Strong concepts for the selection and introduction of digital platforms

For some time now, digital platforms have been having a transformative effect on the economy and society by enabling the networking of individuals, companies and data in real time. This makes it even more crucial to systematically compare the wide range of offerings already available on the market. However, there is often a lack of adequate literature research to provide a reliable basis for comparison of the relevant platform concepts and thus strengthen the ability of manufacturing companies and other users to make accurate judgements with regard to the selection and introduction of platform technologies.

Marcel Rojahn is a Research Associate at the Chair of Business Information, Processes and Systems at the University of Potsdam. His research focuses on digital platforms in the context of the Industrial Internet of Things (IIoT).

Contact
marcel.rojahn@wi.uni-potsdam.de
lswi.de/lehrstuhl

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Digital Platform Frameworks for Manufacturing Companies

A Review

Marcel Rojahn, University of Potsdam

In recent years, digital platforms have established themselves as a central concept in the IT field. Due to the wide variety of digital platforms available on the market, there is still a need for clear comparison with criteria to enable interested parties to select, change, operate and further develop these platforms. The following paper aims to contribute to the facilitation of this comparison by undertaking a systematic literature review of digital platform frameworks in the context of the Industrial Internet of Things (IIOT) for manufacturing companies and thus providing a basis for a number of potential ways to effectively compare current digital platforms and ecosystems.

Introduction

Digital platforms in companies that utilize the Industrial Internet of Things are becoming increasingly complex and pose operational challenges. Digital platforms have interfaces to various international actors, machinery and other assets, and they exchange information across different leviels of the technical infrastructure. These platforms are constantly being adapted due to dynamic internal and external factors, rendering them a challenge to study [1].

Nonetheless, digital platforms exist in various industries, such as energy, chemicals, transportation and trade, and promote the development of smart products and services in the IIOT context [2]. Research is increasingly focusing on new concepts in software architecture. **Figure 1** shows a concrete architecture concept that includes functional components, web services, service-oriented architectures and in-memory databases and focuses on the application, transport and processing layers [3].

The application layer provides specific applications in the context of the Industrial Internet of Things, while the processing layer manages the storage, analysis and transmission of data, which is facilitated by the transport layer. The business and perception layers are outside the scope of this article. In the perception layer, sensors measure physical parameters, while the business layer is concerned with business models and user privacy [3].

In order to address the current challenges of digital platforms, it is essential to formulate specific research questions. There is a significant gap when comparing platform criteria to meet specific business objectives. This underscores the need for a thorough analysis of criteria [4]. In today's complex digital landscape, organizations face the challenge of evaluating factors such as architecture design, scalability and interface utilization to identify the best platform [5]. This article aims to conduct a systematic literature review on digital platforms within the Industrial Internet of Things for manufacturing companies. A basic understanding of the term and current research directions in the field of digital platforms and digital ecosystems have already been highlighted in a previous paper [6]. The aim of this paper is to show the current comparative possibilities in the field of digital platforms. To this end, the following research question was formulated to serve as a guide for the review process: "What are the current frameworks with criteria in the field of digital platform solutions in the context of the Industrial Internet of Things for manufacturing companies?"

To answer this research question, a systematic literature review approach and methodological tools were used. These are described in the following section. The results of the systematic literature review are then explained in the section entitled “summary of framework for industrial digital platforms”. In this section, the current comparative concepts with criteria for digital platforms in the field of the Industrial Internet of Things for manufacturing companies are explained and then summarized.

Approach and Methodological Tools

Before conducting this systematic literature review, a systematic approach tailored to the specific area of information systems was chosen to ensure broad coverage

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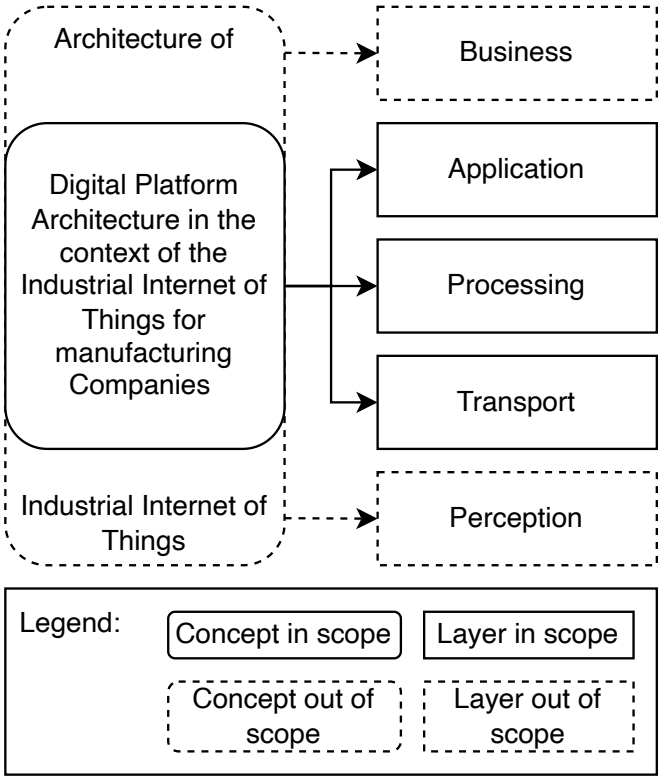


Figure 1: *Digital Platform Architecture in the Industrial Internet of Things according to Sethi and Sarangi [3].*

of current concepts comparing digital platforms within the Industrial Internet of Things. Based on the phases of the review as shown in **Figure 2** [7], the following explains how these phases were applied to the systematic literature review. In the first phase, the problem was defined, narrowed down and specified, leading to the formulation of the research question. The literature was then systematically researched, and checked for relevance, quality and systematization. The results of the literature research were then viewed and evaluated in the context of the formulated research question. In the final phase, the results were processed and presented, with a particular focus on current digital platform comparison concepts within the Industrial Internet of Things for manufacturing companies.

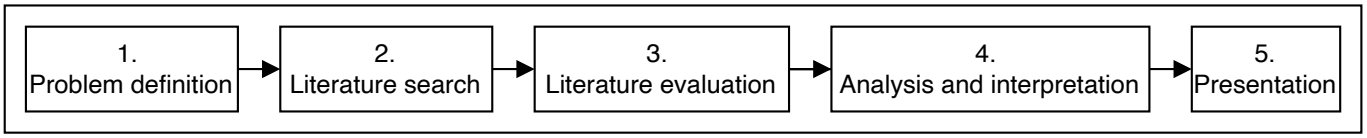
The categories for characterizing reviews in this work were selected and can be seen in **Figure 3**.

The categories used to narrow down the results of this systematic literature review are explained below. Under the category "type", the term "natural language" is selected, which provides verbal explanations and argumentation to enable an analysis of the selected literature. Regarding the methodology of the systematic literature review, the main focus is on the investigation of research findings (empirical results) and methods to answer the research question of the review. To ensure neutrality and transparency, an impartial author perspective is desired and the reasons for the literature selection should be explicitly stated. The scope of the review is limited to representative publications that deal exclusively with current frameworks in the field of digital platforms. A thematic structure is chosen to facilitate the comparative analysis of publications that deal with similar comparison concepts in order to ensure broad comparability within the research areas. Results should be aimed at practitioners and researchers and promote scientific discourse within the research areas. Finally, the "Future research" category should explicitly highlight unresolved issues within the research area and provide insights for the further development of digital platforms.

After narrowing down the characteristics of the results of the systematic literature search, search terms are defined, which can be seen in **Figure 4**.

The categories used to characterize the systematic literature review presented here are explained in more detail below. The main keywords used are "platform" and "ecosystem", while "Industry 4.0", "production" and "manufacturing" are mentioned as general keywords. The literature search is carried out in the Web of Science database, focusing on the subject field (TS), which for the main keywords includes the sections "Title", "Summary", "Author keywords" and "Keywords plus". For the general keywords, the search is carried out in the "Abstract" (AB) section. After applying the specified search terms, 1.627 publications were found in the Web of Science database. In addition, IEEE Xplore was searched for author keywords and abstracts, leading to the identification of 1.511 publications.

Figure 2: *Phases of Research for the Literature Review according to Fettke [7].*



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1. Type		**natural language**		mathematical-statistical	
2. Focus		**research result**	**research method**	theory	experience
3. Goal	Formulation	not explicit		**explicit**	
	Content	**integration**	criticism		**central topics**
4. Perspective		**neutral**		position	
5. Literature	Selection	not explicit		**explicit**	
	Scope	key literature	**representative**	selective	complete
6. Structure		historical	**thematic**		methodical
7. Target Group		general public	**practitioner**	**researchers in general**	**specialized researchers**
8. Future Research		not explicit		**explicit**	

Legend: Characteristic | Category | **Applied category for this paper**

Figure 3: *Category Characterization of Reviews according to Fettke [7].*

The following describes the flow of information through the different phases of the systematic literature review, as shown in **Figure 5**. In particular, only English-language literature published after 2014 was considered, in order to identify the most relevant and recent areas of research related to digital platforms in the Industrial Internet of Things for manufacturing companies. To ensure the integrity of the study, only peer-reviewed publications dealing exclusively with current research on digital platforms in the context of the Industrial Internet of Things for manufacturing are selected. Publications that focus purely on technical, medical, biological and physical topics are excluded from consideration. The distribution across journals with multiple publications underlines the high quality and relevance of the work published in recognized scientific journals such as IEEE Explore, the International Journal of Advanced Manufacturing Technologies, International Journal of Production Research, the International Journal of Computer Integrated Manufacturing and Computers Industrial Engineering.

Figure 4: *Selection of Databases and Search Strings for Review.*

Databases	Search strings	Number of publications
Web of Science	((TS = "platform" OR TS = "ecosystem") AND (AB = "industry" OR AB = "production" OR AB = "manufacturing" OR AB = "factory"))	1.627
IEEE Xplore	(("Author Keywords":platform OR "Author Keywords":ecosystem) AND ("Abstract":industry OR "Abstract":production OR "Abstract":manufacturing OR "Abstract":factory))	1.511

Summary of frameworks for industrial digital platforms

Recent reviews by Ulla et al. [8] and Li et al. [9], among others, shed light on various aspects of comparing digital platforms. The aim of this paper is to provide a basis for understanding the current frameworks in the field of digital platforms. In the following, 23 identified publications are described in more detail.

The article by Ulla et al. [8] builds on previous research that identified 21 critical factors for the evaluation of digital platforms, validated by the Delphi method. By evaluating five well-known digital platforms (Amazon Web Services IoT, Microsoft Azure, Google Cloud IoT, IBM Watson IoT and Oracle IoT) based on their market share, the study shows how these factors can objectively drive platform evaluation for different business applications. Key factors include stability, scalability, pricing model, security, time to market, data analytics, data ownership, protocol support, system performance, interoperability, redundancy, disaster recovery, interface quality, application environment, hybrid cloud support, platform migration, past experience, bandwidth and edge intelligence. A systematic comparison allows companies and researchers to compare their specific requirements with the platform features, simplifying the evaluation process [8].

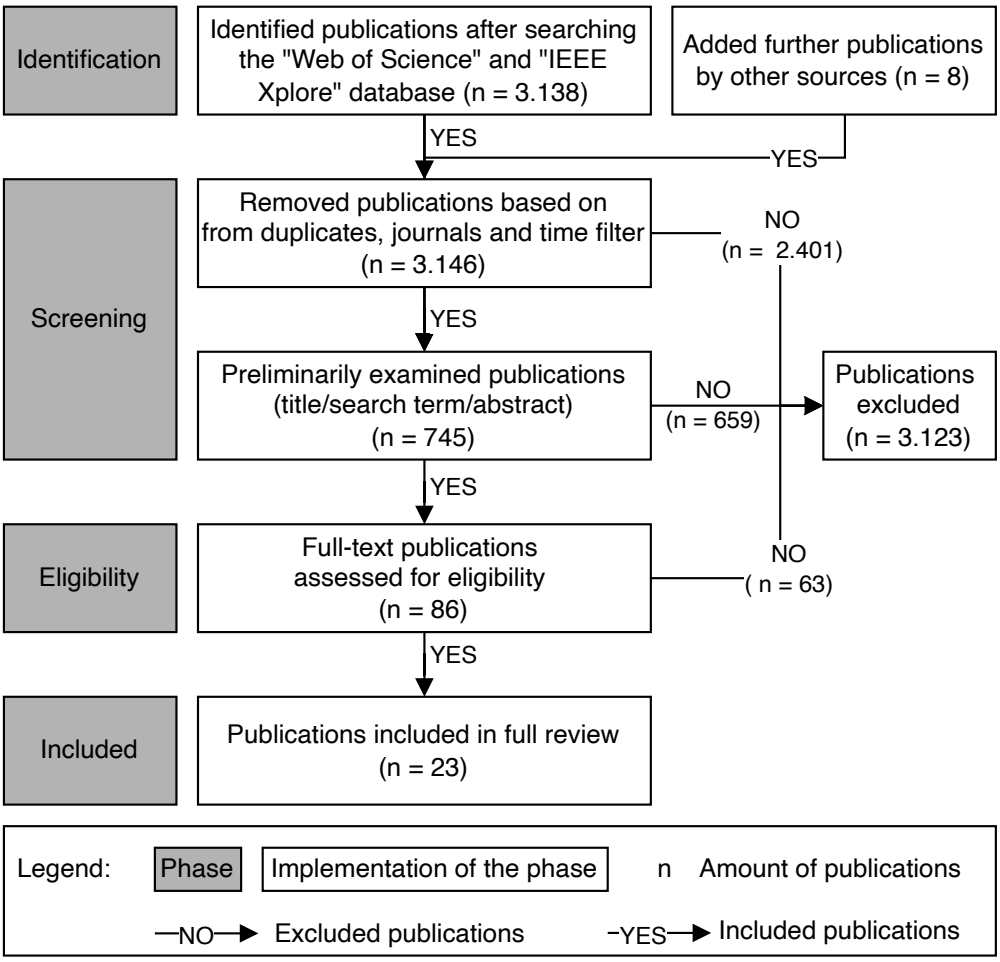

Figure 5: *Flow of Information through the different Phases of the Systematic Review using a Prisma Flow Chart.*

The study by Li et al. [9] presents an evaluation framework for digital platforms. The evaluation framework assesses the use of the digital platform in three areas: Foundation, Key Capability, and Value and Benefits. The evaluation indicators for the key capability of the platform include cloud-based resource management, industrial big data management and mining, microservice deployment and invocation, and industrial application development. These indicators measure the platform's capacity and level in various critical functions. Similarly, the indicators assessing the value and utility of the platform evaluate the scope and value of the applications and the open ecosystem of the platform. These include assessing the platform's user base, profitability, innovation, and openness and sharing of platform data. The study highlights the importance of government-led assessments to measure the development of the information society in different industries and regions to support policy decisions and guidance. Platform stakeholders can use the assessment framework for continuous self-evaluation to facilitate improvement strategies and actions [9].

Benitez et al. examine how innovation ecosystems facilitate the co-creation of Industry 4.0 solutions for small and medium-sized enterprises, tracking the evolution of relationships and value exchange across structural dimensions and lifecycle stages, providing insights for managers on technology development strategies and policymakers on organizing ecosystem evolution [10]. Weking et al. examine the innovation of Industry 4.0 business models by analyzing 32 case studies to develop a taxonomy, identify 13 patterns of Industry 4.0 business models and highlight three super patterns: Integration, Servitization and Expertization. The aim of the exercise is to deepen the understanding of the impact of Industry 4.0 on ecosystems and provide a framework for practitioners to assess Industry 4.0 maturity and capitalize on emerging opportunities [11]. Rajput and Singh aim to identify, analyze, and model Internet of Things enablers crucial for Industry 4.0 success, employing techniques like principal component analysis, interpretive structural modeling, and decision-making trial and evaluation laboratory (DEMATEL), revealing the Internet

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of Things ecosystem and Internet of Things Big Data as the most influential enablers, facilitating effective Industry 4.0 implementation for industry practitioners [12].

Wankhede et al. provide a comparative analysis of the top three cloud platforms—Amazon Web Services IoT, Google Cloud Platform, and Microsoft Azure—focusing on various aspects such as pricing, specifications, support, database, Machine Learning and Artificial Intelligence capabilities, storage, deployment tools, networking, and security, ultimately aiming to assist users in selecting the most suitable cloud platform for their organizational needs [13]. Salami and Yari evaluate platforms like Thingspeak, Xively, and Amazon Web Services IoT based on criteria including data management, monitoring, speed, and latency to assist in selecting the most suitable Platform as a Service solution [14]. Hoffmann et al. address the lack of clarity in workload allocation and platform selection for Internet of Things integration in businesses, particularly in the manufacturing sector, by introducing an Internet of Production reference framework, evaluating 212 digital platforms, and proposing a tailored platform architecture to facilitate intracompany optimizations based on specific needs [15].

Farshidi et al. introduce a decision model for blockchain platform selection, designed to support software-producing organizations in making informed decisions by evaluating functionality, adaptability, and compatibility, as evidenced by its successful application in three real-world case studies [14]. Huo et al. present a survey on the integration of blockchain technology into the Industrial Internet of Things, exploring motivations, benefits, research frameworks, application areas, technical requirements, and future directions to promote innovation and efficiency in manufacturing industries during the Industry 4.0 era [17].

Rojahn and Gronau present a systematic analytical approach to identify and characterize measurable indicators of openness in digital platforms, offering a comprehensive procedure for analysis, categorization, and evaluation of relevant indicators throughout the launch-to-maturity transition [18]. Ismail et al. address the lack of systematic evaluation criteria for digital platforms by developing a performance evaluation framework for open source platforms, specifically assessing scalability and stability through heavy sensor data loads on ThingsBoard and SiteWhere platforms [19].

Moeuf et al. conduct a literature review on Industry 4.0 implementation in small and medium Enterprises, revealing limited adoption beyond Cloud Computing and Internet of Things, particularly in production planning, indicating a prevalent focus on cost-driven initiatives rather than substantial business model transformation [20]. Siqin et al. examine platform operations in the Industry 4.0 era, delineating operational issues and proposing the "3As" framework to guide the adoption of advanced technologies for addressing these challenges and achieving outcomes, thereby contributing to operations and engineering management literature [21].

Ray et al. explore digital platform architectures, addressing the lack of comprehensive architectural knowledge, and aims to enhance understanding of related tools, technologies, and methodologies, offering insights into existing challenges and motivating further research in diverse domains to harness the full potential of digital platforms [22].

Challenges and potential for improvement

This research helps to improve the understanding of the fundamental frameworks for selecting digital IIoT platforms, filling a gap in previous research with regard to the needs of businesses, particularly in the manufacturing sector. The complexity of digital environments emphasizes the importance of comprehensive analyses that consider a variety of criteria. The systematic literature review conducted in this study highlights the considerations for selecting industrial digital platforms. Although this methodological rigor cannot remove all limitations, such as the restriction to the Web of Science and IEEE Xplore databases for the systematic review, the inclusion of additional sources such as Google Scholar and ACM could improve the results by adding new sources. The systematic literature review was based on selected primary, general and specific search terms, however, additional search terms related to Industry 4.0 could provide even more specific results. In practical terms, this research provides insightful contributions. Nevertheless, the research recognizes the need to support the integration principle with technical evidence and real-world validations to confirm their practical utility. Therefore, future research should focus on evaluating the performance and advancement of IIoT platforms, especially refining their suitability for industrial applications. Such efforts promise to improve the practicality and effectiveness of IIoT platforms in real-world industrial scenarios.

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