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Conceptualizing the Industrial Metaverse: From Technological Layers to Business Value☆

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ABSTRACT

The ongoing digitalization of industrial processes has given rise to new concepts, with the Industrial Metaverse (IM) emerging as a promising development. The IM represents an immersive, data-driven ecosystem that integrates technologies such as augmented reality, digital twins, and artificial intelligence to interconnect physical and digital environments. Despite increasing relevance, research on the IM remains scarce, particularly regarding its conceptual structure, application areas, and value contribution. This study addresses this gap by applying a qualitative research design based on 25 expert interviews across multiple industries. Taking an inductive approach, we propose an IM Canvas of seven interdependent layers in a hierarchical structure and identify 16 use cases across six application areas. We then link these areas to four dimensions of business value: creation, capture, enhancement, and protection. The findings advance theory by positioning the IM as both a continuation of digitalization and a disruptive shift that redefines ecosystems. By integrating the actors–resources–activities perspective, the IM Canvas extends existing frameworks of digital transformation and highlights the dual role of the IM as a technological enabler and an organizational transformer. This article provides a conceptual foundation for future IM research and guidance for firms to leverage the potential of this digital ecosystem.

1. Introduction

Digital technologies are transforming industrial processes and value creation (Bamberger et al., 2025). Among the most promising emerging concepts in this transformation is the Industrial Metaverse (IM), which extends the broader Metaverse framework into business-to-business (B2B) contexts. However, while research has well-studied business-to-consumer environments (e.g., gaming, retail) (Cheng et al., 2022; Rauschnabel et al., 2022), it has largely ignored their B2B counterparts (Barrera & Shah, 2023; Dwivedi et al., 2022).

The IM is an immersive, data-driven, and interconnected ecosystem built on technologies such as augmented reality (AR), virtual reality (VR), digital twins (DTs), and artificial intelligence (AI) for industrial applications (Bruni et al., 2025; Jiang et al., 2022; Nleya & Velempini, 2024; Tantawi et al., 2025). Unlike traditional digitalization approaches, the IM extends beyond the mere visualization of machinery and equipment, also affecting business processes, value chains, and inter-organizational relationships (Dwivedi et al., 2022).

Despite the IM's promises, research is still in its early stages and lacks a theoretical framing (Bamberger et al., 2025). A preliminary search in the Web of Science database in March 2025 for the term "Industrial Metaverse" yielded only 184 results, indicating that scholarly exploration of this topic is limited. The existing literature is mainly conceptual and fragmented across domains such as supply chain management, engineering, and digitalization, often focusing on isolated technologies such as DTs (Tlili et al., 2023). Missing from this literature is a holistic, integrative understanding of the IM concept that links these fragmented research areas. Without such an understanding, how the IM operates across layers and application domains to create value remains unclear. Therefore, developing a coherent framework that connects layers, application areas, and value creation is warranted. This research gap is important because industry experts are increasingly recognizing the IM's economic potential. ABI Research (2024) projects that the IM market will exceed $100 billion by 2030. This projected growth further underscores the need for an empirically grounded, integrated understanding that goes beyond isolated technologies and instead offers a holistic view of how the IM is conceptualized and how it creates value. This study responds to this gap by proposing a structured

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conceptualization, empirically grounded in expert interviews, and addressing the following research questions (RQs):

RQ1. How can the concept of the IM be defined and conceptualized?

RQ2. In which application areas can the IM be used?

RQ3. What value does the IM generate for companies?

To answer these RQs, we use a qualitative research design, conducting 25 semi-structured, in-depth interviews with experts involved in the development, adoption, or implementation of the IM across several industries. The findings suggest that the IM encompasses seven interdependent layers, which together form a hierarchical structure. These layers provide clarity on how data and existing technologies are integrated into an IM Canvas and highlight the dependencies between them. In addition, we identify 16 use cases across six application areas that demonstrate where companies are using the IM. By applying the actor–resource–activity (A–R–A) framework (Håkansson & Snehota, 1995), the study offers a structured overview of each application area. Furthermore, it maps these application areas to four identified types of value contribution, thereby structuring the economic potential of the IM and showing its dual character. This study contributes to the ongoing academic discourse in B2B marketing and customer management by offering an empirical basis for the first comprehensive IM framework aimed at application areas and value generation.

The remainder of the paper proceeds as follows: Section 2 presents an overview of the evolution of the Metaverse, providing a foundation for its technological and conceptual development. In addition, we define the IM and highlight its specific role in the digital transformation of B2B markets. Section 3 outlines our qualitative research approach, data collection, and analysis procedures. Building on this, Section 4 presents our conceptualization in the form of an IM Canvas, the identified application areas for the IM, and the IM's possible value contributions. Section 5 discusses the conceptualization of IM, explores its application areas and business value, and offers directions for future research. By shedding light on the role and impact of the IM, this study contributes to the emerging research in this field and provides valuable insights for companies interested in navigating and leveraging this evolving digital landscape.

2. Theoretical background

2.1. The origin and evolution of the Metaverse concept

The term "Metaverse" was first introduced in the 1990s, appearing in Neal Stephenson's (1992) science fiction novel *Snow Crash*, in which he used it to describe a shared virtual space. Early conceptualizations refer to the Metaverse as "a future version of the internet" (Perlin & Goldberg, 1996, p. 205), while more tangible conceptualizations define it as an online environment in which users socialize, work, and play beyond real-world constraints (Ondrejka, 2005). Broadly speaking, the Metaverse refers to three-dimensional (3D) virtual spaces in which users interact in immersive, digital environments while removing physical boundaries and allows unrestricted interaction and collaboration (Davis et al., 2009).

Over time, the conceptualization of the Metaverse has evolved. In their literature review, Barrera and Shah (2023) highlight a shift from a single-world perspective, in which all users operate in a single virtual space, to a multi-world perspective, in which interconnected virtual environments coexist. This also includes a transition from a solely virtual environment to extended reality (XR) applications such as AR, VR, and mixed reality (MR) that blend physical and virtual environments. This shift is being driven by technological advances that increasingly blur the boundaries between the physical and virtual worlds (Dolata & Schwabe, 2023; Hwang & Chien, 2022; Park & Kim, 2022; Sands et al., 2024). These technologies serve as entry points into immersive environments, allowing users to partially or fully engage in virtual worlds (Cheng et al., 2022; Dolata & Schwabe, 2023; Wieland et al., 2024). Reflecting this transformation, Dwivedi et al. (2022, p. 2) describe the Metaverse as a "new iteration of the internet utilizing VR headsets, blockchain technology, and avatars to integrate the physical and virtual worlds." In these virtual worlds, users navigate digital spaces as avatars, which serve as their virtual representations (Hennig-Thurau et al., 2023; Hollensen et al., 2022; Perlin & Goldberg, 1996). Applications such as Second Life, Roblox, and Pokémon Go exemplify environments in which users immerse themselves in avatar-based experiences, interacting within digital environments that transcend real-world constraints (Barrera & Shah, 2023; Dwivedi et al., 2022). According to Hwang and Chien (2022, p. 1), "In such a virtual world, the only limitation is people's imagination." In line with this perspective, Park and Kim (2022, p. 4211) define the Metaverse as a "three-dimensional virtual world where avatars engage in political, economic, social, and cultural activities."

Similarly, Bruni et al. (2025, p. 60) define the Metaverse as "a technology that facilitates communication, actor interaction and knowledge dissemination, both for the competitive advantage of companies and for the social interaction of people in society." Their definition emphasizes the role of the Metaverse in facilitating relational exchanges between actors and its broader economic and social benefits. Similarly, various scholars also highlight the Metaverse's capacity to create, deliver, and sustain value (Hennig-Thurau et al., 2023; Hollensen et al., 2022).

2.2. The IM and its role in digital transformation

The IM refers to the extension of the Metaverse concept to industrial domains, encompassing parts of or even entire value chains for products and services (Jauhiainen, 2024; Nleya & Velempini, 2024). As such, B2B environments are clearly the IM's core field of application. The use of the IM in B2B environments involves the digitalization, virtualization, and digital management of industrial processes through advanced technological solutions (Jiang et al., 2022). Accordingly, Lee and Kundu (2022, p. 12) describe the IM as "a systematic discipline that combines hardware, data analysis, human-machine interfaces, and cyber infrastructure within the Metaverse." In general, scholars conceptualize the IM from various perspectives, emphasizing different dimensions of its technological, operational, and business-related impact. Bhattacharya et al. (2023), for example, adopt a process-oriented approach, highlighting the IM's role in value creation and efficiency enhancement. They define the IM as a system that "obtains data from various sensors and operational lines and provides sensible data analytics and decision-making to enhance the production efficiency of the space, reducing costs and maximizing sales value" (p. 941). This definition underscores the IM's value-generating potential, as input data are leveraged to optimize industrial processes and improve overall output—that is, increased process effectiveness.

Other researchers emphasize the underlying technological infrastructure, thus highlighting the IM's contribution to the expansion of a company's resource base and capabilities. Lyu and Fridenfalk (2024, p. 32) describe the IM as a system driven by technological innovation and new applications, stating that the IM "relies on sensing technology, XR interactive technology, (3D) modeling, real-time rendering technology for games, and data perception technology in the Internet of Things (IoT)." This perspective highlights the critical role of technological advancements in enabling interconnected industrial applications (Endres et al., 2024; Kshetri, 2023). Expanding on this view, Tantawi et al. (2025, p. 1462) offer a more integrative definition by noting that the IM combines "several technologies that include among others digital twins, blockchains, and cloud computing." This technological foundation aligns with the broader strategic perspective of Guo et al. (2024), who position the IM as a key enabler of environments advancing toward Industry 5.0 (Endres et al., 2024; Fernández-Caramés & Fraga-Lamas, 2024; Kshetri, 2023; Lee & Kundu, 2022). The IM is closely associated with the vision of Industry 5.0, as it supports the three core principles of human centricity, sustainability, and resilience (Bamberger et al., 2025; Fernández-Caramés & Fraga-Lamas, 2024; Guo et al., 2024; Lowry et al., 2025). Functioning as a platform ecosystem, it integrates various technologies such as AR, VR, DTs, and AI (Bamberger et al., 2025).

Collectively, these technologies enable the digital representation, real-time monitoring, and intelligent management of industrial processes (Tlili et al., 2023). AR and VR technologies provide immersive access to data and environments, DTs and cyber-physical systems facilitate real-time supervision and simulation, and AI supports process optimization (Bhattacharya et al., 2023). In addition, collaborative virtual environments enable both intra- and inter-organizational interaction between various actors (Maddikunta et al., 2022). These technological building blocks thus enable the IM to bridge the virtual and physical worlds in ways that blur traditional boundaries between, for example, actors and resources (Pardo et al., 2022). Unlike earlier waves of industrial digitalization focused narrowly on automation and interoperability (Nahavandi, 2019), the IM contextualizes technologies as key enablers. It embeds them within broader value-creation ecosystems (Tlili et al., 2023). Moreover, it places actors at the center (Guo et al., 2024; Yao et al., 2024), following the human-centered future vision of Industry 5.0. In doing so, the IM moves beyond the existing discourse on digital transformation by creating immersive, value-oriented environments in which stakeholders actively engage, collaborate, and co-create. This development represents a shift toward ecosystem-centered coordination, thereby expanding the scope of digital transformation (Guo et al., 2024; Martínez-Gutiérrez et al., 2024).

The IM thus exhibits a dual character. On the one hand, it adheres to the established logic of digitalization by integrating existing technologies, thereby representing an incremental continuation of the ongoing trends toward Industry 5.0 (Fernández-Caramés & Fraga-Lamas, 2024). This perspective reflects ongoing technological development in which new solutions such as AR, VR, DTs, and AI are embedded as building blocks within a broader ecosystem (Bharadwaj et al., 2013; Yao et al., 2024). On the other hand, the IM also triggers disruptive organizational and process-related shifts. It challenges established structures by transforming existing processes, enabling new forms of value co-creation in digital ecosystems, and reshaping value chains into more networked and collaborative forms (Dwivedi et al., 2022; Guo et al., 2024). A prominent example is the planning of BMW's new plant in Debrecen, Hungary, which occurred entirely virtually, illustrating how the IM redefines established ways of organizing industrial projects (BMW Group, 2023). From this viewpoint, the IM is not merely a technological extension; it represents a qualitatively new stage of industrial transformation that fundamentally redefines the meaning of digitalization and the structure of industrial ecosystems.

The concept of the IM incorporates three essential dimensions: products, companies, and consumers (Mourtzis, 2023b). This tripartite structure extends the understanding of domain-specific applications by linking them to three critical elements of B2B ecosystems: (1) processes and outputs (*products*), (2) organizational structures and value creation mechanisms (*companies*), and (3) the human and institutional actors involved (*consumers*). This framing enables a holistic perspective that integrates actors, resources, and activities across the entire industrial value network. In contrast with more narrowly scoped approaches, such as consumer-oriented Metaverses or stand-alone DTs, the IM serves as a unifying framework that bridges multiple functional domains and stakeholder groups (Yao et al., 2024). In doing so, it facilitates a more comprehensive, interconnected view of industrial transformation.

Digital transformation can reshape organizational procedures (Shankar et al., 2025), business relationships (Ivens et al., 2024; Obal & Lancioni, 2013; Pagani & Pardo, 2017; Rustholkarhu et al., 2022; Wieland et al., 2024), and even entire business models (Pagani, 2013; Ritter & Pedersen, 2022; Shree et al., 2021). Consequently, the integration of IM concepts is likely to trigger fundamental shifts in industrial operations, supply chain dynamics, and B2B interactions, ultimately redefining how companies operate and capture value. From an organizational perspective, identifying and managing the changes introduced by such a transformative technological concept are crucial (Richard & Devinney, 2005).

By reshaping business networks (Pagani & Pardo, 2017; Pardo et al., 2022), digital technologies help business relationships become embedded in broader systems of interconnected entities, including manufacturers, customers, and other stakeholders (Anderson et al., 1994). An organization therefore acts not as an isolated actor but as a part of a dynamic, interdependent industrial system, performing activities and employing resources in interactions with other actors. To analyze this complexity, the well-established A–R–A model (Håkansson et al., 2009; Håkansson & Snehota, 1995) conceptualizes business exchanges along three interrelated dimensions: actors, resources, and activities. This study applies this model to shed light on how the IM is conceptualized, which application areas it covers, and what forms of business value it creates or enables.

Within this framework,

- *actors* refer to the individuals and organizations engaged in industrial exchange processes,
- *resources* represent the tangible and intangible assets that support value creation, and
- *activities* describe the structured processes that connect actors and apply resources (Håkansson & Snehota, 1995; Håkansson & Waluszewski, 2002).

Therefore, adopting this framework allows us to analyze each application area along three interrelated dimensions: the actors involved, the resources needed, and the activities performed. This approach provides a structured perspective of the potential impact of the IM on actors, resources, and activities.

2.3. Value in B2B markets

Value is a pivotal concept in B2B markets. Value in B2B relationships derives from the trade-offs each customer and supplier perceive between benefits and sacrifices (Eggert & Ulaga, 2002; Vargo & Lusch, 2008). It encompasses economic, technical, and non-economic dimensions. Value creation is the fundamental purpose of all entrepreneurial activity and is a prerequisite for companies to achieve performance. In business markets, it typically requires close cooperation among members of the value chain (or value network). Value capture (also referred to as value sharing, value claiming, and value appropriation) reflects the process that involves determining what share of value each company will appropriate in exchange situations. This notion is often described with the "pie-sharing" image; buyers and suppliers may have conflicting goals and perceptions of how the "value pie" should be shared. Asymmetries in value appropriation can generate perceptions of inequity, and thus achieving a balance is difficult (Bouncken et al., 2020; Corsaro, 2014; Lieberman et al., 2017). Together, "value creation and value sharing [are] the raison d'être of collaborative customer-supplier relationships" (Anderson, 1995, p. 348).

In addition to value creation and value capture, the literature identifies two other value-related processes that matter for the amount and kind of value that can be created. First, value enhancement refers to activities that allow improving value creation processes among actors, such as making production processes more efficient, making better use of available data, or reducing transportation times. Value enhancement helps increase the "pie" that can be shared between partners in exchanges (e.g., Eckert et al., 2010; Ni et al., 2021). Second, value protection serves the purpose of avoiding the "leakage" of value from value creation processes by, for example, protecting intellectual property from non-authorized actors or identifying possible problems in value creation processes that may lead to inefficiencies (Ogachi & Zoltan, 2020; Wadhwa et al., 2017). A key question for both supplier and customer companies in B2B markets is whether and how the IM will affect value and these four main dimensions of value management.

3. Methodology

To address the RQs, we adopt an exploratory qualitative case study approach, using semi-structured, in-depth interviews (Eisenhardt, 1989; Kumar et al., 1993; Patton, 2015; Yin, 1994). Given the scarce and fragmented nature of research on the IM (Dwivedi et al., 2022), an exploratory research design is appropriate (Beverland & Lindgreen, 2010; Bonoma, 1985; Stake, 1995). With this approach, we are able to develop a detailed understanding of the principles of the IM by capturing valuable in-depth insights into its underlying principles. In doing so, we shed more light on the potential of this concept and address a "Grand Challenge" (Eisenhardt et al., 2016, p. 1113) expected to shape the future.

3.1. Data collection and sample description

In this research, we collected primary data in 25 expert interviews with professionals from 20 different companies across various industries. The interviewees have diverse professional backgrounds (e.g., consulting, research and development [R&D], project management), and their career levels vary across different hierarchical positions, including CEOs, senior experts, and other managerial or technical roles, thereby ensuring a broad spectrum of different perspectives. All informants had practical experience with the IM, in its development, adoption, or operational implementation. On average, they had been employed at their company for 11 years. The sample includes five female and 20 male informants, with interview durations ranging from 40 to 127 min and an average length of 60 min.

We initiated data collection via LinkedIn and direct contact between October 2024 and February 2025. All interviews took place online via Microsoft Teams or Google Meet, were recorded with informants' consent, and were transcribed verbatim for analysis. To ensure accessibility, interviews occurred in either German or English. Confidentiality was maintained by assigning pseudonyms to all respondents (see Appendix A).

The companies represent a range of typical B2B industries, including information technology (IT) and services (seven), mechanical engineering (four), manufacturing (three), transportation and logistics (two), management and technology consulting (one), healthcare and medical technology (one), energy and power generation (one), and automotive manufacturing (one). In addition, the companies vary in size: five small enterprises ($\leq$49 employees), two mid-sized firms (50–249 employees), and 13 large corporations (>250 employees). Appendix B provides a detailed company overview.

3.2. Data analysis strategy

Analysis of the interview data follows an inductive research approach, which is particularly well-suited for exploring emerging concepts (Denzin & Lincoln, 1994). To ensure methodological rigor while preserving the qualitative nature of the study, we applied Gioia's systematic approach for qualitative research (Gioia et al., 2013). This inductive, data-driven method enables a structured analysis while emphasizing the originality of the IM concept.

We carried out the coding process in three stages, following the Gioia methodology. First, we conducted open coding of the transcripts (Strauss & Corbin, 1998) to create an initial thematic structure of the material (Miles & Huberman, 1984). In this stage, we developed first-order concepts by closely examining the interview transcripts and categorizing individual statements into distinct concepts. This stage remained closely tied to the transcribed raw data, ensuring capture of the nuances of informants' perspectives on the concept of IM. Second, we identified second-order themes by grouping related first-order concepts, allowing for the recognition of broader patterns across interviews. This stage helped us identify the seven different layers of the IM, along with its various application areas and value contribution. Third, we derived aggregated dimensions from the second-order themes, integrating them into a structured framework. These dimensions provide a comprehensive conceptualization of the IM, its hierarchical structure, application areas, and associated business value.

The first outcome of our approach is a refined conceptualization of the IM as an empirical phenomenon and object for empirical scholarly research. Expanding on the framework proposed by Guo et al. (2024), we introduce two additional stages. First, by distinguishing the IM into seven layers—data infrastructure, data processing, integration, application, ecosystem actor, interaction, and data exchange—we provide an extended, holistic understanding of its essential components. Second, the aggregated dimensions highlight the value proposition of the IM. We map this value proposition across four dimensions—creation, capture, enhancement, and protection—and link them to their respective application areas. To provide deeper context for these application areas, we draw on the A–R–A framework (Håkansson & Snehota, 1995) to examine the IM's impact through the lens of actors, resources, and activities.

Appendix C provides the coding scheme developed during the analysis, and Appendix D contains illustrative quotations from the expert interviews as well as a summary of the frequency with which they mentioned individual themes. Together, these sources support the traceability and robustness of our findings.

4. Findings

4.1. The IM Canvas

To achieve a comprehensive realization of the IM concept, we establish seven distinct technological layers. These layers build on one another, forming a hierarchical structure that extends beyond isolated technological applications, such as AR, VR, or DTs. Instead, these technologies are embedded within an immersive interconnected industrial ecosystem.

Our conceptualization provides a structured framework, which we refer to as the "IM Canvas" to help companies understand the IM concept and realize its value. Insights from expert interviews led to the identification of the layers, illustrated in Fig. 1, addressing RQ1. We first present the IM Canvas and characterize its layers. We then describe how the seven layers reflect the three dimensions of networks as defined in the A–R–A model—namely, actors, resources, and activities.

4.1.1. Seven layers of the IM Canvas

(1) The first layer of the IM is *data infrastructure*, which serves as the central repository for all relevant data. More than two-thirds of the interviewees emphasized the pivotal role of data in enabling the IM, highlighting data's importance as a critical component of its architecture. The data in this layer are typically unstructured and exist in various file formats, encompassing both static and dynamic content. The stored information includes technical documentation (e.g., manuals, bills of materials), computer-aided design (CAD) files, and real-time operational data, such as process data (e.g., air pressure) and quality-related data (e.g., cutting precision). Given its function as the primary data infrastructure, this layer establishes the foundation for all subsequent layers, ensuring that stored data are centralized and made accessible for further processing.

As interviewee Linda emphasized, effective data management is critical: "The topic of data and ensuring that I no longer store different sources in isolated silos, but instead integrate them and leverage them for added value, is essential." Prior research similarly highlights the importance of integrated and standardized databases for facilitating efficient data management and

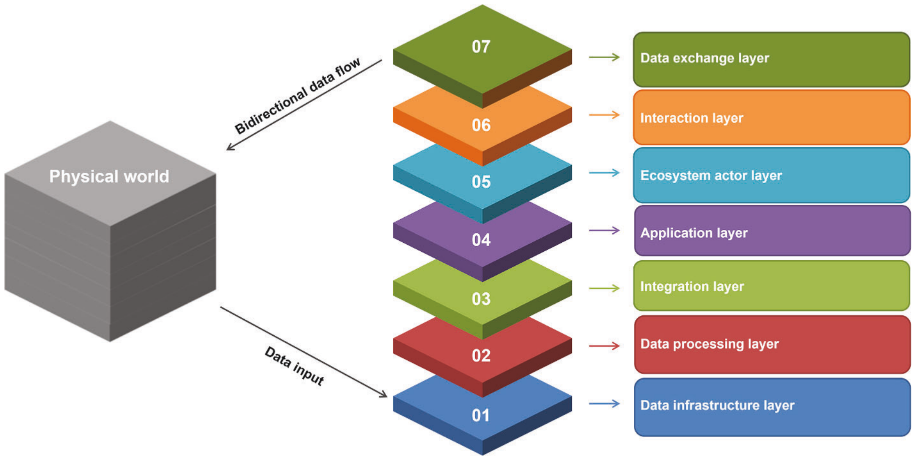


Fig. 1. The IM Canvas.

driving technological advancements (e.g., Alshawi et al., 2011; Bag et al., 2021; Mikalef et al., 2019; Wiersema, 2013).

(2) Building on the first layer, the second layer is *data processing*. In this layer, advanced technologies such as big data analytics and AI convert unstructured raw data into actionable insights, creating a holistic picture. By extracting, cleaning, and structuring data, this layer enables the utilization of input data across a range of applications, such as process automation or pattern detection, in the IM. Linda called attention to the layer's role in the IM, stating: "Given all this data, I can certainly use AI to create logistics or warehouse planning by bringing together aspects such as container prices ... and material prices elsewhere." By focusing on the transformation of given input data into structured formats, this layer provides the foundation for predictive applications.

(3) The third layer, *integration*, transforms structured data into digital 3D representations of products, services, and equipment. As Jack described: "Since we now have a unified data foundation, we are starting to visualize this data as well." This layer ensures that input information is digitally processed and transferred into the virtual environment. In particular, it is responsible for converting data into digital models that enable virtual representations of physical facilities. This transformation creates a digital counterpart to the physical world that reflects real-world entities and processes, thereby blurring the boundaries between the two worlds. This immersive experience enhances interactions in the IM, making it particularly valuable for virtual walk-throughs of manufacturing facilities or machines without disrupting physical real-world operations.

(4) The fourth layer is *application*, which allows users to access the IM. This access is facilitated by AR and VR applications, such as Microsoft HoloLens or Meta Quest Pro. These technologies create an immersive experience, allowing users to interact with digital representations of their surroundings as if they were physically present in the simulated environment. By providing realistic simulations, this layer enhances user engagement and facilitates complex training, remote assistance, and design validation. Prior research emphasizes the importance of immersive experiences in B2B environments, particularly in improving customer engagement and operational efficiency (Boyd & Koles, 2019; Wieland et al., 2024). Similarly, several interviewees highlighted the critical role of technology-driven applications in delivering immersive experiences in unlocking the full potential of the IM: "When people walk through their factories in VR or something like that, it's massive. It's truly a game-changer" (Robert).

(5) The fifth layer, *ecosystem actor*, defines the relevant stakeholders granted access to the IM ecosystem. These stakeholders can be internal (e.g., employees) or external (e.g., customers) and are classified according to their functional roles within the system, such as product development engineers. By structuring access rights by roles, stakeholders can retrieve and use available data and information in the IM itself, thereby reducing reliance on intermediaries, such as customer service representatives, as external stakeholders can directly access much of the information they require. Paul emphasized the importance of the ecosystem-driven approach in the IM because it "promotes innovation, delivery, and observability." Another respondent explained that this layer democratizes the IM by lowering entry barriers and enhancing accessibility for a wider range of users: "The visualization and accessibility of information promote democratization ..., allowing for broader usability and understanding" (Tom).

(6) The sixth layer is *interaction*, which encompasses the exchange of information, data, and actions in the IM. This layer serves as the space where structured interactions and communication between different actors take place. Interactions in this layer can occur on three levels:

- *Intra-organizational (within companies)*: Communication and collaboration in digital workspaces.
- *Inter-organizational (across companies)*: Cross-company engagement, information exchange, negotiations, and process coordination.
- *Human–machine interaction*: Interfacing with digital representations of industrial assets, such as DTs, for the monitoring of processes and observation of systems.

As a meeting point for relational exchange, actors in the IM make use of existing applications, such as digital team rooms or virtual representations of machines and factories; confirming this, Linda described the IM as "the home of digital twins." The findings further suggest that the interaction layer enables collaboration in the IM, which goes beyond transactional relationships. As Michael noted: "The focus is shifting toward problem understanding. It's no longer just about selling a product but also examining the customer's processes."

(7) The seventh layer, *data exchange*, ensures real-time data flow between the virtual and physical environment. Here, companies can only realize the whole potential of the IM if actions occurring in the virtual space also have an impact on the physical world (Rauschnabel et al., 2022). This feedback loop is widely regarded as one of the most important factors that sets the IM apart from related concepts (Kour et al., 2025; Lyu & Fridenfalk, 2024;

Mourtzis, 2023a). However, despite its significance, the majority of respondents indicated that, at present, data flow only in one direction—from the physical world to the virtual space. As Robert stated: "Right now, our systems simply push data into the Metaverse. The flow is strictly one way." While the respondents widely recognize the potential benefits of a bidirectional exchange, its implementation remains a future challenge. As Jack noted: "The bidirectional level will come later. But it is definitely necessary." Furthermore, the interviewees identified several key obstacles preventing the realization of a full bidirectional data exchange, primarily technical challenges and legal concerns, such as liability issues in cases in which actions in the virtual world influence real-world operations.

4.1.2. The IM Canvas as reflection of the A–R–A model in B2B markets

Companies can use and interpret all seven layers of the IM individually; however, together they also reflect the three dimensions of networks as defined in the A–R–A model for B2B exchanges (e.g., Håkansson & Snehota, 1995): actors, resources, and activities.

First, the actor dimension in the IM Canvas is represented by layer 5, the ecosystem actor. This layer identifies actors' roles so as to assign rights that enable them to perform activities and obtain access to resources. As such, this layer plays both a connecting role and a structuring role.

The two layers reflecting the resource dimension are data infrastructure (1) and application (4). The data infrastructure layer encompasses the broad and deep data resources that form the starting point and is an essential asset for any IM activity. The application layer encompasses the technologies, both publicly available and proprietary to one or several actors, that allow companies to achieve important outcomes such as human immersion in virtual spaces or replication of physical objects in the digital space.

The activities dimension involves the remaining four layers (i.e., data processing [2], integration [3], interaction [6], and data exchange [7]), which involve all types of processes performed by humans and/or by machine actors in the context of using the IM for business purposes in B2B markets. A predominant part of these activities is machine-based and prepares the IM as a technological system that helps optimize the efficiency and effectiveness of business processes for goal-oriented use of human actors in different application areas.

4.2. Application areas

In this sub-section, we address RQ2 regarding the application areas of the IM and its value contribution (RQ3). From the 25 in-depth interviews, we identified 16 use cases within six application areas: *design & engineering*, *process & workflow management*, *commissioning & manufacturing*, *training & knowledge transfer*, *customer engagement & marketing*, and *operations & maintenance*. These six areas cover the two types of activities in companies' value chains (Porter, 1985): primary and support. Primary activities are involved in the physical creation of a product, its sales, and its transfer to customers; they also encompass value activities that occur after initial purchase. Support activities help ensure the effective and efficient functioning of primary activities. Commissioning & manufacturing, customer engagement & marketing, and operations & maintenance represent primary activities, while design & engineering, process & workflow management, and training & knowledge transfer are support activities. Thus, the IM is not focused on improving one value activity in a firm, nor is it focused on contributing to one specific type of value activity; rather, it contributes to the performance of a broad range of value activities across application areas in companies (see Appendix D for frequency of code occurrence supporting this classification and illustrative comments). We structure the description of these application areas using the A–R–A framework (Håkansson & Snehota, 1995) and summarize the results in Table 1.

4.2.1. Design & engineering

The first identified application area, design & engineering, encompasses the phases of innovation, conceptualization, and product development that can be modeled in the IM, thereby highlighting the growing relevance of virtual environments for engineering and innovation processes. The interviews emphasized the collaborative potential of the IM for design and engineering, with experts such as innovation managers and engineers and users interacting in virtual environments during the initial development phase. This setup enables these actors to co-develop solutions and address existing design challenges before the first physical prototype has even been built (John). The involved actors contribute their specialized knowledge and work together to design and refine a product or service (Robert). By removing physical constraints and visualizing multiple scenarios, the IM allows firms to simulate various design alternatives with modified parameters (e.g., material composition, structural dimensions), thereby facilitating more precise product and service development.

The ability to refine designs through iterative simulations is particularly valuable, as Noah, a product developer at a German automotive company, noted: "You can repeat processes. You can make precise modifications with exact values. For example, if I calibrate this worm gear to one degree, ... later, I can test various scenarios through simulation." This advantage is particularly important in B2B environments when companies do not rely on standardized products but instead develop customized machinery (Susan), which can be virtually preassembled (Olivia). In addition, the IM facilitates the exploration of scenarios, such as reversing assembly lines, which would otherwise be technically challenging or infeasible with current technology (Noah).

4.2.2. Process & workflow management

Process & workflow management, the second key application area, involves all tasks and planning procedures related to a company's manufacturing processes, focusing on workflows and intra- and interorganizational coordination. In this context, both suppliers and customers use the IM to coordinate and refine existing processes and procedures. From an internal perspective, the IM enhances workflow and organizational planning, addressing important aspects such as the optimal positioning of robots within a factory (Sally), the configuration of machine-based manufacturing processes (Jack), or the ideal arrangement of tools and equipment used by manufacturing employees (Noah). By visualizing the environment and conducting virtual preplanning, companies can simulate planned processes and facility outlets to gain a holistic view of the whole manufacturing process and its interdependencies. This comprehensive perspective enables targeted

Table 1
Application areas of the IM.

	Design & engineering	Process & workflow management	Commissioning & manufacturing	Training & knowledge transfer	Customer engagement & marketing	Operations & maintenance
Actors	R&D, engineering teams	Suppliers, customers	Production planners, system engineers	Human resources, training divisions	Customers	Maintenance teams, customers
Resources	Knowledge and expertise, product data	Process and logistics data	Factory layout, real-time product data	Training materials	Product and service visualization	Operational data
Activities	Product and service development	Workflow and supply chain optimization	Real-time production compliance validation	Interactive training	Virtual product showcases and sales consultations	Remote maintenance, remote support

optimizations, such as reducing unnecessary movements and streamlining workflows. Edward, an innovation manager at a Swiss transportation company, provides an example of this, explaining that his organization leverages the IM to enhance process planning for train maintenance.

Interviewees emphasized that cross-company planning processes within the supply chain are essential; however, these require that all relevant stakeholders provide the necessary data to ensure seamless integration and coordination. The layers of the IM enable real-time data exchange, visualization, and simulation of inter-organizational supply chain activities (James), helping companies to detect cross-organizational dependencies and proactively anticipate disruptions. Robert also highlighted this, describing how his company uses the IM for more agile and responsive supply chain process planning:

"I have ten robots … that experience a delay in planning and will be listed five weeks later. Using traditional project management tools, these ten robots would simply appear as a delayed block in the timeline. However, perhaps two of these robots are immediately needed to integrate into the system–otherwise, all subsequent processes will come to a halt. By visualizing the production plan within a digital layout, this issue becomes instantly tangible and visually accessible. This allows more agile decision-making. For instance, I might choose to have the two critical robots delivered by air freight while the rest follow via standard shipping."

4.2.3. Commissioning & manufacturing

The third application area, commissioning & manufacturing, subsumes all tasks related to the manufacturing process, quality assurance, and commissioning of products. In this context, several interviewees emphasized the role of the IM in increasing transparency in manufacturing processes. By consolidating all relevant data within the virtual environment, such as input factors, resource consumption, and manufacturing cycle times, companies can gain a comprehensive and real-time overview of the product and its manufacturing requirements. This level of visibility facilitates continuous process optimization and drives product life-cycle management. Anna highlighted this asset: "If I have continuous insights into the manufactured product and the production process, such as resource consumption and required materials, I can conduct a more precise life-cycle assessment." This statement emphasizes that life-cycle assessment, a method used to analyze the ecological impact of a product or service from its raw material extraction to its end of life, benefits from the IM's ability to track and visualize manufacturing data in real time (Susan).

In addition, the increased transparency related to life-cycle assessment enables companies to comply with legal regulations, such as the European Union Digital Product Passport or the United Nations Sustainable Development Goals, by making material compositions, components, and manufacturing resources traceable and verifiable. Christoph, a CEO in the IT and services industry, described this as a "prime example of an [IM] application."

In production processes, another key application is IM-driven certification and product approval. Instead of conducting quality tests on physical products and machine components, these approvals occur in an immersive digital environment, reducing the need for physical prototypes and associated resource expenditures. By visualizing products and integrating them with real-time data, the IM enables the simulation of various testing scenarios, such as different weather conditions (Noah), extreme wear and tear (Susan), and sensors under specific conditions (William). For example, in the automotive sector, crash tests—still predominantly conducted in the physical world today—can be replicated in the IM. This approach allows for the virtual testing of crashes without the need for physical prototypes, providing reliable, real-time, data-based evidence for certification and regulatory approval, while reducing costs and material consumption (Alexander).

4.2.4. Training & knowledge transfer

Fourth, training & knowledge transfer covers all activities related to competence development and the transfer of knowledge to actors (e.g., employees). In the current context, learning and training refer to all skills and competences that need to be acquired to operate production facilities or perform specific job-related tasks.

A critical factor for learning and skills development is the availability of the data infrastructure layer, which provides relevant information and enables immersive training environments, primarily facilitated by AR and VR applications. However, respondents expressed different perspectives on the required level of immersion in training scenarios. For example, while Victor considers a web-based learning environment sufficient, others emphasized the need for MR applications (Daniel) or fully immersive AR or VR learning environments (Linda).

Regardless of the degree of immersion, these training scenarios serve as a major tool for knowledge acquisition (Samuel). Employees undergo interactive simulations to enhance their skills in areas such as occupational safety, technical applications, and manufacturing processes (Christoph). These simulations enable both skill refreshment and the acquisition of new competences. For example, the operation of heavy machinery, such as excavators, can be simulated in the IM. This approach enables employees to train on complex tasks without causing disruption to real-world production facilities, thereby minimizing downtime and mitigating operational risks (Ben).

4.2.5. Customer engagement & marketing

Customer engagement & marketing, the fifth application area, focuses on the interaction between suppliers and customers in the IM context. These use cases center on enhancing customer relationships, improving product visualization, and facilitating more immersive sales processes.

One of the most frequently emphasized tools in our interviews is the role of virtual trade shows in fostering customer engagement. By visualizing production facilities and individual components in a detailed and interactive way, customers can gain a better understanding of products and services (Victor). The capacity to virtually disassemble and examine components facilitates a more comprehensive product evaluation, thereby fostering trust and assisting companies in making informed purchasing decisions. In addition, virtual trade shows provide on-demand access to all relevant product-related information, which is particularly valuable for addressing service- and maintenance-related inquiries. The immersive nature of the IM enables companies to overcome spatial and temporal barriers, creating a consolidated and standardized customer touchpoint (Anna). This has a dual positive effect: (1) it meets the informational needs of existing customers while also expanding market reach by engaging potential customers who are not accessible through conventional trade shows, and (2) it seamlessly showcases large, complex, and difficult-to-transport products, such as entire production facilities, without the logistical constraints of physical events (John).

Beyond virtual trade shows, this application area also includes virtual facility walk-throughs, which are particularly useful in pre-sale or pre-installation phases. These IM-based walk-throughs help companies illustrate the final implementation of a product or production system, ensuring greater clarity and alignment between actors (Robin).

While traditional AR and VR applications primarily help with visualization (Wieland et al., 2024), the IM represents a more advanced concept, allowing not only the viewing but also the interactive adjustment of machine positions and plant layouts in real time. This functionality enhances the precision of planning, as modifications can be executed and evaluated in real time. The immersive nature of the environment ensures that all participants are working in the same virtual space, facilitating the identification and resolution of potential misunderstandings at an early stage and fostering a shared understanding. As James noted: "What does the system look like? How does it fit into my production? Many customers operate within brownfield environments .... They can scan their existing facility, integrate the new system into the virtual space, and then evaluate how it aligns with their production layout."

4.2.6. Operations & maintenance

Sixth, operations & maintenance covers all activities that occur after the purchase process, such as deployment, customer service, and maintenance. This application area plays a crucial role in ensuring the continuous functionality and efficiency of industrial equipment by optimizing service in the IM.

A central aspect emphasized by more than half the interviewees is the role of remote support. This approach enables service technicians to diagnose problems off-site, rather than being physically present at the machine or plant. The identification of technical issues is facilitated in the IM, if all real-time operational data are accessible in the virtual environment (Sally). After identifying a technical issue, a support technician can provide guidance to an on-site colleague through the requisite steps to rectify the issue. In cases of minor malfunctions, such as incorrect system configurations, the issue can even be resolved remotely through bidirectional data exchange, thereby negating the need for on-site intervention (George). Especially for highly customized and specialized industrial equipment, such as trains (George) or filtration systems (William), only a limited number of experts are available for problem solving and maintenance (Harry), further underscoring the Metaverse's relevance in industrial contexts.

Beyond remote support, the IM facilitates AI-driven predictive maintenance, enabling companies to anticipate future service and repair needs. By leveraging centralized real-time data and continuous system monitoring, simulations can predict when technical wear and tear will occur and when maintenance will be required. These forecasts allow for proactive planning and the efficient allocation of maintenance resources, ensuring optimized service schedules and reduced downtime (Samuel). As a key resource for predictive maintenance, several interviewees emphasized the importance of ensuring data accuracy and relevance. Anna, for example, explained: "But then you have to critically ask yourself: What information do I really need for this? … Maybe, quite simply, just tracking the machine's operating hours is already sufficient."

4.3. Value contribution

The IM reshapes how companies create, capture, enhance, and protect value, enabling a more efficient, data-driven, and agile approach to industrial operations. Table 2 provides an overview of six key application areas and their respective contributions to value creation, capture, enhancement, and protection.

Value creation in the IM is driven by increased efficiency, optimized resource utilization, and improved decision-making capabilities. By digitalizing planning, development, and production processes, companies are able to optimize their operations, leading to reduced input factors and cost reductions. This process enhances not only operational efficiency but also more sustainable practices, such as the reduction of material consumption (Linda) and the need for physical documentation (Michael). A fundamental value driver is the IM's capacity to visualize data and render them accessible. Here, conventional operations often struggle with data silos and fragmented information, leading to higher coordination expenses. The IM centralizes and visualizes critical operational data in real time, enabling faster, data-driven decisions. Alexander, CEO of a German consulting firm, highlighted this advantage, noting that the IM helps overcome coordination issues by creating seamless transitions between different interfaces.

The acceleration of go-to-market processes is another key aspect of value creation, allowing companies to respond more quickly to changing market conditions than their competitors (Edward). By shifting their planning, development, and production processes from linear workflows to agile and dynamically adaptable IM-based planning, companies can realize positive effects for value creation as decision-making becomes faster and more accurate due to enhanced data visualization and comprehensive access to all relevant information (Robert). In this way, companies can develop a competitive advantage over their rivals. Olivia summarized the advantages of the IM as follows: "We're faster and we're cheaper."

Beyond operational improvements, the IM enables companies to *capture value* through new revenue streams. By gaining a holistic view of data and information, companies can use AI-driven applications to extract value from these data, identify emerging trends and developments, and strategically align their offerings. This capability helps companies identify specific customer needs and anticipate market demands (James). As a result, companies can offer subscription-based simulation services, remote support, and virtual product configurations, enabling customers to interact with and customize solutions in the IM. In addition, Michael emphasized that paid consulting is an additional revenue opportunity, stating that companies can charge for the service to "delve deeper into a specific customer problem" and provide tailored solutions.

Moreover, the IM enables the development of more customizable and customer-centric product and service solutions, contributing to *value enhancement*. A key driver of this enhancement is the collaborative exchange of knowledge and expertise in the IM, which facilitates real-time communication between internal and external actors across different departments, companies, and geographic locations (Ben). As these actors come together and collaborate, improved product solutions, enhanced services, and optimized processes emerge (Erik). Therefore, IM-based interactions remove communication barriers and help actors improve their overall products and services more effectively.

In addition, as described in Section 4.1.1, the democratization of data and knowledge in the IM increases overall product understanding and engagement. By providing actors with direct access to real-time insights, interactive product visualizations, and DT-based data, companies can improve the alignment of their offerings with customer expectations. This transparency fosters stronger collaboration between buyers and suppliers, enabling the creation of highly tailored solutions (Tom).

Moreover, the operations & maintenance application area plays a crucial role in the *value protection* of products and services. By ensuring that digital and physical environments remain continuously synchronized, companies can identify inefficiencies, such as increased resource consumption, and implement immediate corrective actions (George). Furthermore, AI-driven predictive analytics enable companies to anticipate maintenance needs proactively, allowing for timely interventions

Table 2
Application areas and their value contribution.

	Value creation	Value capture	Value enhancement	Value protection
Design & engineering	X	X	X	
Process & workflow management	X	X	X	
Commissioning & manufacturing	X	X		
Training & knowledge transfer		X	X	
Customer engagement & marketing		X		
Operations & maintenance		X		X

that prevent equipment degradation and suboptimal performance.

By leveraging real-time monitoring, companies can ensure that production systems maintain consistent output quality, to detect deviations and address them immediately. This proactive approach reduces downtime, extends asset life cycles, and optimizes overall operational efficiency. However, the foundation of this process is real-time, bidirectional information flow, which ensures that data-driven insights from the digital environment can directly influence and optimize physical operations (Jack).

5. Discussion

5.1. Theoretical implications

The concept of the IM builds on various digital technologies and integrates them into a digital landscape, moving beyond abstract promises of digital transformation. It holds potential as a collaborative ecosystem that can drive both innovation and operational efficiency, thereby reflecting its dual character—being incremental in technological development and disruptive in organizational transformation. However, empirical research remains scarce, revealing significant gaps in scholarly understanding of its conceptual foundations, application areas, and business value (Bamberger et al., 2025; Barrera & Shah, 2023; Dwivedi et al., 2022).

Given the novelty of the IM and the limited empirical understanding of its application in B2B environments, we adopt an exploratory, theory-building approach in our study. To help close the research gap, we present an empirically derived IM Canvas. This layered architecture demonstrates that successful implementation requires more than the isolated adoption of technologies; it also requires an integrated orchestration of interdependent applications across seven interconnected layers. With the IM Canvas, we build on and extend previous technical conceptualizations (e.g., Guo et al., 2024) and offer a more refined, data-driven perspective of the IM. This perspective also demonstrates that the IM is a logical continuation of existing digitalization trends while opening up new avenues for industrial transformation.

The IM Canvas establishes a comprehensive understanding of the interplay between actors, resources, and activities, which form the conceptual backbone of our model. By embedding the perspective of the A–R–A framework, the IM Canvas conceptualizes the IM as a business ecosystem in which physical and digital elements increasingly converge. The integration of actors, resources, and activities enables a rethinking of traditional network theories in industrial marketing and offers new insights into how these interdependencies evolve in data-driven environments. Thus, the IM Canvas not only is an analytical structuring tool but also represents an ecosystem-oriented theoretical starting point for advancing existing theories such as resource network theory. As such, it can serve as a basis for future conceptual and empirical research examining how the IM transforms industrial value-creation networks.

Moreover, the IM Canvas reveals that the IM should not be conceived of as a mere extension of conventional Metaverse concepts, such as those found in gaming or healthcare contexts. Whereas some researchers (e.g., Lowry et al., 2025) argue for a unified understanding of the Metaverse across domains, our interview data suggest a fundamentally different interpretation. Rather than focusing on immersive experiences or user perceptions of core elements of consumer-oriented Metaverse applications (e.g., Dwinggo Samala et al., 2023), the IM centers on the virtualization of physical organizational processes, planning routines, and collaborative value mechanisms. More important, instead of focusing primarily on specific user groups, such as customers or end users, it involves both internal and external stakeholders. Consequently, the present article helps expand understanding of the Metaverse by defining the IM as an ecosystem that extends beyond isolated technologies to enable more complex forms of collaboration and coordination in industrial contexts.

By identifying six distinct application areas and linking them to four value dimensions—creation, capture, enhancement, and protection—this study provides a structured lens for examining how value is generated in the IM. Our findings resonate with contemporary perspectives in industrial marketing literature that conceptualize value not as a static, firm-generated outcome but as a dynamic, multi-dimensional construct shaped by network interactions (Kindström & Kowalkowski, 2014; Perks et al., 2017; Storbacka, 2011). In industrial contexts, value extends beyond simple creation to include the capture of benefits by stakeholders (*actors*), the safeguarding of intellectual property (*resources*), and the continuous enhancement of processes and offerings (*activities*) (Anderson et al., 1994; Håkansson & Snehota, 1995). Drawing on the A–R–A framework, we demonstrate that value derives from the coordinated interaction of internal and external actors who mobilize resources to perform activities within the digital-industrial environment. This paradigm shift signifies a transition from conventional manufacturing firms to ecosystem-oriented organizations, with value collectively constructed through intricate, interdisciplinary networks (Jacobides et al., 2018; Pagani & Pardo, 2017; Pardo et al., 2022). In doing so, it highlights the disruptive organizational and processual transformations that stem from IM-based collaborations, in which immersive, cross-organizational interactions challenge conventional coordination mechanisms and thereby necessitate a rethinking of established theories and conceptual vocabularies.

In addition, our study aims to provide a more refined understanding of digital technologies and their transformative potential for processes and workflows. In line with Ritter and Pedersen's (2022, p. 188) observation that "extant literature on industrial marketing has not yet realized the full potential of digitization and digitalization in industrial relationships," we explore ways the IM can facilitate this realization. Our IM conceptualization builds on this observation by redefining how business actors interact, collaborate and co-create value across organizational boundaries. By identifying 16 use cases in six application areas, we demonstrate that the IM is not limited to process optimization; it also accounts for the critical role of various stakeholders within industrial ecosystems. Furthermore, the findings show that the IM evolves along two trajectories. While it follows an incremental path by embedding existing technologies and applications into a broader ecosystem, its disruptive impact depends on bidirectional data flows that enable deep integration, real-time feedback, and novel forms of coordination within and across organizational boundaries.

We also add to the emerging discourse on data quality and accessibility, both critical enablers of digitalization (Wang & Strong, 1996). Our contribution advances this discussion by showing that the IM relies not only on customer-related data but also on the integration of multiple, heterogeneous data types and sources. In particular, it requires the integration of internal product and process data (e.g., bills of materials, CAD files), external supplier data (e.g., logistics information), and customer data (e.g., consumption information) to unlock the potential of the IM. This necessity increases the need for a clearly defined data governance framework on data ownership, authentication, and accountability that provides the essential structures and policies for managing data assets across organizational boundaries (Akter et al., 2022; Weber et al., 2009). Such a framework must define clear rules on how companies exchange data streams, establish obligations for data handling, and define mechanisms to safeguard against potential misuse (Khatri & Brown, 2010). Furthermore, given the inherently cross-organizational nature of the IM, legal frameworks must also be considered and observed—particularly the European Union Data Act, which came into force in 2023 and sets important standards for data access and usage rights (Eckardt & Kerber, 2024).

Furthermore, by highlighting the dual nature of the IM, this article sheds light on the role of organizational ambidexterity in the context of capability research (O'Reilly III & Tushman, 2008). On the one hand, the application areas demonstrate how companies leverage the IM to enhance efficiency by process optimization (*exploitation*); on the other hand, the IM's cross-departmental and cross-organizational collaboration capabilities enable firms to pursue new opportunities, such as developing innovative products and services (*exploration*). This duality establishes the IM as a technological and organizational concept that supports organizational ambidexterity. Moreover, our findings suggest that ambidexterity in the IM extends from the firm to the ecosystem level, on which multiple stakeholders jointly balance between operations and innovation (Wareham et al., 2014). Thus, the IM is an environment that enables collective ambidexterity, fostering efficiency gains and collaborative innovation within digitally connected industrial networks. This perspective also responds to Kauppila's (2010) call for research on ambidexterity in diverse organizational contexts, offering novel insights into its application in emerging digital-industrial ecosystems.

Taken together, these insights reveal that the IM should not be perceived solely as a continuation of existing digitalization efforts or as a disruptive break with established practices; instead, it incorporates both. It advances industrial digitalization incrementally by embedding established technologies into layered ecosystems and thereby supports the human-centered vision of Industry 5.0. At the same time, its disruptive potential emerges when bidirectional data flows enable deep integration between virtual and physical worlds, allowing real-time feedback and new forms of coordination. Acknowledging this duality enriches theoretical understanding of digital transformation in industrial ecosystems and positions the IM as both an evolutionary and a transformative force.

5.2. Managerial implications

The insights from the expert interviews yield several implications that provide practical guidance for organizations aiming to adopt an IM. First, data stored in the data infrastructure layer and leveraged in the processing layer form the essential foundation of the IM, as they enable the functionality of higher layers. These include both standardized and non-standardized data from internal (e.g., DT datasets) and external (e.g., production data from suppliers) sources. Organizations face the critical challenge of harmonizing these various data streams and integrating them into a robust infrastructure; this requires breaking down existing data silos. A unified data lake infrastructure can then provide the foundation for the upper layers of the IM Canvas. At the same time, ensuring real-time, bidirectional data flows is essential to maintain the system's responsiveness and adaptability. Within this context, the IM Canvas provides a clear roadmap for structuring and systematically implementing IM initiatives. It offers decision-makers a holistic view of actors, resources, and activities, enabling effective planning and management of the transformation process.

Second, managers should shift their focus from individual use cases or technologies to the development of an all-encompassing IM strategy. Doing so requires defining an overarching vision for how the company will incorporate the IM into its corporate strategy. This strategy needs to encompass actors, resources, and activities and to establish clear guidelines for inter-organizational data exchange and performance metrics to evaluate success. Simultaneously, companies must align already-existing technologies, such as AR and VR solutions, with the overall IM strategy to ensure coherence. To achieve this, they need to proactively engage in these strategic considerations, ensuring that senior management levels take ownership of the topic and integrate it into the company's long-term agenda.

Third, companies should view emerging regulatory frameworks not as compliance obligations but as strategic opportunities to align internal processes with an IM vision. Transparent data sharing, traceability, and life-cycle documentation requirements can serve as drivers for digital transformation. To ensure successful integration, managers should translate regulatory requirements into a structured implementation roadmap, embedding them within the broader digitalization strategy. Doing so would enable organizations to fulfill regulatory mandates and unlock additional value through improved transparency and efficiency.

Finally, organizations should put particular emphasis on human centricity, as emphasized in the Industry 5.0 paradigm (Longo et al., 2020). Any implementation of IM technologies should be accompanied by comprehensive change management initiatives to foster collaboration between users and systems. Furthermore, companies should actively mitigate potential risks such as technostress and barriers to technology adoption, ensuring that employees are prepared to navigate this new stage of digital transformation successfully. At the same time, ethical considerations, such as workforce replacement and the broader societal impact of automation, must be taken into account to ensure responsible and sustainable implementation.

5.3. Limitations and future research directions

While this study provides valuable insights into the concept of the IM, several limitations must be noted. A key limitation lies in the qualitative research design, which limits the generalizability of our findings. Although we attempted to mitigate this by selecting a heterogeneous set of cases across industries and roles (see Appendix A) and ensuring comprehensive data collection by adding interviews until theoretical saturation was reached, we recommend that future research investigate specific industries to explore sectoral-specific challenges. Consequently, future research could concentrate on the identification of adoption barriers and drivers across diverse sectors, including manufacturing and logistics.

Another limitation pertains to the study's scope regarding actor relationships in the IM. Although our findings provide initial insights into the interaction dynamics between actors in the IM, the complexity of these relationships was outside the scope of the study. Business relationships typically evolve through multiple phases, each influencing actor behavior (Pagani & Pardo, 2017; Purmonen et al., 2023). Future research could investigate how dyadic and multi-actor exchange relationships develop in an IM environment and whether new patterns of collaboration emerge. Research could also explore the extent to which this novel concept may also influence the emergence and shaping of industrial markets.

The conceptualized IM Canvas provides a roadmap for how companies can leverage the IM to create value. However, important questions remain about how firms can successfully adopt the IM in practice. Future research could address this gap by investigating the key success drivers and barriers that shape the adoption process and how these elements influence the effective implementation and use of the IM. Premised on such research, and given the lack of a single approach to IM implementation and use in companies, a taxonomical perspective on IM could be highly valuable. For example, industry, firm size, and other factors determine the role of the IM in each individual company. Future research could provide an empirically grounded typology that could contribute important theoretical as well as managerial insights.

Furthermore, this study identifies four distinct types of value, but it does not assess their actual impact on business performance or corporate value creation. While our findings indicate potential benefits for operational process management—highlighting effects on value creation, capture, enhancement, and protection—we did not quantify these improvements. Future studies could adopt empirical research methods to evaluate these contributions. We therefore encourage scholars to develop robust metrics for evaluating the impact of the IM at the firm level, particularly with respect to operational efficiency and long-term value co-creation.

Beyond its business applications, the broader societal and environmental implications of the IM are still largely unexplored. Future research could investigate whether the IM fosters more sustainable business practices, such as reducing business travel through virtual collaboration, or whether it inadvertently increases the ecological footprint given the high energy demands of data processing, visualization, and immersive virtual interactions. Such studies would provide valuable insights into the trade-offs between digital innovation and environmental sustainability.

Last, future research could address the potential downsides (or dark sides) of the IM. Existing studies on emerging technologies (e.g., Gligor et al., 2021; Ivens et al., 2024; Papagiannidis et al., 2023) such as AI and blockchain highlight risks related to data misuse, fraudulent activities, and alienation effects in business relationships. These concerns are particularly important in the context of increasingly ecosystem-driven business models, in which the growing decentralization and physical separation of stakeholders may further foster challenges related to trust, data security, and governance. Therefore, future research should address this research gap to close this blind spot.

CRediT authorship contribution statement

Dominik A. Henkel: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Björn S. Ivens:** Writing – original draft, Supervision, Formal analysis, Data curation, Conceptualization.

Appendix A. Interview sample

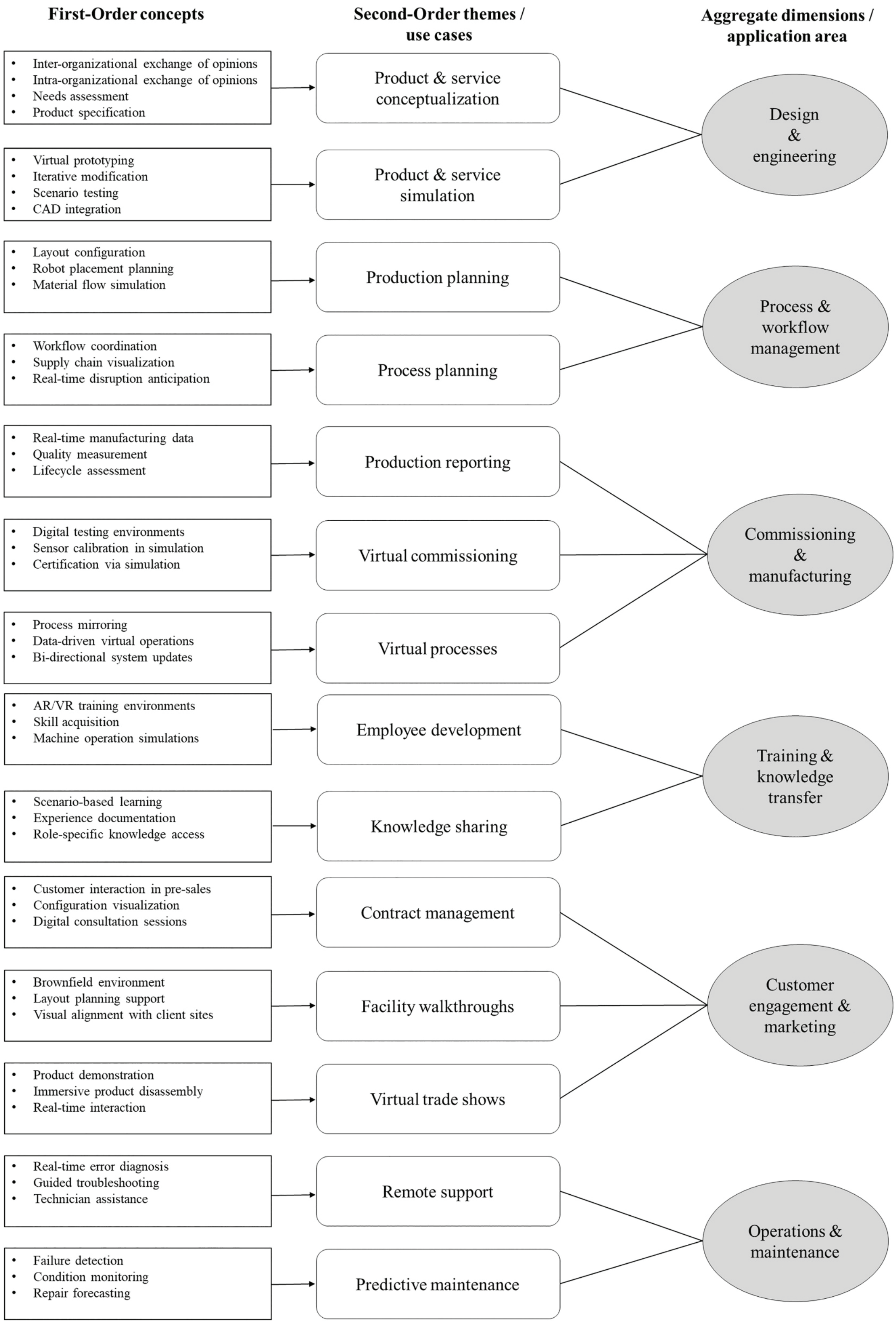
Identifier	Gender, age	Industrial sector	Role, experience	Interview duration	Company affiliation
John	Male, 30s	IT and services	Consultant, ≈2 years	70 min.	C1
Alexander	Male, 40s	Management and technology consulting	CEO, ≈16 years	47 min.	C2
Christoph	Male, 50s	IT and services	CEO, ≈5 years	85 min.	C3
Susan	Female, 30s	Manufacturing industries	IT project manager, ≈8 years	46 min.	C4
Michael	Male, 30s	Mechanical engineering	Senior expert R&D, ≈14 years	54 min.	C5
Robert	Male, 40s	Mechanical engineering	Head of technology, ≈11 years	40 min.	C6
Sally	Female, 30s	IT and services	Product owner, ≈6 years	46 min.	C7
Olivia	Female, 20s	Automotive manufacturing	Metaverse developer, ≈1 year	46 min.	C8
Jack	Male, 50s	IT and services	Project lead smart factory, ≈9 years	85 min.	C7
Linda	Female, 40s	Mechanical engineering	Senior expert digitization, ≈25 years	61 min.	C6
Noah	Male, 30s	Automotive manufacturing	R&D, ≈3 years	66 min.	C8
Victor	Male, 40s	IT and services	CEO, ≈18 years	49 min.	C9
Ben	Male, 30s	Mechanical engineering	R&D, ≈9 years	50 min.	C10
Harry	Male, 50s	Transportation and logistics	Internal consulting, ≈22 years	60 min.	C11
Paul	Male, 50s	IT and services	CEO, ≈10 years	127 min.	C12
James	Male, 50s	Mechanical engineering	Vice president digital factory, ≈14 years	51 min.	C13
Daniel	Male, 50s	Energy and power generation	Innovation manager, ≈10 years	44 min.	C14
Tom	Male, 30s	Manufacturing industries	IT project manager, ≈6 years	56 min.	C15
Anna	Female, 30s	Manufacturing industries	Business development, ≈2 years	52 min.	C16
Erik	Male, 50s	IT and services	Innovation manager, ≈7 years	65 min.	C17
George	Male, 40s	Transportation and logistics	Team lead innovation management, ≈15 years	65 min.	C18
Samuel	Male, 40s	Transportation and logistics	Team lead lifecycle management, ≈14 years	51 min.	C18
Edward	Male, 30s	IT and services	Sales director, ≈6 years	57 min.	C19
Robin	Male, 40s	Healthcare and medical technology	Change manager, ≈11 years	72 min.	C20
William	Male, 40s	Healthcare and medical technology	Business development, ≈23 years	58 min.	C20

Appendix B. Case description

Identifier	Industrial sector	Headquarter	Company size[a]
C1	IT and services	United States	Small
C2	Management and technology consulting	Germany	Small
C3	IT and services	Malta	Small
C4	Manufacturing industries	Germany	Large
C5	Mechanical engineering	Germany	Large
C6	Mechanical engineering	Switzerland	Large
C7	IT and services	Germany	Large
C8	Automotive manufacturing	Germany	Large
C9	IT and services	Germany	Small
C10	Mechanical engineering	Germany	Large
C11	Transportation and logistics	Germany	Large
C12	IT and services	Switzerland	Small
C13	Mechanical engineering	Germany	Large
C14	Energy and power generation	Germany	Large
C15	Manufacturing industries	Germany	Large
C16	Manufacturing industries	Germany	Large
C17	IT and services	Germany	Medium-sized
C18	Transportation and logistics	Switzerland	Large
C19	IT and services	Germany	Medium-sized
C20	Healthcare and medical technology	Germany	Large

[a] For number of employees, large means more than 249 employees or turnover of more than €50 million, medium-sized means up to 249 employees and turnover of up to €50 million, and small means up to 49 employees and turnover of up to €10 million.

Appendix C. Data structure based on Gioia et al. (2013)



Appendix D. Identified themes with frequency and exemplary quotes

Use cases	Frequency of code occurrence	Number of interviews (n = 25)	Representative quotes
Product & service conceptualization	34	17	"People from around the world join a shared virtual scene to discuss ongoing developments and realize where adjustments are needed." (Linda)
Product & service simulation	46	20	"Given the current focus on sustainability and circularity, such scenarios can first be simulated virtually before being tested and implemented in the real world." (Ben)
Production planning	31	19	"We use the [DT] to simulate future workshop capacities and layout requirements long before actual investments are made. This helps us better plan our production and maintenance infrastructure." (Samuel)
Process planning	35	20	"They also used it to optimize workflows – identifying what the operator needs, where and how often, and how best to arrange everything accordingly." (Noah)
Production reporting	17	10	"Life-cycle assessment means that I continuously know – for both the manufactured product and the production process – what resources are being consumed and which materials are required." (Linda)
Virtual commissioning	7	6	"In certification use cases, you have to demonstrate specific capabilities – for example, detecting an oncoming vehicle with varying speed, while your own speed also changes. You need to prove recognition within a defined distance. So how do you do that? Our test track … is mapped with millimeter precision and fully available in Omniverse. This allows relatively straightforward simulation and calculation." (Noah)
Virtual processes	20	12	"These models are, of course, mirrored with real-world data – we receive information from reality and feed it back into the virtual environment to assess how accurate the model is." (Jack)
Employee development	21	15	"The big advantage is that we can train people more effectively." (John)
Knowledge sharing	9	8	"Because if I'm dealing with highly specialized components, I also need highly specialized engineers to work on them. And given the shortage of skilled workers and demographic trends, this expertise is often scarce. I believe immersive technologies can help provide much more effective guidance for repair, installation, and even maintenance tasks." (Harry)
Contract management	6	5	"This is primarily about finally establishing a consolidated external touchpoint for our customers." (Anna)
Facility walk-throughs	10	7	"Many pilot projects … aim to virtualize parts of the factory – for example, to carry out planning and restructuring measures, including virtual facility walk-throughs, in order to make this possible." (Sally)
Virtual trade shows	9	6	"The most prominent topics in this context were marketing and product visualization." (Ben)
Remote support	15	12	"Our use cases are increasingly moving toward the [IM] on the shop floor – for example, by supporting employees through immersive technologies and enabling remote assistance." (Edward)
Predictive maintenance	11	10	"If production data is collected within the Metaverse – for example via sensor-equipped systems – then applying predictive maintenance becomes both useful and valuable." (Linda)

Data availability

Data will be made available on request.

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