Data-driven Services and Servitization in Manufacturing: Innovation, Engineering, Transformation, and Management

Christian Koldewey
Paderborn University
christian.koldewey@hni.upb.de

Martin Ebel
Ruhr-University Bochum
martin.ebel@isse.rub.de

Johannes Winter
L3S Research Center & acatech
winter@l3s.de

Roman Dumitrescu
Paderborn U. & Fraunhofer IEM
roman.dumitrescu@hni.upb.de

Manufacturing is a mainstay of the global economy and a driver of its prosperity. However, the sector is also confronted with a myriad of challenges. As a large contributor to greenhouse gas emissions worldwide (United Nations, 2023), the manufacturing industry faces transformational changes in its production processes and business models. Coordinated actions across value chains are needed to drive net zero goals (IPCC, 2023), and technological opportunities, especially artificial intelligence, need to be uncovered for competitive advantages.

Digital servitization is a framework that can incorporate and leverage solutions for those challenges. It describes the emerging interplay of digitalization and servitization (Kohtamäki et al., 2022). The core of digital servitization is the transformational shift from a product-centric to a service-centric business model enabled by digital technologies (Sklyar et al., 2019). Research suggests that a high degree of digitalization and high degrees of service-centricity in conjunction benefit a firm's financial performance (Kohtamäki, Parida, et al., 2020).

Digital technologies like the Industrial Internet of Things (IIoT) enable manufacturing companies to introduce smart, connected products and, e.g., gather data from the operations phase (Suppatvech et al., 2019). Analyzing such data and exploiting gathered information is changing competition, value chains, and service delivery (Porter & Heppelmann, 2014, 2015). Besides product data, a plethora of additional heterogeneous data sources can be exploited (Opresnik & Taisch, 2015).

Companies attempt to benefit from these developments by employing innovative value propositions – namely digital services (Favoretto et al., 2022), smart services (Beverungen et al., 2017; Koldewey et al., 2021) or data-driven services (Schüritz et al., 2017). The aim of such services can be to support the circular economy, to make processes more autonomous and efficient, to make machine failures and inefficiencies more predictable, to be able to offer proactive service and to hedge possible risks. They, hence, can be utilized to improve frontend operations, backend operations, or as a means to introduce new digitally-enabled offerings (Coreynen et al., 2017).

These kinds of services are often part of larger emerging (smart) service systems (Beverungen et al., 2019) and differ strongly from established businesses in manufacturing (Kohtamäki et al., 2019). They, hence, prove to be a socio-technical challenge, i.e., humans, organizations, and technologies must be considered integrative, and established firms might be confronted with occurring paradoxes when transforming (Kohtamäki, Einola & Rabetino, 2020).

Engaging in digital servitization is not trivial for manufacturing companies, numerous barriers emerge in the process (Azkan et al., 2023; Klein et al., 2018; Marcon et al., 2019; Peillon & Dubruc, 2019), e.g., since a digital service business is significantly different from their established product and service businesses (e.g., spare parts) (Kowalkowski et al., 2022; Schüritz et al., 2017). The product is no longer a means to an end. The smart services developed around the product enhance it, making it unique and valuable (Kagermann & Winter, 2018; Winter, 2023). Manufacturing companies must consider not only technology but also the company and its' ecosystem (Kowalkowski et al., 2022). Many research questions regarding digital servitization remain open (Favoretto et al., 2022), and companies are seeking answers to their strategic needs.

With this minitrack that we offer for the third time now, we strive to add to the body of knowledge and to provide managers and engineers with tangible support. Seven papers were submitted to the minitrack, with four being accepted for publication after the peer

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review (acceptance rate 57,1%). The papers address multiple facets of digital servitization, starting with innovation, organizational aspects, and technical perspectives. Compared to the last years, the minitrack offers a stronger technical perspective exploring the foundations for digital service offerings.

The first paper by Adler, Ebel, Gebauer, and Rathi is titled *"Design Principles for Product-Service-Software-System Innovation for Healthcare Manufacturers."* In their paper, the authors conducted a comprehensive interview study and developed six design principles for Product-Service-Software-Systems (PSSS) offerings in healthcare. The design principles are demonstrated in an organizational context to design features for a PSSS. The study allows managers in healthcare to understand service design and innovation, evaluate their existing, and create new offerings (Adler et al., 2024).

Koldewey and colleagues present a paper titled *"Exploring Capabilities for the Smart Service Transformation in Manufacturing: Insights from Theory and Practice."* They combine a systematic literature review with an interview study to derive 78 capabilities for transforming a manufacturing company towards a smart service provider. The capabilities were clustered into six dimensions. The results enable practitioners to reflect on their transformation processes and workstreams, identify further potentials, and raise awareness regarding the complexity of the transformation (Koldewey et al., 2024).

The third paper, "AI-Driven Comprehension of Autonomous Construction Equipment Behavior for Improved PSS Development," was written by Aeddula, Ruvald, Wall, and Larsson. They used a development case from the mining industry and investigated a fleet of autonomous haulers using deep learning-based object detection and computer vision to understand their behavior. For practitioners, understanding the system behavior in the early development phases of a PSS could provide valuable insights that allow them to optimize the system (Aeddula et al., 2024).

The last paper, "From Scarcity to Abundance: Expansion Manufacturing Data through Limited Defect Images," was written by Moon, Yang, Park, and Jeong. It provides an approach to expand training data sets for deep learning approaches in manufacturing. Generative artificial intelligence (Stable Diffusion, LoRA, and BLIP) is used for that. The approach improves AI performance and reduces data collection costs, paving the way for AI-based services in manufacturing (Moon et al., 2024).

We hope you will enjoy the papers and can draw valuable insight from them. We would also like to thank the reviewers for their comprehensive work, which helped the authors further develop their papers.

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