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Leveraging Digital Technologies in Logistics 4.0: Insights on Affordances from Intralogistics Processes

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Abstract

Emerging digital technologies are transforming logistics processes on a large scale. Despite a growing body of knowledge on individual use cases ranging from collaborative robots to platform-based planning systems in the frontline industrial development of Logistics 4.0, organizations lack a systematic understanding of the opportunities digital technologies afford for logistics processes. To foster such understanding, this study takes an intra-organizational perspective as a central starting point for digitalization initiatives toward Logistics 4.0. It synthesizes current academic research and industrial insights from a systematic literature review and an expert interview study through an affordance lens. The result is a catalog and conceptual framework of ten digital technology affordances in intralogistics (DTAILs) and 46 practical manifestations. Thereby, this study contributes to understanding and leveraging the opportunities digital technologies afford in a leading-edge information systems application domain. It serves as a foundation for further theorizing on Logistics 4.0 and for structuring strategic discussions among organizational stakeholders.

Keywords Affordance theory · Digital technology · Industry 4.0 · Logistics 4.0 · Logistics process · Supply chain management

1 Introduction

Industry 4.0 – enabled by digital technology and accelerated by governmental initiatives, industrial plans, and research programs (Büchi et al., 2020) – has been increasing the pace of innovation and digital transformation in manufacturing companies (Huber et al., 2022; Margherita & Braccini, 2020). The resulting boost in production capacity and flexibility at its core sets new requirements for all dimensions of Industry 4.0 (Lu, 2021; Meindl et al., 2021). As such, logistics and supply chain management (SCM) are becoming a leading-edge information systems (IS) application domain while undergoing rapid transformations to support the horizontal integration of production systems with suppliers and customers through digital technologies (Gupta et al., 2019).

In this frontline industrial development of Logistics 4.0 (Strandhagen et al., 2017a), Smart Logistics (Lee et al., 2016), or Smart Supply Chain (Frank et al., 2019a), digital technologies such as artificial intelligence (AI), blockchain, cloud computing, and the internet of things (IoT) are driving automation and planning from the execution of programmed tasks to a level where functions are (partially) autonomously performed and information is shared in a cross-organizational environment of cyber-physical processes (Klumpp & Zijm, 2019; Sigov et al., 2022). Yet, organizations are only able to benefit from such integrated cyber-physical systems when aligning their internal technology implementation efforts with the pace of external stakeholders (i.e., customers and suppliers) (Gupta et al., 2019; Shao et al., 2021). Consequently, organizations need to respond with investments in emerging technologies to redesign their logistics structures and practices (Frank et al., 2019b). For

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this transformation toward Logistics 4.0 to succeed, the adoption of digital technology needs to be closely governed and managed (Margherita & Braccini, 2021). So far, very few companies have successfully completed this transformation (Zhang et al., 2021). To do so, corporate decision-makers need to understand the opportunities brought about by digital technologies for as well as their interplay with diverse tasks in logistics processes (Yang et al., 2021).

In the literature, research on the systematic application of digital technologies in the context of Logistics 4.0 – contrary to extensive work on other Industry 4.0 dimensions like smart products (Kahle et al., 2020) or smart manufacturing (Tabim et al., 2021) – is limited. The existing body of knowledge covers important insights on global supply chains in Industry 4.0 (Han et al., 2021; Shao et al., 2021; von der Gracht & Stillings, 2013) as well as on organizational drivers for leveraging smart supply chains (Gupta et al., 2019; Yang et al., 2021). Other studies indicate the enormous potential of individual technologies in Logistics 4.0 (Fescioglu-Unver et al., 2015; Kopyto et al., 2020; Leofante et al., 2019) and provide knowledge on their positive impacts like increased decision-making efficiency (Barreto et al., 2017), supply chain transparency (Zhu et al., 2021), or resilience (Rajesh, 2017). Only very few studies adopt a holistic perspective on digital technologies in Logistics 4.0 by classifying Industry 4.0 applications (Strandhagen et al., 2017b), defining base technologies (Frank et al., 2019a), and identifying technological building blocks (Winkelhaus & Grosse, 2020) of Logistics 4.0. Although these studies provide a good understanding of the technological advances of Logistics 4.0, a cross-technology perspective on the systematic opportunities digital technologies provide for logistics processes is needed to form a more robust basis for them to be implemented, combined, and leveraged to improve logistics workflows and management (Shao et al., 2021; Winkelhaus & Grosse, 2020). In this regard, intralogistics is currently seen as the area of Logistics 4.0 that will benefit the most from this transformation (Winkelhaus et al., 2022).

Against this backdrop, this study aims to identify and systemize the opportunities digital technologies afford for logistics processes by adopting an intra-organizational perspective as a central starting point for digitalization initiatives toward Logistics 4.0. To this end, it means to synthesize current academic research and frontline industrial insights through the lens of affordance theory (Gibson, 1986; Majchrzak & Markus, 2013), which has gained momentum in IS research for developing a fine-grained understanding of the action potential of digital technologies in different organizational environments (Islam et al., 2020; Seidel et al., 2013; Wendt et al., 2021).

To pursue this research objective, we draw on a two-phase research approach. First, we perform a systematic literature review (Webster & Watson, 2002; Wolfswinkel et al., 2013) to rigorously develop a catalog and conceptual framework of digital technology affordances in intralogistics (DTAILs) and associated practical manifestations as cues for potential use. Second, we conduct a qualitative interview study with ten subject matter experts from academia and industry to evaluate, expand, and refine the results (Bettis et al., 2015; Goldkuhl, 2012). Thereby, the key contribution of our work is a theoretically well-founded and practically relevant catalog and conceptual framework of DTAILs in the context of Logistics 4.0 as a frontline industrial development.

Our results are novel as they are the first to systematically illustrate the opportunities provided by a comprehensive spectrum of digital technologies to logistics processes. While previous research focuses on the main Industry 4.0 technologies (e.g., AI, blockchain, cloud computing, IoT), this study's perspective makes it a proper basis for further theorizing on Logistics 4.0. From an IS perspective, this work advances the understanding of the opportunities provided by digital technologies as the interplay of actors and a leading-edge application domain by analyzing and emphasizing the interrelation of tasks and technology through process orientation. Apart from its theoretical contribution, the catalog and conceptual framework of DTAILs support practitioners not only in understanding the areas of opportunity in Logistics 4.0 but also stimulate structured discussions on the development of their portfolio of digital technologies in specific intralogistics processes.

The remainder of this paper is structured as follows. In Section 2, we provide relevant background on Logistics 4.0, intralogistics, and affordance theory. We present our two-phase research approach in Section 3. Section 4 illustrates the results and discusses them against the background of the theoretical foundation. Section 5 amplifies theoretical and managerial implications before Section 6 concludes by pointing out limitations and indicating avenues for future research.

2 Theoretical Background

2.1 A Task-Technology Perspective on Logistics 4.0

Logistics 4.0 is the logistical system that enables the sustainable and cost-effective satisfaction of new market demands of customer-oriented, individualized, and more responsive supply chains and logistics based on emerging digital technologies (Strandhagen et al., 2017a; Winkelhaus & Grosse, 2020). As part of SCM, logistics encompasses the management of planning, implementing, and controlling procedures for the efficient movement and storage of materials and related information from the point of origin to the point of consumption (CSCMP, 2013). Logistics 4.0 affects the key logistics activities of transport, inventory management, material handling, supply chain structure, and information flow. It facilitates improvements in areas such as sustainability, traceability, efficiency, and responsiveness to customers (Strandhagen et al., 2017a) and makes the physical supply chain dimension and the digital data value chain dimension converge to cyber-physical processes (Hofmann & Rüsch, 2017). The resulting combination of the inevitable involvement of the physical movement of goods and the high dependency on accurate and up-to-date data in the rapid environment of Industry 4.0 (Lai et al., 2018) makes logistics a key domain for digital technology integration into business operations (Gunasekaran & Ngai, 2004). Technological capabilities and targeted technology investments are found to have a significant impact on firm performance in Logistics 4.0 (Bag et al., 2020).

In the literature, the potential of a variety of individual technologies like AI (Chung, 2021; Toorajipour et al., 2021), blockchain (Chen et al., 2022; Kopyto et al., 2020; Pournader et al., 2020), and IoT (Ben-Daya et al., 2019; Wang et al., 2020; Zhu et al., 2021) as well as 5G (Dolgui & Ivanov, 2022), augmented reality (AR) (Rejeb et al., 2021), cloud computing (Xu et al., 2018), and radio-frequency identification (RFID) (Fosso Wamba & Chatfield, 2011) for different logistics activities such as real-time tracking of material flows, improved transport handling as well as smart procurement and risk management has been investigated (Hofmann & Rüsch, 2017). However, Logistics 4.0 is premised on the systematic interconnection of intelligent process elements, each relying on a spectrum of digital technologies and their interplay (Delfmann et al., 2018). Strandhagen et al. (2017b) made a step toward a more holistic perspective by classifying Industry 4.0 applications in logistics into the categories of decision support and decision-making, identification and interconnectivity, seamless information flow as well as automation, robots, and new production technology. In the recent literature, Winkelhaus and Grosse (2020) identify technological building blocks of Logistics 4.0 and describe groups of technologies to generate, handle, and use information. Frank et al. (2019a) define base technologies (i.e., IoT, cloud, big data, analytics) providing connectivity and intelligence to smart supply chains in Industry 4.0, while Koh et al. (2019) find IoT, big data analytics, cloud, 3D printing, and robotic systems to be the disruptive Industry 4.0 technologies for SCM. Balouei Jamkhaneh et al. (2022) identify AI, advanced robotics, blockchain, and additive manufacturing as the most important enablers for Logistics 4.0 service quality from a perspective of sustainability and value creation. Further, Kayikci (2018) examines enablers of digital logistics ecosystems and exemplary applications (e.g., AR, big data, IoT). So far, the analysis of digital technologies in Logistics 4.0 is primarily centered around the main Industry 4.0 technologies originating from a smart production perspective. In this connection, Winkelhaus and Grosse (2020) as well as Shao et al. (2021) point out the need to systematically consider the application of a more comprehensive spectrum of technologies and to relate their potential to specific logistics processes and tasks.

Logistics 4.0 is found to have a particularly strong impact on intralogistics as the central component of most distribution networks (Winkelhaus & Grosse, 2020). Intralogistics processes concentrate many of the typical characteristics of Logistics 4.0, such as the automation, digital assistance, or autonomous execution of physical and cognitive tasks (Fragapane et al., 2020; Winkelhaus et al., 2022), the real-time exchange of information among different (digital) actors (Strandhagen et al., 2017a), and the overall fusion of physical and digital operations in cyber-physical processes (Coelho et al., 2021). In addition, intralogistics is highly affected by Industry 4.0's shift in production from standardization to flexibility and variability (Ivanov et al., 2021; Scholz et al., 2016). However, intralogistics (also referred to as internal or in-house logistics) exceeds the context of manufacturing companies (Fragapane et al., 2021). It comprises organizing, controlling, implementing, and optimizing the internal flow of information and material as well as the handling of goods in industry, trade, and public institutions (Arnold, 2006; VDMA, 2003). In contrast to inter-organizational logistics, its focus is on managing in-house goods and information flow activities as well as on the efficient interaction of all (technological) entities involved in its processes (Ballou, 2007). Table 1 summarizes the main process elements of intralogistics derived from existing definitions of pertinent academic literature.

While many tasks like order picking or internal transportation are still labor-intensive, intralogistics is currently seen as the area of Logistics 4.0 that will benefit the most from the implementation of emerging digital technologies (Winkelhaus et al., 2022). These advances toward Intralogistics 4.0 are found to enhance the organizational base of precise process-related data and act as a condition for effective supply chain integration (Zhang et al., 2016). In the current literature, only individual technological solutions to intralogistics challenges like autonomous mobile robots (Fragapane et al., 2021), digital twins (Coelho et al., 2021), or intelligent bin systems (Schuhmacher et al., 2017) are investigated. Further, Winkelhaus et al. (2022) explore changes of work characteristics of employees in Intralogistics 4.0. Based on the review of related literature, we infer that the work that has so far been done on the role of digital technologies in Logistics 4.0 provides a useful overview of predominant Industry 4.0 applications and detailed insights into some specific use cases. However, a comprehensive and theoretically well-founded cross-technology perspective on the systematic opportunities digital technologies afford in logistics processes is still required. To achieve such a conceptualization, this paper takes an IS perspective on Logistics 4.0.

Table 1 Main process elements in intralogistics

Process Element	Explanation	Ballou (2007)	Beyer et al. (2016)	Coelho et al. (2021)	CSCMP (2013)	Winkelhaus et al. (2022)	Flow of Goods	Flow of Information
Material Handling	The (un-)loading of goods from any means of transportation for internal or external processing. These activities include the reception, unloading, inspection, and storage preparation (e.g., reloading) of inbound goods and the loading and inspection of packaged outbound goods.	x		x	x	o		
Material Storage	The bridging of temporal distance, i.e., the holding and buffering of raw or (half-)finished goods at any point in time from procurement to distribution. These activities include locating the goods physically and recording and monitoring their storage position for future pick-up.	o	x	x	x			
Material Transportation	The bridging of spatial distance from any source to any destination within the organization. These activities include the physical movement of goods between or within production plants, warehouses, and distribution points.	x	x	x	x			
Material Assortment	The bundling of specific goods and their processing to movable units for internal or external transport. These activities include the picking, i.e., commissioning, packaging, palletizing, or labelling of goods for economical shipping and/or easier handling.		x	o	x	o		
Disposition & Management	The operational allocation of tasks and resources among all organizational units based on data at hand. These activities include order scheduling, inventory management, and monitoring plant and warehouse operations.	x	o	x	o	x		
Controlling & Planning	Strategic decision-making in terms of products, infrastructure, technology, and management, based on measured and/or forecasted data. These activities include forecasting, cost planning, calculation, potential analysis, and project management.	o	x	x	x	x		

(x) explicitly mentioned, (o) implicitly mentioned

In the IS discipline, the relation of tasks and technology is a pervasive subject of research that ranges from the fundamental question of the nature of digital technology (Faulkner & Runde, 2019; Orlikowski & Iacono, 2001) to the concept of task-technology fit (Goodhue & Thompson, 1995; Howard & Rose, 2019) and its implications for, e.g., technology acceptance (Dishaw & Strong, 1999) or business value of IT (Kohli & Grover, 2008). Addressing the matter of what constitutes technology, Kline (1985) points out that understanding technology depends on its intended purpose and how it functions in different contexts, particularly as an element of sociotechnical systems. In this connection, digital objects become digital technologies when they are assigned a meaning for application by actors (Hund et al., 2021). That is, the potential of digital technologies is closely related to the purpose it provides within a social context which in turn is determined by the actors using them (Baier et al., 2023; Faulkner & Runde, 2019). This sociotechnical approach is also included in work system theory by Alter (2003), which suggests that IS research should consider work systems rather than IT artifacts, where human participants and/or machines perform work (i.e., tasks and processes) using information, technology, and other resources. Instead of just focusing on technological progress, it includes a dynamic view of how work systems change over time through a combination of planned and unplanned change that can be driven by all system elements (Alter, 2015). This view corroborates the implication that a shift of the functions and tasks of actors caused by frontline industrial developments such as Logistics 4.0 also brings about new opportunities digital technologies may afford. This notion is substantiated by IS research on task-technology fit that is concerned with the extent to which a given technology assists an individual in performing a portfolio of tasks (Goodhue & Thompson, 1995; Howard & Rose, 2019). As such, task-technology fit theory underlines the interlinkage of technologies and the context they are applied in (Teo & Men, 2008). In this respect, the interactions between the individual, task, and technology are considered as the antecedents of task-technology fit (Muchenje & Seppänen, 2023). Consequently, the potential that can be realized through the application of digital technologies depends on their alignment with the processes they are supposed to support (Zigurs & Khazanchi, 2008). Hence, exploring the opportunities digital technologies afford in leading-edge application domains with transforming tasks and processes is a recurring challenge at the frontiers of IS research.

In line with the IS perspective on the strong relation of tasks and technology, this research aims to act on the suggestion to relate the opportunities digital technologies afford to specific logistics processes and tasks. To do so, this study adopts an Intralogistics 4.0 perspective as the central starting point for organizational digitalization initiatives in logistics and employs a domain-independent classification scheme of technology patterns suited to serve as a basis for examining the affordances of digital technologies. Berger et al. (2018) present an empirically validated multi-layer taxonomy of 45 real-world digital technologies resulting in seven purpose-related archetypes that deliberately abstract from granular features of individual technologies (Table 2). Instead, each archetype reflects a typical combination of digital technology characteristics (e.g., data treatment, human involvement, multiplicity, role) occurring in practice. In this paper, the archetypes enable us to achieve our research goal by arranging digital technologies as the artifact of analysis in a systematic and extendable scheme of technology patterns. Given the fast-moving nature of digital technologies and their application areas in Industry 4.0 (Lu, 2021), it presents a sound basis for research in Logistics 4.0.

2.2 Affordance Lens

We draw on affordance theory to develop a fine-grained understanding of the opportunities digital technologies provide in intralogistics processes. In IS research, the concept of affordances aims to capture an action potential that originates from the relation between a technology with certain features and a user (i.e., an individual or organization) with a particular purpose in a specific environment (Majchrzak et al., 2016; Nambisan et al., 2017). Recent work has successfully applied affordance theory in various IS contexts to build theory about digital technology use (Islam et al., 2020; Pal et al., 2021; Seidel et al., 2013; Wendt et al., 2021).

Gibson (1986) first introduced the term *affordance* as part of his research in influential ecological psychology to express that actors initially do not perceive the physical properties of an object (e.g., a bed made of wood) but rather what objects offer or afford to them (e.g., a bed to lie on) (Gibson, 1986). Thus, the action potential of an object is relative to the observer and its context. Gibson's work has been most notably applied to discussions of technology by Norman (1990, 1999), who argued that affordances are properties of designed artifacts that are built-in to be perceived by the users. Today, many scholars seek a balance between these two concepts and embrace affordances as bidirectional relations between actors and technological artifacts to study their action potential in a given context (Hutchby, 2001; Leonardi, 2011; Majchrzak et al., 2013). Yet, varying uses and interpretations of the term *affordance* can be observed in current literature (for further review, e.g., see Burlamaqui & Dong, 2015; Markus & Silver, 2008; Volkoff & Strong, 2017; Zammuto et al., 2007). Hereafter, we understand affordances as action potentials emerging from the multi-faceted relation between digital technologies with certain features and a user with a particular purpose in a specific

Table 2 Archetypes of digital technologies based on Berger et al. (2018)

Archetype	Description	Examples
Platform	Digital technologies that focus on providing unified access to data or services	Cloud computing Serverless PaaS
Connectivity	Digital technologies that focus on efficient data processing or exchange	802.11 ax Blockchain
Actor-based product	Digital technologies that focus on the transformation of digital data into physical action or artifacts	3D printing Autonomous vehicles
Sensor-based data collection	Digital technologies that focus on the collection of real-world data and their transformation into digital data	Gesture recognition Smart dust
Analytical insight generation	Digital technologies that focus on the analysis of digital data to support knowledge creation and decision-making	Machine learning Data science
Analytical interaction	Digital technologies that focus on the analysis of digital data and their presentation in a physical form that supports humans in their tasks	Smart advisor Virtual assistant
Augmented interaction	Digital technologies that focus on enabling human–computer interfaces perceived as natural by humans	Conversational user interfacew Wearables

environment (Faraj & Azad, 2012; Majchrzak & Markus, 2013; Nambisan et al., 2017).

In IS research, affordance theory has attracted significant attention, as it has proven useful in understanding how a technology affords different ways for reciprocal actions to a goal-oriented actor (Lehrer et al., 2018). Following this logic, affordances are not properties of a technology or an actor alone but rather result from their interaction (Majchrzak & Markus, 2013). Thus, as relational concepts, affordances are not necessarily identical for different actors or contexts (Leonardi, 2011; Seidel et al., 2013). Further, goal-oriented properties of a technology as perceived by humans may not only offer action potentials but also constrain specific uses (Majchrzak & Markus, 2013). Recent studies take up this perspective of affordances and constraints to investigate beneficial and hindering factors for the use of digital technologies (e.g., Benbunan-Fich, 2019; Pal et al., 2021). Following the opportunity-led research focus of this study, we concentrate on affordances and do not further elaborate on constraints.

In this paper, affordance theory serves as a theoretical lens to investigate the contextual and user-specific action potential emerging from the interplay between archetypes of digital technologies and intralogistics processes at the center of the frontline industrial development of Logistics 4.0. Thereby, we aim to identify patterns that exist through the symbiotic relationship of a technological artifact (i.e., digital technologies) and an actor's set of actions in a leading-edge process environment (i.e., intralogistics) instead of focusing on latent technology capabilities (Leidner et al., 2018; Majchrzak et al., 2013).

3 Research Design

We investigate the affordances of digital technologies for intralogistics processes including the perspectives of current research and practitioners. To account for the interdisciplinary nature of the frontline industrial development of Logistics 4.0, we followed an iterative research approach (Fig. 1).

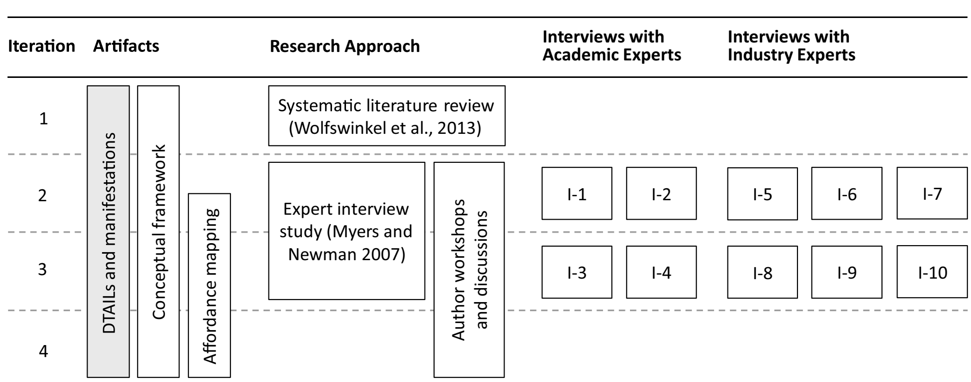
First, we performed a systematic literature review to rigorously develop an initial catalog and conceptual framework of DTAILs and associated practical manifestations based on the insights from current research (Webster & Watson, 2002; Wolfswinkel et al., 2013). We then evaluated the preliminary results by conducting a qualitative interview study with ten logistics experts from academia and industry (Bettis et al., 2015; Goldkuhl, 2012). We continuously synthesized the theoretical and practical insights in workshops and discussions of the author team to finally obtain a catalog and conceptual framework of ten coherent DTAILs and 46 manifestations that substantiate their relevance to industry.

For the initial version of DTAILs, we conducted a systematic literature review consistent with the well-established recommendations of Webster and Watson (2002) and Wolfswinkel et al. (2013). Accordingly, we followed the five-stage process: define, search, select, analyze, and present. Figure 2 illustrates the key steps of the process – excluding *present* (i.e., the communication and presentation of results that is provided by this paper) – and specifies relevant criteria we applied.

The *define* stage aims to determine the scope of the review by developing the set of search criteria (Wolfswinkel et al., 2013). To this end, we take a multidisciplinary approach and review literature from the fields of both IS and logistics research (see Fig. 2). As digital technologies are a fast-moving topic, we included high-impact journal publications as well as conferences from both fields, which feature short review cycles and report on the latest technological developments (vom Brocke et al., 2015). We searched for relevant articles using four scientific databases. In an iterative process of refining search terms and reviewing random samples of the search results, we carefully developed a single search string including synonyms for digital technologies as well as terms narrowing down their application to SCM, logistics, and intralogistics processes.

The *search* stage refers to the application of the search terms to the identified sources (Wolfswinkel et al., 2013). We used our search string for a title, abstract, and keyword search in the selected databases. We examined extant studies

Fig. 1 Iterative research process



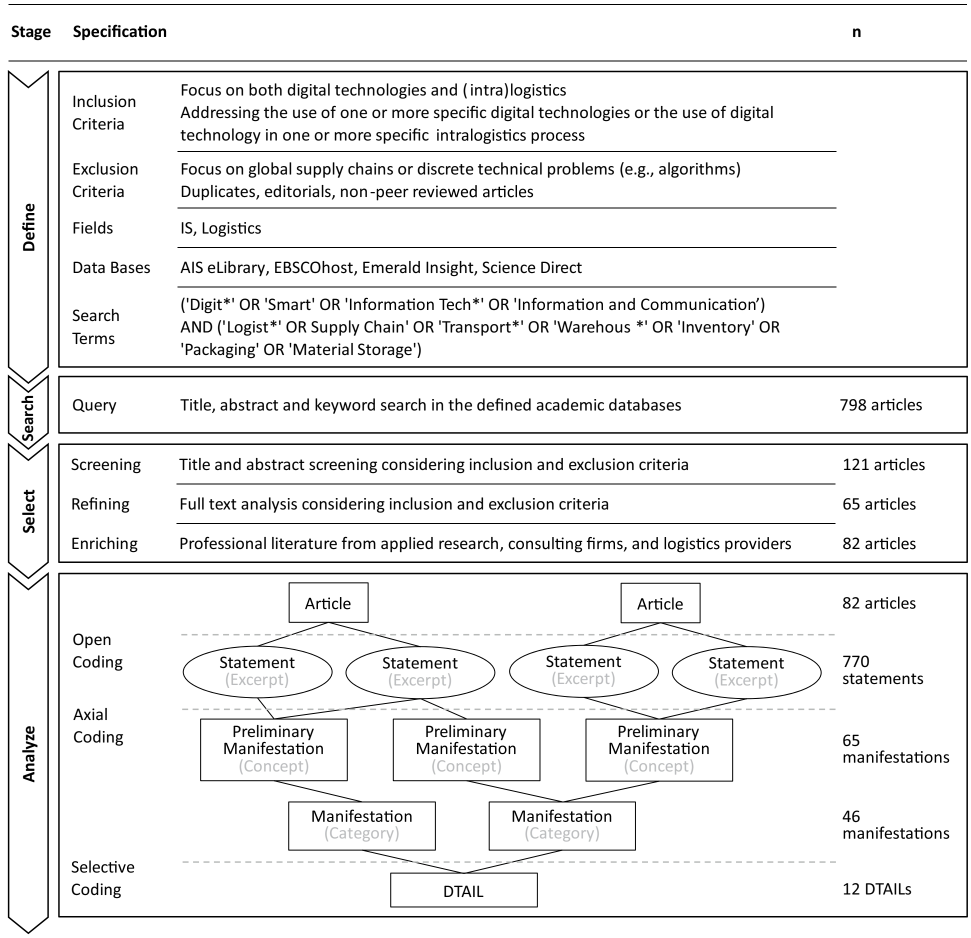


Fig. 2 Systematic literature review process based on Wolfswinkel et al. (2013)

between 2010 and 2022 to ensure timeliness and focus on emerging digital technologies in the recent scientific discourse. The initial search yielded 798 articles.

In the *select* stage, the literature sample is refined by applying the defined inclusion and exclusion criteria (Wolfswinkel et al., 2013). We first screened all titles and abstracts for relevance to determine the thematic fit of every article against the background of the research goal. For this purpose, we used a three-point Likert scale classifying each publication according to whether they displayed no focus (score = 0), a low focus (score = 1), or a high focus (score = 2) on the application of specific digital technologies in intralogistics. In doing so, we identified 121 articles worthy of a full-text screening. During this process, we further excluded articles without a clear (intra) logistics focus in accordance with our research objective (e.g., smart city concepts or theoretical models on urban city transport) as well as articles without an appropriate level of generalizability. Including a forward and backward search, we ended up with 65 articles relevant to the scope of our research. Finally, we augmented the set of academic articles by reviewing professional literature following the key principles of Garousi et al. (2019) to increase the practical relevance and timeliness of the results. We obtained an overview of current trends and developments in the industry by searching in public and industrial databases and screening appropriate professional publications in the context of applied research (e.g., Fraunhofer), whitepapers by leading consulting firms (e.g., Accenture, PwC), and reports from influential logistics providers (e.g., DHL, FedEx). The final literature sample comprised 82 academic and professional articles.

The *analyze* stage deals with the extraction of concepts and constructs from the selected set of literature (Wolfswinkel et al., 2013). We drew on the proposed three-step coding approach including open, axial, and selective coding. During open coding, we closely read every article to highlight and extract all statements (i.e., excerpts) related to our research goal. We structured the resulting 770 statements in a process-technology-matrix (1:n mapping) comprising the main process elements in intralogistics (Table 1) and the archetypes of digital technologies (Table 2). Continuing with axial coding, we aggregated statements within the same cell to one or more preliminary manifestations with a single-sentence definition in several joint workshops of the author team. Focusing on their interrelation and level of order, we then re-evaluated, adapted, and abstracted the results to 46 manifestations (i.e., categories). In the final coding step, we used selective coding to derive affordances from the set of practical manifestations. We shaped and refined the affordances by continuously linking and comparing the categories and their underlying statements in the author team. During the process, we repeatedly reconsidered our results to consolidate, eliminate, or shift DTAILs, and refine their names and descriptions where necessary. By cross-referencing our thoughts with established concepts of Logistics 4.0 (Winkelhaus & Grosse, 2020), we finally developed a conceptual framework as a logical structure representing the focus areas and interrelations of the DTAILs. This step resulted in an initial catalog and framework of 12 DTAILs and 46 manifestations.

To evaluate the theoretically developed results against first-hand practical experience, we conducted ten semi-structured interviews with domain experts (Table 3) following the guidelines of Myers and Newman (2007). The sample of participants is considered adequate as it provided great information value through high-quality and in-depth conversation with specialized interviewees on the basis of previously established concepts (Malterud et al., 2016). The interviews were performed by two researchers and lasted between 70 and 90 min each. Every interview was recorded and transcribed for further analysis to ensure data integrity. During the interviews, we introduced the participants to the theoretical background of our research before presenting the conceptual framework and discussing all DTAILs in terms of understandability, completeness, consistency, level of detail, and applicability (Sonnenberg & vom Brocke 2011). We also requested feedback from personal practical experience and specific use cases in connection with the affordances presented. After each interview, we compared new insights with extant literature, discussed them within the author team, and refined the preliminary findings where necessary. Ultimately, the interviews revealed new perspectives on multiple DTAILs that had not yet been sufficiently covered in the literature due to the rapid developments of the topic. Accordingly, we revised several descriptions and rearranged affordances to yield a final coherent catalog and conceptual framework of ten DTAILs specified by 46 manifestations.

4 Results

In this section, we present the catalog and conceptual framework of DTAILs. Table 4 explains each DTAIL, indicates its associated practical manifestations, and provides concrete examples for application from literature to foster practical understanding. For a detailed explanation of every manifestation of the DTAILs and their references, please refer to the Appendix. The conceptual framework of DTAILs then illustrates their scope and interrelation in four affordance layers: Data, Manual Tasks, Goods & Assets, and Decisions & Management (Fig. 3). The affordance layers emerge from the logistics tasks and functions the DTAILs address and reflect key aspects of previous research on the impact of digital technology on logistics systems (i.e., the generation, handling, and use of information, the shift of human involvement and material movement, and the transformation of execution and management activities) (Winkelhaus & Grosse, 2020). Finally, Table 5 links the DTAILs to the archetypes of digital technologies and the intralogistics process elements they apply to (see Section 2.1) to allow deeper insights into how (technology perspective) and where (process perspective) the affordances emerge.

The conceptual framework of affordance layers (Fig. 3) illustrates the interrelations and scopes of DTAILs, building on the action potential they comprise and the nature of logistics processes they concern. Overall, *(1) Ubiquitous Data Availability* defines the core *Data* layer that facilitates all other DTAILs in the *Goods & Assets*, *Manual Tasks*, and *Decisions & Management* layers by enabling location- and time-independent data availability through the systematic capturing of data over all logistics processes and the (horizontal and vertical) integration by means of a central data hub.

Table 3 Expert interview study

Focus	ID	Current position	Job title	Experience
Academia	I-1	Technical Business School	Researcher (IS & Logistics)	8 years
	I-2	Technical Business School	Researcher (IS & Logistics)	4 years
	I-3	University	Postdoctoral Researcher (Production & SCM)	13 years
	I-4	University	Researcher (Production & SCM)	4 years
Industry	I-5	Automotive Industry	Head of Operational Logistics Services	10 years
	I-6	Automotive Industry	Head of Strategical Logistics Services	10 years
	I-7	Polymer Processing	Head of Plant Logistics	9 years
	I-8	Logistics Services	Executive Board Member	9 years
	I-9	Health Care	Head of Logistics	15 years
	I-10	Logistics Consulting	Director of SCM	12 years

Table 4 Affordances of digital technologies in intralogistics processes

	Affordance	Explanation / Examples	Manifestations
1	Ubiquitous data availability	Digital technologies afford the location- and time-independent availability of data by providing interoperability and integrating data from different processes, functions, locations, and hierarchical levels based on data collection along the whole (internal) supply chain	– Data access – Data availability – Data collection – Horizontal integration – Information exchange – Trajectory pattern documentation – Vertical integration
		• 'Blockchains provide data to the network on the origins of materials, purchase orders, inventory levels, goods received, shipping manifests and invoices' (Cole et al., 2019) • 'Cloud-based information systems (…) provide flexibility to manage and obtain available data from the supply chain partners over the web, anytime and anywhere in the world' (Kochan et al., 2018) • 'Cloud computing capabilities are interlinked with big data analytics, in turn improving real-time connectivity and traceability across the supply chains' (Nayernia et al., 2021)	
2	Assistance of manual tasks	Digital technologies afford the less demanding execution of manual tasks by assisting physically demanding tasks or by providing timely and relevant information for optimal task execution	– Enhancement of physical strength – Job instructions – Loading guidance – Navigation support – Storage guidance – Transportation assistance – Worker training
		• 'Augmented reality supports workers with an interactive and real-time guidance for the necessary steps of the tasks to be made'(Frank et al., 2019a) • 'Smart exoskeletons use algorithms that automatically adjust (…) devices to human body motion, enabling workers to handle heavy loads' (Meindl et al., 2021) • 'Virtual reality accelerates workers trainings with an immersive simulation of the maintenance routines' (Frank et al., 2019a)	
3	Monitoring of manual tasks	Digital technologies afford the reduction or elimination of errors in manual tasks by monitoring and checking process compliance, by supporting correct execution, and by verifying quality standards	– Assembly control – Picking control – Workload control
		• 'An internal logistics operator (…) carries a mobile RFID reader to pick up the required materials and deliver them to a specific machine when he gets a logistics job' (Zhong et al., 2015) • 'RFID technology may automate the verification activities involved in the shipping process, thus reducing potential errors' (Fosso Wamba & Chatfield, 2011) • 'The reduction of unnecessary processes can reduce the workload of the picker by applying the IoT-based technology in the receiving process instead of a manual paper record of the inventory' (Lee et al., 2018)	

Table 4 (continued)

	Affordance	Explanation / Examples	Manifestations
4	Automation of manual tasks	Digital technologies afford the automation of manual tasks by intelligently collecting and maneuvering goods, by performing repetitive and/or physically demanding tasks, or by autonomously recording goods-related information	– Automatic data capturing – Automatic goods inspection – Automatic handling operations – Automatic (un-)loading – Automatic picking & packaging – Automatic transportation
		• 'Automated picking and picking robot systems use machines for order picking and are preferred for the picking of small, valuable, and delicate items' (Piccinini et al., 2013) • 'Handling of raw materials (input of the production line) and manufactured outputs on the shop floor (…) can be supported by the use of robotic sensing technologies, including Automatic-Guided-Vehicles (AGVs) and Autonomous Mobile Robots (AMR)' (Meindl et al., 2021) • 'Robotics and autonomous vehicles will impact the internal and external manufacturing transport by increasing its degree of autonomy and sharing' (Kusiak, 2018)	
5	Tracking of goods and assets	Digital technologies afford the (real-time) localization and identification of goods and mobile assets by autonomously tracking, documenting, checking, and transmitting their positions and movements	– Asset visibility – Automatic goods tracking – Goods visibility – Inventory control
		• 'IoT has been extensively applied in factories and transportations to monitor the production process, and track and trace the logistics and warehouse operations' (Yang et al., 2021) • 'The convergence of cloud computing, mobile technology, distributed computing, and data integration technologies has enabled managers for the first time to have real-time visibility of material flows in end-to-end supply chains' (Oliveira & Handfield, 2019) • 'The recent development of RFID and Electronic Product Code networks has increased the visibility of accurate real-time inventory information in supply chains' (Dai et al., 2016)	
6	Condition monitoring of goods and assets	Digital technologies afford the (real-time) condition monitoring of goods and assets in terms of integrity or proper handling by detecting and transmitting external forces, displacements, environmental changes, or any changes directly affecting the object itself	– Ambient condition monitoring – Goods condition monitoring – Predictive maintenance – Smart packaging – Surveillance of infrastructure
		• 'Analytics enables advanced predictive capacity, identifying events that can affect production before it happens' (Frank et al., 2019a) • 'Nanosensors can be applied to detect the environmental and quality changes in storage and distribution processes' (Bowles & Lu, 2014) • 'Technologies applied to integrity control (e.g., sensors, big data analytics, decentralized agent-driven control) can ensure the right products, at the right time, place, quantity, and condition' (Meindl et al., 2021)	
7	Operational scheduling support	Digital technologies support in dynamic planning and control activities for the continuous adaption of operations and processes to operational challenges by analyzing (real-time) data and by optimizing resource allocation and utilization	– Dynamic coordination – Fleet optimization – Route optimization
		• '5G can be applied to support scheduling and routing decisions in tailored supply chains in Industry 4.0 environments' (Dolgui & Ivanov, 2022) • 'Automated vehicles with GPS-based navigation systems decide the route to take while interacting with the environment' (Calatayud et al., 2019) • 'Platforms also provide the necessary technical capability for firms to coordinate their activities and increase their productivity' (Ba & Nault, 2017)	

Table 4 (continued)

	Affordance	Explanation / Examples	Manifestations
8	Operational decision automation	Digital technologies afford the automation of operational decisions in logistics planning and control, reacting dynamically to changing conditions by applying (intelligent) algorithms analyzing (real-time) data	– Automatic goods replenishment – Automatic storage policy – Self-steering process
		• 'IoT allows to monitor and optimally replenish the inventory in warehouses' (Bogataj et al., 2017) • 'AI systems allow inventory optimization and automatic and intelligent ordering when stock reaches the safety level' (Oliveira-Dias et al., 2022) • 'To improve efficiency in terms of the overall operation productivity within the supply chain, (…) cyber-physical systems can variably adjust the order of the operation and resource capacity' (Park et al., 2021)	
9	Interruption management	Digital technologies support the anticipation, identification, and management of (operational) interruptions and (tactical) risks by providing (real-time) information on process execution and by potentially providing ad-hoc solution alternatives	– Interruption identification – Interruption management – Origin tracing – Risk prevention
		• 'Performance can be improved with (…) digital twins and IoT to capture, analyze and in almost real-time visualize disruptions along the supply chain' (Nayernia et al., 2021) • 'The digital ledger blockchain technology solution provides visible, honest and immutable records of physical asset origins' (Cole et al., 2019) • 'The blockchain removes the need for a trusted central organization that operates and maintains this system and allows (…) to inspect the uninterrupted chain of custody and transactions from the raw materials to the end sale' (Saberi et al., 2019)	
10	Strategic decision support	Digital technologies support strategic decision-making by filtering relevant data and by providing analytical and predictive capabilities for a better understanding of patterns, impacts, and interactions of performance drivers	– Descriptive and diagnostic accuracy – Facility planning support – Knowledge discovery – Predictive and prescriptive accuracy
		• 'Dynamic networking capabilities enhanced by 5G will advance the reconfigurability at the levels of machines, processes, flows, and network structures' (Dolgui & Ivanov, 2022) • 'IoT-generated data feeds decision-making at both the strategic level, performed by human intelligence, and the operational level, which is performed by machine intelligence' (Calatayud et al., 2019) • 'RFID is supposed to facilitate end-users' decision-making in production logistics control. To assist the managers' determination of appropriate operational and environmental conditions' (Zhong et al., 2015)	

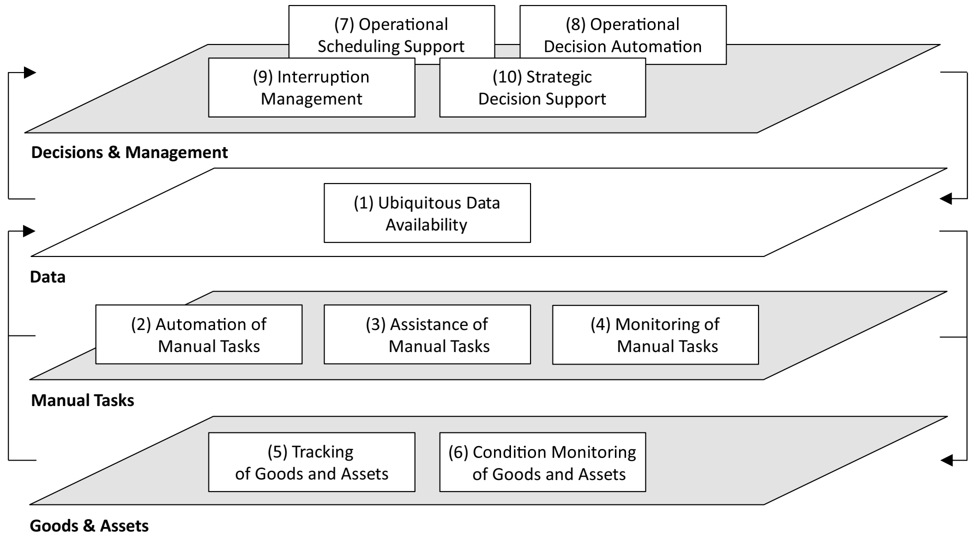


Fig. 3 Conceptual framework of affordance layers

(1) Ubiquitous Data Availability supports the assistance, monitoring, and automation of Manual Tasks: While the *(2) Assistance of Manual Tasks* refers to digital technologies augmenting manual workflows with real-time instructions, task-related information, location- or load-based guidance, and automatic physical support through human-technology interaction, the *(4) Automation of Manual Tasks* describes the end-to-end execution of (formerly) manual tasks, e.g., handling activities around physical resources, quality control, and data capturing, by digital technologies resulting in digital process autonomy. At the intersection of these two DTAILs, the *(3) Monitoring of Manual Tasks* does not focus on the execution of tasks itself but on the control of process data and workflows to reduce or eliminate errors in manual tasks, ensure health sustainability of physical activities, and increase task efficiency.

In addition, *(1) Ubiquitous Data Availability* taps action potential related to physical Goods & Assets by continuously tracking and monitoring activities that directly affect the physical objects handled. While *(5) Tracking of Goods and Assets* relates to their autonomous identification and real-time localization, *(6) Condition Monitoring of Goods and Assets* comprises checking and predicting their physical condition subject to environmental factors or usage-related changes (e.g., external forces or displacements). Both DTAILs include secure documentation and real-time synchronization of the corresponding data. Up to this, all DTAILs mentioned affect the flow of goods and the flow of information on an operational level.

In contrast, the four DTAILs in the Decisions & Management layer predominantly build on *(1) Ubiquitous Data Availability* to handle the flow of information by processing and analyzing data for (operational) decision-making or logistics management on a (partly) strategic level. In this respect, *(7) Operational Scheduling Support* and *(8) Operational Decision Automation* facilitate operational processes and decisions through autonomation, optimization, and coordination of resources. Beyond, *(9) Interruption Management* is located at the intersection of supporting the management of both interruptions (operational) and risks (tactical). Finally, *(10) Strategic Decision Support* addresses a purely strategic level to enhance analytical and predictive capabilities. Unlike all other DTAILs closely involving the physical environment in the form of the flow of goods, (9) and (10) both relate to the digital world and its flow of information.

Building on the catalog and conceptual framework of DTAILs that provide insights into their scope and interrelation, Table 5 maps the DTAILs to their underlying archetypes of digital technologies and to the specific intralogistics process elements they concern. Adding the perspective of tasks and technology grounded in IS research enables us to take a more detailed look at the sociotechnical system building the context in which the affordances emerge.

First, the emergence of opportunities of digital technologies related to Sensor-based Data Collection (e.g., gesture recognition, IoT) in the form of *(1) Ubiquitous Data Availability* across all process elements is notable. In this connection, RFID sensors, for instance, capture real-world data and transmit signals to provide real-time visibility into the execution of manual tasks, the movement of goods, or current inventory levels. To provide *(1) Ubiquitous Data Availability* as a basis for (nearly) all following DTAILs, the extensive collection of data can be carried out via the integration of different layers of sensors and communication capabilities (i.e., the IoT paradigm) and complemented by the processing (i.e., Connectivity technologies like blockchain) and provision (i.e., Platform technologies like cloud computing) of data for further decision-support along the internal supply chain. Moreover, digital technologies associated with the archetype of Sensor-based Data Collection

Table 5 Mapping of DTAILs across archetypes of digital technologies and intralogistics process elements

		Archetypes of Digital Technologies							Intralogistics Process Elements					
		Platform	Connectivity	Actor-based Product	Sensor-based Data Collection	Analytical Insight Generation	Analytical Interaction	Augmented Interaction	Material Handling	Material Storage	Material Transportation	Material Assortment	Disposition & Management	Controlling & Planning
1	**Ubiquitous Data Availability**	X	X		X		X		X	X	X	X	X	X
2	**Assistance of Manual Tasks**			X	X	X	X	X	X	X	X	X		
3	**Monitoring of Manual Tasks**		X		X	X	X		X			X	X	
4	**Automation of Manual Tasks**			X	X	X	X	X	X	X	X	X		
5	**Tracking of Goods and Assets**	X	X	X	X	X				X	X		X	
6	**Condition Monitoring of Goods and Assets**		X	X	X	X			X	X	X	X	X	
7	**Operational Scheduling Support**	X	X			X					X		X	
8	**Operational Decision Automation**				X	X				X			X	
9	**Interruption Management**	X	X		X	X							X	X
10	**Strategic Decision Support**				X	X	X						X	X
Σ		4	6	4	9	9	5	2	5	6	6	5	8	3

Affordance Layer: ··········· Data — — — Manual Tasks — · — · Goods & Assets ——— Decisions & Management

as well as with Analytical Insight Generation (e.g., AI and data analytics) are connected to almost all other DTAILs. This finding reflects the relevance of object-generated data and resulting analytical insights for operational and strategic decision-making in logistic processes. While *(1) Ubiquitous Data Availability* is enabled by the associated digital technologies across all intralogistics process elements, the remaining DTAILs relate to specific (i.e., one to three) process elements. This finding highlights the problem–solution-fit between the individual affordances identified and the diverse potential of digital technologies for various intralogistics process elements.

Second, the differences in focus on Manual Tasks (i.e., (2), (3), and (4)) or on physical Goods & Assets (i.e., (5) and (6)) between two clusters of DTAILs reconfirms the view of affordances as multifaceted relational structures of technologies with certain features and sets of actions of an actor in a specific process environment. Regarding Manual Tasks, a human actor uses digital technologies primarily associated with the archetypes of Analytical Interaction (e.g., virtual assistants) and Augmented Interaction (e.g., augmented reality devices) to support or monitor manual process steps. In contrast, when it comes to DTAILs related to the control of Goods & Assets, the actor applying the digital technology needs to be defined at a higher level. In this case, the tracking, monitoring, and controlling of goods through object-generated data can be viewed as the outcome of the goal-orientation of an entire organization with a data-based (intra)logistics system (programmed by humans) operating automated processes. In this setting, physical objects (i.e., goods and assets) moving in the context of different process elements deliver information that allows operational adaptions and, in turn, enables other DTAILs. Here, the archetypes of Platform and Connectivity are essential for the critical data infrastructure.

Third, the DTAILs focusing on (operational) decisions or logistics management and emerging in the corresponding digital process elements distinguish themselves from DTAILs associated with cyber-physical processes. Naturally, the latter primarily relate to an operational level, while the rest also includes a strategic perspective. Precisely, the DTAILs (2) to (6) originate in a cyber-physical process environment, (7) and (8) form a transition zone, where the data-based optimization of planning activities and decision-making leads to the adaption of physical processes, and (9) and (10) mainly concern digital processes linked with managing information flows.

Fourth, every DTAIL is linked with multiple archetypes of digital technologies complementing one another. Particularly, infrastructure-focused technologies (e.g., Platform or Connectivity) and specific application-oriented technologies (e.g., *Sensor-based Data Collection* or *Analytical Insight Generation*) interact (i.e., (1), (5), (7), (9)). For instance, the combination of blockchain with IoT can enable smart logistics contracts that facilitate logistics process automation by transparently and inalterably documenting micro-transactions. This finding emphasizes the increasing importance of digital technology convergence that, in logistic processes, is observed in the form of cyber-physical systems.

Finally, the above findings also indicate that the systematic interconnection of intelligent process elements and multiple archetypes of digital technologies brings about potential constraints that present avenues for future in-depth analyses. For instance, digital technologies associated with the archetypes of Sensor-based Data Collection and Analytical Insight Generation are vital for the availability and informative value of object-generated data that in turn enables other archetypes. Consequently, the interdependence of certain archetypes creates technological base requirements in Logistics 4.0 that may present constraints and market barriers for some organizations. Thus, not all technological opportunities may be readily available for all market players. Further, the development of integrated cyber-physical systems along the supply chain may constrain internal technology implementation efforts of organizations in the sense that they need to be aligned with external stakeholders in a cross-organizational environment.

5 Discussion

5.1 Theoretical Implications

Our work connects to ongoing discussions on the role of digital technologies in the concept of Logistics 4.0 (Bag et al., 2020; Shao et al., 2021; Strandhagen et al., 2017a, b; Winkelhaus & Grosse, 2020) and offers valuable implications for IS research in terms of understanding technology affordances in frontline industrial developments. Along these lines, the main theoretical implications of this study to the IS body of knowledge are twofold as they provide new insights into the opportunities digital technologies afford in Logistics 4.0 and lay the foundation for further theorizing.

First, our work contributes to a systematic understanding of the affordances of digital technologies in Logistics 4.0. The literature provides a useful overview of the predominant Industry 4.0 applications in logistics and detailed insights into individual use cases (Frank et al., 2019a; Leofante et al., 2019). However, it does not offer a comprehensive cross-technology perspective on the systematic opportunities digital technologies afford in this context. Further, previous studies do not relate their potential to specific logistics processes and tasks (Shao et al., 2021; Winkelhaus & Grosse, 2020). Consequently, this study complements existing knowledge by presenting a novel and theoretically well-founded affordance perspective on Logistics 4.0 that is in line with recent IS research drawing on affordance theory (e.g., Islam et al., 2020; Seidel et al., 2013; Wendt et al., 2021). It is the first to offer a cross-technology and process-oriented perspective on how digital technologies can be used in Logistics 4.0. To do so, it draws on archetypes of digital technologies (Berger et al., 2018) and intralogistics processes as the central starting point for digitalization initiatives toward Logistics 4.0. The presented catalog and conceptual framework of affordances establish holistic patterns of the action potential that emerges from the interplay between digital technologies with certain features and intralogistics processes as specific organizational sets of actions. To achieve a close connection between theoretical and application-oriented research, we combined our theory-based knowledge from the structured literature review with detailed expert insights on real-world examples from an interview study. Thus, the catalog of DTAILs and associated practical manifestations appreciates the need for a comprehensive understanding of how digital technologies can support organizational processes in Logistics 4.0. The conceptual framework of affordance layers adds to theory on Logistics 4.0 as a leading-edge IS application domain by systemizing the DTAILs based on their effectual focus areas and interrelations. Further, these results add a new level of granularity to the field of intralogistics and advance the existing body of knowledge on the fit of Industry 4.0 applications (Strandhagen et al., 2017b), work characteristic changes (Winkelhaus et al., 2022), and digital technology impact (Zhang et al., 2016).

Second, our work facilitates further theorizing on the role of digital technologies in frontline industrial developments. It advances the understanding of the opportunities of digital technologies as interplay of actors and a leading-edge application domain by analyzing and emphasizing the interrelation of tasks and technology through process orientation. The methodological approach to rigorous affordance development introduced in this paper presents a blueprint for investigating affordances in a broader range of domains in a cross-technology and process-oriented manner. Thereby, this study also extends affordance theory applications by underscoring the dynamic interrelation between digital technologies, processes, and the domain-specific environment (Faraj & Azad, 2012; Majchrzak & Markus, 2013). Further, the presented results lay the foundation for fellow scholars to build theory beyond the level of individual technologies and develop a holistic understanding of the concept of Logistics 4.0 as per Winkelhaus and Grosse (2020). The presented catalog and conceptual framework of DTAILs may serve as a starting point to explore the affordances of digital technologies for inter-organizational processes and at different levels of the supply chain, as requested by Shao et al. (2021). Finally, the results of this study build a sound basis for relating research on Logistics 4.0 transformations (e.g., IS capability frameworks or maturity models) to the specific affordances of digital technologies.

5.2 Managerial Implications

Our work has two main practical implications that became evident in the interviews and support managers as organizational decision-makers in Logistics 4.0 initiatives (e.g., business development representatives, digital solutions specialists, logistics executives).

First, our results support managers in assessing and actively monitoring the extent to which their own Logistics 4.0 initiatives leverage the opportunities of digital technologies in intralogistics processes. Based on our results, managers can determine the technological status quo of logistics processes in their organizations by assessing which DTAILs are currently covered and which may advance certain processes. As managers are facing a variety of individual technology solutions in Logistics 4.0 (e.g., via trend reports) (Strandhagen et al., 2017b), abstracting from technological fads and taking a process-oriented cross-technology perspective can help them identify untapped action potential. Further, managers may evaluate the progress of their transformation toward Logistics 4.0 compared to competitors or up- and downstream partners. In this way, Logistics 4.0 initiatives can be strategically and technologically aligned to promote the horizontal integration of intralogistics processes and cyber-physical systems with all levels of the supply chain (Gupta et al., 2019). Moreover, our results lay the foundation for defining suitable affordance-oriented indicators for the progress organizations make when transforming their intralogistics processes.

Second, managers should leverage our results to structure strategic discussions on the development of their portfolio of digital technologies in intralogistics processes. In Logistics 4.0, managers constantly need to make decisions related to the fit between new technological solutions and current as well as planned initiatives (Yang et al., 2021). To this end, our results tackle the main concern raised by the interviewed experts, who repeatedly described a clutter of available digital technologies that makes it difficult to determine their action potential and identify suitable areas of application (I-5, I-6, I-8, I-10). The catalog and conceptual framework of DTAILs support managers in considering all relevant opportunities provided by comprehensible technology patterns. The process orientation of this study further encourages managers to adopt a task-technology-fit perspective when discussing where to catch up or how and where to proceed when developing their technology portfolio. This helps avoid isolated solutions and offsets potential subjective biases toward certain technologies. Finally, our results should be particularly relevant for organizations with different maturity levels and technological needs (Müller et al., 2018). Especially organizations at early stages of digital technology adoption (e.g., start-ups, small and medium-sized enterprises) deal with limited financial and personnel resources to obtain the interdisciplinary competencies necessary to manage the transformation toward Logistics 4.0.

6 Limitations and Future Research

The present study has limitations that may point fellow scholars in the direction for further beneficial research. First, we established our results inductively based on a systematic literature review and a qualitative interview study. While domain experts validated the representativeness and conceptual accurateness of our findings, the literature sample is restricted to recognized outlets of the IS and logistics disciplines. Future research could expand its scope to more technical outlets, patent databases, or inter-organizational logistics processes to evaluate the transferability of the framework and catalog of affordances to related domains and expand them if required. A further limitation of this study is that it is not longitudinal in design. In this sense, it is necessary to update the results periodically as new digital technologies emerge. This is supposed to be facilitated by the scheme of archetypes of digital technologies that allows for the easy integration of new technologies. Finally, this study's scope does not include the actualization of affordances or their interplay with broader organizational criteria for technology selection and adoption (e.g., IT business value, IS capabilities, and trust). From a theoretical perspective, future research could investigate how the actualization of the DTAILs in organizations is influenced by present sociotechnical factors on the actor level (e.g., employee expertise), the structure level (e.g., organizational structures), and the technology level (e.g., technological infrastructure). In addition, future work should explore constraints as the perceived barriers to goal achievement that hinder realizing the benefits of the use of digital technologies in Logistics 4.0 and form the counterpart to affordances. From a managerial point of view, future research could seek to provide additional methodological guidance to navigate managers through the process of transferring the DTAILs to their individual business settings. Shedding light on individual application areas, future researchers may wish to consider adding a demonstration phase to the present results and to explore different industry cases.

The above limitations notwithstanding, we are confident that the catalog and conceptual framework of ten DTAILs and 46 manifestations developed in this study offer a comprehensive IS understanding of the opportunities digital technologies provide for intralogistics processes. We expect that the results serve as a foundation for fellow researchers for further theorizing on Logistics 4.0 and practitioners for purposefully managing digitalization initiatives toward Logistics 4.0.

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Declarations

Competing Interests The authors have no competing interests to declare that are relevant to the content of this article.

References

Alter, S. (2003). Sidestepping the IT artifact, scrapping the IS silo, and laying claim to "systems in organizations". *Communications of the Association for Information Systems, 12*. https://doi.org/10.17705/1cais.01230

Alter, S. (2015). The concept of 'IT artifact' has outlived its usefulness and should be retired now. *Information Systems Journal, 25*(1), 47–60. https://doi.org/10.1111/isj.12048

Arnold, D. (Ed.). (2006). *Intralogistik: Potentiale, Perspektiven, Prognosen.* Springer.

Ba, S., & Nault, B. R. (2017). Emergent themes in the interface between economics of information systems and management of technology. *Production and Operations Management, 26*(4), 652–666. https://doi.org/10.1111/poms.12644

Bag, S., Gupta, S., & Luo, Z. (2020). Examining the role of logistics 4.0 enabled dynamic capabilities on firm performance. *The International Journal of Logistics Management, 31*(3), 607–628. https://doi.org/10.1108/IJLM-11-2019-0311

Baier, M.-S., Berger, S., Kreuzer, T., Oberländer, A. M., & Röglinger, M. (2023). What makes digital technology? A categorization based on purpose. *Communications of the Association for Information Systems, 52*, 556–609.

Ballou, R. H. (2007). The evolution and future of logistics and supply chain management. *European Business Review, 19*(4), 332–348. https://doi.org/10.1108/09555340710760152

Balouei Jamkhaneh, H., Shahin, R., & Tortorella, G. L. (2022). Analysis of Logistics 4.0 service quality and its sustainability enabler scenarios in emerging economy. *Cleaner Logistics and Supply Chain, 4*, 100053. https://doi.org/10.1016/j.clscn.2022.100053

Barreto, L., Amaral, A., & Pereira, T. (2017). Industry 4.0 implications in logistics: An overview. *Procedia Manufacturing, 13*, 1245–1252. https://doi.org/10.1016/j.promfg.2017.09.045

Benbunan-Fich, R. (2019). An affordance lens for wearable information systems. *European Journal of Information Systems, 28*(3), 256–271. https://doi.org/10.1080/0960085X.2018.1512945

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: A literature review. *International Journal of Production Research, 57*(15–16), 4719–4742. https://doi.org/10.1080/00207543.2017.1402140

Berger, S., Denner, M.-S., & Röglinger, M. (2018). "The Nature of Digital Technologies - Development of a Multilayer Taxonomy," *ECIS 2018 Proceedings* (92).

Bettis, R. A., Gambardella, A., Helfat, C., & Mitchell, W. (2015). Qualitative empirical research in strategic management. *Strategic Management Journal, 36*(5), 637–639. https://doi.org/10.1002/smj.2317

Bogataj, D., Bogataj, M., & Hudoklin, D. (2017). Mitigating risks of perishable products in the cyber-physical systems based on the extended MRP model. *International Journal of Production Economics, 193*, 51–62. https://doi.org/10.1016/j.ijpe.2017.06.028

Bowles, M., & Lu, J. (2014). Removing the blinders: A literature review on the potential of nanoscale technologies for the management of supply chains. *Technological Forecasting and Social Change, 82*, 190–198. https://doi.org/10.1016/j.techfore.2013.10.017

Büchi, G., Cugno, M., & Castagnoli, R. (2020). Smart factory performance and Industry 4.0. *Technological Forecasting and Social Change, 150*, 119790. https://doi.org/10.1016/j.techfore.2019.119790

Burlamaqui, L., & Dong, A. (2015). The Use and Misuse of the Concept of Affordance. In J. S. Gero, & S. Hanna (Eds.), *Design Computing and Cognition '14* (pp. 295–311). Springer International Publishing. https://doi.org/10.1007/978-3-319-14956-1_17

Calatayud, A., Mangan, J., & Christopher, M. (2019). The self-thinking supply chain. *Supply Chain Management: An International Journal, 24*(1), 22–38. https://doi.org/10.1108/SCM-03-2018-0136

Chen, Y., Lu, Y., Bulysheva, L., & Kataev, M. Y. (2022). Applications of blockchain in industry 4.0: a review. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-022-10248-7

Chung, S.-H. (2021). Applications of smart technologies in logistics and transport: A review. *Transportation Research Part E: Logistics and Transportation Review, 153*, 102455. https://doi.org/10.1016/j.tre.2021.102455

Coelho, F., Relvas, S., & Barbosa-Póvoa, A. P. (2021). Simulation-based decision support tool for in-house logistics: the basis for a digital twin. *Computers & Industrial Engineering, 153*, 107094. https://doi.org/10.1016/j.cie.2020.107094

Cole, R., Stevenson, M., & Aitken, J. (2019). Blockchain technology: Implications for operations and supply chain management. *Supply Chain Management: An International Journal, 24*(4), 469–483. https://doi.org/10.1108/SCM-09-2018-0309

CSCMP. (2013). “Supply Chain Management Terms and Glossary,” *CSCMP’s Definition of Supply Chain Management,* Council of Supply Chain Management Professionals (ed.).

Dai, H., Li, J., Yan, N., & Zhou, W. (2016). Bullwhip effect and supply chain costs with low- and high-quality information on inventory shrinkage. *European Journal of Operational Research, 250*(2), 457–469. https://doi.org/10.1016/j.ejor.2015.11.004

Delfmann, W., ten Hompel, M., Kersten, W., Schmidt, T., & Stölzle, W. (2018). Logistics as a science – central research questions in the era of the fourth industrial revolution. *Logistics Research, 11*(9), 1–13. https://doi.org/10.23773/2018_9

Dishaw, M. T., & Strong, D. M. (1999). Extending the technology acceptance model with task–technology fit constructs. *Information & Management, 36*(1), 9–21. https://doi.org/10.1016/S0378-7206(98)00101-3

Dolgui, A., & Ivanov, D. (2022). 5G in digital supply chain and operations management: Fostering flexibility, end-to-end connectivity and real-time visibility through internet-of-everything. *International Journal of Production Research, 60*(2), 442–451. https://doi.org/10.1080/00207543.2021.2002969

Faraj, S., & Azad, B. (2012). The Materiality of Technology: An Affordance Perspective, pp. 237–258. https://doi.org/10.1093/acprof:oso/9780199664054.003.0012

Faulkner, P., & Runde, J. (2019). Theorizing the digital object. https://doi.org/10.25300/MISQ/2019/13136

Fescioglu-Unver, N., Choi, S. H., Sheen, D., & Kumara, S. (2015). RFID in production and service systems: Technology, applications and issues. *Information Systems Frontiers, 17*(6), 1369–1380. https://doi.org/10.1007/s10796-014-9518-1

Fosso Wamba, S., & Chatfield, A. T. (2011). The impact of RFID technology on warehouse process innovation: A pilot project in the TPL industry. *Information Systems Frontiers, 13*(5), 693–706. https://doi.org/10.1007/s10796-010-9246-0

Fragapane, G., Ivanov, D., Peron, M., Sgarbossa, F., & Strandhagen, J. O. (2020). Increasing flexibility and productivity in Industry 4.0 production networks with autonomous mobile robots and smart intralogistics. *Annals of Operations Research*. https://doi.org/10.1007/s10479-020-03526-7

Fragapane, G., de Koster, R., Sgarbossa, F., & Strandhagen, J. O. (2021). Planning and control of autonomous mobile robots for intralogistics: Literature review and research agenda. *European Journal of Operational Research, 294*(2), 405–426. https://doi.org/10.1016/j.ejor.2021.01.019

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019a). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics, 210*, 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004

Frank, A. G., Mendes, G. H., Ayala, N. F., & Ghezzi, A. (2019b). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technological Forecasting and Social Change, 141*, 341–351. https://doi.org/10.1016/j.techfore.2019.01.014

Garousi, V., Felderer, M., & Mäntylä, M. V. (2019). Guidelines for including grey literature and conducting multivocal literature reviews in software engineering. *Information and Software Technology, 106*, 101–121. https://doi.org/10.1016/j.infsof.2018.09.006

Gibson, J. J. (1986). *The Ecological Approach to Visual Perception*. Routledge

Goldkuhl, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. *European Journal of Information Systems, 21*(2), 135–146. https://doi.org/10.1057/ejis.2011.54

Goodhue, D. L., & Thompson, R. L. (1995). Task-technology fit and individual performance. *MIS Quarterly, 19*(2), 213. https://doi.org/10.2307/249689

Gunasekaran, A., & Ngai, E. W. (2004). Information systems in supply chain integration and management. *European Journal of Operational Research, 159*(2), 269–295. https://doi.org/10.1016/j.ejor.2003.08.016

Gupta, S., Drave, V. A., Bag, S., & Luo, Z. (2019). Leveraging smart supply chain and information system agility for supply chain flexibility. *Information Systems Frontiers, 21*(3), 547–564. https://doi.org/10.1007/s10796-019-09901-5

Han, L., Hou, H., Bi, Z. M., Yang, J., & Zheng, X. (2021). Functional requirements and supply chain digitalization in industry 4.0. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-021-10173-1

Hofmann, E., & Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry, 89*, 23–34. https://doi.org/10.1016/j.compind.2017.04.002

Howard, M. C., & Rose, J. C. (2019). Refining and extending task–technology fit theory: Creation of two task–technology fit scales and empirical clarification of the construct. *Information & Management, 56*(6), 103134. https://doi.org/10.1016/j.im.2018.12.002

Huber, R., Oberländer, A. M., Faisst, U., & Röglinger, M. (2022). Disentangling Capabilities for Industry 4.0 - an Information Systems Capability Perspective. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-022-10260-x

Hund, A., Wagner, H.-T., Beimborn, D., & Weitzel, T. (2021). Digital innovation: Review and novel perspective. *The Journal of Strategic Information Systems, 30*(4), 101695. https://doi.org/10.1016/j.jsis.2021.101695

Hutchby, I. (2001). Technologies, Texts and Affordances. *Sociology, 35*(2), 441–456. https://doi.org/10.1177/S0038038501000219

Islam, A. K. M. N., Laato, S., Talukder, S., & Sutinen, E. (2020). Misinformation sharing and social media fatigue during COVID-19: An affordance and cognitive load perspective. *Technological Forecasting and Social Change, 159*, 120201. https://doi.org/10.1016/j.techfore.2020.120201

Ivanov, D., Tang, C. S., Dolgui, A., Battini, D., & Das, A. (2021). Researchers’ perspectives on Industry 4.0: Multi-disciplinary analysis and opportunities for operations management. *International Journal of Production Research, 59*(7), 2055–2078. https://doi.org/10.1080/00207543.2020.1798035

Kahle, J. H., Marcon, É., Ghezzi, A., & Frank, A. G. (2020). Smart Products value creation in SMEs innovation ecosystems. *Technological Forecasting and Social Change, 156*, 120024. https://doi.org/10.1016/j.techfore.2020.120024

Kayikci, Y. (2018). Sustainability impact of digitization in logistics. *Procedia Manufacturing, 21*, 782–789. https://doi.org/10.1016/j.promfg.2018.02.184

Kline, S. J. (1985). What is technology? *Bulletin of Science, Technology & Society, 5*(3), 215–218. https://doi.org/10.1177/027046768500500301

Klumpp, M., & Zijm, H. (2019). Logistics innovation and social sustainability: How to prevent an artificial divide in human-computer interaction. *Journal of Business Logistics, 40*(3), 265–278. https://doi.org/10.1111/jbl.12198

Kochan, C., Nowicki, D. R., Sauser, B., & Randall, W. S. (2018). Impact of cloud-based information sharing on hospital supply chain performance: A system dynamics framework. *International Journal of Production Economics, 195*, 168–185. https://doi.org/10.1016/j.ijpe.2017.10.008

Koh, L., Orzes, G., & Jia, F. (2019). The fourth industrial revolution (Industry 4.0): technologies disruption on operations and supply chain management. *International Journal of Operations & Production Management, 39*(6/7/8), 817–828. https://doi.org/10.1108/IJOPM-08-2019-788

Kohli, R., & Grover, V. (2008). Business value of IT: An essay on expanding research directions to keep up with the times. *Journal of the Association for Information Systems, 9*(1), 23–39. https://doi.org/10.17705/1jais.00147

Kopyto, M., Lechler, S., von der Gracht, H. A., & Hartmann, E. (2020). Potentials of blockchain technology in supply chain management: Long-term judgments of an international expert panel. *Technological Forecasting and Social Change, 161*, 120330. https://doi.org/10.1016/j.techfore.2020.120330

Kusiak, A. (2018). Smart manufacturing. *International Journal of Production Research, 56*(1–2), 508–517. https://doi.org/10.1080/00207543.2017.1351644

Lai, Y., Sun, H., & Ren, J. (2018). Understanding the determinants of big data analytics (BDA) adoption in logistics and supply chain management. *The International Journal of Logistics Management, 29*(2), 676–703. https://doi.org/10.1108/IJLM-06-2017-0153

Lee, C., Lv, Y., Ng, K., Ho, W., & Choy, K. L. (2018). Design and application of Internet of things-based warehouse management system for smart logistics. *International Journal of Production Research, 56*(8), 2753–2768. https://doi.org/10.1080/00207543.2017.1394592

Lee, S., Kang, Y., & Prabhu, V. V. (2016). Smart logistics: Distributed control of green crowdsourced parcel services. *International Journal of Production Research, 54*(23), 6956–6968. https://doi.org/10.1080/00207543.2015.1132856

Lehrer, C., Wieneke, A., vom Brocke, J., Jung, R., & Seidel, S. (2018). How big data analytics enables service innovation: Materiality, affordance, and the individualization of service. *Journal of Management Information Systems, 35*(2), 424–460. https://doi.org/10.1080/07421222.2018.1451953

Leidner, D. E., Gonzalez, E., & Koch, H. (2018). An affordance perspective of enterprise social media and organizational socialization. *The Journal of Strategic Information Systems, 27*(2), 117–138. https://doi.org/10.1016/j.jsis.2018.03.003

Leofante, F., Ábrahám, E., Niemueller, T., Lakemeyer, G., & Tacchella, A. (2019). Integrated synthesis and execution of optimal plans for multi-robot systems in logistics. *Information Systems Frontiers, 21*(1), 87–107. https://doi.org/10.1007/s10796-018-9858-3

Leonardi, P. M. (2011). When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies. *MIS Quarterly, 35*(1), 147. https://doi.org/10.2307/23043493

Lu, Y. (2021). The current status and developing trends of industry 4.0: a review. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-021-10221-w

Majchrzak, A., Faraj, S., Kane, G. C., & Azad, B. (2013). The contradictory influence of social media affordances on online communal knowledge sharing. *Journal of Computer-Mediated Communication, 19*(1), 38–55. https://doi.org/10.1111/jcc4.12030

Majchrzak, A., & Markus, M. L. (2013). Technology affordances and constraints in management information systems (MIS). *Encyclopedia of Management Theory* (1). https://doi.org/10.4135/9781452276090.n256

Majchrzak, A., Markus, M. L., & Wareham, J. (2016). Designing for digital transformation: Lessons for information systems research from the study of ICT and societal challenges. *MIS Quarterly, 40*(2), 267–277. https://doi.org/10.25300/MISQ/2016/40:2.03

Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: Guided by information power. *Qualitative Health Research, 26*(13), 1753–1760. https://doi.org/10.1177/1049732315617444

Margherita, E. G., & Braccini, A. M. (2020). Industry 4.0 technologies in flexible manufacturing for sustainable organizational value: Reflections from a multiple case study of italian manufacturers. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-020-10047-y

Margherita, E. G., & Braccini, A. M. (2021). Managing industry 4.0 automation for fair ethical business development: A single case study. *Technological Forecasting and Social Change, 172*, 121048. https://doi.org/10.1016/j.techfore.2021.121048

Markus, M. L., & Silver, M. (2008). A foundation for the study of IT effects: A new look at desanctis and poole's concepts of structural features and spirit. *Journal of the Association for Information Systems, 9*(10), 609–632. https://doi.org/10.17705/1jais.00176

Meindl, B., Ayala, N. F., Mendonça, J., & Frank, A. G. (2021). The four smarts of Industry 4.0: Evolution of ten years of research and future perspectives. *Technological Forecasting and Social Change, 168*, 120784. https://doi.org/10.1016/j.techfore.2021.120784

Muchenje, G., & Seppänen, M. (2023). Unpacking task-technology fit to explore the business value of big data analytics. *International Journal of Information Management, 69*, 102619. https://doi.org/10.1016/j.ijinfomgt.2022.102619

Müller, J. M., Buliga, O., & Voigt, K.-I. (2018). Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. *Technological Forecasting and Social Change, 132*, 2–17. https://doi.org/10.1016/j.techfore.2017.12.019

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and Organization, 17*(1), 2–26. https://doi.org/10.1016/j.infoandorg.2006.11.001

Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital innovation management: reinventing innovation management research in a digital world. *MIS Quarterly, 41*(1), 223–238. https://doi.org/10.25300/MISQ/2017/41:1.03

Nayernia, H., Bahemia, H., & Papagiannidis, S. (2021). A systematic review of the implementation of industry 4.0 from the organisational perspective. *International Journal of Production Research, 60*(14), 4365–4396. https://doi.org/10.1080/00207543.2021.2002964

Norman, D. A. (1990). *The Design of Everyday Things*. Doubleday/Currency.

Norman, D. A. (1999). Affordance, conventions, and design. *Interactions, 6*, 38–43.

de Oliveira, M. P. V., & Handfield, R. (2019). Analytical foundations for development of real-time supply chain capabilities. *International Journal of Production Research, 57*(5), 1571–1589. https://doi.org/10.1080/00207543.2018.1493240

Oliveira-Dias, D., Maqueira-Marín, J. M., & Moyano-Fuentes, J. (2022). The link between information and digital technologies of industry 4.0 and agile supply chain: Mapping current research and establishing new research avenues. *Computers & Industrial Engineering, 167*, 108000. https://doi.org/10.1016/j.cie.2022.108000

Orlikowski, W. J., & Iacono, C. S. (2001). Research commentary: Desperately seeking the "IT" in IT research—a call to theorizing the IT artifact. *Information Systems Research, 12*(2), 121–134. https://doi.org/10.1287/isre.12.2.121.9700

Pal, A., Herath, T., De', R., & Raghav Rao, H. (2021). Why do people use mobile payment technologies and why would they continue? An examination and implications from India. *Research Policy, 50*(6), 104228. https://doi.org/10.1016/j.respol.2021.104228

Park, K. T., Son, Y. H., & Noh, S. D. (2021). The architectural framework of a cyber physical logistics system for digital-twin-based supply chain control. *International Journal of Production Research, 59*(19), 5721–5742. https://doi.org/10.1080/00207543.2020.1788738

Piccinini, P., Gamberini, R., Prati, A., Rimini, B., & Cucchiara, R. (2013). An automated picking workstation for healthcare applications. *Computers & Industrial Engineering, 64*(2), 653–668. https://doi.org/10.1016/j.cie.2012.11.004

Pournader, M., Shi, Y., Seuring, S., & Koh, L. (2020). Blockchain applications in supply chains, transport and logistics: A systematic review of the literature. *International Journal of Production Research, 58*(7), 2063–2081. https://doi.org/10.1080/00207543.2019.1650976

Rajesh, R. (2017). Technological capabilities and supply chain resilience of firms: A relational analysis using Total Interpretive Structural Modeling (TISM). *Technological Forecasting and Social Change, 118*, 161–169. https://doi.org/10.1016/j.techfore.2017.02.017

Rejeb, A., Keogh, J. G., Leong, G. K., & Treiblmaier, H. (2021). Potentials and challenges of augmented reality smart glasses in logistics and supply chain management: A systematic literature review. *International Journal of Production Research, 59*(12), 3747–3776. https://doi.org/10.1080/00207543.2021.1876942

Saberi, S., Kouhizadeh, M., Sarkis, J., & Shen, L. (2019). Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research, 57*(7), 2117–2135. https://doi.org/10.1080/00207543.2018.1533261

Scholz, M., Kreitlein, S., Lehmann, C., Böhner, J., Franke, J., & Steinhilper, R. (2016). Integrating intralogistics into resource efficiency oriented learning factories. *Procedia CIRP, 54*, 239–244. https://doi.org/10.1016/j.procir.2016.05.067

Schuhmacher, J., Baumung, W., & Hummel, V. (2017). An intelligent bin system for decentrally controlled intralogistic systems in context of industrie 4.0. *Procedia Manufacturing, 9*, 135–142. https://doi.org/10.1016/j.promfg.2017.04.005

Seidel, S., Recker, J., & vom Brocke, J. (2013). Sensemaking and sustainable practicing: Functional affordances of information systems in green transformations. *MIS Quarterly, 37*(4), 1275–1299. https://doi.org/10.25300/MISQ/2013/37.4.13

Shao, X.-F., Liu, W., Li, Y., Chaudhry, H. R., & Yue, X.-G. (2021). Multistage implementation framework for smart supply chain management under industry 4.0. *Technological Forecasting and Social Change, 162*, 120354. https://doi.org/10.1016/j.techfore.2020.120354

Sigov, A., Ratkin, L., Ivanov, L. A., & Da Xu, L. (2022). Emerging enabling technologies for industry 4.0 and beyond. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-021-10213-w

Sonnenberg, C., & vom Brocke, J. (2011). Evaluation patterns for design science research artefacts. *286*, 71–83. https://doi.org/10.1007/978-3-642-33681-2_7

Strandhagen, J. O., Vallandingham, L. R., Fragapane, G., Strandhagen, J. W., Stangeland, A. B. H., & Sharma, N. (2017a). Logistics 4.0 and emerging sustainable business models. *Advances in Manufacturing, 5*(4), 359–369. https://doi.org/10.1007/s40436-017-0198-1

Strandhagen, J. W., Alfnes, E., Strandhagen, J. O., & Vallandingham, L. R. (2017b). The fit of Industry 4.0 applications in manufacturing logistics: A multiple case study. *Advances in Manufacturing, 5*(4), 344–358. https://doi.org/10.1007/s40436-017-0200-y

Tabim, V. M., Ayala, N. F., & Frank, A. G. (2021). Implementing vertical integration in the industry 4.0 journey: Which factors influence the process of information systems adoption? *Information Systems Frontiers*, 1–18. https://doi.org/10.1007/s10796-021-10220-x

Teo, T. S. H., & Men, B. (2008). Knowledge portals in Chinese consulting firms: A task–technology fit perspective. *European Journal of Information Systems, 17*(6), 557–574. https://doi.org/10.1057/ejis.2008.41

Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2021). Artificial intelligence in supply chain management: A systematic literature review. *Journal of Business Research, 122*, 502–517. https://doi.org/10.1016/j.jbusres.2020.09.009

VDMA. (2003). "Materials Handling and Intralogistics," available at https://foerd.vdma.org/en/viewer/-/v2article/render/16118581. Accessed on Apr 30 2021.

Volkoff, O., & Strong, D. M. (2017). Affordance theory and how to use it in IS research. *The routledge companion to management information systems* (pp. 232–245).

vom Brocke, J., Simons, A., Riemer, K., Niehaves, B., Plattfaut, R., & Cleven, A. 2015. Standing on the shoulders of giants: Challenges and recommendations of literature search in information systems research. *Communications of the Association for Information Systems, 37*. https://doi.org/10.17705/1CAIS.03709

von der Gracht, H. A., & Stillings, C. (2013). An innovation-focused scenario process — A case from the materials producing industry. *Technological Forecasting and Social Change, 80*(4), 599–610. https://doi.org/10.1016/j.techfore.2012.05.009

Wang, J., Lim, M. K., Zhan, Y., & Wang, X. (2020). An intelligent logistics service system for enhancing dispatching operations in an IoT environment. *Transportation Research Part E: Logistics and Transportation Review, 135*, 101886. https://doi.org/10.1016/j.tre.2020.101886

Webster, J., & Watson, R. T. (2002). Guest editorial: Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, xiii-xxiii. https://doi.org/10.2307/4132319

Wendt, C., Adam, M., Benlian, A., & Kraus, S. (2021). Let's connect to keep the distance: How SMEs leverage information and communication technologies to address the COVID-19 crisis. *Information Systems Frontiers*, 1–19. https://doi.org/10.1007/s10796-021-10210-z

Winkelhaus, S., & Grosse, E. H. (2020). Logistics 4.0: A systematic review towards a new logistics system. *International Journal of Production Research, 58*(1), 18–43. https://doi.org/10.1080/00207543.2019.1612964

Winkelhaus, S., Grosse, E. H., & Glock, C. H. (2022). Job satisfaction: An explorative study on work characteristics changes of employees in Intralogistics 4.0. *Journal of Business Logistics, 43*(3), 343–367. https://doi.org/10.1111/jbl.12296

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. M. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems, 22*(1), 45–55. https://doi.org/10.1057/ejis.2011.51

Xu, L. D., Xu, E. L., & Li, L. (2018). Industry 4.0: State of the art and future trends. *International Journal of Production Research, 56*(8), 2941–2962. https://doi.org/10.1080/00207543.2018.1444806

Yang, M., Fu, M., & Zhang, Z. (2021). The adoption of digital technologies in supply chains: Drivers, process and impact. *Technological Forecasting and Social Change, 169*, 120795. https://doi.org/10.1016/j.techfore.2021.120795

Zammuto, R. F., Griffith, T. L., Majchrzak, A., Dougherty, D. J., & Faraj, S. (2007). Information technology and the changing fabric of organization. *Organization Science, 18*(5), 749–762. https://doi.org/10.1287/orsc.1070.0307

Zhang, C., Chen, Y., Chen, H., & Chong, D. (2021). Industry 4.0 and its implementation: A review. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-021-10153-5

Zhang, X., van Donk, D. P., & van der Vaart, T. (2016). The different impact of inter-organizational and intra-organizational ICT on supply chain performance. *International Journal of Operations & Production Management, 36*(7), 803–824. https://doi.org/10.1108/IJOPM-11-2014-0516

Zhong, R. Y., Huang, G. Q., Lan, S., Dai, Q. Y., Chen, X., & Zhang, T. (2015). A big data approach for logistics trajectory discovery from RFID-enabled production data. *International Journal of Production Economics, 165*, 260–272. https://doi.org/10.1016/j.ijpe.2015.02.014

Zhu, X. N., Peko, G., Sundaram, D., & Piramuthu, S. (2021). Blockchain-based agile supply chain framework with IoT. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-021-10114-y

Zigurs, I., & Khazanchi, D. (2008). From profiles to patterns: A new view of task-technology fit. *Information Systems Management, 25*(1), 8–13. https://doi.org/10.1080/10580530701777107

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