų pritaikymo, ir b) skaitmeninių technologijų nulemtų įgalinimų aktualizavimo.

Pirmosios krypties tyrėjai gilinosi į iš skaitmeninių technologijų atsirandančius įgalinimus. Volkoff ir Strong (2013) bei Strong ir kt. (2014) pažymėjo, kad iš skaitmeninių technologijų atsirandantys įgalinimai gali būti skirstomi į individualaus, organizacinio ir proceso lygmens įgalinimus. Jie pabrėžė, kad šie įgalinimų lygiai yra tarpusavyje susiję ir persipynę. Panašiai Chatterjee ir kiti (2015) nagrinėjo individualius, organizacinius ir proceso prieinamumo įgalinimus, kylančius iš skaitmeninių technologijų. Vyas ir kiti (2017) taip pat nagrinėjo skaitmeninių technologijų nulemtus įgalinimus, skirstydami juos į vieno vartotojo, organizacijos (arba darbo grupės) ir visuomenės. Be to, kai kurie mokslininkai sutelkė dėmesį į įgalinimus, atsirandančius dėl konkrečių skaitmeninių technologijų naudojimo organizacijose. Pavyzdžiui, Du ir kt. (2019) aptarė įgalinimus, atsirandančius dėl blokų grandinės technologijos, o Gunter ir Braga (2018) pabrėžė įgalinimus, atsirandančius dėl mobiliųjų programėlių naudojimo. Kita vertus, dalis tyrėjų nagrinėjo įgalinimus, atsirandančius dėl įvairių skaitmeninių technologijų diegimo organizacijoje. Pavyzdžiui, Øvrelid ir Kempton (2019) nustatė tokius skaitmeninių technologijų naudojimo atsirandančius įgalinimus, kaip išteklių integravimo įgalinimai (pavyzdžiui, prieiga, užsakymas ir tyliosios ataskaitos), matomumo įgalinimai (pavyzdžiui, stebėjimas ir individualizavimas), procesų eigos įgalinimai (įskaitant progresavimą ir sinchronizavimą). Be to, tokie mokslininkai, kaip Bobsin ir kt. (2019), Markus ir Silver (2008), Zammuto ir kt. (2007), Vitari ir Pigni (2014), Herterich ir kt. (2016) ir Stendal ir kt. (2016), gilinosi į įgalinimus, gaunamus vienu metu organizacijoje naudojant kelias skaitmenines technologijas. Svarbiausia jų tyrimuose buvo skaitmeninių technologijų ir žmonių naudotojų santykis. Daugumoje čia minimų tyrimų taikytas kokybinis metodas. Šioje tyrimų kryptyje pastebima didelė spraga, kai kalbama apie kiekybinę skaitmeninių technologijų nulemtų įgalinimų analizę.

Antrosios krypties tyrėjai nagrinėjo skaitmeninių technologijų nulemtų įgalinimų aktualizavimą. Ostern ir Rosemann (2021) gilinosi į procesinį įgalinimų modelį, tačiau jų aktualizacijos reiškinių aprašymas buvo daugiausia teorinis. Be to, jie nenagrinėjo kelių įgalinimų aktualizacijos. Chatterjee ir kiti (2020) nagrinėjo, kaip aktualizuojami informacinių technologijų nulemti įgalinimai siekiant skatinti organizacines inovacijas. Dremel ir kt. (2020) analizavo didžiųjų duomenų analitikos nulemtų įgalinimų aktualizavimą, ypač daug dėmesio skirdami analitikos įgalinimo aktualizavimui. Strong ir kiti (2014) nagrinėjo įvairių skaitmeninių technologijų nulemtų įgalinimų aktualizavimą ir siekė atskleisti sąsajas tarp kelių IT technologijų nulemtų įgalinimų. Tačiau jų analizė apsiribojo vienos įmonės kokybiniu tyrimu vienu atveju. Anderson ir Robey (2017) nagrinėjo potenciją ir siekė išsiaiškinti technologijų nulemtų įgalinimų aktualizaciją naudodami kokybinio tyrimo prizmę. Tačiau jų analizė apsiribojo viena viešojo sektoriaus organizacija. Apibendrinant galima teigti, kad išsamių tyrimų, susijusių su kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimu, trūksta. Kokybiniai tyrimai šia tema dažnai apibendrina vieno įgalinimo aktualizavimą arba sutelkia dėmesį tik į tam tikrus šio reiškinio aspektus. Šių siaurų kokybinių tyrimų išvados nėra universaliai pritaikomos įvairiose pramonės šakose (Volkoff ir Strong, 2017). Norint visapusiškai suprasti kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimą, būtina sukurti tai nagrinėjantį proceso modelį. Be to, tyrėjai diskusijose apie kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimą turi pabrėžti įgalinimų papildomumą. Taip pat reikia daugiau dėmesio skirti kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo greičio analizei (Volkoff ir Strong, 2017).

Vis dėlto kai kurios sritys vis dar nepakankamai ištirtos:

- Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesas organizacijose nėra išsamiai analizuojamas.
- Nepakankamai ištirtas kelių skaitmeninių technologijų nulemtų įgalinimų papildomumas.
- Nepakankamai ištirtas kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso greitis.

Argumentai:

- Nors įmonės įsisavina įvairias skaitmenines technologijas, jos negali būti įsisavinamos vienu metu, nes organizacija turi ribotus išteklius (Barney ir Clark, 2007).

- Skaitmeninių technologijų nulemtų įgalinimų tyrimuose dominuoja kokybiniai tyrimai (t. y. atvejo studijos), o kiekybiniai tyrimai gali suteikti naujų įžvalgų.

- Įmonės turi savo taisykles ir skaitmeninimo strategijas, jos žingsnis po žingsnio įsisavina įvairias skaitmenines technologijas.

**Tyrimo problema:**

Kaip keli skaitmeninių technologijų nulemti įgalinimai aktualizuojami ir papildo vienas kitą aktualizavimo procese organizacijose?

**Tyrimo objektas:**

Skaitmeninių technologijų nulemtų įgalinimų aktualizavimas organizacijose ir skaitmeninių technologijų nulemtų įgalinimų tarpusavio papildomumas šiame procese.

**Tyrimo tikslas:**

Nustatyti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesą ir skaitmeninių technologijų nulemtų įgalinimų tarpusavio papildomumą organizacijose.

**Tyrimo uždaviniai:**

1) Atlikus išsamią literatūros apžvalgą, parengti struktūruotą skaitmeninių technologijų nulemtų įgalinimų apžvalgą.

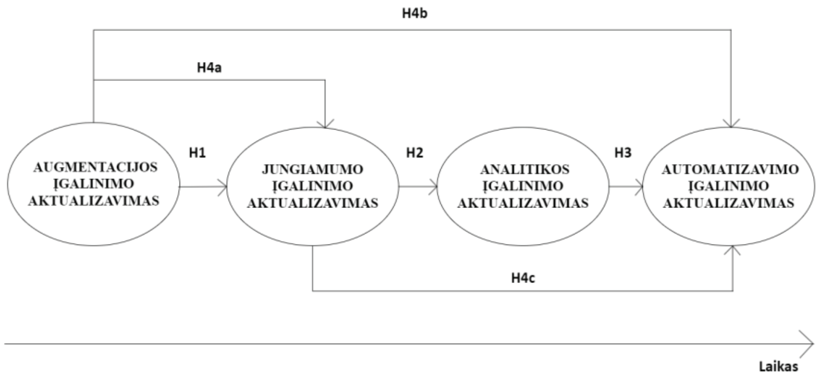
2) Pagrįsti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso modelį.

3) Sukurti ir pagrįsti kiekybinio tyrimo metodiką, leidžiančią empiriškai patikrinti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso modelį.

4) Empiriškai patikrinti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso modelį ir atskleisti, kaip skaitmeninių technologijų nulemti įgalinimai papildo vienas kitą aktualizavimo procese organizacijose.

### Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso modelis

Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso modelis, pateiktas 9 paveiksle, buvo sukurtas atlikus išsamią mokslinės literatūros analizę. Pateiktame modelyje apibrėžiamas skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesas. Šis procesas grindžiamas šešiomis hipotezėmis, kurios išsamiau aptariamos metodų skiltyje.




**9 pav.** Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso modelis

### Metodai

Šio tyrimo filosofinis pagrindas – pozityvizmas ir pragmatizmas. Tyrime naudojami Europos gamybos apklausos duomenys, kurie pasirinkti būtent dėl to, kad jie parodo įvairių skaitmeninių technologijų naudojimą organizacijose. Be to, ši apklausa suteikia galimybę susipažinti su įgalinimais, kurie atsiranda Europos gamintojams diegiant skaitmenines technologijas. Atsižvelgiant į platų skaitmeninių technologijų naudojimą ir polinkį į naujoves, pagrindinis šio tyrimo dėmesys buvo skiriamas gamybos įmonėms. Tyrimas apima gamybos organizacijas (N=798) Vidurio ir Rytų Europos šalyse, konkrečiai Lietuvoje, Slovėnijoje, Kroatijoje, Slovakijoje, Kroatijoje ir Austrijoje.

Kiekybiniam tyrimui atlikti buvo taikomi įvairūs metodai, siekiant patikrinti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso modelį. Siekiant įvertinti kelių koeficientų stiprumą ir nustatyti jų statistinį reikšmingumą tarp proceso modelio konstruktų, taikytas dalinių mažiausių kvadratų struktūrinių lygčių modeliavimo (PLS-SEM) metodas.

Siekiant patikimai ištirti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose seką, tyrime taikytas sekų dažnių nustatymo metodas, naudojant procesų tyrybos analizės įrankį, papildytą *chi* kvadrato testu. Be to, siekiant įvertinti greičio ir kitų pasirinktų kriterijų skirtumų statistinį reikšmingumą aktualizacijos proceso metu įvairiose potencialiose sekose, naudotas Mann-Whitney U testas. PLS-SEM daugiagrupė analizė atlikta siekiant patikrinti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso modelio kelių koeficientų skirtumus. Kiekybiniame tyrime buvo vertinami tokie konstruktai, kaip augmentacija, jungiamumas, analitikos ir automatizavimo įgalinimas pasitelkiant daugialypes skaitmenines technologijas. Matavimo modelio (patvirtinamosios faktorinės analizės) rezultatai parodė, kad visi matavimo modelio parametrai yra priimtini ir reikšmingi.

*Tyrime buvo iškeltos šios hipotezės:*

H1: Augmentacijos įgalinimo aktualizavimas turi tiesioginį teigiamą poveikį jungiamumo įgalinimo aktualizavimui.

H2: Jungiamumo įgalinimo aktualizavimas turi tiesioginį teigiamą poveikį analitikos įgalinimo aktualizavimui.

H3: Analitikos įgalinimo aktualizavimas turi tiesioginį teigiamą poveikį automatizavimo įgalinimo aktualizavimui.

H4a: Augmentacijos įgalinimo aktualizavimas turi netiesioginį teigiamą poveikį analitikos įgalinimo aktualizavimui.

H4b: Augmentacijos įgalinimo aktualizavimas turi netiesioginį teigiamą poveikį automatizavimo įgalinimo aktualizavimui.

H4c: Jungiamumo įgalinimo aktualizavimas turi netiesioginį teigiamą poveikį automatizavimo įgalinimo aktualizavimui.

H5: Skaitmeninių technologijų nulemti įgalinimai aktualizuojami tokia seka: augmentacija, jungiamumas, analitika ir automatizavimas.

H6: Įmonės, kurios skaitmeninių technologijų nulemtus įgalinimus aktualizuoja pagal šią seką augmentacijos įgalinimas->jungiamumo įgalinimas->analitikos įgalinimas->automatizavimo įgalinimas, vidutiniškai greičiau aktualizuoja skaitmeninių technologijų nulemtus įgalinimus nei įmonės, kurios taiko visas kitas galimas aktualizavimo sekas.

Su skaitmeninių technologijų nulemtų įgalinimų tarpusavio papildomumu susijusios hipotezės (H1, H2, H3, H4a, H4b, H4c) tikrinamos naudojant PLS-SEM. Kad šios hipotezės būtų priimtinos, rezultatas turėtų būti toks: visi ryšiai yra teigiami ir statistiškai reikšmingi. Priešingu atveju su tarpusavio papildomumu susijusios hipotezės atmetamos, jei bent vienas ryšys yra neigiamas arba statistiškai nereikšmingas.

Hipotezė (H5), susijusi su skaitmeninių technologijų nulemtų įgalinimų aktualizavimo seka organizacijose, buvo tikrinama pasitelkiant sekų dažnių nustatymą, papildytą *chi* kvadrato testu. Kad hipotezė (H5) būtų patvirtinta, rezultatas turėjo atitikti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekos eiliškumą. Be to, ši seka turi būti populiariausia, palyginti su visomis kitomis galimomis skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekomis. Priešingu atveju hipotezė (H5) atmetama, jei rezultatas neatitinka sekos ir skaitmeninių technologijų nulemtų įgalinimų aktualizacijos seka nėra populiariausia, palyginti su kitomis galimomis skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekomis.

Sekų dažnių nustatymo rezultatų reikšmingumui patikrinti buvo naudojamas *chi* kvadrato testas. Šis testas yra labai vertingas tais atvejais, kai reikia įvertinti stebimų duomenų atitiktį iš anksto nustatytam pasiskirstymui. Dažniausiai pasitaikančios sekos paplitimas (augmentacijos įgalinimas->jungiamumo įgalinimas->analitikos įgalinimas->automatizavimo įgalinimas) buvo lyginamas su antra labiausiai paplitusia seka. Kiekviena iš jų buvo lyginama su vienodomis tikimybėmis 0,5. Jei pirmosios ir antrosios sekos paplitimo skirtumas būtų statistiškai reikšmingas, tuomet, remiantis *chi* kvadrato testo logika, paplitimo skirtumas tarp pirmosios sekos ir trečiosios, ketvirtosios ir visų kitų vėlesnių sekų taip pat būtų statistiškai reikšmingas. Kad H5 būtų priimta, sekos (augmentacijos įgalinimas->jungiamumo įgalinimas->analitikos įgalinimas->automatizavimo įgalinimas) paplitimas turi būti statistiškai reikšmingas, palyginti su antrąja ir visomis kitomis sekomis. Priešingu atveju H5 hipotezė atmetama, jei šios sekos paplitimas nėra statistiškai reikšmingas, palyginti su antrąja ir visomis kitomis sekomis.

Su greičiu susijusi hipotezė (H6) buvo tikrinama naudojant sekų greičio nustatymo ir Mann-Whitney U testą. Kad H6 būtų priimta, skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso seka (augmentacijos įgalinimas->jungiamumo įgalinimas->analitikos įgalinimas->automatizavimo įgalinimas) turėtų būti vidutiniškai greitesnė, palyginti su visomis kitomis galimomis skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekomis. Šis greičio skirtumas turėtų būti statistiškai reikšmingas. Priešingu atveju hipotezė (H6) atmetama, jei skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso seka (augmentacijos įgalinimas->jungiamumo įgalinimas->analitikos įgalinimas->automatizavimo įgalinimas) nėra vidutiniškai greitesnė, palyginti su visomis kitomis galimomis skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekomis. Taip pat hipotezė (H6) atmetama, jei greičio skirtumas tarp dominuojančios sekos ir visų kitų galimų skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekų nėra statistiškai reikšmingas.

**Teorinis indėlis**

Šiame tyrime yra keletas svarbių indėlių į teoriją. Pirma, šis tyrimas teoriškai pagrindžia universalių skaitmeninių technologijų nulemtų įgalinimų egzistavimą organizacijose ir nagrinėja, kaip jos sąveikauja aktualizavimo proceso metu. Tyrimo metu nustatyta, kad kai aktualizuojami keli skaitmeninių technologijų nulemti įgalinimai – konkrečiai, augmentacijos, analitikos, automatizavimo ir jungiamumo, jie yra linkę papildyti vienas kitą. Tai praturtina ir įgalinimų, ir ištekliais pagrįsto požiūrio (RBV) teorijas. Iki šiol trūko išsamių tyrimų ir straipsnių, kuriuose būtų aptarta, kaip įvairūs skaitmeninių technologijų nulemti įgalinimai sinergizuojasi aktualizacijos proceso metu (Volkoff ir Strong, 2017). Raisch ir Krakowski (2021) savo darbe palietė augmentacijos ir automatizavimo įgalinimų papildomumą. Panašiai Zammuto ir kiti (2007) gilinosi į keletą skaitmeninių technologijų nulemtų įgalinimų, tokių kaip ištisų darbo procesų vizualizavimas, lankstus produktų ir paslaugų kūrimas, plataus masto bendradarbiavimas internete ir imituojama realybė, tačiau jų atliktas šių įgalinimų sinergijos tyrimas buvo šiek tiek ribotas. Lenka ir kt. (2017) aptarė skaitmeninimo gebėjimus, įskaitant intelekto, ryšio ir analitinius gebėjimus, ir jų pridėtinę vertę organizacijoms. Nors jie paminėjo galimas sąsajas ir ryšius tarp skirtingų skaitmeninimo gebėjimų, jų perspektyva atrodė fragmentiška ir neapėmė visų galimų sąveikų. Strong ir Volkoff (2013) atidžiau pažvelgė į bazinius ir aukštesnio lygio įgalinimus, nagrinėdami jų tarpusavio sąsajas. Vis dėlto jų analizė, paremta tik keliais įmonių atvejais, apėmė tik dalį galimų sąveikų. Priešingai, šioje disertacijoje gilinamasi į visas galimas įvairių skaitmeninių technologijų nulemtų įgalinimų sąveikas. Joje pirmą kartą nuodugniai nagrinėjama keturių universalių skaitmeninių technologijų nulemtų įgalinimų – augmentacijos, analitikos, automatizavimo ir jungiamumo – sąveika jų aktualizavimo proceso metu.

Antra, jis tiksliai apibrėžia įvairių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesą organizacijose. Tyrimas rodo, kad aktualizavimo procesas vyksta nuosekliai: 1) augmentacijos įgalinimas, 2) jungiamumo įgalinimas, 3) analitikos įgalinimas ir 4) automatizavimo įgalinimas. Apibrėždamas šį procesą, tyrimas praturtina ir įgalinimų teoriją, ir ištekliais pagrįsto požiūrio teoriją. Iki šiol moksliniuose tyrimuose šie įgalinimai dažniausiai buvo nagrinėjami atskirai. Daugelis mokslininkų, pavyzdžiui, Volkoff ir Strong (2017), dažnai susitelkdavo tik į vieną skaitmeninių technologijų lemiamą įgalinimą. Pavyzdžiui, Chatterjee ir kiti (2020) nagrinėjo informacinių technologijų nulemtų įgalinimų aktualizavimą organizacinių inovacijų kontekste, apsiribodami vienu skaitmeninių technologijų nulemtu įgalinimu. Panašiai Dremel ir kt. (2020) nagrinėjo didžiųjų duomenų analitikos įgalinimų aktualizavimą, tačiau susitelkė tik į analitikos įgalinimą. Strong ir kt. (2014) aptarė įvairių skaitmeninių technologijų nulemtų įgalinimų aktualizavimą, tačiau jų atliktas kelių IT technologijų nulemtų įgalinimų sąsajų tyrimas apsiribojo vienos įmonės kokybine analize. Tyrimuose, susijusiuose su kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimu organizacijose, esama pastebimos spragos, ir šis tyrimas ją užpildo, pateikdamas skaitmeninių technologijų nulemtų įgalinimų proceso modelį.

Trečia, šiame tyrime pateikiama įžvalgų, kaip gamybos įmonėse aktualizuojami įvairūs skaitmeninių technologijų nulemti įgalinimai, taip praturtinant įgalinimų teoriją. Iki šiol buvo atlikta nedaug tyrimų, susijusių su kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesu būtent gamybos sektoriuje. Nors Lenka ir kt. (2017) tyrinėjo skaitmeninimo gebėjimus gamybos įmonėse, jų tyrimas rėmėsi tik keturių įmonių imtimi: sunkiosios technikos, telekomunikacijų infrastruktūros, staklių ir atsinaujinančių pakavimo medžiagų įmonių. Panašiai Volkoff ir Strong (2013) atliko skaitmeninių technologijų nulemtų įgalinimų tyrimą, daugiausia dėmesio skirdami tik dviejų gamybos įmonių atvejų studijoms. Ribotos imtys šiuose minėtuose tyrimuose trukdo apibendrinti jų išvadas visoje gamybos pramonėje. Be to, Lenka ir kt. (2017) ir Strong ir Volkoff (2013) darbuose analizuotų gamybos įmonių aprėptis buvo gana ribota – jos apėmė tik kelis gamybos pramonės sektorius. Priešingai, šis tyrimas apima 798 gamybos įmonių iš įvairių šalių imtį, todėl pateikiamas išsamus visų gamybos sektorių pagal NACE klasifikaciją vaizdas. Tokia plati aprėptis palengvina tyrimo apie skaitmeninių technologijų nulemtų įgalinimų aktualizavimą išvadų apibendrinimą visoje gamybos pramonėje.

Ketvirta, šiame tyrime nagrinėjama skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso trukmė organizacijose, detalizuojant kiekvienos galimos sekos vidutinę trukmę. Tokios išvados iš esmės praturtina tiek įgalinimų, tiek ištekliais pagrįsto požiūrio teorijas. Istoriškai įgalinimų teorijos srityje, nors buvo atliekami skaitmeninių technologijų nulemtų įgalinimų aktualizacijos proceso tyrimai (Volkoff ir Strong, 2017; Strong ir Volkoff, 2013; Ostern ir Rosemann, 2021), šių aktualizacijos procesų trukmė iš esmės buvo ignoruojama. Panašiai ir ištekliais grindžiamo požiūrio srityje, nors tokie mokslininkai, kaip Szalavetz (2019), aptarė gamybos, technologinių, inovacinių, mokslinių tyrimų ir kūrybos gebėjimų raidą, o Wu ir kt. (2022) palietė vidinių ir išorinių skaitmeninimo gebėjimų raidą, šių gebėjimų raidos trukmė lieka nenagrinėta. Be to, kadangi šie tyrimai daugiausia remiasi kokybiniais metodais, jų išvados nėra lengvai apibendrinamos visose organizacijose. Priešingai, Lu ir kiti (2022) taikė kiekybinį metodą veiklos ir skaitmeninimo gebėjimų raidai tirti, tačiau nesigilino į susijusias trukmes. Tačiau šioje disertacijoje ne tik tiriama kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso trukmė, bet ir pateikiamos vidutinės kiekvienos sekos trukmės. Taikyta kiekybinė metodika palengvina išvadų, susijusių su skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso trukme, apibendrinimą.

Taip pat šis tyrimas praturtina tyrimų, susijusių su skaitmenine transformacija, lauką, nes pateikia naujų įžvalgų apie skaitmeninių technologijų plėtrą organizacijose. Nors egzistuoja daugybė tyrimų apie galimus skaitmeninės transformacijos planus (Zaouia ir Souissi, 2020; Issa ir kt., 2018; Schallmo ir kt., 2017), šiuose ankstesniuose tyrimuose nebuvo pritaikyta skaitmeninių technologijų nulemtų įgalinimų perspektyva. Priešingai nei kiti skaitmeninės transformacijos tyrimai, ši disertacija gali pasigirti keliais privalumais: didelė 798 gamybos įmonių iš penkių šalių (Lietuvos, Slovakijos, Slovėnijos, Kroatijos, Austrijos) imtis palengvina duomenų apibendrinimą, o procesų tyrybos analizė užtikrina išsamų visų galimų skaitmeninių technologijų nulemtų įgalinimų aktualizavimo kelių žemėlapių nagrinėjimą.

**Praktinės implikacijos**

Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso modelis, apibrėžtas kaip „augmentacija->jungiamumas->analitika->automatizavimas“, yra labai svarbus tiek vadovams, tiek organizacijoms. Suprasdami šią seką, vadovai gali apgalvotai diegti skaitmenines technologijas, didinti organizacijos veiklos efektyvumą, skatinti inovacijas ir užsitikrinti konkurencinį pranašumą rinkoje. Ši seka yra neįkainojama organizacijoms, nes joje pateikiama sisteminė metodika, kaip išnaudoti visą skaitmeninių technologijų potencialą. Toliau pateikiama informacija apie tai, kodėl kiekvienas etapas yra labai svarbus, ir apie jų galimą naudą organizacijoms.

Augmentacijos įgalinimo aktualizavimo etape organizacijos sutelkia dėmesį į asmens galimybių didinimą naudojant skaitmenines technologijas, taip sustiprindamos ir išplėsdamos jo gebėjimus. Šis įgalinimas gali padidinti produktyvumą, patobulinti sprendimų priėmimo procesus ir paskatinti bendradarbiavimą. Be to, tai gali padėti kurti naujus produktus ir paslaugas, o tai gali pagerinti klientų patirtį. Šis etapas yra pagrindas vėlesniems įgalinimams aktualizuoti.

Jungiamumo įgalinimo aktualizavimo etape daugiausia dėmesio skiriama ryšių ir tinklų tarp asmenų, procesų ir technologijų kūrimui. Tai atveria kelią sklandžiam bendravimui ir bendradarbiavimui tiek viduje, tiek išorėje. Glaudesnis bendravimas skatina inovacijas, nes palengvina dalijimąsi žiniomis ir keitimąsi idėjomis. Geresnis ryšys taip pat gali padėti sutaupyti lėšų, padidinti veiklos efektyvumą ir užtikrinti skaidresnę bei labiau kontroliuojamą aplinką. Tinkamai įgyvendinus jungiamumo įgalinimą, sukuriamas pagrindas vėlesniam analitikos įgalinimo aktualizavimui.

Analitikos įgalinimo aktualizavimo etape analitika padeda organizacijoms iššifruoti daugybę skaitmeninių technologijų sukurtų duomenų. Naudodamos pažangias analitikos ir didžiųjų duomenų technologijas, organizacijos gali išgauti vertingų įžvalgų ir priimti pagrįstus, duomenimis paremtus sprendimus. Šis gebėjimas leidžia joms įžvelgti dėsningumus, numatyti rezultatus ir tobulinti procesus, o visa tai didina konkurencingumą. Stipriai aktualizuotas analitikos įgalinimas sudaro pagrindą vėlesniam automatizavimo įgalinimo aktualizavimui.

Automatizavimo įgalinimo aktualizavimo etape organizacijos naudojasi kolektyvinėmis žiniomis, gautomis anksčiau aktualizavus augmentacijos, jungiamumo ir analitikos įgalinimus. Skaitmeninės technologijos palengvina įprastų užduočių ir procesų automatizavimą, o tai savo ruožtu didina organizacijos efektyvumą ir mažina išlaidas.

Įmonės, kurios laikosi skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekos, t. y. pradedant nuo augmentacijos įgalinimo, po to jungiamumo įgalinimas, tada eina analitikos įgalinimas ir galiausiai automatizavimo įgalinimas, šiuos įgalinimus aktualizuoja vidutiniškai 2,8 metų greičiau nei bet kuria kita seka besivadovaujančios įmonės. Empirinis tyrimas parodė, kad šis rezultatas yra statistiškai reikšmingas. Tos organizacijos, kurios laikosi šio konkretaus aktualizavimo eiliškumo, gali užsitikrinti konkurencinį pranašumą.

Šis tyrimas parodo, kaip įmonės turėtų elgtis su skaitmeninių technologijų nulemtais įgalinimais ir išnaudoti jų sinergiją, kad maksimaliai padidintų vertę turėdamos ribotus išteklius.

## Tyrimo apribojimai ir ateities tyrimų kryptys

Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso organizacijose nagrinėjimas yra sudėtingas uždavinys, turintis keletą galimų apribojimų. Šioje diskusijoje apibūdinami šie tyrimo apribojimai:

- Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sąvoka iš esmės yra subjektyvi. Ji priklauso nuo naudotojo suvokimo ir interpretacijos. Todėl nustatyti aiškų, visuotinai priimtiną skaitmeninių technologijų nulemtų įgalinimų apibrėžimą yra sudėtinga.

- Skaitmeninių technologijų nulemtų įgalinimų aktualizavimas yra daugialypis procesas, kuriam įtakos turi daugybė veiksnių, įskaitant individualius kognityvinius gebėjimus, motyvaciją, socialinį kontekstą ir kultūrines normas. Sudėtingas šio proceso pobūdis apsunkina pastangas išskirti ir įvertinti konkrečius komponentus.

- Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo kiekybiniai tyrimai grindžiami savęs pačių pateiktais vertinimais. Jie gali būti šališki, pavyzdžiui, dėl noro pateikti save palankiai, galimų netikslumų prisimenant įvykius, taip pat dėl to, kad per daug arba per mažai vertinami savo įgūdžiai ir technologijų naudojimas. Be to, kiekybiniai tyrimai kartais gali pernelyg supaprastinti sudėtingus reiškinius, suskirstydami juos į atskirus kintamuosius ir ryšius, todėl gali būti neatsižvelgiama į kognityvinių, socialinių ir kultūrinių aspektų sąveikos niuansus.

- Europos gamybos įmonių tyrimas matuoja riboto laikotarpio duomenis apie finansinę veiklą, apsiribodamas konkrečiais metais. Jame nerenkami kasmetiniai finansiniai rodikliai. Atsižvelgiant į tai, kad skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesas gali trukti kelerius metus, o tam tikrose organizacijose kartais net ir dešimtmetį, analizuojant aktualizavimo ir finansinių rezultatų santykį, be prieigos prie išsamių longitudinių finansinių duomenų nepavyktų gauti statistiškai reikšmingų rezultatų.

Galima išskirti keletą ateities tyrimų krypčių:

- Ateities tyrimuose daugiausia dėmesio galėtų būti skiriama tam, kaip individualūs skirtumai, pavyzdžiui, naudotojų išankstinės žinios, kognityviniai gebėjimai, motyvacija, kultūrinės normos ir socialiniai veiksniai, daro įtaką skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesui gamybos įmonėse. Tai galėtų padėti išsiaiškinti, kaip geriau pritaikyti skaitmeninių technologijų kūrimą ir diegimą, kad būtų patenkinti skirtingi naudotojų poreikiai ir pageidavimai gamybos įmonėse.

- Ilgalaikėje perspektyvoje būtų naudinga dar kartą ištirti skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesą, nes nuolat atsiranda naujų skaitmeninių technologijų, kurios arba papildo esamus skaitmeninių technologijų nulemtus įgalinimus, arba leidžia atsirasti naujiems skaitmeninių technologijų nulemtiems įgalinimams.

- Kiekybinio tyrimo prieigą būtų galima panaudoti tiriant skaitmeninių technologijų nulemtų įgalinimų aktualizavimo procesą kituose Europos ar pasaulio regionuose.

## Tyrimo išvados

Teoriniai ir empiriniai skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso organizacijose tyrimo rezultatai leido padaryti šias išvadas:

1. Disertacijoje buvo apžvelgta mokslinė literatūra apie skaitmeninių technologijų nulemtus įgalinimus. Mokslinės literatūros analizė atskleidė, kad universalūs skaitmeninių technologijų nulemti įgalinimai, aktualūs daugeliui organizacijų, yra augmentacijos, analitikos, automatizavimo ir jungiamumo. Siūlomi šių universalių skaitmeninių technologijų nulemtų įgalinimų apibrėžimai konceptualizuoti taip: augmentacijos įgalinimas suprantamas kaip įgalinimas ir pagerinimas žmogaus veiklos atliekant įvairias užduotis; analitikos įgalinimas suprantamas kaip įgalinimas rinkti duomenis iš organizacijos veiklos operacijų ir

aplinkos ir naudoti programinės įrangos įrankius, siekiant juos paversti naudingomis žiniomis ir gairėmis įmonei; automatizavimo įgalinimas suprantamas kaip įgalinimas operacijai arba sistemai veikti nepriklausomai; jungiamumo įgalinimas suprantamas kaip įgalinimas išnaudoti belaidžio ryšio tinklus organizacijoje, siekiant palengvinti keitimąsi duomenimis ir informacija tarp asmenų ir skaitmeninių įrenginių.

2. Remiantis mokslinės literatūros analize, buvo teoriškai pagrįstas kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso modelis. Šiame proceso modelyje pirmiausia yra aktualizuojamas augmentacijos įgalinimas. Antras yra aktualizuojamas jungiamumo įgalinimas. Trečias yra aktualizuojamas analitikos įgalinimas. Paskutinis yra aktualizuojamas automatizavimo įgalinimas. Šiame proceso modelyje pateikiami kelių skaitmeninių technologijų nulemtų įgalinimų ryšiai. Teoriškai yra pagrįsta kelių skaitmeninių technologijų nulemtų įgalinimų papildomumo svarba aktualizavimo procese. Šis proceso modelis leidžia tirti galimas kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekas, ne tik pavienių skaitmeninių technologijų nulemtų įgalinimų aktualizavimą. Šio proceso modelio seka lemia greitesnį kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimą. Siūlomas kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso modelis įneša teorinį indėlį į įgalinimų ir ištekliais pagrįsto požiūrio teorijas.

3. Sukurta ir pagrįsta metodologija, skirta empiriškai patikrinti kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso modelį. Kiekybinis tyrimas leido patikrinti kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo organizacijose proceso modelio patikimumą. Ši metodologija suteikė visapusišką požiūrį į kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo sekų tyrimą ir padidino sekų analizės patikimumą. Šiame tyrime sukurta ir pagrįsta metodologija yra universali. Šio tyrimo metodologija leidžia kitiems tyrėjams nagrinėti sekas, susijusias su kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimu.

4. Disertacijoje buvo atliktas kelių skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso organizacijose empirinis patikrinimas:

4.1. PLS-SEM analizė atskleidė, kad kelių skaitmeninių technologijų nulemtų įgalinimų papildomumas leidžia efektyviau ir sklandžiau išnaudoti visą skaitmeninių technologijų potencialą organizacijose. Tai rodo, kad keli skaitmeninių technologijų nulemti įgalinimai reikšmingai sustiprina vienas kitą aktualizavimo proceso metu.

4.2. Sekų dažnio analizė patvirtino, kad gamybos organizacijos, siekdamos aktualizuoti kelis skaitmeninių technologijų nulemtus įgalinimus, dažniausiai vadovaujasi tam tikru proceso modeliu. Labiausiai paplitusi buvo seka, prasidedanti augmentacijos įgalinimo aktualizavimu, po kurio ėjo jungiamumo, analitikos ir automatizavimo įgalinimų aktualizavimas. *Chi* kvadrato testas taip pat patvirtino, kad ši konkreti seka yra statistiškai reikšmingesnė už kitas galimas sekas. Ši seka yra struktūrizuotas būdas, kuriuo organizacijos gali aktualizuoti skaitmeninių technologijų nulemtus įgalinimus.

4.3. Sekų greičio nustatymas naudojant Mann Whitney U testą patvirtino, kad skaitmeninių technologijų nulemtų įgalinimų aktualizavimo greičio skirtumai tarp dominuojančios sekos ir visų kitų galimų sekų yra reikšmingi. Įmonės, kurios skaitmeninių technologijų nulemtus įgalinimus aktualizuoja pagal tokią seką: augmentacijos įgalinimas->jungiamumo įgalinimas->analitikos įgalinimas->automatizavimo įgalinimas, vidutiniškai 2,8 metų greičiau aktualizuoja skaitmeninių technologijų nulemtus įgalinimus nei įmonės, kurios laikosi visų kitų galimų aktualizavimo sekų. Ši skaitmeninių technologijų nulemtų įgalinimų aktualizavimo seka, kai įmonės seka augmentacijos įgalinimu->jungiamumo įgalinimu->analitikos įgalinimu->automatizavimo įgalinimu, taupo organizacijų laiką.

4.4. Atsparumo analizė parodė, kad skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso modelis (augmentacijos įgalinimas->jungiamumo įgalinimas->analitikos įgalinimas->automatizavimo įgalinimas) yra stabilus. Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso modelio patikimumo analizė parodė, kad dauguma kelių koeficientų skirtumų pagal kriterijus (šalis; įmonės dydis; sektorius; įmonės amžius; įtraukti esminiai techniniai patobulinimai / pristatyti nauji produktai; MTEP vystymas) yra statistiškai nereikšmingi. Skaitmeninių technologijų nulemtų įgalinimų aktualizavimo proceso modelį (augmentacijos įgalinimas->jungiamumo įgalinimas->analitikos įgalinimas->automatizavimo įgalinimas) galima taikyti įvairiomis sąlygomis.

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## CURRICULUM VITAE


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| 2012 – 2016 | BA of Political Science and Business (with honor), Kaunas University of Technology |
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|---|---|
| 2016 – 2016 | Trainee at the Office of the Government of the Republic of Lithuania |
| 2016 – 2016 | Trainee at the Lithuanian Department of Statistics, Kaunas Branch of Data Preparation |
| 2015 – 2018 | Student representative in the Senate of Kaunas University of Technology |
| 2021 – 2022 | Lecturer at Kaunas University of Technology School of Economics and Business |
| 2021 – 2023 | Junior researcher in the project "AI-driven real-time digitalization roadmaps for upgrading small and medium manufacturing enterprises." |
| 2018 – now | Member of Lithuania Team in the European Manufacturing Survey (EMS) |
| 2019 – now | Member of the Kaunas University of Technology SEB Digitalization Research Group |
| 2023 – now | Adviser to a Member of the Parliament of the Republic of Lithuania |

**Areas of research interest:**
Digital technologies, affordances, digital technologies affordances, digital transformation, manufacturing companies.

## SCIENTIFIC PAPERS RELATED TO THE TOPIC OF DISSERTATION:

**Indexed in the Web of Science or Scopus with Impact Factor or SNIP:**

1. [S1; GB] Vilkas, Mantas; Bikfalvi, Andrea; Rauleckas, Rimantas; **Marcinkevicius, Gediminas.** The interplay between product innovation and servitization: the mediating role of digitalization // Journal of business and industrial marketing. Bingley: Emerald. ISSN 0885-8624. eISSN 2052-1189. 2022, vol. 37, iss. 11, p. 2169- 2184. DOI: 10.1108/JBIM-03-2021-0182. [Social Sciences Citation Index (Web of Science); Scopus] [IF: 3,319; AIF: 6,610; IF/AIF: 0,502; Q3 (2021, InCites JCR SSCI)] [CiteScore: 4,80; SNIP: 1,091; SJR: 0,782; Q1 (2021, Scopus Sources)] [FOR: S 003] [Input: 0,250]
2. [S2; GB] **Marcinkevičius, Gediminas**; Vilkas, Mantas. The affordances of digital technologies for business processes integration // Journal of systems and information technology. Bingley: Emerald. ISSN 1328-7265. eISSN 1758-8847. 2023, vol. 25, iss. 1, p. 74-90. DOI: 10.1108/JSIT-06-2022-0149. [Scopus] [CiteScore: 3,80; SNIP: 0,885; SJR: 0,421; Q2 (2021, Scopus Sources)] [FOR: S 003] [Input: 0,500]
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**Articles in conference proceedings**

1. [T2; LT; OA] **Marcinkevicius, Gediminas**; Vilkas, Mantas. The affordances of digital technologies for integration of business processes // 2021 IEEE International Conference on Technology and Entrepreneurship (ICTE) "Leading digital transformation in business and society": book of abstracts / edited by Agne Gadeikiene, Asta Pundziene, Jurate Banyte. Kaunas : Technologija. ISSN 2783-6037. 2021, p. 28. [FOR: S 003] [Input: 0,500]
2. [T2; LT] Sermontytė-Baniulė, Rima; Maženytė, Brigita; **Marcinkevičius, Gediminas**; Pundzienė, Asta. Categorization of digital health unicorn platforms: position in the value chain and platform openness // 1st KEEN forum phd colloquium: artificiality and sustainability in entrepreneurship, 20

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## PRESENTATIONS AT INTERNATIONAL RESEARCH CONFERENCES ON THE DISSERTATION TOPIC:

1. **Marcinkevicius, G**., Vilkas, M., International conference “EurOMA 2020: Managing Operations for Impact”, Presentation: “The process model of development of capabilities of organization resulting from adoption of digital innovations” 29-30 June, 2020, Warwick, United Kingdom.
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3. Vilkas, M., Bikfalvi, A., Rauleckas, R., **Marcinkevicius, G.,** International conference “EURAM-2020 Online Conference The Business of Now: Future Stars Here”, Presentation: “Competitive capability progression of service-oriented product firms”, 4-6 December, 2020, Dublin, Ireland.
4. Vilkas, M., Bikfalvi, A., Rauleckas, R., **Marcinkevicius, G**, International conference “EURAM-2021: Reshaping Capitalism for a sustainable world”, Presentation: “The interplay between product innovation and servitization: the mediating role of digitalization”, 16-18 June, 2021, Montreal, Canada.
5. **Marcinkevicius, G**., Vilkas, M., International conference “EurOMA 2021: Managing the “new normal”: The future of Operations and Supply Chain Management in unprecedented times“, Presentation: “The affordances of digital technologies for the integration of business processes”, 5-7 July, 2021, Berlin, Germany.
6. **Marcinkevicius, G**., Vilkas, M., International conference “2021 IEEE ICTE: Leading Digital Transformation in Business and Society”, Presentation: “The Affordances of Digital Technologies for Integration of Business Processes”, 24-27 August, 2021, Kaunas, Lithuania.
7. **Marcinkevicius, G**., Vilkas, M., International Conference “EurOMA 2022 - Brilliance in resilience: operations and supply chain management’s role in achieving a sustainable future”, Presentation: “The process of actualization of digital technologies affordances: a multi-method approach”, 3-6 July, 2022, Berlin, Germany.
8. Stefanini, A., Vilkas, M., Ghobakhloo, M., Grybauskas, A., **Marcinkevicius, G**., Petraite, M., Alipour Sarvari, P., International Conference “EurOMA 2022 - Brilliance in resilience: operations and supply chain management’s role in achieving a sustainable future”, Presentation: “Driving Digital Transformation: An Investigation of

Roadmapping Approaches and an Illustrative Case Study", 3-6 July, 2022, Berlin, Germany.

9. **Marcinkevicius, G.**, Ghobakhloo, M., Vilkas, M., Stefanini, A., Grybauskas, A., Petraite, M., Alipour Sarvari, P., International Conference "ISPIM 2023-Innovation and Circular Economy", Presentation: "Developing capabilities underlying Industry 4.0 principles", 4-7 June, 2023, Ljubljana, Slovenia.
10. Stefanini, A., Ghobakhloo, M., Vilkas, M., Grybauskas, A., **Marcinkevicius, G.**, Petraite, M., Alipour Sarvari, P., International Conference "EURAM-2023: Transforming Business for Good", Presentation: "The precedence and codependence of readiness for digitalization and Industry 4.0 capabilities", 14-16 June, 2023, Dublin, Ireland.
11. Vilkas, M., Stefanini, A., Ghobakhloo, M., Grybauskas, A., Petraite, M., **Marcinkevicius, G.**, Alipour Sarvari, P., International Conference "R&D Management Conference 2023: Responsible and Responsive Innovation for a Better Future", Presentation: "Digitalization capability development pathways: a process mining approach", 19-21, June, 2023, Seville, Spain.
12. **Marcinkevicius, G**., Vilkas, M., Rauleckas, R. International Conference "IEEE TEMS-ICTE 2023: Digital Ecosystems for Sustainable Society", Presentation: "The Process of Actualization of Digital Technologies Affordances in the Manufacturing Companies: A Multi-Method Approach", 9-11, October, 2023, Kaunas, Lithuania.
13. Alipour Sarvari, P., Grybauskas, A., Vilkas, M., Ghobakhloo, M., Stefanini, A., Petraite, M., **Marcinkevicius, G.**, International Conference "IEEE TEMS-ICTE 2023: Digital Ecosystems for Sustainable Society", Presentation: "Strategic Digital Roadmapping Using Intelligent Automation", 9-11, October, 2023, Kaunas, Lithuania.

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1. Vrije Universiteit Amsterdam (VU), Vrije Universiteit Amsterdam Graduate Winter School, Study module: "Digital Transformation series: Your Disruptive Advantage in Digital Economy", 11-15 January, 2021, Amsterdam, Netherlands.
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## ANNEXES

### Annex 1. Questionnaire of quantitative study (European Manufacturing Survey, 2018-2019)

**2) Please indicate your industry and the main (line of) product(s) produced at your factory. (NACE code)**

**6) Which of the following organizational concepts are currently used in your factory?**

- Display boards in production to illustrate work processes and work status (e.g. Visual Management) (First used (year); Extent of used potential (l=low; m=medium; h=high))

**7) Which of the following technologies are currently used in your factory? (Yes/No)**

***Technologies***

1. Mobile/wireless devices for programming and controlling facilities and machinery (e.g. tablets) (First used (year); Extent of used potential (l=low; m=medium; h=high))
2. Digital solutions to provide drawings, work schedules or work instructions directly on the shop floor (First used (year); Extent of used potential (l=low; m=medium; h=high))
3. Software for production planning and scheduling (e.g. ERP system) (First used (year); Extent of used potential (l=low; m=medium; h=high))
4. Digital Exchange of product/process data with suppliers / customers (Electronic Data Interchange EDI) (First used (year); Extent of used potential (l=low; m=medium; h=high))
5. Near real-time production control system (e.g. Systems of centralized operating and machine data acquisition, MES) (First used (year); Extent of used potential (l=low; m=medium; h=high))
6. Systems for automation and management of internal logistics (e.g. Warehouse management systems, RFID) (First used (year); Extent of used potential (l=low; m=medium; h=high))
7. Virtual Reality or simulation for product design or product development (e.g. FEM, Digital Prototyping, computer models) (First used (year); Extent of used potential (l=low; m=medium; h=high))
8. Industrial robots for manufacturing processes (e.g. welding, painting, cutting) (First used (year); Extent of used potential (l=low; m=medium; h=high))
9. Industrial robots for handling processes (e.g. depositing, assembling, sorting, packing processes) (First used (year); Extent of used potential (l=low; m=medium; h=high))
10. 3D printing technologies for prototyping (prototypes, demonstration models, 0 series), (First used (year); Extent of used potential (l=low; m=medium; h=high))

11. 3D printing technologies for manufacturing of products, components and forms, tools, etc.) (First used (year); Extent of used potential (l=low; m=medium; h=high))

**10) Has your factory introduced products since 2015 that where new to your factory or incorporated major technical improvements? (e. g. use of new materials, modifications to product function, changes in operating principle etc.) (Yes/No)**

**12) Did your factory perform research and development (R&D) or award R&D contracts to external partners in 2017? (Yes/No)**

**13) Please characterize your factory**

- Annual turnover (2015 and 2017)
- Number of employees (2015 and 2017)
- Year of the factory was established

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