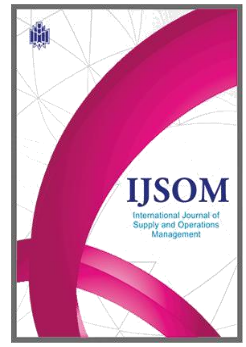
International Journal of Supply and Operations Management

IJSOM

2025, Volume 12, Issue 4, pp. 601-638
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com



Mapping Procurement 4.0: A Heatmap Framework from a Systematic Literature Review

Johannes Dirnberger-Wild [a*], Jörg Schweiger [a], Martin Tschandl [a] and Guido Nassimbeni [b]

[a] *Institute of Industrial Management, Department of Management, University of Applied Sciences JOANNEUM, Kapfenberg, Austria*
[b] *Polytechnic Department of Engineering and Architecture, University of Udine, Udine, Italy*

Abstract

Procurement 4.0 represents a fundamental change in procurement, driven by the adoption of advanced Industry 4.0 technologies. However, despite growing academic interest and recognized benefits, including efficiency gains through process automation, technology implementation faces significant delays in procurement. As a result, opportunities, such as mitigating labor shortages, are underutilized. Persistent barriers, including limited awareness, and uncertainty regarding the most effective technologies, continue to impede progress. Against this backdrop, this paper proposes a conceptual heatmap framework to support the integration of advanced technologies into procurement. By systematically mapping Procurement 4.0 applications across sub-processes, the heatmap provides a comprehensive overview of use cases and reveals existing research gaps. A Systematic Literature Review (SLR), supplemented by thematic, content, and frequency analyses, examines 275 applications categorized by automation potential. The findings reveal dominant technology clusters in the academic debate, yet a persistent gap between research and practice remains. The most extensively studied cluster demonstrates only moderate automation, indicating that research tends to position technology as a decision-support tool rather than a driver of full automation. In this context autonomous procurement remains an aspirational goal rather than an established reality. The introduced heatmap offers researchers a systematic and current synthesis of key applications and unresolved research questions, while providing practitioners with a structured foundation for implementing Procurement 4.0 technologies.

Keywords: Procurement 4.0; Heatmap; Systematic Literature Review; Process Automation.

1. Introduction

The digital revolution in Supply Chain Management (SCM) remains incomplete, with procurement, one of its key processes, highlighting this gap (Waller & Fawcett, 2013). While digitalization has demonstrated the potential to enhance procurement's contribution to business success, a significant discrepancy persists between the transformative capabilities of digital technologies and their actual adoption in practice (Althabatah et al., 2023; Bigliardi et al., 2022; Klünder et al., 2019).

Historically, procurement has evolved significantly, transitioning from an administrative support function to one of strategic importance. Porter's (1979) five forces model underscored the strategic impact of supplier power on firm competitiveness. The need for a strategic orientation of procurement gained recognition with Kraljic's (1983) seminal article "Purchasing must become supply management". Building on this foundation, subsequent scholarship has

*Corresponding author email address: Johannes.Dirnberger@fh-joanneum.at
DOI: 10.22034/ijsom.2025.110710.3328

highlighted procurement's critical contributions to organizational competitiveness.[1] However, recent challenges and developments signal a novel paradigm shift in procurement, driven by a confluence of factors. Alongside the ongoing megatrends of digitalization and sustainability, disruptions such as supply bottlenecks during the COVID-19 pandemic (e.g., semiconductor shortages) and the instability of supply chains caused by geopolitical events like the Russian—Ukrainian war, have impacted the availability of raw materials, technical components, and agricultural products (Ankenbrand et al., 2022; Diekhans, 2023; Köller, 2022; Ma & Chang, 2024).

Emerging technologies, including big data, artificial intelligence (AI), and the Internet of Things (IoT), collectively discussed in academics under the umbrella term Industry 4.0, offer new opportunities for the procurement function beyond traditional e-procurement solutions, which, despite their maturity, still require significant human input (Delke et al., 2023; Jahani et al., 2021). These new technologies can positively impact supply chain performance (Govindan et al., 2022), mitigate risks (Aisyah & Ulkhaq, 2024; Bag, Wood, et al., 2020), and enable seamless and tamper-proof supply chain monitoring (Saberi et al., 2019). A central benefit also lies in relieving employees of operational tasks, thereby allowing them to devote greater attention to strategic activities (Flechsig et al., 2022). This shift is particularly relevant given today's increased supply chain complexity (Hajian Heidary, 2023; Maleki et al., 2024; Molamohamadi & Shah, 2024), ongoing labor shortages and the scarcity of skilled workers in Western industrialized countries, as well as the evolving values of younger generations in the workforce (Maloni et al., 2019; E. S. W. Ng & Johnson, 2015).

In summary, a company's ability to cope with the described procurement challenges is closely linked to its ability to effectively apply advanced Industry 4.0 technologies to procurement. The term "Procurement 4.0" represents the research in this area and is seen as a critical enabler for future-oriented business (Jain et al., 2024). The concept of Procurement 4.0 first appeared in 2016 within the gray literature (Geissbauer et al., 2016; Pellengahr et al., 2016) and was first documented in a Scopus-indexed scientific publication in 2018. Bag et al. (2020) note that Bienhaus and Haddud formally introduced the term "Procurement 4.0" in 2018. Nonetheless, earlier works including those by Batran et al. (2017), along with various pilot studies and white papers, have contributed to understanding the origins of this concept. Since then, Procurement 4.0 has gained traction, but remains in its early stages, with market dynamics still in infancy, underscoring this paper's relevance (Bueno et al., 2024; Jain et al., 2024).

Given the potential benefits of transitioning to Procurement 4.0, it is essential to explore the adoption of advanced technologies in procurement processes, as many organizations encounter challenges in integrating and embedding technology into their operations (Althabatah et al., 2023; Bigliardi et al., 2022). The 2024 PricewaterhouseCoopers Digital Procurement Survey indicates consistently low digitalization rates in procurement, ranging from 36% to 43%, showing no substantial change compared to 2022. Although companies aim to increase digitalization to 69% by 2027, recent trends suggest a slowdown in the pace of digital transformation within procurement. This delay hinders the automation of routine, low-value tasks (Ivalua, 2019), keeping process automation limited. Furthermore, procurement—along with sales—lags behind other functional areas in the use of AI, reflecting a delay in technological advancement (Bakir & Borozan, 2023).

In summary, the digitalization of procurement remains insufficiently developed, with organizational adoption of advanced technologies failing to keep pace with the rapid progress driven by Industry 4.0 (Althabatah et al., 2023; Bigliardi et al., 2022; PricewaterhouseCoopers, 2024). This gap, amplified by evolving technologies and the growing diversity of tools, creates significant challenges in decision-making processes, underscoring the necessity for further research in this domain.

Motivated by these unresolved issues, this study addresses several critical research gaps in the field of procurement digitalization. One significant challenge, as noted by Bienhaus and Haddud (2018), is the uncertainty that companies face in identifying which technologies can effectively support their digital transformation efforts. Althabatah et al. (2023) substantiate this by emphasizing that implementing I4.0 technologies requires considerable investments and presents hurdles such as data security, interoperability, and organizational adaptations, underscoring the need for thorough pre-implementation analysis. Similarly, Bruzzi et al. (2021) highlight only a moderate level of awareness regarding the influence of advanced technologies on procurement management and activities, further complicating adoption strategies. Another key issue, identified by Bueno et al. (2022), is the absence of systematic frameworks for

[1] On this, see for example the article *"The changing role of procurement: the development of professional efficiency"* (Tassabehji & Moorhouse, 2008).

integrating Industry 4.0 concepts into procurement processes, despite a growing body of literature on the topic. While progress is being made, the lack of structured approaches leaves companies without clear pathways to implement these concepts effectively. Moreover, there is a pressing need for holistic solutions that combine multiple advanced technologies into cohesive and integrated bundles to maximize their impact on procurement digitalization. Srai and Lorentz (2019) underscore this requirement, advocating for a broader, more unified approach to applying advanced technologies in procurement. Finally, the literature lacks a uniform definition and clear conceptualization of Procurement 4.0 (Bueno et al., 2022). Scholars have described it in multiple ways: as a strategic function reshaping business models (Alabdali & Salam, 2022), as the digitalization of procurement activities aimed at process automation (Bag, Wood, et al., 2020), as an Industry 4.0 component (Jahani et al., 2021; Nicoletti, 2020) or as a concept extending the paradigm of Industry 4.0 (Althabatah et al., 2025), as an approach to creating new value propositions and integrating data across value chains (Chandrasekara et al., 2020), and as a technology-enabled new procurement role that reconfigures supply chains through process redesign (Jain et al., 2024). Taken together, these views underscore the need to further conceptualize Procurement 4.0 and arrive at a comprehensive definition. To address these gaps, this study explores the current landscape of Procurement 4.0 applications and their technological underpinnings, guided by the following research questions (RQ):

- RQ1: Which conceptual elements characterize Procurement 4.0 in theory, and how can they be synthesized into a comprehensive definition?
- RQ2: What are the Procurement 4.0 applications described in the current literature?
- RQ3: What procurement processes can be supported by technologies or technology bundles, forming an application?

The objective of this paper is to answer the research questions by developing a comprehensive and structured conceptual framework that integrates Procurement 4.0 applications[2] identified in the literature with an extended procurement process model, specifically tailored to the private manufacturing industry. The framework, designed to guide both practitioners and researchers, is presented as a heatmap that uses color coding to visually highlight key clusters of technologies and related concepts, revealing significant patterns (Bojko, 2009; insightsoftware, 2022). It provides a concise overview of critical applications, systematic guidance for integrating advanced technologies, and identifies areas requiring further research. The focus on the private manufacturing industry is based on four considerations:

1. Strategic importance of procurement: Given that material costs typically constitute 50–60% of total expenditures (Barth & Barth, 2013; Zafari & Teuteberg, 2018), procurement is a key driver of business success in the manufacturing industry (Schulte, 2013; Schweiger, 2017; Tschandl & Bäck, 2008).
2. Industry 4.0 origins: The Industry 4.0 concept, closely tied to Procurement 4.0, was originally designed to optimize manufacturing processes (Culot et al., 2020).
3. Unique structural characteristics: Unlike industries such as construction, which feature strong project orientation, limited standardization potential, and lower material costs (approximately 23%), manufacturing has distinct structural requirements (Bosch & Zühlke-Robinet, 2000; Pekrul, 2006).
4. Regulatory environment: The manufacturing sector, being predominantly privately organized, faces fewer regulations compared to the public sector, resulting in unique procurement dynamics (van Weele & Eßig, 2017).

To ensure an unbiased, objective, and evidence-based analysis of the literature, this study follows a Systematic Literature Review (SLR) methodology (Tranfield et al., 2003). While prior studies, such as those by Jahani et al. (2021) and Althabatah et al. (2023), have conducted literature reviews on the application of Industry 4.0 in procurement processes, this review differs in several key aspects. First, it incorporates more recent developments, considering publications up to October 2024; second, it draws from a broader range of literature due to an extended analysis period; third, the methodological approach integrates the SLR with qualitative content and quantitative frequency analysis; finally, by employing an extended procurement process model, this study provides a fine-grained

[2] The term "application" here refers to the use of a technology or technology-related concept in procurement (Cambridge University Press & Assessment, n.d.).

analysis of specific applications, further advancing the understanding of Procurement 4.0 implementation.

Building on the theoretical background on Procurement 4.0 and the effort to establish a comprehensive definition in Section 0, this paper follows the three-stage SLR framework proposed by Tranfield et al. (2003). Section 0 outlines the SLR methodology, detailing phases (I) Planning and (II) Conducting, while Section 0 presents the results corresponding to phase (III) Reporting and dissemination. These findings are further analyzed in Section 0 (Discussion), before concluding remarks and avenues for future research are provided in Section 6.

2. Theoretical Background – The Concept of Procurement 4.0

The literature lacks a uniform definition and a clear conceptualization of Procurement 4.0 (Bueno et al., 2022). Therefore, this section aims to formulate a comprehensive definition by comparing existing definitions from scientific literature and analyzing their key conceptual elements. Based on this analysis, 16 core elements are identified, forming the basis of the proposed Procurement 4.0 definition. These elements are presented in Figure 1, ranked by their frequency of occurrence in the reviewed definitions, as frequency serves as an indicator of their relevance in shaping Procurement 4.0.

The elements provided by Figure 1 along with other noteworthy findings that emerged during this phase of the research are explained in the following.

- Advanced technology use: Procurement 4.0 leverages advanced Industry 4.0 technologies, surpassing conventional e-procurement methods that primarily rely on the Internet or on Supplier Relationship Management (SRM) system functionalities (Herold et al., 2023).
- Data-based: Emphasis is placed on the use and analysis of data as a prerequisite for Procurement 4.0 applications.
- Part of Industry 4.0: Procurement 4.0 originates from the broader Industry 4.0 debate.
- Automation: Process automation is often mentioned as one of the most significant benefits of leveraging advanced (information) technologies.
- Digitalization: Digitalization is the central prerequisite for Procurement 4.0 applications.
- Network: Advanced technologies expand the focus to the entire value network, moving beyond traditional buyer-supplier relationships (Chandrasekara et al., 2020; Nicoletti, 2020).
- Performance (efficiency) improvement: Procurement 4.0 aims to enhance performance, particularly through automation and data integration. This includes streamlined supplier onboarding and improved material planning efficiency via increased visibility (Jahani et al., 2021; Joseph Jerome et al., 2022).
- Transformation: This trait encompasses the change and partial reorganization of the procurement function itself. In this context, Bag et al. (2020), Bruzzi et al. (2019), Trautmann (2021), and Tripathi & Gupta (2021) are even proposing that a "revolutionary" change is underway.
- Value proposition: The emergence of new value propositions, such as those from suppliers, is evident in definitions of Procurement 4.0. For example, Sjödin et al. (2023) state: "This definition acknowledges the strategic role of procurement in digitalization by driving new value propositions from suppliers (…)".
- Cooperation intensity: This aspect highlights that a more structured process, facilitated by technology, enables more intensive and, at the same time, improved cooperation and partnership between buyers and suppliers.
- Real-time information: The exchange and availability of real-time information is emphasized.
- Strategic positioning: This attribute covers the increasingly strategic orientation of procurement in the context of Procurement 4.0.
- Novelty: This attribute refers to the introduction of novel concepts, distinguishing Procurement 4.0 from earlier approaches such as e-Procurement.
- Innovation (effectiveness) increase: The enhancement of innovation capability, often associated with the concept of "innovation scouting," becomes possible through a stronger emphasis on Procurement 4.0 technologies (Pirrone & Meyer, 2021).
- Agility or flexibility: Several studies highlight that Procurement 4.0 promotes responsiveness, resilience, and adaptability, enabling organizations to quickly adjust processes in response to market changes and disruptions.
- Autonomy: "Autonomous" refers to processes carried out without human intervention (Tripathi & Gupta, 2021). In practical terms, this can be achieved, for example, by employing intelligent chatbots that are capable of autonomously negotiating supplier contracts (Flechsig et al., 2022). Accordingly, "autonomy" is included in the definition as the most advanced form of automation. As (Herold et al., 2023) note, autonomization ("machine acts independently") represents the pinnacle of machine intelligence in digital procurement technologies,

following automation ("machine acts – human supports") and augmentation ("human acts – machine supports").

- Other: Additional topics less frequently discussed in Procurement 4.0 definitions include sustainability and transparent procurement (Bueno et al., 2022), as well as circular economy aspects (Bueno et al., 2024). Procurement 4.0 is also recognized as a precursor to Procurement 5.0 (Nicoletti, 2020). Furthermore, the evolving role of buyers is highlighted, exemplified by the transition from buyer to consultant (Pirrone & Meyer, 2021).

Definition component	**Frequency of occurence**	Bueno et al., 2024	Jain et al., 2024	Althabatah et al., 2023	Alabdali & Salam, 2022	Bueno et al., 2022	Govindan et al., 2022	Herold et al., 2022	Joseph Jerome et al., 2022	Taghipour et al., 2022	Flechsig, 2021	Jahani et al., 2021	Lorentz et al., 2021	Pirrone & Meyer, 2021	Sjodin et al., 2021	Trautmann, 2021	Tripathi & Gupta, 2021	Bag et al., 2020a	Bag et al., 2020b	Chandrasekara et al., 2020	Hofmann et al., 2020	Nicoletti, 2020	Bruzzi et al., 2019	Klünder et al., 2019	Srai & Lorentz, 2019	Pause & Blum, 2018
Advanced technology use	19	x	x	x			x	x			x	x	x	x		x	x	x	x	x	x	x	x	x	x	
Data-based	14	x					x		x	x				x	x	x	x	x	x	x	x	x				x
Part of Industry 4.0	14	x	x	x					x			x		x		x	x	x	x			x	x		x	x
Automation	12	x				x			x		x			x		x	x	x	x	x		x		x		
Digitalization	11	x		x									x	x	x			x	x			x		x	x	x
Network	10		x	x						x		x		x	x		x			x		x		x		
Performance (efficiency) improvement	10		x		x		x		x			x		x	x	x						x		x		
Transformation	10				x	x		x			x					x	x	x				x	x	x		
Value proposition	10					x						x		x	x	x		x		x	x	x		x		
Cooperation intensity	9	x		x		x						x		x	x							x		x		x
Real-time information	8	x		x			x			x							x			x		x				x
Novelty	7	x	x			x						x					x			x		x				
Innovation (effectiveness) increase	6				x							x		x	x	x						x				
Strategic positioning	6		x		x						x				x	x	x									
Agility / Flexibility	5					x						x			x	x						x				
Autonomy	4			x		x											x							x		
	Σ	8	6	7	4	7	4	2	4	3	4	9	2	10	9	10	10	7	5	7	3	14	3	8	3	5

Figure 1. Elements with strong reference to Procurement 4.0

As a result of the elaboration summarized in Figure 1 and described above, the following Procurement 4.0 definition can be derived:

Procurement 4.0 is the result of a ***novel transformation*** *into a* ***strategically*** *relevant corporate function enabled by leveraging the* ***technological basis*** *and* ***principles*** *of* ***digitalization*** *and* ***Industry 4.0.*** *It involves performing procurement tasks …*

1. *using* ***data*** *resulting in* ***real-time information****, consequently providing the capability of…*
2. *reacting flexibly to unforeseen events facilitating genuine* ***agility*** *and…*
3. *embracing extensive process* ***automation*** *striving for process* ***autonomization****, resulting in…*
4. *increased intensity of* ***cooperation*** *with partners in the supply* ***network*** *and…*
5. *enhanced* ***performance*** *on the one hand (efficiency) and* ***innovation*** *on the other (effectiveness) manifesting in…*
6. *a new* ***value proposition*** *adding value to the entire organization.*

Following this Procurement 4.0 definition, it should be noted that alternative terms such as "advanced procurement digitalization", "purchasing 4.0", "digital procurement" (Herold et al., 2023), or "transformative procurement" (Althabatah et al., 2025) could be used interchangeably by other authors referring to the integration of advanced digital technologies in procurement processes.

3. Methodology – Planning and Conducting the SLR

This SLR follows the three-stage framework outlined by Tranfield et al. (2003), which has been widely applied in Industry 4.0 and procurement research, as demonstrated by Culot et al. (2020) and Herold et al. (2023). The methodological phases—(I) Planning and (II) Conducting—and the descriptive analysis of the literature corpus are detailed in this section, while the results, corresponding to phase (III) Reporting and dissemination, are presented in Section 0.

3.1. Planning the SLR

Since this SLR delves into the current scientific landscape of Procurement 4.0, Scopus is chosen as the database due to its broad coverage of scientific journals (Mongeon & Paul-Hus, 2016). To identify the literature corpus, the next step is to define the search terms, the search period, and the linking operators that form the search query (Culot et al., 2020; Herold et al., 2023; Selepe et al., 2025). The keywords used in the query, along with their justifications, are presented in Table 1.

Table 1. Structure of the search query

"4.0" related		*Procurement related*	
Keyword	**Comment**	**Keyword**	**Comment**
"industry 4.0"	Procurement 4.0 emerged from the fourth industrial revolution transforming procurement (Bag, Dhamija, et al., 2020).	**procure***	This key word is used to restrict the search to publications relevant to procurement.
"process automation"	Procurement 4.0 emphasizes automating processes to achieve benefits like increased efficiency and more time for strategic tasks,		
"industry 5.0"	The concept "Industry 5.0" emerged during this research alongside Industry 4.0, emphasizing sustainability, human-centricity, and resilience.		
"4.0"	The aim of this keyword is to identify potential procurement-relevant articles with the addition of "4.0" (e.g., "Purchasing 4.0").	**"supply management"**	This key word is used to limit the search to procurement-related publications that have been published
"5.0"	The aim of this keyword is to identify potential procurement-relevant articles with the addition of "5.0" (e.g., "Procurement 5.0" or "Purchasing 5.0").		

"4.0" related		*Procurement related*	
Keyword	**Comment**	**Keyword**	**Comment**
digitalization	Procurement 4.0 is a concept enabled by digitalization (Sjödin et al., 2023),		using the term "supply management."
digitalisation	For the sake of completeness, the British spelling is also considered.	**purchas***	This key word is used to limit the search to procurement-related publications that have been published using the term "purchasing."
digitization	This keyword is used to include publications that distinguish "digitization" from "digitalization" in their definition.		
digitisation	For the sake of completeness, the British spelling is also considered.		

Furthermore, the following inclusion criteria are defined to narrow the identified references:

1. Language: Publications in English or German are considered.
2. Relevance of content: According to the scope of this research, publications addressing procurement in the private manufacturing industry are considered. Furthermore, due to the use of the term "purchas*" in the search query, several B2C papers dealing with the purchasing behavior of consumers are excluded.
3. Journal quality: The SLR prioritizes a scientific perspective on Procurement 4.0 applications. Consequently, all highly relevant scientific articles are included, while potentially relevant publications from the screening phase are considered only if they are published in a Q1 journal.
4. Application description: Papers explicitly describing Procurement 4.0 applications are included in the analysis.
5. Additional paper: Studies not identified in the initial search but deemed relevant during the literature analysis (e.g., through citations) are added to the literature corpus.

The final step of the SLR involves systematically analyzing the content of the identified references (Culot et al., 2020; Herold et al., 2023). Given that the selected publications consist of textual data, a qualitative data analysis approach is employed (Saunders et al., 2019). A key technique in this process is the categorization of qualitative, unstructured text data, enabling the systematic extraction of textual characteristics (Diekmann, 2004; Kuckartz, 2018; Saunders et al., 2019).

To achieve this, coding is used to categorize relevant text passages (Kuckartz, 2018). Each piece of extracted data is analyzed and assigned the same code if it conveys a similar meaning (Saunders et al., 2019). Codes can be defined before analysis, following a theory-driven approach, or developed during analysis in a data-driven manner (Gläser & Laudel, 2006; Saunders et al., 2019). This study follows a hybrid approach, beginning with predefined categories ("application" and "technology") and refining them inductively based on the text (Reichertz, 2016). The process follows thematic analysis, as described by Braun and Clarke (2006) to identify key patterns within the dataset (Saunders et al. 2019).

To enhance transparency and efficiency, thematic analysis is supported by Computer-Assisted Qualitative Data Analysis Software (CAQDAS). CAQDAS tools facilitate systematic coding, cross-document searching, and automated word frequency/combination analysis, thereby improving the rigor and replicability of the research process (MAXQDA, n.d.; Saunders et al., 2019).
For this study, the widely used tool MAXQDA is chosen for its advanced text analysis capabilities and intuitive coding features. MAXQDA exports were further processed in MS Excel to perform customized analyses and visualize key findings.

3.2. Conducting the SLR

The SLR was conducted in accordance with the previously outlined planning phase. Figure 2 presents the applied procedure.

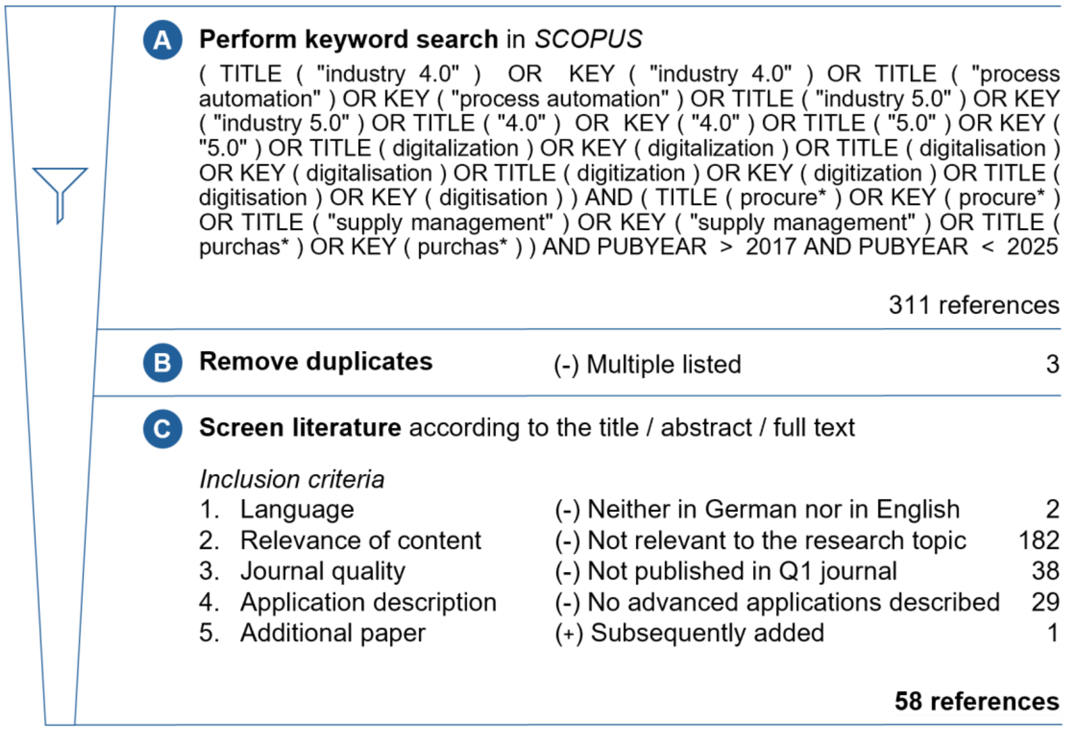


Figure 2. SLR selection funnel

This funnel-shaped approach stems from the inclusion criteria, which resulted in the selection of 58 of the 311 references initially identified through the search query (see Table 2 in Appendix A). These 58 references encompass 275 identified applications, which were systematically documented in a table developed during the qualitative analysis (see Table 3 in Appendix B). As this table is grounded in the literature corpus and will provide the foundation for presenting all subsequent findings, a descriptive analysis of the corpus is offered before the results are discussed.

3.3. Descriptive Analysis

Figure 3 shows that academic journal publications dominate the source composition, providing a strong scholarly foundation, while the inclusion of conference papers—typically reflecting more recent advancements—further enhances the timeliness and relevance of the findings (Islam & Agarwal, 2023).

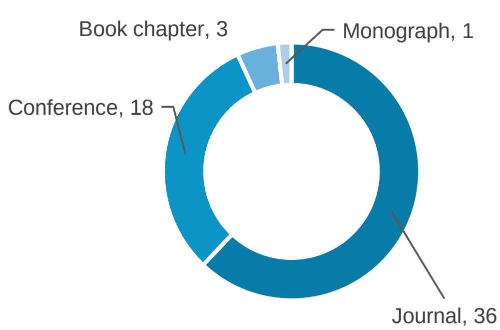


Figure 3. Composition of source types

Regarding the geographic distribution of the included studies (see Figure 4), most originated from Europe (52), followed by Asia (20), as inferred from the authors' institutional affiliations. The remaining continents show comparatively lower representation. At the country level, Germany accounts for the highest number of publications (13), followed by India (8) and the United Kingdom (7). This pattern indicates a strong European orientation of the academic Industry 4.0 debate, which originated in Germany and appears to continue influencing research on Procurement 4.0. Notably, the search strategy was deliberately broad, encompassing the digitalization of procurement in general rather than focusing solely on Industry 4.0 terminology. Despite this broader scope and the qualitative screening of all identified sources, European research remains particularly prominent, suggesting that scholars in this region are especially engaged with practical applications of Procurement 4.0.

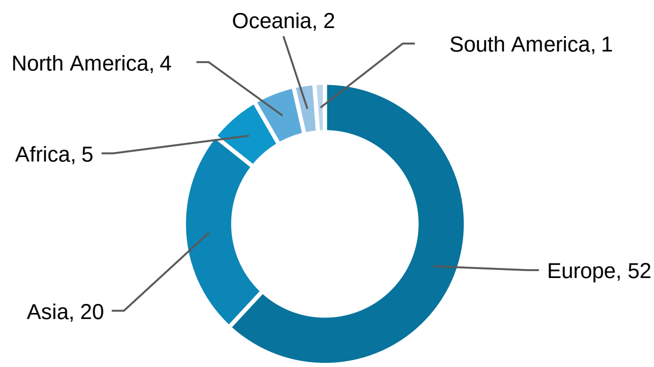


Figure 4. Geographic distribution of the reviewed studies by continent

Several studies employed a combination of research methods (e.g., Sai et al., 2022; Spreitzenbarth et al., 2024). Furthermore, validation through supplementary expert interviews was noteworthy (Komdeur & Ingenbleek, 2021; Miehle et al., 2019; Pirrone & Meyer, 2021). Therefore, Figure 5 presents the primary research design underlying each study. All main methods that appeared only once, such as bibliometric analysis, simulation, or exploratory research using the World Café method, are grouped together under the category "Others."

As this study aimed to capture a wide range of concrete Procurement 4.0 applications, the inclusion of 15 case studies (nine multiple and six single) aligns well with this objective, since they provide in-depth insights into procurement practices facilitated by emerging digital technologies. In studies employing literature reviews as their primary methodological approach, the analysis likewise focuses on specific aspects of Procurement 4.0, including the application of technologies such as blockchain (Govindan et al., 2024) or AI (El Asri & Benhlima, 2022), required dynamic capabilities (Herold et al., 2023), aspects of circularity (Rejeb & Appolloni, 2022), and procurement measurement systems or supply chain performance measurement (Govindan et al., 2022; Pirrone & Meyer, 2021). While these contributions yield valuable insights into particular dimensions of the domain, they do not provide an overarching synthesis of technology applications associated with Procurement 4.0. The present SLR therefore seeks to address this gap by examining the technologies discussed in prior research through the lens of concrete applications identified in the literature, thereby enabling a more comprehensive understanding of how advanced technologies are or can be applied across procurement sub-processes. Surveys, in turn, indicate that quantitative research on the topic is already advancing, suggesting that the field is gradually moving toward theory testing. The presence of several conceptual and design science research papers further illustrates the dynamic and innovative nature of the ongoing discourse on procurement digitalization, in which academic research increasingly contributes to practical innovation. Finally, the fact that only two Delphi studies were identified suggests that additional research is needed to explore the future of Procurement 4.0.

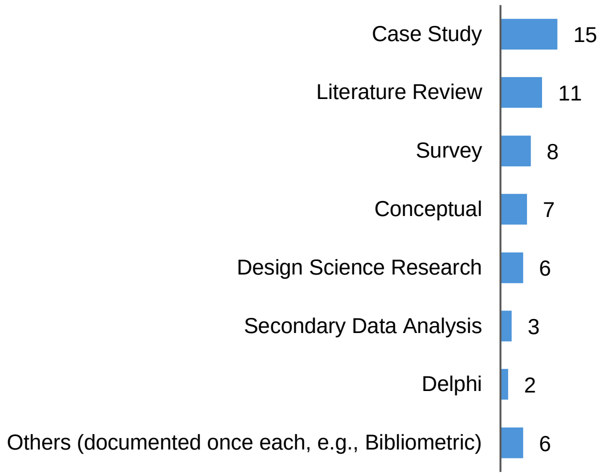


Figure 5. Distribution of research designs in the reviewed literature (n = 58)

4. Results – Conceptual Heatmap Framework for Procurement 4.0 Applications

In accordance with the SLR approach outlined in the previous section, all sources were analyzed to identify Procurement 4.0 applications, which refer to the implementation of advanced digital technologies and technology-related concepts.

During the analysis, these technologies and concepts were coded based on their occurrence in specific procurement applications. Each application was then summarized, documented, and linked to relevant procurement processes and tasks. To structure the analysis, an extended procurement model (see Figure 6) was applied, encompassing Source-to-Contract (S2C), Purchase-to-Pay (P2P), as well as procurement-system-related and nonprocess-related tasks. A similar categorization is found in Bals et al. (2019), Büsch (2013), Schentler (2008), and van Weele and Eßig (2017).

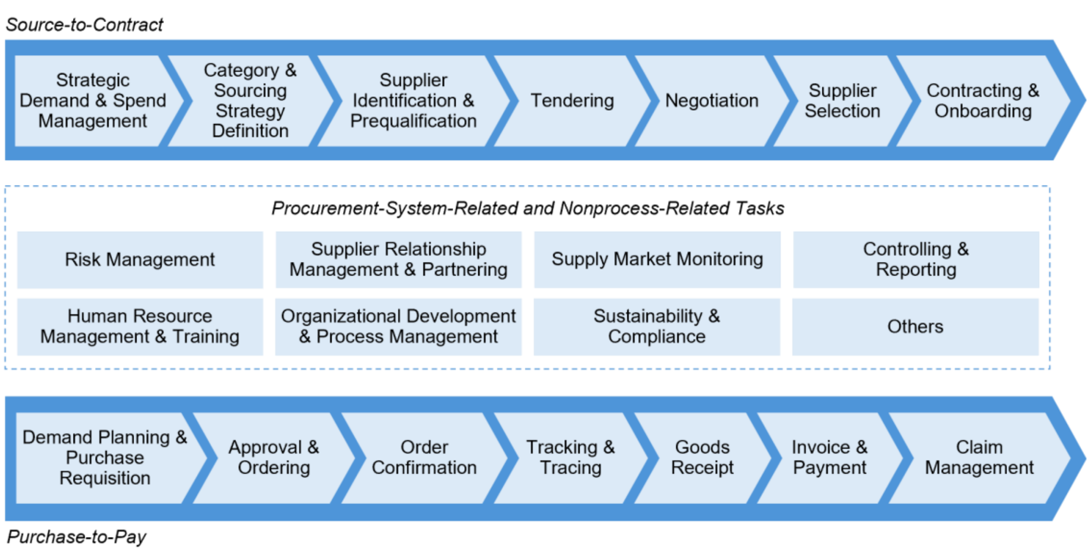


Figure 6. Reference framework of procurement processes and tasks. Adapted from Bals et al. (2019); Büsch (2013); Schentler (2008); and van Weele and Eßig (2017).

The qualitative content analysis identified 275 applications incorporating 100 distinct technologies, related concepts, or solutions, which were referenced 673 times across procurement processes and nonprocess-related task areas. Given the scope and frequency of these references, a systematic prioritization approach was necessary. To this end, the classification follows the 70-20-10 ABC analysis framework (Arangies & van Rensburg, 1995) to identify and categorize the most prevalent technologies and related concepts within the analyzed applications. Applied to this study, 18 out of the 100 identified technologies, related concepts, and solutions account for 70%[3] of total mentions across applications. Figure 7 serves as a dashboard, providing an overview of the distribution of applications across sub-processes and task areas. It also presents the 18 A-category technologies and related concepts, detailing their occurrence frequency, relative and cumulative[4] percentages, which form the basis for the A classification up to 70%. For transparency, all 275 applications, along with the referenced technologies, processes, and task areas, are detailed in Table 3 in Appendix B.

Figure 7 identifies the most frequently discussed technologies or related concepts in Procurement applications, namely blockchain, IoT, AI, and big data. The most addressed applications involve procurement system and nonprocess-related tasks, particularly controlling & reporting and supplier relationship management & partnering.

The applications were further categorized by degree of automation and information content (low, medium, high)[5] during thematic analysis. Additionally, the number of technologies used per application was quantified to assess the significance of technology bundles in Procurement 4.0. Figure 8 summarizes these findings and highlights the significance of process automation in Procurement 4.0, with 76% of applications exhibiting a medium or high degree of automation. Most applications are described in detail, while 14% include only basic components of a use case. In 149 of 275 applications, 2 to 7 technologies are used, emphasizing the need for technology integration.

The most frequently addressed technologies and technology-related concepts are examined in relation to processes and task areas in the Procurement 4.0 application heatmap (Figure 9) to highlight practical potential and identify areas with limited visibility. To facilitate interpretation, the heatmap's structure is first explained, followed by a discussion of the study's findings in the next section.

[3] Of the 534 mentions of 100 technologies or related concepts, 375 refer to these 18.

[4] From the second row onward, cumulative figures are rounded to whole numbers for clarity.

[5] Applications with limited or no evidence of automation were rated as "low," those with implicit indications were rated as "medium," and applications with explicit references, such as "fully automated transmission," were rated as "high." Similarly, information content was assessed on a scale from low to high.

Procurement Processes and Tasks	Number of Applications	%
Source-to-Contract	187	28
Strategic Demand & Spend Management	27	4
Category & Sourcing Strategy Definition	22	3
Supplier Identification & Prequalification	34	5
Tendering	32	5
Negotiation	25	4
Supplier Selection	27	4
Contracting & Onboarding	20	3
Purchase-to-Pay	144	21
Demand Planning & Purchase Requisition	42	6
Approval & Ordering	39	6
Order Confirmation	3	0
Tracking & Tracing	29	4
Goods Receipt	10	1
Invoice & Payment	18	3
Claim Management	3	0
Procurement System and Non-process-related Tasks	342	51
Risk Management	36	5
Human Resource Management & Training	6	1
Supplier Relationship Management & Partnering	57	8
Organizational Development & Process Management	50	7
Supply Market Monitoring	21	3
Sustainability & Compliance	29	4
Controlling & Reporting	80	12
Others	63	9
∑ Intersections of Procurement 4.0 Applications	673	100

#	Technologies and Related Concepts	Fre-quency	Relative share [%]	Cum-ulative [%]
1	blockchain	47	8.8	8,8
2	internet of things	47	8.8	18
3	artificial intelligence	41	7.7	25
4	big data	38	7.1	32
5	real-time information	30	5.6	38
6	cloud computing	23	4.3	42
7	robotic process automation	22	4.1	46
8	platform	22	4.1	51
9	smart contracts	18	3.4	54
10	algorithm	15	2.8	57
11	intelligent process automation	13	2.4	59
12	sensors	11	2.1	61
13	business intelligence	10	1.9	63
14	rfid	8	1.5	65
15	simulation	8	1.5	66
16	e-procurement	8	1.5	68
17	social media	7	1.3	69
18	cps	7	1.3	70
…	…	…	…	
∑ Frequencies		534	100	100

Figure 7. Application counts by processes and task areas, along with "A" technologies or concepts they employ

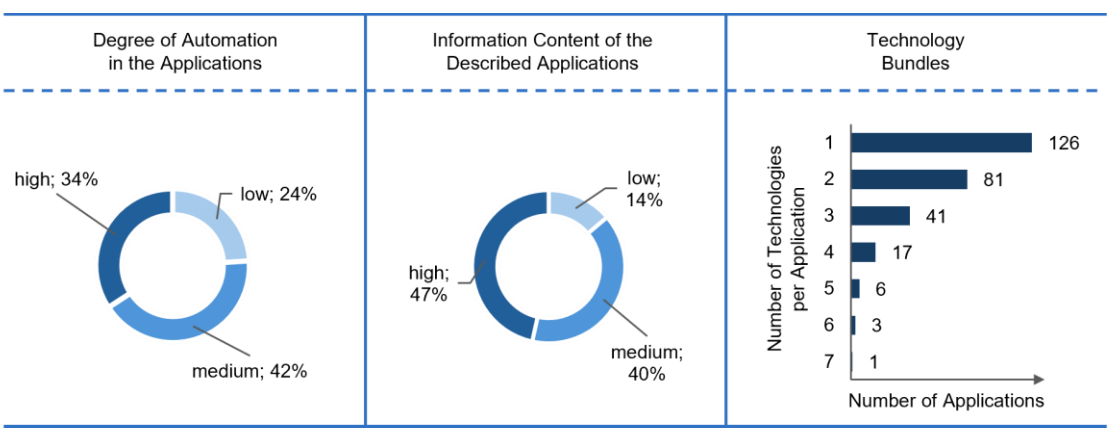


Figure 8. Characteristics of the 275 applications identified

4.1. Heatmap Structure

The heatmap visualizes the thematic analysis results, with the full dataset available in Table 3 in Appendix B. It illustrates the frequency of technologies or related concepts classified as A based on the previously described ABC analysis across procurement processes and tasks. The color gradient ranges from white (no recorded applications) to progressively darker shades, representing higher occurrences.

The heatmap employs a chessboard-style alternating grid for two main purposes: (1) to enhance readability and guide the reader through the data seamlessly, and (2) to highlight key findings distinctly. The y-axis (Figure 9, column D, rows 6-27) represents procurement processes and tasks (as outlined in Figure 6), while the x-axis (columns F-W, row 2) displays Procurement 4.0 technologies and related concepts most frequently discussed in the literature, identified via ABC analysis (see Figure 7). While e-procurement was frequently referenced in the context of advanced technologies and was therefore included in Table 3, it is excluded from the heatmap, as Procurement 4.0 extends beyond traditional e-procurement (Herold et al., 2023).
Technologies and related concepts not classified as category A (82 in total) are grouped under "Others," which are visually distinguished by an orange color code. This category is listed separately because it represents a collective classification that is not directly comparable to category A technologies and related concepts.

4.2. Procurement 4.0 Application Heatmap

The Procurement 4.0 Application Heatmap, developed as a conceptual framework in this study, is presented in Figure 9. The following descriptions of rows and columns form the legend, providing further key information for interpreting the heatmap, an aspect often overlooked in heatmap presentations (Bojko, 2009):

- Row 3 (starting from column F): Number of sources describing an application involving the respective technology.
- Row 4: Total number of applications (out of 275) referencing the respective technology.
- Column E (green): Frequency of applications addressing a given process or task area.
- Column X: Frequency of references to processes or task areas from a technology perspective, including bundles. For instance, an application in strategic demand & spend management using both AI and blockchain is recorded once in column E (process level) and twice in column X (technology perspective), reflecting dual technological usage.
- Column Y (purple): Bundle intensity expressed as a percentage, calculated based on data from columns E and X. Darker shades represent a higher frequency of technology combinations.
- Columns AA to AC: Represent the three degrees of automation. Additionally, row 30 reports the percentage of applications with a high degree of automation (3) per technology and concept.
- Totals: Calculated in row 28 (total frequency an applied technology or related concept supports processes or tasks, including multiple mentions and occurrences within technology bundles), row 29 (total sum of the values in row 28 from columns F to V), column C (sum of column E for each process/task area), and column Z (sum of column X for each process/task area).
- The hashtag symbol (#) represents "number of."

The results are discussed in the following Section 5.

5. Discussion

The analysis highlights several key areas for discussion, which are examined in this section. To ensure structural clarity, the discussion follows the two axes of the heatmap: the horizontal axis, which focuses on advanced technologies and related concepts, and the vertical axis, which addresses the most represented processes and task areas.

5.1. Technologies and Related Concepts

The heatmap organizes the technologies and technology-related concepts according to the frequency with which they are referenced in the identified applications (row 3) and illustrates three distinct clusters based on the processes and tasks they support (row 28). The first cluster includes blockchain, IoT, AI, and big data, each supporting processes or tasks at least 97 times across the identified applications, with blockchain contributing up to 137 occurrences of process or task support. The second visually distinct cluster (J28 to P28) consists of technologies and related concepts mentioned from 37 to 73 times, such as real-time information, cloud computing, robotic process automation (RPA), platforms, smart contracts, algorithms, and intelligent process automation (IPA). The third and least prominent cluster in the heatmap comprises technologies and related concepts mentioned between 9 and 21 times, including sensors, business intelligence, RFID, simulation, social media, and cyber-physical systems.

In the academic debate on Procurement 4.0, blockchain technology emerges as the most extensively examined technology regarding its application potential. The findings of the SLR indicate that blockchain can enhance and create value across nearly all procurement processes and tasks, apart from the order confirmation sub-process and the human resource management & training task area, for which no explicit references were identified. These insights, as visualized in the heatmap, align with existing literature, which highlights blockchain's capacity to ensure tamper-proof documentation throughout the procurement process (Miehle et al., 2019). In particular, supply chain monitoring processes—including tracking and tracing, controlling & reporting—appear especially well-suited for blockchain applications, as they foster synergies in sustainability and compliance.

These broader implications of blockchain's role in Procurement 4.0 become even more apparent when examining its specific applications. In particular, blockchain is explicitly referenced in nine applications related to tendering, highlighting its critical role in ensuring secure, tamper-proof execution and data protection (El Asri & Benhlima, 2022; Govindan et al., 2024; Gunasekara et al., 2022; Jain et al., 2024). Regarding automation, blockchain ranks in the mid-range, with 28% of its applications demonstrating a high (3) degree of automation. However, blockchain technology facilitates instant, automated electronic payments via smart contracts, which autonomously execute transactions upon the fulfilment of procurement agreement obligations—eliminating the need for intermediaries, including financial and legal institutions (Gunasekara et al., 2022; Raj et al., 2022). As these capabilities extend to P2P sub-processes, particularly within invoice & payment domain traditionally managed by finance departments, blockchain offers significant potential for cross-departmental and cross-functional process optimization. Furthermore, blockchain enhances internal data access and exchange mechanisms, as evidenced by its 10 mentions in the context of organizational development & process management.

Despite its theoretical advantages, blockchain illustrates the gap between academic debate and practical adoption. While one-third of the top 50 Forbes companies have implemented blockchain in supply chain applications (Keresztes et al., 2022) its adoption rate among German companies remains low, with only 7% reporting current or planned implementation (Bunde & Wolf, 2024). This highlights the pressing need for methodologies, and tools to support businesses in realizing the potential of advanced digital technologies such as blockchain—an objective demonstrated through the heatmap analysis presented here.

IoT applications are predominantly concentrated in the task areas of supplier relationship management & partnering, as well as controlling & reporting. In supplier management, IoT is expected to enhance data exchange (Rejeb & Appolloni, 2022) and improve supplier evaluation by enabling holistic assessments across all stages of the supply chain through the integration of IoT, big data analytics, and real-time information (Gottge et al., 2020). This interplay between multiple technologies underscores the growing importance of technology bundling. With IoT referenced in 47 applications, a detailed analysis of the dataset reveals 140 distinct technology and concept entries associated with these applications. As evidenced by our findings, the implementation of IoT within Procurement 4.0 entails significant integration complexity, necessitating the convergence of multiple technologies to fully harness its potential.

Regarding applications with a high degree of automation, a defining element of Procurement 4.0, the IoT ranks in the lower half of the A-category technologies and concepts, with 26% of its applications falling into this category (G30). In contrast, IPA (100%), and RPA (91%), as well as smart contracts (56%), exhibit significantly higher automation levels. Our heatmap reveals that Procurement 4.0 applications using technologies from the most intensively debated cluster generally exhibit a moderate degree of automation. These findings suggest that the academic debate on procurement 4.0 continues to focus on technology as an enabler, primarily supporting human decision-making (augmentation) or, at most, facilitating automation where machines execute tasks with human oversight. While initial use cases involving AI (Herold et al., 2023), in combination with blockchain, smart contracts (Hofbauer & Sangl, 2019; Jahani et al., 2021), and IPA (Flechsig et al., 2022) indicate a gradual shift toward autonomization, fully autonomous procurement processes remain an aspirational Procurement 4.0 objective rather than an established reality.

This academic perspective aligns with industry trends, as reflected in the Gartner Hype Cycle for Procurement and Sourcing Solutions 2024 (Gartner, 2024; Zip, 2024). According to Gartner (2024), autonomous procurement remains in the early “innovation trigger” phase and is projected to reach the “plateau of productivity” within the next decade. In contrast, RPA has progressed into the “enlightenment” phase, demonstrating its value in mitigating media disruptions and automating repetitive tasks, thereby freeing procurement professionals to focus on strategic objectives (Flechsig et al., 2022). However, caution is warranted. RPA has often been subject to inflated expectations, and, as a bridge technology, it carries inherent limitations. Eulerich et al. (2022) highlight several risks, including addressing symptoms rather than root causes and the potential for organizations to implement RPA without fundamentally redesigning processes, leading to delayed system improvements and increased complexity. Moreover, cost concerns, as well as control and security issues, highlight the need for a balanced approach to automation adoption (Eulerich et al., 2022). The integration of new technologies, particularly those adopted in response to current hype, requires careful consideration of their long-term impact. In this context, our heatmap serves as a systematically compiled and comprehensive selection of potential use cases, providing a foundation for strategic planning and operational deployment. Nevertheless, ensuring the effectiveness and process integrity of these technologies should remain a central priority in their implementation.

A notable gap in the literature concerns the limited discussion of several technologies in process applications where they have potential advantages. For instance, AI, algorithms, and simulations are rarely discussed in relation to operational procurement processes, even though they have been widely explored in other areas. AI, for example, has been studied as a question-answering assistant (Nicoletti, 2020), while simulation models have been used to assess the impact of factors such as delivery times and to support the optimization of procurement-related decision-making (Rejeb & Appolloni, 2022). These models employ algorithms to evaluate process changes and system dynamics (Rejeb & Appolloni, 2022). However, AI could also be applied within the P2P process to mitigate data limitations (Culot et al., 2024). Data collection via sensors and RFID has been discussed in relation to decision-making in procurement-system-related tasks such as controlling & reporting (ElAmmari et al., 2024; Govindan et al., 2022). However, it has not been explicitly examined within the strategic S2C process. A similar pattern emerges with social media, as applications within the S2C and P2P processes are largely absent in the heatmap (U6-U19), even though social media platforms are discussed in the context of enhancing both internal and external collaboration (Lorentz et al., 2021). These gaps highlight an opportunity for further research to systematically investigate the role of these technologies and related concepts in currently overlooked procurement processes and tasks. This interpretation of the heatmap underscores its dual utility: practitioners can leverage it to identify potential use cases, while scholars may draw on it as a source of new research avenues.

Furthermore, the breadth of emerging technologies and related concepts in procurement extends beyond both the A-category technologies and related concepts explicitly categorized in the heatmap (see column W and Table 3 in Appendix B), illustrating the complexity and dynamics of the Procurement 4.0 transformation. Additionally, only 126 of the 275 applications reference a single technology, whereas the remaining 149 involve the integration of two to seven technologies or concepts within bundles. This indicates that many procurement tasks can only be effectively addressed through the combined implementation of multiple technologies and concepts. Consequently, relying on a single advanced technology is insufficient; organizations must systematically evaluate a diverse set of technologies based on their potential benefits and develop the necessary implementation expertise.

Finally, futuristic applications are also emerging in procurement. Tripathi and Gupta (2021) describe nanotechnology chips embedded in physical objects—such as light bulbs, cars, and mobile devices—turning them into smart objects capable of collecting and transmitting data in real time. Furthermore, discussions on blockchain-based micropayments and the use of cryptocurrencies in procurement suggest the potential for reduced bank dependency and automated machine-to-machine transactions for consumables (Gunasekara et al., 2022; Miehle et al., 2019). These developments highlight the transformative potential of advanced technologies in reshaping procurement practices in the future.

5.2. Procurement Processes and Tasks

Among the identified procurement tasks, controlling & reporting and supplier relationship management & partnering emerge as particularly significant, alongside the category labeled others (columns D and E on the heatmap). Given the key elements of Procurement 4.0—performance (efficiency) improvement, data-driven decision-making, and digitalization (see Figure 1)—it is reasonable to expect that advanced technologies significantly affect controlling & reporting tasks. Indeed, the heatmap analysis reveals a particularly strong intersection, with 16 instances of overlap between big data, blockchain, and controlling & reporting. This finding highlights the potential of real-time availability and analytics of vast amounts of data, enabled by advanced technologies such as big data, IoT, and AI, for enhancing controlling processes and further developing planning, management, and information systems (Eisl et al., 2023), thereby strengthening controlling's role as a target-oriented, decision-supporting subsystem within procurement management (Schentler & Tschandl, 2016). Key applications include price forecasting, optimized price identification, supplier performance measurement, enhanced information transparency, and real-time procurement process monitoring.

Supplier relationship management & partnering is another critical task area in procurement, encompassing activities such as supplier selection, development, and performance monitoring (Lysons & Farrington, 2012). To align with enterprise priorities such as operational efficiency, ESG/CSR initiatives, and digital transformation, fostering supplier collaboration has become a strategic focus (Addicoat et al., 2023). The literature highlights numerous advanced applications in this area, reflecting promising developments. The heatmap indicates that technologies facilitating information exchange—such as IoT, big data, cloud computing, platforms, and social media—are particularly prominent in supplier management. IoT, the technology most frequently associated with supplier management, enables real-time data exchange, leading to new management capabilities. Automated data collection allows organizations to make more informed decisions with greater speed and accuracy. This approach, which may be termed "high-resolution supplier management" (Fleisch et al., 2014), enhances supply chain resilience by enabling firms to anticipate and respond to disruptions effectively (Herold et al., 2023; Nicoletti, 2020). Furthermore, as discussed in Section 0 the integration of big data analytics and IoT facilitates real-time, holistic supplier evaluations—including assessments of sub-suppliers—and supports root cause analysis for procurement challenges (Gottge et al., 2020).

Another key observation is the prevalence of procurement-system-related and nonprocess-related tasks compared to the two main procurement processes within the dataset. While digitalization per se is appealing due to its numerous advantages, and the use of advanced technologies in individual tasks may therefore seem attractive, practitioners considering digital applications should adopt a process-oriented digitalization approach from the outset. This ensures optimal resource allocation and mitigates the risk of costly, suboptimal solutions (Hierzer, 2017). However, successful implementation requires a high degree of process transparency and understanding (Brunnhofer, 2021; Dumas et al., 2018). From a process management perspective, achieving this transparency remains a persistent challenge (Opitz et al., 2024). Consequently, organizations must first address fundamental business process management requirements, which are critical to the Procurement 4.0 transformation.

As outlined in the introduction, another contemporary trend influencing the Procurement 4.0 transformation is the shift in labor market dynamics, including workforce shortages and evolving generational expectations. However, while academic discussions on Procurement 4.0 primarily emphasize strategic and tactical applications, our heatmap analysis reveals that comparatively less attention is given to the operational P2P process. This discrepancy may be attributed to Gartner's Hype Cycle for Procurement, which suggests that many P2P solutions have reached a "plateau of productivity" (Gartner, 2024; Zip, 2024). Conversely, emerging strategic applications—such as predictive analytics and smart contracts—are still in their initial stages, attracting significant attention in public and scientific discussions. Despite this, employees remain unable to fully shift toward strategic priorities. Vanson Bourne on behalf of Ivalua (2019) found that 77% of procurement, supply chain, and finance professionals struggle to allocate sufficient time to strategic tasks due to inadequate digitalization. This indicates that challenges related to P2P optimization persist, which is unsurprising given the high number of process variants that complicate standardization and efficiency improvements (Berti et al., 2025). However, technologies such as RPA and IPA are increasingly gaining academic attention due to their potential to support precisely these operational procurement tasks—along with the advantages and limitations discussed in Section 0 above (Eulerich et al., 2022; Flechsig, 2021; Ng et al., 2021). Looking ahead, intelligent automation technologies, including self-learning autonomous agents, could further enhance procurement efficiency by autonomously handling exceptions, thereby minimizing the need for human intervention and allowing professionals to focus on required strategic priorities (Ng et al., 2021).

Figure 9. Procurement 4.0 application heatmap

6. Conclusion

Based on the challenges outlined in the introduction, we conducted an SLR to develop a conceptual framework that maps 275 Procurement 4.0 applications identified in the literature to an extended procurement process model. In response to the research questions, this study aimed to (1) identify the conceptual elements of Procurement 4.0 and provide a comprehensive definition (RQ1), (2) identify Procurement 4.0 applications discussed in the current literature (RQ2) and (3) analyze the procurement processes and tasks supported by these applications (RQ3). These objectives were addressed by systematically reviewing the Procurement 4.0 literature and developing the heatmap (Figure 9), which provides a comprehensive and structured overview of potential use cases, serving as a foundation for both strategic planning and operational deployment.

Nevertheless, the rapid pace at which new technological solutions are emerging in the market means that new Procurement 4.0 applications are continually being developed. Research in this area therefore needs to be updated regularly and should evolve in tandem with these advancements. In addition, this study identifies several critical research gaps that warrant further exploration.

First, a persistent gap between the academic debate and practical implementation is evident, as exemplified by blockchain applications. While blockchain is widely analyzed in procurement research, its adoption in practice remains substantially limited. This observation extends to procurement digitalization in general, where considerable potential for process improvement has yet to be realized. These findings highlight opportunities for future research, particularly in bridging the gap between technological advancements and real-world implementation. Additionally, technology vendors play a critical role in addressing this challenge by developing cost-effective and scalable solutions that can be integrated across diverse organizational contexts, thereby accelerating adoption and enabling firms to fully leverage the potential of emerging technologies.

Beyond the gaps discussed in Section 5, this study finds that procurement applications employing technologies from the most frequently discussed technology cluster often exhibit only a moderate level of automation. This suggests that current research tends to view technology mainly as a support tool for human decision-making—an approach of augmentation rather than full automation. However, early examples involving AI (Herold et al., 2023), blockchain and smart contracts (Hofbauer & Sangl, 2019; Jahani et al., 2021), and IPA (Flechsig, 2021) indicate a gradual shift toward autonomization. Yet, fully autonomous procurement processes in line with the Industry 4.0 vision (Ghodrati Abbassi et al., 2025) still appear to be more aspirational than realized. This opens new opportunities for researchers to examine how procurement processes can evolve toward higher levels of automation in practice.

On the one hand, design-science–oriented scholars could build on these findings to create innovative frameworks that enable more autonomous forms of procurement. On the other hand, the conceptual and design science studies identified in this review offer a foundation for empirical testing and validation. Future research might also explore the broader evolution and trajectory of Procurement 4.0 itself. While this paper provides a comprehensive Procurement 4.0 definition and outlines its main conceptual elements, questions remain about the extent to which the outlined transformation will unfold in organizations, and which areas firms will prioritize in the early stages of implementation. Since this review identified only two Delphi studies addressing practical future applications, such forward-looking research designs appear particularly promising for advancing understanding of emerging developments—especially as the field continues to progress toward concepts such as Procurement 5.0 (Ahuja et al., 2025). Consequently, looking ahead, the question arises as to when Procurement 4.0 might become outdated in view of rapid advances in AI and in what ways procurement will evolve beyond it. Building on the results and discussions presented in this paper, future research should further explore these dynamics and shed light on how procurement practices may advance.

Finally, the transformation toward Procurement 4.0 is not purely technological. Decisions about technology adoption and successful implementation are also shaped by environmental and organizational factors, as well as considerations related to the people involved (Baker, 2011; Dirnberger-Wild & Roth, 2024). The findings presented here—summarized in the heatmap and detailed in Table 3 in Appendix B—do not cover these broader contexts. Nevertheless, they can provide a basis for further academic discussions at the intersection of theory and practice and help practitioners identify which technologies and concepts hold the greatest potential for specific applications along the path toward Procurement 4.0.

References

Addicoat, A., Flynn, R., Kilpatrick, J., Brown, J., & Mitchell, P. (2023). *2023 Global Chief Procurement Officer Survey*. Deloitte United States. https://www.deloitte.com/us/en/pages/operations/articles/procurement-strategy.html

Afanasiev, M., Rachenko, I., & Arbuzov, M. (2019). Role and significance of mobile technologies in digitalization of procurement systems in oil and gas companies. *IOP Conference Series: Materials Science and Engineering*, *497*(1), 012021. https://doi.org/10.1088/1757-899X/497/1/012021

Ahuja, T. S., Chikatmarla, S., Skirnevskiy, V., & Shoniya, I. (2025, July 16). *Procurement 5.0: Imperatives for the Next Decade*. McKinsey & Company. https://www.mckinsey.com/au/our-insights/australia-and-new-zealand-perspectives/procurement-5-imperatives-for-the-next-decade

Aisyah, M., & Ulkhaq, M. M. (2024). Inventory Control Analysis of Materials for Network Installation: A Case Study at PT Pratama Persada Teknologi. *Management Science and Information Technology*, *1*(1), 57–65. https://doi.org/10.22034/ISS.2024.8011.1016

Alabdali, M. A., & Salam, M. A. (2022). The Impact of Digital Transformation on Supply Chain Procurement for Creating Competitive Advantage: An Empirical Study. *Sustainability (Switzerland)*, *14*(19), 12269. https://doi.org/10.3390/su141912269

Alnuaimi, N. T., Chatha, K. A., & Abdallah, S. (2025). Role of big data analytics and information processing capabilities in enhancing transparency and accountability in e-procurement applications. *Journal of Engineering, Design and Technology*, *23*(5), 1729–1750. https://doi.org/10.1108/JEDT-12-2023-0544

Althabatah, A., Padmanabhan, R., Yaqot, M., Hadid, M., & Kerbache, L. (2025). Assessing transformative procurement maturity: A general framework using a fuzzy model. *Journal of Open Innovation: Technology, Market, and Complexity*, *11*(3), 100622. https://doi.org/10.1016/j.joitmc.2025.100622

Althabatah, A., Yaqot, M., Menezes, B., & Kerbache, L. (2023). Transformative Procurement Trends: Integrating Industry 4.0 Technologies for Enhanced Procurement Processes. *Logistics*, *7*(3), 63. https://doi.org/10.3390/logistics7030063

Angrian, B., & Sahroni, T. R. (2019). Development of vendor management and e-Procurement systems using android platform. *IOP Conference Series: Materials Science and Engineering*, *528*(1), 012082. https://doi.org/10.1088/1757-899X/528/1/012082

Ankenbrand, H., Hein, C., Junge, S., & Löhr, J. (2022, April 6). Wie der Ukraine-Krieg Lieferketten und Globalisierung bedroht. *FAZ.NET*. https://www.faz.net/aktuell/wirtschaft/wie-der-ukraine-krieg-lieferketten-und-globalisierung-bedroht-17940015.html

Arangies, J., & van Rensburg, L. R. J. (1995). Management techniques. In J. Kroon (Ed.), *General management* (2nd ed., pp. 483–506). Kagiso Tertiary.

Bag, S., Dhamija, P., Gupta, S., & Sivarajah, U. (2020). Examining the role of procurement 4.0 towards remanufacturing operations and circular economy. *Production Planning and Control*, *32*(16), 1368–1383. https://doi.org/10.1080/09537287.2020.1817602

Bag, S., Wood, L. C., Mangla, S. K., & Luthra, S. (2020). Procurement 4.0 and its implications on business process performance in a circular economy. *Resources, Conservation and Recycling*, *152*, 104502. https://doi.org/10.1016/j.resconrec.2019.104502

Bahaweres, R. B., Amna, H., & Nurnaningsih, D. (2022). Improving Purchase to Pay Process Efficiency with RPA using Fuzzy Miner Algorithm in Process Mining. *2022 International Conference on Decision Aid Sciences and Applications, DASA 2022*, 1483–1488. https://doi.org/10.1109/DASA54658.2022.9765091

Baker, J. (2011). The Technology–Organization–Environment Framework. In Y. K. Dwivedi, M. R. Wade, & S. L. Schneberger (Eds.), *Information Systems Theory* (Vol. 28, pp. 231–245). Springer New York. https://doi.org/10.1007/978-1-4419-6108-2_12

Bakir, E., & Borozan, S. (2023). *Deloitte AI Quick Study—Der Einfluss künstlicher Intelligenz auf Österreichs Unternehmen* (pp. 1–24). Deloitte. https://www.deloitte.com/content/dam/assets-zone2/at/de/docs/about/2024/at-deloitte-ai-quick-study-2023.pdf

Bals, L., Schulze, H., Kelly, S., & Stek, K. (2019). Purchasing and supply management (PSM) competencies: Current and future requirements. *Journal of Purchasing and Supply Management*, *25*(5), 100572. https://doi.org/10.1016/j.pursup.2019.100572

Barth, T., & Barth, D. (2013). *Kosten- und Erfolgsrechnung für Industrie und Handel* (2. aktualisierte und erweiterte Auflage). Kohlhammer Verlag.

Batran, A., Erben, A., Schulz, R., & Sperl, F. (2017). *Procurement 4.0: A survival guide in a digital, disruptive world*. Campus Verlag.

Bavrin, A., Koop, V., Lukashevich, N., Simakova, Z., & Temirgaliev, E. (2021). The analysis of digitalization impact on personnel functions in logistics. *E3S Web of Conferences*, *258*, 02025. https://doi.org/10.1051/e3sconf/202125802025

Berti, A., Jessen, U., Park, G., Rafiei, M., & van der Aalst, W. M. P. (2025). Analyzing interconnected processes: Using object-centric process mining to analyze procurement processes. *International Journal of Data Science and Analytics*, *20*, 475–497. https://doi.org/10.1007/s41060-023-00427-3

Bienhaus, F., & Haddud, A. (2018). Procurement 4.0: Factors influencing the digitisation of procurement and supply chains. *Business Process Management Journal*, *24*(4), 965–984. https://doi.org/10.1108/BPMJ-06-2017-0139

Bigliardi, B., Filippelli, S., Petroni, A., & Tagliente, L. (2022). The digitalization of supply chain: A review. *Procedia Computer Science*, *200*, 1806–1815. https://doi.org/10.1016/j.procs.2022.01.381

Bojko, A. (2009). Informative or Misleading? Heatmaps Deconstructed. In J. A. Jacko (Ed.), *Human-Computer Interaction. New Trends* (Vol. 5610, pp. 30–39). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-02574-7_4

Bosch, G., & Zühlke-Robinet, K. (2000). *Der Bauarbeitsmarkt: Soziologie und Ökonomie einer Branche*. Campus Verlag.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brunnhofer, M. (2021). Process Analysis & Documentation. In M. Tschandl, U. Brunner, & G. Obmann (Eds.), *Supply Chain Captain* (pp. 203–206). Leykam.

Bruzzi, S., Balbi, N., Barcellini, L., & Genco, V. (2021). Toward the strengthening of enabling technologies in Italy: Results of the second survey on procurement 4.0. *Sinergie*, *39*(3), 75–97. https://doi.org/10.7433/S116.2021.05

Bruzzi, S., Genco, V., & Balbi, N. (2019). The new frontiers of procurement in the digital age. Results of an empirical survey on procurement 4.0 in Italy. *Sinergie Italian Journal of Management*, *37*(2), 93–118. https://doi.org/10.7433/s109.2019.06

Bueno, R. E., Almeida dos Santos, H., de Junior Freitas, M., Toloi, R. C., & Gonçalves, R. F. (2022). Procurement 4.0: A Systematic Review of Its Technological Evolution. In D. Y. Kim, G. Cieminski, & D. Romero (Eds.), *Advances in Production Management Systems. Smart Manufacturing and Logistics Systems: Turning Ideas into Action. APMS 2022* (Vol. 664, pp. 148–156). Springer. https://doi.org/10.1007/978-3-031-16411-8_19

Bueno, R. E., Pohlmann, M. N., dos Santos, H. A., & Gonçalves, R. F. (2024). The Procurement 4.0 Contributions to Circular Economy. *Sustainability*, *16*(14), 5838. https://doi.org/10.3390/su16145838

Bunde, N., & Wolf, A. (2024). Blockchain – Hype oder Querschnittstechnologie? *ifo Schnelldienst*, *77*(6), 36–42.

Büsch, M. (2013). *Praxishandbuch strategischer Einkauf: Methoden, Verfahren, Arbeitsblätter für professionelles Beschaffungsmanagement* (3., korrigierte Aufl). Springer Gabler. https://doi.org/10.1007/978-3-8349-4567-9

Cambridge University Press & Assessment. (n.d.). Application. In *Cambridge Dictionary*. Retrieved January 30, 2024, from https://dictionary.cambridge.org/dictionary/english/application

Chandrasekara, S., Vidanagamachchi, K., & Wickramarachchi, R. (2020). A literature-based survey on industry 4.0 technologies for procurement optimization. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 1097–1106.

Colombo, J., Boffelli, A., Kalchschmidt, M., & Legenvre, H. (2023). Navigating the socio-technical impacts of purchasing digitalisation: A multiple-case study. *Journal of Purchasing and Supply Management*, *29*(3), 100849. https://doi.org/10.1016/j.pursup.2023.100849

Culot, G., Nassimbeni, G., Orzes, G., & Sartor, M. (2020). Behind the definition of Industry 4.0: Analysis and open questions. *International Journal of Production Economics*, *226*, 107617. https://doi.org/10.1016/j.ijpe.2020.107617

Culot, G., Podrecca, M., & Nassimbeni, G. (2024). Artificial intelligence in supply chain management: A systematic literature review of empirical studies and research directions. *Computers in Industry*, *162*, 104132. https://doi.org/10.1016/j.compind.2024.104132

Delke, V., Schiele, H., & Buchholz, W. (2023). Differentiating Between Direct and Indirect Procurement: Roles, Skills and Industry 4.0. *International Journal of Procurement Management*, *16*(1), 1–30. https://doi.org/10.1504/IJPM.2022.10050671

Diekhans, A. (2023, May 2). *Ukraine-Krieg könnte Hungerkrise in Afrika auslösen*. tagesschau.de. https://www.tagesschau.de/wirtschaft/weltwirtschaft/weizen-preis-afrika-ukraine-krieg-101.html

Diekmann, A. (2004). *Empirische Sozialforschung: Grundlagen, Methoden, Anwendungen* (Orig.-Ausg., 17. Aufl). Rowohlt Taschenbuch Verl.

Dirnberger-Wild, J., & Roth, M. (2024). Conceptual Framework Introducing the Success Factors for Implementing Intelligent Automation-A Qualitative Multiple Case Study. *Proceedings of the 2024 10th International Conference on Computer Technology Applications*, 8–14. https://doi.org/10.1145/3674558.3674560

Dumas, M., La Rosa, M., Mendling, J., & Reijers, H. A. (2018). *Fundamentals of Business Process Management*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-56509-4

Eisl, C., Rockenschaub, T., & Mitterlehner, D. (2023). Die Top-Zukunftsthemen des Controllings. *Controlling & Management Review*, *67*(1), 42–47. https://doi.org/10.1007/s12176-022-1021-9

El Asri, H., & Benhlima, L. (2022). Artificial intelligence-based process automation in e procurement: A systematic literature review. *Journal of Theoretical and Applied Information Technology*, *100*(15), 4560–4581.

ElAmmari, A., Arif, J., & Jawab, F. (2024). Procurement Improvement Process Based on Industry 4.0 & Lean Manufacturing: A Case Study. *2024 IEEE 15th International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA)*, 1–6. https://doi.org/10.1109/LOGISTIQUA61063.2024.10571531

Eriksson, K. M., Vallhagen, J., & Rudqvist, A. (2024). Virtual Commissioning During the Manufacturing Equipment Procurement Process: From an Industrial Expert Point of View. In J. Andersson, S. Joshi, L. Malmsköld, & F. Hanning (Eds.), *Advances in Transdisciplinary Engineering*. IOS Press. https://doi.org/10.3233/ATDE240184

Eulerich, M., Waddoups, N., Wagener, M., & Wood, D. A. (2022). The Dark Side of Robotic Process Automation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4026996

Flechsig, C. (2021). The Impact of Intelligent Process Automation on Purchasing and Supply Management – Initial Insights from a Multiple Case Study. In U. Buscher, R. Lasch, & J. Schönberger (Eds.), *Logistics Management. Lecture Notes in Logistics* (pp. 67–89). Springer. https://doi.org/10.1007/978-3-030-85843-8_5

Flechsig, C., Anslinger, F., & Lasch, R. (2022). Robotic Process Automation in purchasing and supply management: A multiple case study on potentials, barriers, and implementation. *Journal of Purchasing and Supply Management*, *28*(1), 100718. https://doi.org/10.1016/j.pursup.2021.100718

Fleisch, E., Weinberger, M., & Wortmann, F. (2014). Geschäftsmodelle im Internet der Dinge. *HMD Praxis der Wirtschaftsinformatik*, *51*(6), 812–826. https://doi.org/10.1365/s40702-014-0083-3

Gartner. (2024). *Hype Cycle for Procurement and Sourcing Solutions, 2024*. https://www.gartner.com/en/documents/5523495

Geissbauer, R., Weissbarth, R., & Wetzstein, J. (2016). *Procurement 4.0: Are you ready for the digital revolution?* Strategy& (PwC).

Ghodrati Abbassi, H., Rabieh, M., Rezaei Pandari, A., & Esmaeili, M. (2025). Supply Chain Management 4.0 Research Area Maturity: A Systematic Literature Review. *International Journal of Supply and Operations Management*, *12*(3), 336–363. https://doi.org/10.22034/ijsom.2025.110532.3206

Ghouri, A. M., & Mani, V. (2019). Role of real-time information-sharing through SaaS: An industry 4.0 perspective. *International Journal of Information Management*, *49*, 301–315. https://doi.org/10.1016/j.ijinfomgt.2019.05.026

Gläser, J., & Laudel, G. (2006). *Experteninterviews und qualitative Inhaltsanalyse als Instrumente rekonstruierender Untersuchungen* (2., durchges. Aufl). VS Verlag für Sozialwissenschaften.

Gottge, S., Menzel, T., & Forslund, H. (2020). Industry 4.0 technologies in the purchasing process. *Industrial Management and Data Systems*, *120*(4), 730–748. https://doi.org/10.1108/IMDS-05-2019-0304

Govindan, K., Jain, P., Kr. Singh, R., & Mishra, R. (2024). Blockchain technology as a strategic weapon to bring procurement 4.0 truly alive: Literature review and future research agenda. *Transportation Research Part E: Logistics and Transportation Review*, *181*, 103352. https://doi.org/10.1016/j.tre.2023.103352

Govindan, K., Kannan, D., Jørgensen, T. B., & Nielsen, T. S. (2022). Supply Chain 4.0 performance measurement: A systematic literature review, framework development, and empirical evidence. *Transportation Research Part E: Logistics and Transportation Review*, *164*, 102725. https://doi.org/10.1016/j.tre.2022.102725

Gunasekara, H. G., Sridarran, P., & Rajaratnam, D. (2022). Effective use of blockchain technology for facilities management procurement process. *Journal of Facilities Management*, *20*(3), 452–468. https://doi.org/10.1108/JFM-10-2020-0077

Hajian Heidary, M. (2023). Risk assessment in the global supplier selection considering supply disruption: A simulation optimization approach. *International Journal of Supply and Operations Management*, *10*(4), 501–522. https://doi.org/10.22034/ijsom.2023.108989.2110

Hallikas, J., Immonen, M., & Brax, S. (2021). Digitalizing procurement: The impact of data analytics on supply chain performance. *Supply Chain Management*, *26*(5), 629–646. https://doi.org/10.1108/SCM-05-2020-0201

Haoud, N. E., & Hasnaoui, M. E. (2019). Supply Chain and Industry 4.0: Impact and Performance Analysis: Case of BIOMERIEUX. *International Colloquium on Logistics and Supply Chain Management, LOGISTIQUA 2019*. https://doi.org/10.1109/LOGISTIQUA.2019.8907242

Herold, S., Heller, J., Rozemeijer, F., & Mahr, D. (2023). Dynamic capabilities for digital procurement transformation: A systematic literature review. *International Journal of Physical Distribution & Logistics Management*, *53*(4), 424–447. https://doi.org/10.1108/IJPDLM-12-2021-0535

Hierzer, R. (2017). *Prozessoptimierung 4.0: Den digitalen Wandel als Chance nutzen* (1. Auflage). Haufe Gruppe.

Hofbauer, G., & Sangl, A. (2019). Blockchain technology and application possibilities in the digital transformation of transaction processes. *Forum Scientiae Oeconomia*, *7*(4), 25–40. https://doi.org/10.23762/FSO_VOL7_NO4_2

insightsoftware. (2022, June 4). *Wann und warum sollte man Heat Maps verwenden?* insightsoftware. https://insightsoftware.com/de/blog/when-and-why-to-use-heat-maps/

Islam, Md. A., & Agarwal, N. K. (2023). Proceedings of the annual meetings of the association for information science and technology: Analysis of two decades of published research. *Information Discovery and Delivery*, *51*(1), 105–120. https://doi.org/10.1108/IDD-09-2021-0100

ivalua. (2019, August 29). *Inefficient Procurement is Costing UK Businesses ~£2m Per Year*. Ivalua. https://www.ivalua.com/newsroom/inefficient-procurement-processes-are-costing-uk-businesses-almost-2m-per-year-reveals-research/

Jahani, N., Sepehri, A., Vandchali, H. R., & Tirkolaee, E. B. (2021). Application of industry 4.0 in the procurement processes of supply chains: A systematic literature review. *Sustainability (Switzerland)*, *13*(14), 7520. https://doi.org/10.3390/su13147520

Jain, P., Priyadarshini, J., & Gupta, A. K. (2024). Frameworks, Linkages, Benefits, Challenges, and Future Scope in Procurement 4.0: A Systematic Literature Review From 2014 to 2023. *IEEE Transactions on Engineering Management*, *71*, 10295–10313. https://doi.org/10.1109/TEM.2023.3321086

Jonen, A. (2023). Current Trends and Future Potentials of Digitalization in Procurement Controlling. In I. Keimer & U. Egle (Eds.), *The Digitalization of Management Accounting* (pp. 319–340). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-41524-2_20

Joseph Jerome, J. J., Saxena, D., Sonwaney, V., & Foropon, C. (2022). Procurement 4.0 to the rescue: Catalysing its adoption by modelling the challenges. *Benchmarking*, *29*(1), 217–254. https://doi.org/10.1108/BIJ-01-2021-0030

Keresztes, É. R., Kovács, I., Horváth, A., & Zimányi, K. (2022). Exploratory Analysis of Blockchain Platforms in Supply Chain Management. *Economies*, *10*(9), 206. https://doi.org/10.3390/economies10090206

Klünder, T., Dörseln, J. N., & Steven, M. (2019). Procurement 4.0: How the digital disruption supports cost-reduction in Procurement. *Production*, *29*. https://doi.org/10.1590/0103-6513.20180104

Köller, C. (2022, January 7). *Das müssen Sie zur Halbleiter-Krise wissen*. springerprofessional.de. https://www.springerprofessional.de/halbleiter/halbleitertechnik/das-muessen-sie-zur-halbleiter-krise-wissen/19356172

Komdeur, E. F. M., & Ingenbleek, P. T. M. (2021). The potential of blockchain technology in the procurement of sustainable timber products. *International Wood Products Journal*, *12*(4), 249–257. https://doi.org/10.1080/20426445.2021.1967624

Kraljic, P. (1983, September 1). Purchasing Must Become Supply Management. *Harvard Business Review*. https://hbr.org/1983/09/purchasing-must-become-supply-management

Křenková, E., Rieser, K., & Sato, A. (2021). How software robots can facilitate the procurement process? A case study of Siemens in the Czech Republic. *Entrepreneurial Business and Economics Review*, *9*(3), 191–203. https://doi.org/10.15678/EBER.2021.090312

Kuckartz, U. (2018). *Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung* (4., überarbeitete Aufl). Beltz.

Kuruvilla, J. M., Kathrine, G. J. W., Kirubakaran, S., Prem Prasad, G., & Evangelina, G. (2023). Implementation of Industry 4.0 in Supply Chain Management in the Healthcare Industry. *2023 2nd International Conference on Edge Computing and Applications (ICECAA)*, 1445–1449. https://doi.org/10.1109/ICECAA58104.2023.10212417

Lee, C.-Y., Chou, B.-J., & Huang, C.-F. (2022). Data science and reinforcement learning for price forecasting and raw material procurement in petrochemical industry. *Advanced Engineering Informatics*, *51*, 101443. https://doi.org/10.1016/j.aei.2021.101443

Lorentz, H., Aminoff, A., Kaipia, R., & Srai, J. S. (2021). Structuring the phenomenon of procurement digitalisation: Contexts, interventions and mechanisms. *International Journal of Operations and Production Management*, *41*(2), 157–192. https://doi.org/10.1108/IJOPM-03-2020-0150

Lysons, K., & Farrington, B. (2012). *Purchasing and supply chain management* (8th ed.). Pearson Financial Times.

Ma, L., & Chang, R. (2024). How big data analytics and artificial intelligence facilitate digital supply chain transformation: The role of integration and agility. *Management Decision*. https://doi.org/10.1108/MD-10-2023-1822

Maedche, A. (2019). Interview with Joerg Mimmel on “Digitalization of Purchasing at Bosch.” *Business and Information Systems Engineering*, *61*(6), 755–758. https://doi.org/10.1007/s12599-019-00616-0

Maheshwari, P., Kamble, S., Belhadi, A., Venkatesh, M., & Abedin, M. Z. (2023). Digital twin-driven real-time planning, monitoring, and controlling in food supply chains. *Technological Forecasting and Social Change*, *195*, 122799. https://doi.org/10.1016/j.techfore.2023.122799

Maleki, H., Khademi Zare, H., Fakhrzad, M. B., & Hosseini Nasab, H. (2024). Applying a safety system versus the risky suppliers. *International Journal of Supply and Operations Management*, *11*(2), 203–215. https://doi.org/10.22034/ijsom.2023.108161.1592

Maloni, M., Hiatt, M. S., & Campbell, S. (2019). Understanding the work values of Gen Z business students. *The International Journal of Management Education*, *17*(3), 100320. https://doi.org/10.1016/j.ijme.2019.100320

MAXQDA. (n.d.). *Was leistet MAXDictio?* Retrieved December 29, 2023, from https://www.maxqda.com/de/hilfe-mx20-dictio/was-leistet-maxdictio

Miehle, D., Meyer, M. M., Luckow, A., Bruegge, B., & Essig, M. (2019). Toward a decentralized marketplace for self-maintaining machines. *Proceedings - 2019 2nd IEEE International Conference on Blockchain, Blockchain 2019*, 431–438. https://doi.org/10.1109/Blockchain.2019.00066

Molamohamadi, Z., & Shah, N. (2024). Reviewing the Literature on Inventory Models with Permissible Delay in Payment. *Journal of Optimization and Supply Chain Management*, *1*(1), 1–27. https://doi.org/10.22034/iss.2024.2477

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of Web of Science and Scopus: A comparative analysis. *Scientometrics*, *106*(1), 213–228. https://doi.org/10.1007/s11192-015-1765-5

Mukherjee, D., & Ahmad, S. (2023). Impact of Digital Transformation in Sourcing & Tender Management Processes on Employee Job Satisfaction—A Study on Malaysian Multinational Electricity Company. *2023 1st International Conference on Intelligent Computing and Research Trends (ICRT)*, 1–7. https://doi.org/10.1109/ICRT57042.2023.10146729

Ng, E. S. W., & Johnson, J. M. (2015). Millennials: Who are they, how are they different, and why should we care? In R. J. Burke, C. Cooper, & A.-S. Antoniou (Eds.), *The Multi-generational and Aging Workforce*. Edward Elgar Publishing. https://doi.org/10.4337/9781783476589.00014

Ng, K. K. H., Chen, C.-H., Lee, C. K. M., Jiao, J. (Roger), & Yang, Z.-X. (2021). A systematic literature review on intelligent automation: Aligning concepts from theory, practice, and future perspectives. *Advanced Engineering Informatics*, *47*, 101246. https://doi.org/10.1016/j.aei.2021.101246

Nicoletti, B. (2020). *Procurement 4.0 and the fourth industrial revolution: The opportunities and challenges of a digital world*. Palgrave Macmillan.

Opitz, C., Simon, A., Schnägelberger, S., Savu, S., Knedelstorfer, C., Schwarz, F., & Bernstorf, J. (2024). *Prozessexzellenz durch Kompetenzaufbau und digitale Werkzeuge—Prozessmanagement & Analytik Studie 2024*. BearingPoint/BPM&O. https://www.bearingpoint.com/de-de/downloadformular/?item=36126&module=1203822

Pause, D., & Blum, M. (2018). Conceptual design of a digital shadow for the procurement of stocked products. In I. Moon, G. Lee, J. Park, D. Kiritsis, & G. von Cieminski (Eds.), *Advances in Production Management Systems. Smart Manufacturing for Industry 4.0* (Vol. 536, pp. 288–295). Springer. https://doi.org/10.1007/978-3-319-99707-0_36

Pekrul, S. (2006). *Strategien und Maßnahmen zur Steigerung der Wettbewerbsfähigkeit deutscher Bauunternehmen: Ein Branchenvergleich mit dem Anlagenbau*. Univerlagtuberlin.

Pellengahr, K., Schulte, A. T., Richard, J., & Berg, M. (2016). *Pilot Study—Procurement 4.0—The Digitalisation of Procurement*. Fraunhofer Institute for Material Flow and Logistics (IML) & Bundesverband Materialwirtschaft, Einkauf und Logistik e. V. (BME). https://www.iml.fraunhofer.de/content/dam/iml/en/documents/OE260/Pilot%20Study_Procurement%204-0_Fraunhofer%20IML_BME.pdf

Pirrone, L., & Meyer, D. (2021). Development of a Procurement-4.0-PMS using the Balanced Scorecard. *Proceedings of the Hamburg International Conference of Logistics*, *31*, 691–721. https://doi.org/10.15480/882.3984

Porter, M. E. (1979). How Competitive Forces Shape Strategy. *Harvard Business Review*, *57*(2), 137–145.

PricewaterhouseCoopers. (2024, March). *Digital Procurement Survey 2024*. https://www.pwc.de/de/strategie-organisation-prozesse-systeme/operations/digital-procurement-survey.html

Reichertz, J. (2016). *Qualitative und interpretative Sozialforschung: Eine Einladung*. Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-13462-4

Rejeb, A., & Appolloni, A. (2022). The Nexus of Industry 4.0 and Circular Procurement: A Systematic Literature Review and Research Agenda. *Sustainability (Switzerland)*, *14*(23), 15633. https://doi.org/10.3390/su142315633

Ruel, S., El Baz, J., Ivanov, D., & Azadegan, A. (2023). Can organizational legitimacy stimulate digitalization and affect operational performance? The impact of COVID-19 on uncertainty in supply management. *Journal of Purchasing and Supply Management*, *29*(5), 100880. https://doi.org/10.1016/j.pursup.2023.100880

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

Sahoo, S., & Jakhar, S. K. (2024). Industry 4.0 deployment for circular economy performance—Understanding the role of green procurement and remanufacturing activities. *Business Strategy and the Environment*, *33*(2), 1144–1160. https://doi.org/10.1002/bse.3542

Sai, B., Thanigaivelu, S., Shivaani, N., Shyamala Babu, C. S., & Ramaa, A. (2022). Integration of Chatbots in the Procurement Stage of a Supply Chain. *2022 6th International Conference on Computation System and Information Technology for Sustainable Solutions (CSITSS)*, 1–5. https://doi.org/10.1109/CSITSS57437.2022.10026367

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research methods for business students* (8th ed.). Pearson.

Schentler, P. (2008). *Beschaffungscontrolling in der kundenindividuellen Massenproduktion*. Leykam.

Schentler, P., & Tschandl, M. (2016). Beschaffungscontrolling: Den Einkauf zielorientiert steuern. In A. Klein & P. Schentler (Eds.), *Einkaufscontrolling: Instrumente und Kennzahlen für einen höheren Wertbeitrag des Einkaufs* (pp. 25–44). Haufe.

Schulte, C. (2013). *Logistik: Wege zur Optimierung der Supply Chain*. Vahlen.

Schweiger, J. (2017). *Purchasing and supply management maturity: Maturity models and purchasing & supply management (PSM) assessment and transformation*. Leykam.

Selepe, R., Munyai, T., & Makinde, O. (2025). A Systematic Literature Review on the Application of Industry 4.0 Technologies in Manufacturing Supply Chain Planning Phase. *International Journal of Supply and Operations Management*, *12*(3), 274–292. https://doi.org/10.22034/ijsom.2025.110610.3259

Shetty, M., Habib, F., Imran Ali, S., Haq, A., & Khan, M. (2023). Impact of Digitalisation in Developing Procurement and Supply Chain Resilience in the Post Pandemic Era—A Study of the Global Manufacturing Sector. In H. Qudrat-Ullah & S. I. Ali (Eds.), *Advanced Technologies and the Management of Disruptive Supply Chains* (pp. 109–151). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-45229-1_6

Simões, A., Madureira, R. C., & Amorim, M. (2023). Unlocking the Potential of Procurement 4.0: The Role of Digitalization, Industry 4.0, and Information Systems. *2023 18th Iberian Conference on Information Systems and Technologies (CISTI)*, 1–6. https://doi.org/10.23919/CISTI58278.2023.10211830

Sjödin, D., Kamalaldin, A., Parida, V., & Islam, N. (2023). Procurement 4.0: How Industrial Customers Transform Procurement Processes to Capitalize on Digital Servitization. *IEEE Transactions on Engineering Management*, *70*(12), 4175–4190. https://doi.org/10.1109/TEM.2021.3110424

Spreitzenbarth, J. M., Bode, C., & Stuckenschmidt, H. (2024). Designing an AI purchasing requisition bundling generator. *Computers in Industry*, *155*, 104043. https://doi.org/10.1016/j.compind.2023.104043

Srai, J. S., & Lorentz, H. (2019). Developing design principles for the digitalisation of purchasing and supply management. *Journal of Purchasing and Supply Management*, *25*(1), 78–98. https://doi.org/10.1016/j.pursup.2018.07.001

Stoykova, S., Hrischev, R., & Shakev, N. (2022). Intelligent Robotic Process Automation for Small and Medium-sized Enterprises. *International Conference Automatics and Informatics, ICAI 2022 - Proceedings*, 223–228. https://doi.org/10.1109/ICAI55857.2022.9960077

Taghipour, A., Lu, X., Derradji, M., & Sow, A. D. (2022). The impact of digitalization on supply chain management: A literature review. *ACM International Conference Proceeding Series*, 75–78. https://doi.org/10.1145/3551690.3551702

Tassabehji, R., & Moorhouse, A. (2008). The changing role of procurement: Developing professional effectiveness. *Journal of Purchasing and Supply Management*, *14*(1), 55–68. https://doi.org/10.1016/j.pursup.2008.01.005

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *British Journal of Management*, *14*(3), 207–222. https://doi.org/10.1111/1467-8551.00375

Trautmann, L. (2021). MAP 4.0 – Proposal for a Prescriptive Maturity Model to Assess the Digitalization of Procurement. In U. Buscher, R. Lasch, & J. Schönberger (Eds.), *Logistics Management. Lecture Notes in Logistics.* (pp. 90–104). Springer. https://doi.org/10.1007/978-3-030-85843-8_6

Tripathi, S., & Gupta, M. (2021). A framework for procurement process re-engineering in Industry 4.0. *Business Process Management Journal*, *27*(2), 439–458. https://doi.org/10.1108/BPMJ-07-2020-0321

Tschandl, M., & Bäck, S. (Eds.). (2008). *Supply chain performance*. Leykam.

van Hoek, R., Gorm Larsen, J., & Lacity, M. (2022). Robotic process automation in Maersk procurement–applicability of action principles and research opportunities. *International Journal of Physical Distribution and Logistics Management*, *52*(3), 285–298. https://doi.org/10.1108/IJPDLM-09-2021-0399

van Weele, A. J., & Eßig, M. (2017). *Strategische Beschaffung: Grundlagen, Planung und Umsetzung eines integrierten Supply Management*. Springer Gabler. https://doi.org/10.1007/978-3-658-08491-2

Viale, L., & Zouari, D. (2020). Impact of digitalization on procurement: The case of robotic process automation. *Supply Chain Forum*, *21*(3), 185–195. https://doi.org/10.1080/16258312.2020.1776089

Waller, M. A., & Fawcett, S. E. (2013). Data Science, Predictive Analytics, and Big Data: A Revolution That Will Transform Supply Chain Design and Management. *Journal of Business Logistics*, *34*(2), 77–84. https://doi.org/10.1111/jbl.12010

Wehrle, M., Birkel, H., von der Gracht, H. A., & Hartmann, E. (2022). The impact of digitalization on the future of the PSM function managing purchasing and innovation in new product development – Evidence from a Delphi study. *Journal of Purchasing and Supply Management*, *28*(2), 100732. https://doi.org/10.1016/j.pursup.2021.100732

Zafari, F., & Teuteberg, F. (2018). Der Weg zum Einkauf 4.0: Herausforderungen bei der Automatisierung und Digitalisierung im Einkauf-Eine multi-methodische Analyse am Beispiel der Logistikbranche. *Multikonferenz Wirtschaftsinformatik 2018*, 2069–2080.

Zip. (2024, July 31). *Zip recognized in the Gartner® Hype Cycle™ for Procurement and Sourcing Solutions, 2024*. Ziphq.Com. https://ziphq.com/blog/zip-recognized-in-gartner-hype-cycle-2024

Appendix A.

Table 2. Sources considered in the SLR

#	Source	Title	Source Type	Number of Applications
1	Afanasiev et al., 2019	Role and significance of mobile technologies in digitalization of procurement systems in oil and gas companies	Conference	1
2	Alnuaimi et al., 2025	Role of big data analytics and information processing capabilities in enhancing transparency and accountability in e-procurement applications	Journal	1
3	Althabatah et al., 2023	Transformative Procurement Trends: Integrating Industry 4.0 Technologies for Enhanced Procurement Processes	Journal	4
4	Angrian & Sahroni, 2019	Development of vendor management and e-Procurement systems using android platform	Conference	1
5	Bahaweres et al., 2022	Improving Purchase to Pay Process Efficiency with RPA using Fuzzy Miner Algorithm in Process Mining	Conference	2
6	Bavrin et al., 2021	The analysis of digitalization impact on personnel functions in logistics	Conference	2
7	Bienhaus & Haddud, 2018	Procurement 4.0: factors influencing the digitisation of procurement and supply chains	Journal	2
8	Bigliardi et al., 2022	The digitalization of supply chain: A review	Conference	3
9	Bruzzi et al., 2021	Toward the strengthening of enabling technologies in Italy: results of the second survey on procurement 4.0	Journal	1
10	Bueno et al., 2024	The Procurement 4.0 Contributions to Circular Economy	Journal	4
11	Chandrasekara et al., 2020	A literature-based survey on industry 4.0 technologies for procurement optimization	Conference	2
12	Colombo et al., 2023	Navigating the socio-technical impacts of purchasing digitalisation: A multiple-case study	Journal	10
13	Delke et al., 2023	Differentiating Between Direct and Indirect Procurement: Roles, Skills and Industry 4.0	Journal	4
14	ElAmmari et al., 2024	Procurement Improvement Process Based on Industry 4.0 & Lean Manufacturing: A Case Study	Conference	1
15	El Asri & Benhlima, 2022	ARTIFICIAL INTELLIGENCE-BASED PROCESS AUTOMATION IN E PROCUREMENT: A SYSTEMATIC LITERATURE REVIEW	Journal	9
16	Eriksson et al., 2024	Virtual Commissioning During the Manufacturing Equipment Procurement Process: From an Industrial Expert Point of View	Book chapter	1
17	Flechsig, 2021	The Impact of Intelligent Process Automation on Purchasing and Supply Management – Initial Insights from a Multiple Case Study	Conference	10
18	Flechsig et al., 2022	Robotic Process Automation in purchasing and supply management: A multiple case study on potentials, barriers, and implementation	Journal	7
19	Ghouri & Mani, 2019	Role of real-time information-sharing through SaaS: An industry 4.0 perspective	Journal	1
20	Gottge et al., 2020	Industry 4.0 technologies in the purchasing process	Journal	12
21	Govindan et al., 2024	Blockchain technology as a strategic weapon to bring procurement 4.0 truly alive: Literature review and future research agenda	Journal	7
22	Govindan et al., 2022	Supply Chain 4.0 performance measurement: A systematic literature review, framework development, and empirical evidence	Journal	13
23	Gunasekara et al., 2022	Effective use of blockchain technology for facilities management procurement process	Journal	5
24	Hallikas et al., 2021	Digitalizing procurement: the impact of data analytics on supply chain performance	Journal	1
25	Haoud & Hasnaoui, 2019	Supply Chain and Industry 4.0: Impact and Performance Analysis: Case of BIOMERIEUX	Conference	1
26	Herold et al., 2023	Dynamic capabilities for digital procurement transformation: a systematic literature review	Journal	1
27	Hofbauer & Sangl, 2019	Blockchain technology and application possibilities in the digital transformation of transaction processes	Journal	5
28	Jahani et al., 2021	Application of industry 4.0 in the procurement processes of supply chains: A systematic literature review	Journal	30
29	Jain et al., 2024	Frameworks, Linkages, Benefits, Challenges, and Future Scope in Procurement 4.0: A Systematic Literature Review From 2014 to 2023	Journal	3
30	Jonen, 2023	Current Trends and Future Potentials of Digitalization in Procurement Controlling	Book chapter	7
31	Klünder et al., 2019	Procurement 4.0: How the digital disruption supports cost-reduction in Procurement	Journal	7
32	Komdeur & Ingenbleek, 2021	The potential of blockchain technology in the procurement of sustainable timber products	Journal	1
33	Křenková et al., 2021	How software robots can facilitate the procurement process? A case study of siemens in the Czech Republic	Journal	2
34	Kuruvilla et al., 2023	Implementation of Industry 4.0 in Supply Chain Management in the Healthcare Industry	Conference	1
35	C.-Y. Lee et al., 2022	Data science and reinforcement learning for price forecasting and raw material procurement in petrochemical industry	Journal	1
36	Lorentz et al., 2021	Structuring the phenomenon of procurement digitalisation: contexts, interventions and mechanisms	Journal	5
37	Maedche, 2019	Interview with Joerg Mimmel on "Digitalization of Purchasing at Bosch"	Journal	1
38	Maheshwari et al., 2023	Digital twin-driven real-time planning, monitoring, and controlling in food supply chains	Journal	1
39	Miehle et al., 2019	Toward a decentralized marketplace for self-maintaining machines	Conference	3
40	Mukherjee & Ahmad, 2023	Impact of Digital Transformation in Sourcing & Tender Management Processes on Employee Job Satisfaction - A Study on Malaysian Multinational Electricity Company	Conference	1
41	Nicoletti, 2020	Procurement 4.0 and the fourth industrial revolution: The opportunities and challenges of a digital world	Monograph	8
42	Pause & Blum, 2018	Conceptual design of a digital shadow for the procurement of stocked products	Conference	1
43	Pirrone & Meyer, 2021	Development of a Procurement-4.0-PMS using the Balanced Scorecard	Conference	4
44	Rejeb & Appolloni, 2022	The Nexus of Industry 4.0 and Circular Procurement: A Systematic Literature Review and Research Agenda	Journal	23
45	Ruel et al., 2023	Can organizational legitimacy stimulate digitalization and affect operational performance? The impact of COVID-19 on uncertainty in supply management	Journal	2

#	Source	Title	Source Type	Number of Applications
46	Sahoo & Jakhar, 2024	Industry 4.0 deployment for circular economy performance—Understanding the role of green procurement and remanufacturing activities	Journal	2
47	Sai et al., 2022	Integration of Chatbots in the Procurement Stage of a Supply Chain	Conference	3
48	Shetty et al., 2023	Impact of Digitalisation in Developing Procurement and Supply Chain Resilience in the Post Pandemic Era—A Study of the Global Manufacturing Sector	Book chapter	6
49	Simões et al., 2023	Unlocking the Potential of Procurement 4.0 : The Role of Digitalization, Industry 4.0, and Information Systems	Conference	1
50	Sjödin et al., 2023	Procurement 4.0: How Industrial Customers Transform Procurement Processes to Capitalize on Digital Servitization	Journal	1
51	Spreitzenbarth et al., 2024	Designing an AI purchasing requisition bundling generator	Journal	3
52	Srai & Lorentz, 2019	Developing design principles for the digitalisation of purchasing and supply management	Journal	13
53	Stoykova et al., 2022	Intelligent Robotic Process Automation for Small and Medium-sized Enterprises	Conference	3
54	Taghipour et al., 2022	The impact of digitalization on supply chain management: A literature review	Conference	6
55	Tripathi & Gupta, 2021	A framework for procurement process re-engineering in Industry 4.0	Journal	11
56	van Hoek et al., 2022	Robotic process automation in Maersk procurement–applicability of action principles and research opportunities	Journal	4
57	Viale & Zouari, 2020	Impact of digitalization on procurement: the case of robotic process automation	Journal	2
58	Wehrle et al., 2022	The impact of digitalization on the future of the PSM function managing purchasing and innovation in new product development – Evidence from a Delphi study	Journal	8

Appendix B.

Table 3. Procurement 4.0 applications – analysis table | Legend: DoA: Degree of Automation, IC: Information Content

#	Source	Technologies and Concepts			Procurement Processes and Tasks					DoA	DoI	Application description (paraphrased)
1	Afanasiev et al., 2019	chatbot			Others					3	2	Use of a chatbot that searches through existing procurements and qualifications 24/7 and answers questions
2	Alnuaimi et al., 2025	big data	real-time information	e-procurement	Sustainability & Compliance	Controlling & Reporting	Risk Management			2	3	Use of BDA to facilitate real-time analysis of extensive data, enabling informed decision-making while promoting fairness, compliance, and integrity within procurement activities, thereby supporting ethical procurement practices. This approach not only enhances operational efficiency but also strengthens adherence to ethical standards. Moreover, through the implementation of e-procurement systems that improve data collection and processing, BDA increases transparency, mitigates corruption risks, and enhances fraud detection capabilities.
3	Althabatah et al., 2023	big data			Supplier Relationship Management & Partnering	Supplier Identification & Prequalification				2	2	Use of big data analytics in the supplier appraisal phase, where improved knowledge can reduce procurement costs
4	Althabatah et al., 2023	big data			Negotiation					3	2	Use of big data analytics in negotiations to avoid professional intervention
5	Althabatah et al., 2023	big data			Tendering	Approval & Ordering	Demand Planning & Purchase Requisition	Strategic Demand & Spend Management	Supply Market Monitoring	2	3	Use of big data to assess material prices by accessing the commodities' database of each supplier's cost structure to determine the best timing and price for making a purchase
6	Althabatah et al., 2023	blockchain	smart contracts		Contracting & Onboarding	Invoice & Payment	Controlling & Reporting	Sustainability & Compliance		2	3	Use of blockchain technology in smart contracts to enable secure and transparent transactions, as well as in the rationalisation of payment processes, thereby ensuring traceability and transparency while guaranteeing security and confidentiality
7	Angrian & Sahroni, 2019	smartphone	e-procurement		Others					1	1	Use of a vendor management and e-procurement system on the smartphone
8	Bahaweres et al., 2022	process mining	algorithm		Organizational Development & Process Management					3	2	Use of a process mining tool with a fuzzy miner algorithm to create intuitive and accurate process maps
9	Bahaweres et al., 2022	process mining	robotic process automation		Organizational Development & Process Management					2	2	Use of process mining to identify opportunities for process automation (e.g., RPA) by identifying repetitive manual tasks
10	Bavrin et al., 2021	rfid			Tracking & Tracing	Goods Receipt				3	2	Use of RFID to simplify goods location tracking and organize goods receipt without the physical presence of a purchasing manager
11	Bavrin et al., 2021	artificial intelligence			Strategic Demand & Spend Management	Demand Planning & Purchase Requisition	Approval & Ordering	Controlling & Reporting		3	3	Build a large database and use of artificial intelligence to improve demand and total cost forecasts by taking possible risks into account. This creates an information system that can independently calculate needs and place orders by analyzing suppliers through online resources.
12	Bienhaus & Haddud, 2018	simulation			Risk Management	Controlling & Reporting				2	2	Simulation of supply chain events to create scenarios in advance to effectively and efficiently control the supply chain and evaluate and mitigate risks before they occur
13	Bienhaus & Haddud, 2018	big data	real-time information		Controlling & Reporting	Others				1	2	Use of big data deriving from supply chain interfaces to achieve a high "response velocity" based on real-time transparency in the supply chain
14	Bigliardi et al., 2022	artificial neural network	artificial intelligence		Strategic Demand & Spend Management	Demand Planning & Purchase Requisition	Negotiation	Supplier Selection	Controlling & Reporting	2	2	Use of an Artificial Neural Network (ANN) to identify patterns from large datasets and its application to demand forecasting, pricing, supplier selection, and consumption forecasting
15	Bigliardi et al., 2022	blockchain			Risk Management	Tracking & Tracing	Sustainability & Compliance	Controlling & Reporting		2	2	Use of blockchain to ensure transparency and efficient data exchange, minimizing risks and uncertainties in the supply chain, as the origin of raw materials and all steps to the final product are traceable
16	Bigliardi et al., 2022	internet of things	rfid		Controlling & Reporting	Tracking & Tracing	Sustainability & Compliance			2	2	Raw material status monitoring via the acquisition of information by the IoT and RFID to guarantee health standards or food safety for example
17	Bruzzi et al., 2021	real-time information	platform		Organizational Development & Process Management	Others				1	1	Use of digital platforms for transparent data and information sharing among all supply chain actors in real time
18	Bueno et al., 2024	internet of things	real-time information		Supplier Relationship Management & Partnering	Tracking & Tracing				1	3	Use of the IoT to ensure interconnectivity between elements and devices, creating a transparent environment for suppliers and buyers that enhances traceability and enables trust in the integration of diverse devices from different participants with different functionalities, into a unified real-time network
19	Bueno et al., 2024	blockchain	smart contracts	cryptography	Supplier Relationship Management & Partnering	Sustainability & Compliance	Invoice & Payment	Tracking & Tracing		3	3	Use of Blockchain technology to enable secure, reliable, and tamper-proof data recording and sharing through cryptographic methods, enhance supply chain reliability and traceability by utilizing smart contracts, and facilitate decentralization and independence from traditional financial systems
20	Bueno et al., 2024	cps	sensors	actuators	Controlling & Reporting	Demand Planning & Purchase Requisition				2	1	Use of cyber-physical systems that use sensors and actuators to collect physical data enabling physical inventory control
21	Bueno et al., 2024	artificial intelligence			Supplier Identification & Prequalification	Contracting & Onboarding				3	1	Use of AI to assist with day-to-day administrative business tasks and decision-making in contract management and automated supplier discovery
22	Chandrasekara et al., 2020	web-based applications	real-time information		Supplier Relationship Management & Partnering					1	1	Use of web-based applications for real-time communication across supply chains
23	Chandrasekara et al., 2020	real-time information	internet of things	cloud computing	Supply Market Monitoring	Controlling & Reporting				1	2	Real-time acquisition of market data via the IoT, which is then stored and structured in the cloud to enable real-time sharing of market information
24	Colombo et al., 2023	business intelligence	market intelligence	e-procurement	Controlling & Reporting	Supply Market Monitoring				2	2	Use of augmentation technologies such as business intelligence solutions and market intelligence tools to analyse data from the e-procurement tool and other sources to generate insights for different segments, regions, business units or supplier groups, saving time
25	Colombo et al., 2023	artificial intelligence			Contracting & Onboarding	Controlling & Reporting	Supplier Relationship Management & Partnering			2	1	Use of AI in contract management, costing and supplier management
26	Colombo et al., 2023	platform			Controlling & Reporting	Strategic Demand & Spend Management	Category & Sourcing Strategy Definition	Supplier Relationship Management & Partnering	Organizational Development & Process Management	2	3	Use of a supply chain management portal linked to a supplier management platform to support the development of forecasts and the management of supplier production capacities. These tools ensure that all suppliers have access to consistent information, such as specifications and related clarifications. While automation within these tools simplifies certain tasks, strategic-level activities often require complementary knowledge and human intervention due to their complexity.
27	Colombo et al., 2023	artificial intelligence			Controlling & Reporting	Supply Market Monitoring				2	1	Use of AI to support the analysis of the procurement market
28	Colombo et al., 2023	big data			Supplier Selection	Category & Sourcing Strategy Definition	Risk Management			2	1	Use of big data to select suppliers, formulate sourcing strategies and predict supply chain disruptions

29	Colombo et al., 2023	agent technology	multi-agent			Supplier Identification & Prequalification	Supplier Selection				2	1	Use of multi-agent technology to support the identification and selection of suppliers
30	Colombo et al., 2023	cps				Demand Planning & Purchase Requisition					3	1	Use of cyber-physical systems to automate demand generation
31	Colombo et al., 2023	robotic process automation				Tendering	Others				3	1	Use of RPA in the RFQ and RFI process as well as to reduce manual data and input collection from other departments and save time
32	Colombo et al., 2023	e-signatures				Contracting & Onboarding	Organizational Development & Process Management	Others			2	1	Use of electronic signatures in contract management to reduce manual data and input collection from other departments and save time
33	Colombo et al., 2023	artificial intelligence				Contracting & Onboarding	Organizational Development & Process Management				3	2	Use of an AI-based application in contract management that automatically reads contracts, establishes a contract hierarchy, and identifies which contracts need updates and where, thereby saving time
34	Delke et al., 2023	big data				Strategic Demand & Spend Management	Demand Planning & Purchase Requisition				2	2	Use of big data analytics in demand forecasting, thereby reducing operational planning decisions
35	Delke et al., 2023	artificial intelligence	chatbot	text mining	algorithm	Supplier Identification & Prequalification	Tendering	Supplier Selection			3	3	Use of AI, text mining, data analysis, and interactive communication bots in the identification and selection of suppliers by preparing RFQs based on previous quotations as well as well-coded algorithms in the offer pre-selection process, thereby reducing the effort and increasing the number of addressed suppliers
36	Delke et al., 2023	artificial intelligence				Negotiation	Contracting & Onboarding				2	2	Use of AI in the design and execution of negotiations
37	Delke et al., 2023	blockchain				Risk Management	Tracking & Tracing	Controlling & Reporting			3	3	Use of blockchain in risk management to improve process and supply chain transparency, allowing potential delays and disruptions to be identified at an early stage and corrective measures to be initiated
38	El Asri & Benhlima, 2022	blockchain	algorithm	cryptography		Tendering	Sustainability & Compliance	Negotiation	Supplier Selection		3	3	• Use of blockchain technology for electronic tenders to ensure the confidentiality of electronic seals, reduce the possibility of fraud and exclude third parties, and employ various algorithms to create the tender, submit bids, evaluate and negotiate the bids, select the winners and publish the results • Use of complex cryptographic algorithms (e.g., SHA-256) to ensure security and confidentiality
39	El Asri & Benhlima, 2022	data mining	algorithm	machine learning		Sustainability & Compliance	Organizational Development & Process Management				2	3	• Use of data mining techniques to detect anomalies in procurement processes using the open contracting data standard • Use of the unsupervised learning algorithm "Isolation Forest" to develop a model and increase its accuracy
40	El Asri & Benhlima, 2022	data mining	linear regression	e-procurement		Controlling & Reporting	Supplier Identification & Prequalification				2	3	Supplier performance prediction in an e-procurement system based on data mining techniques using linear regression to identify the best supplier
41	El Asri & Benhlima, 2022	artificial neural network	artificial intelligence			Supplier Identification & Prequalification	Supplier Selection	Supply Market Monitoring			3	3	Use of AI technologies and an Artificial Neural Network to capture and store sourcing information, as well as for benchmarking purposes by comparing different suppliers and suggesting the most suitable one
42	El Asri & Benhlima, 2022	agent technology	multi-agent	e-procurement		Negotiation	Contracting & Onboarding				3	2	Leverage agent technology to search, negotiate, contract, and monitor within a multi-agent e-procurement exception management system
43	El Asri & Benhlima, 2022	semantic technology				Supplier Relationship Management & Partnering	Controlling & Reporting				1	3	• Application of a hybrid middleware-oriented architecture that combines SOA and EDA features using semantic technologies for procurement. • The architecture includes four functionalities: Semantic Web Services discovery, Semantic Web Services orchestration, process activity monitoring, and Semantic Web Services management. These functionalities provide a framework for developing business integration, collaboration, and monitoring in the procurement supply chain.
44	El Asri & Benhlima, 2022	text processing algorithms	e-procurement			Organizational Development & Process Management	Others				3	3	Use of text processing algorithms (vector space model algorithms such as Term Frequency-Inverse Document Frequency [TF-IDF] and Latent Semantic Indexing [LSI]) as a question-answering service for an e-procurement system, where several algorithms aim to find document similarities between user queries and an archive of question-answer pairs
45	El Asri & Benhlima, 2022	artificial intelligence	simulation			Negotiation	Controlling & Reporting				2	1	Use of AI in the procurement process to avoid over-engineering, identify hidden costs, analyze supplier behaviors, and simulate negotiations
46	El Asri & Benhlima, 2022	artificial intelligence				Supplier Relationship Management & Partnering	Controlling & Reporting				2	2	Use of AI in several supplier management sub-processes such as supplier evaluation and supplier classification by capturing KPIs like the supplier score, on-time delivery, nonconforming deliveries or cycle times
47	ElAmmari et al., 2024	rfid				Demand Planning & Purchase Requisition	Controlling & Reporting				2	2	Use of RFID to clearly determine stock levels, increasing stock accuracy for the ordering process
48	Eriksson et al., 2024	virtual commissioning				Organizational Development & Process Management	Supplier Relationship Management & Partnering				2	2	Use of virtual commissioning in the procurement of manufacturing equipment to test and verify it in advance in order to reduce commissioning time and costs
49	Flechsig et al., 2022	robotic process automation	e-procurement			Organizational Development & Process Management	Others				3	2	Use of RPA to compensate for shortcomings in e-procurement systems and to automate tedious (transaction and master) data management tasks
50	Flechsig et al., 2022	robotic process automation				Supplier Relationship Management & Partnering	Others				2	2	Use of RPA for the rapid exchange of data between supply chain partners, potentially reducing the bullwhip effect by avoiding delayed communication
51	Flechsig et al., 2022	robotic process automation	real-time information			Approval & Ordering	Order Confirmation	Tracking & Tracing	Goods Receipt	Invoice & Payment	3	1	Use of RPA that considers real-time information to optimize ordering and monitor order fulfillment
52	Flechsig et al., 2022	robotic process automation				Goods Receipt	Controlling & Reporting	Approval & Ordering	Others		3	2	Use of RPA to supervise and book goods receipt, report KPIs, update e-catalogs, product groups and product information records and process "guided buying" by leading the buyer to the suitable supplier
53	Flechsig et al., 2022	robotic process automation				Strategic Demand & Spend Management	Risk Management				3	3	Use of RPA to analyze spends from different systems and create supplier risk maps by evaluating their capability based on predetermined criteria
54	Flechsig et al., 2022	intelligent process automation	chatbot			Negotiation	Contracting & Onboarding				3	2	Use of chatbots powered by intelligent RPA software to autonomously negotiate supplier contracts
55	Flechsig et al., 2022	robotic process automation				Demand Planning & Purchase Requisition	Approval & Ordering	Tendering	Supplier Relationship Management & Partnering	Others	3	1	Use of RPA for several tasks in the procure-to-pay process and sourcing such as the creation of requests for quotation and purchase orders, communication, and supplier categorization
56	Flechsig, 2021	robotic process automation				Approval & Ordering	Supplier Relationship Management & Partnering	Others			3	2	Use of RPA in back-office processes to generate purchase orders, support communication with suppliers, and to collect and maintain data
57	Flechsig, 2021	intelligent process automation	real-time information			Demand Planning & Purchase Requisition	Strategic Demand & Spend Management	Supply Market Monitoring	Controlling & Reporting	Others	3	2	Leverage IPA to identify buying needs through continuous real-time monitoring, collaborative forecasting and balancing of supply and demand, automated replenishment, monitoring and prediction of market trends, and real-time e-catalog updates based on current inventory

58	Flechsig, 2021	intelligent process automation				Tendering	Approval & Ordering				3	2	Use of IPA in Purchase Order Management for guided buying, RFQs (generation, verification, categorization, and intelligent distribution), response handling (digitization, standardization, and evaluation), optimized purchase order generation, approval, and sending to suitable suppliers based on real-time indices, exchange rates, and raw material prices, as well as purchase order updates
59	Flechsig, 2021	intelligent process automation				Tracking & Tracing	Goods Receipt	Order Confirmation			3	2	Use of IPA in order fulfillment to schedule and track shipments based on order numbers, send notifications, alerts, and reminders to operators and suppliers, reconcile the delivery note with the order, and post goods received
60	Flechsig, 2021	intelligent process automation				Approval & Ordering	Tendering	Invoice & Payment			3	2	Use of IPA for invoice processing and approval to reconcile the RFQ, purchase order, and invoice; check, process, authorize (up to predefined limits), and post invoices; and digitize and standardize multiple invoice formats
61	Flechsig, 2021	intelligent process automation				Strategic Demand & Spend Management	Risk Management	Supplier Relationship Management & Partnering	Controlling & Reporting		3	2	Use of IPA in sourcing analyses to identify patterns and classify transactions with suppliers (spend analysis), answer queries, and generate reports for supplier evaluation and risk management (e.g., scoring data to create risk profiles and potential analyses), and track and benchmark KPIs
62	Flechsig, 2021	intelligent process automation				Supply Market Monitoring	Others				3	2	Use of IPA in the specification of need to research supply markets, analyze products, prices, and quality, prepare specifications, and interpret procurement laws
63	Flechsig, 2021	intelligent process automation				Category & Sourcing Strategy Definition	Tendering	Supplier Identification & Prequalificatio n	Supply Market Monitoring		3	3	Use of IPA in sourcing strategy development to standardize templates for tendering, request information from potential suppliers, and search the Internet for current supplier information (e.g., negative press releases, difficulties, insolvency)
64	Flechsig, 2021	intelligent process automation	market intelligence			Supplier Identification & Prequalificatio n	Tendering	Supplier Selection	Supply Market Monitoring		3	2	Use of IPA in supplier selection to compare tenderer's responses and provide objective sourcing recommendations based on supply market intelligence and analysis
65	Flechsig, 2021	intelligent process automation				Negotiation	Contracting & Onboarding	Supplier Relationship Management & Partnering			3	3	• Use of IPA in contracting for supplier negotiation (e.g., optimized quantities and pricing), supplier onboarding and communication (e.g., sending evaluation forms, requesting [legal] documents and quality certificates, verifying their validity and highlighting discrepancies, and handling and responding to questions and complaints) • Use of IPA in contracting to review, create and update contracts and compare them to best-in-class templates, and analyze contract usage to negotiate adjustments, discounts, or penalties
66	Ghouri & Mani, 2019	real-time information	saas			Organizational Development & Process Management	Others				1	1	Use of software-as-a-service (SaaS) for real-time information sharing with stakeholders
67	Gottge et al., 2020	internet of things	business intelligence			Supplier Selection					2	1	Use of IoT and/or Business Intelligence in IT-supported supplier selection
68	Gottge et al., 2020	business intelligence				Negotiation					3	1	• Use of BI for analyzing previous negotiations to suggest strategies • Use of BI to enable automatic price changes in negotiations
69	Gottge et al., 2020	big data	internet of things	business intelligence		Negotiation					3	1	Use of BD/BI for electronic negotiations and strategies as well as the IoT and BI for automated negotiations for simple products
70	Gottge et al., 2020	business intelligence	big data			Supplier Relationship Management & Partnering					1	1	Use of BD/BI to improve the feedback to the suppliers
71	Gottge et al., 2020	internet of things	real-time information			Tracking & Tracing					2	1	Use of IoT to track the delivery and production status in real-time
72	Gottge et al., 2020	internet of things	big data	business intelligence		Others					1	1	Use of IoT and BD/BI with additional information for proactive trouble shooting
73	Gottge et al., 2020	internet of things	business intelligence			Approval & Ordering					3	1	Use of IoT and BI to automate the order process, also for pre-serial production
74	Gottge et al., 2020	internet of things	big data	business intelligence		Risk Management	Controlling & Reporting				1	1	Use of BD/BI and IoT for early warning systems (e.g. regarding weather)
75	Gottge et al., 2020	big data	internet of things	real-time information		Supplier Relationship Management & Partnering	Controlling & Reporting				2	2	Use of IoT and Big Data for real-time, holistic supplier evaluations, including sub-suppliers, enabling the identification of performance issues at their root
76	Gottge et al., 2020	big data	business intelligence			Category & Sourcing Strategy Definition	Supply Market Monitoring	Risk Management	Controlling & Reporting		2	1	Use of BD/BI to analyze the purchasing process, facilitate strategic sourcing, analyze supply market trends and suppliers, and predict supply disruptions
77	Gottge et al., 2020	internet of things	real-time information	platform		Supplier Relationship Management & Partnering	Risk Management	Organizational Development & Process Management	Others		1	3	Use of IoT for information sharing between suppliers and buyers as well as uncertainty reduction (e.g. supplier capabilities to fulfill demand) through increased transparency based on real-time information (e. g. collaborative information databases)
78	Gottge et al., 2020	internet of things	business intelligence			Supplier Identification & Prequalificatio n					3	1	Use of IoT/BI for suggestions in the pre-qualification of the supplier selection process
79	Govindan et al., 2022	sensors	real-time information			Tracking & Tracing	Controlling & Reporting				1	3	Use of embedded sensors collecting and recording product process and environmental data to allow the traceability and supply chain monitoring in real-time
80	Govindan et al., 2022	cloud computing	platform	real-time information		Strategic Demand & Spend Management	Demand Planning & Purchase Requisition	Supplier Relationship Management & Partnering			2	3	Use of a cloud platform that allows the entire supply chain to access cloud-based applications in real time to create accurate demand forecasts for supply chain partners based on analytics of sales data collected via the Internet, thereby reducing the bullwhip effect
81	Govindan et al., 2022	cloud computing	additive manufacturin g			Supplier Relationship Management & Partnering	Strategic Demand & Spend Management	Category & Sourcing Strategy Definition	Others		2	3	• Use of cloud computing in inventory management to reduce safety stocks and the bullwhip effect through better coordination among supply chain partners, as well as utilizing additive manufacturing to decentralize production and consequently influence (safety) stocks. • Consideration of additive manufacturing technology as an alternative, for example for spare parts or tools, in procurement decisions (make-or-buy, strategic sourcing, etc.), since decentralized production has the potential to shorten transportation lead times.
82	Govindan et al., 2022	internet of things	cloud computing	real-time information	platform	Organizational Development & Process Management	Others				2	3	Use of IoT sensor technologies and CC to enable real-time collection, accessing, sharing, and processing of information via a digital platform by using a standard user interface enabling remote accessibility
83	Govindan et al., 2022	big data	cloud computing	internet of things		Supplier Relationship Management & Partnering	Risk Management				2	2	Use of big data analytics, cloud computing and IoT in the collaboration with suppliers and thereby reducing supply risk via improved information flow transparency
84	Govindan et al., 2022	big data	predictive analytics			Strategic Demand & Spend Management	Category & Sourcing Strategy Definition	Controlling & Reporting	Demand Planning & Purchase Requisition		1	2	Leverage big data collection to enable more accurate forecasts within predictive analytical tools, facilitating agile responses to demand volatility and market changes
85	Govindan et al., 2022	cloud computing	horizontal integration			Demand Planning & Purchase Requisition	Approval & Ordering	Supplier Relationship Management & Partnering			3	2	Use of cloud systems for the horizontal integration of manufacturers and suppliers, which enables raw material demand to be recognized automatically and orders to be sent automatically without human interfaces
86	Govindan et al., 2022	digital twin	simulation			Organizational Development & Process Management	Strategic Demand & Spend Management	Supplier Relationship Management & Partnering	Risk Management	Others	2	3	Application of the Digital Twin (DT) concept using simulation modeling to test products in a virtual environment in full detail. This approach allows for optimization and provides accurate predictions of maintenance and productivity using data from the sensor system, enhancing efficiency throughout the entire production line and supply chain. Consequently, the use of a Digital Twin in procurement can enhance early supplier involvement and facilitate forward sourcing strategies.

87	Govindan et al., 2022	internet of things	big data	cloud computing	vertical integration	horizontal integration		Risk Management	Supplier Relationship Management & Partnering			1	1	Use of IoT, BDA, CC, and vertical and horizontal integration to increase transparency in the supply chain and improve risk management
88	Govindan et al., 2022	internet of things	big data	platform	cloud computing	horizontal integration	vertical integration	Demand Planning & Purchase Requisition	Strategic Demand & Spend Management			1	2	Use of IoT, big data analytics (BDA), cloud-based platforms (CC), and both vertical and horizontal integration to improve the accuracy of demand forecasting through enhanced data collection from customers
89	Govindan et al., 2022	internet of things	cps	cloud computing	big data	sensors	real-time information	Tracking & Tracing				1	2	Use of IoT, CPS, CC, and BDA to improve real-time traceability based on embedded sensors that collect relevant production process and environmental data
90	Govindan et al., 2022	big data						Supplier Relationship Management & Partnering	Controlling & Reporting			1	2	Use of big data analytics to improve supplier evaluation by analyzing the performance of suppliers based on big data collected from them
91	Govindan et al., 2022	digital twin						Demand Planning & Purchase Requisition	Others			2	3	Use of a Digital Twin to optimize the spare parts inventory by tracking the life cycles of machines to determine the need for spare parts
92	Govindan et al., 2024	blockchain						Tracking & Tracing	Controlling & Reporting	Organizational Development & Process Management		1	2	Use of BCT to trace and monitor all activities of suppliers and stakeholders using timestamps, thereby eliminating information asymmetry
93	Govindan et al., 2024	blockchain						Negotiation	Sustainability & Compliance			1	2	Use of BCT to enable direct negotiations, thereby combating corruption and fraudulent practices
94	Govindan et al., 2024	blockchain						Sustainability & Compliance	Controlling & Reporting	Supplier Relationship Management & Partnering		1	3	Use of BCT, which employs a proof-of-work mechanism to prevent data manipulation through its immutable structure. This tamper-proof capability establishes a secure audit trail, enabling network participants to reach consensus on matters such as verifying asset ownership.
95	Govindan et al., 2024	blockchain						Tendering				1	3	Use of BCT, data encryption, and hashing mechanisms in the tendering process to ensure a high level of privacy when comparing suppliers' prices and quality assessment results without disclosing them to the individual parties involved
96	Govindan et al., 2024	blockchain	real-time information	platform				Supplier Relationship Management & Partnering	Demand Planning & Purchase Requisition	Organizational Development & Process Management		2	2	Use of BCT for seamless integration and collaboration on a single platform, enabling real-time information sharing to reduce turnaround time, address demand-supply gaps, and shorten procurement lead times
97	Govindan et al., 2024	blockchain						Supplier Identification & Prequalification	Tendering	Supplier Selection		2	2	Use of BCT to evaluate suppliers based on various key performance indicators (KPIs), thereby accelerating the shortlisting process, ensuring equitable awarding, and reducing cognitive bias
98	Govindan et al., 2024	blockchain	smart contracts					Controlling & Reporting	Sustainability & Compliance	Risk Management		2	2	Use of BCT-based smart contracts to control procurement at all stages, from planning to execution, to prevent hidden brokering or unauthorised activities. Smart contracts also ensure adherence to product specifications across the value chain of digital procurement and governance, supported by digital certification.
99	Gunasekara et al., 2022	blockchain						Tendering	Supplier Identification & Prequalification			2	2	Use of BCT to provide a unified buisness messaging system with improved security and transparency in the communication of the pre-tendering phase
100	Gunasekara et al., 2022	blockchain						Tendering	Organizational Development & Process Management			1	2	Use of BCT as a digital register that is visible to all, enables the secure storage of all digital information on the Internet, verifies the completeness of documents, facilitates easy data retrieval, eliminates the need for central authorities and serves as an indestructible public database during the pre-tendering phase
101	Gunasekara et al., 2022	blockchain	cryptography					Tendering				2	2	Use of BCT for encryption and decryption to verify the participation of a service provider in the tendering phase (e.g. authenticity check)
102	Gunasekara et al., 2022	blockchain	smart contracts					Contracting & Onboarding	Claim Management	Demand Planning & Purchase Requisition		3	2	• Use of BCT for decentralized secured automatic contract excecution by means of smart contracts in the post awarding phase • Use of BCT in contract automation by means of smart contracts in the post-award phase, enabling data sharing in real-time, reducing contract risks, responding quickly to dynamic supply chain demands and managing claims using immutable data as evidence
103	Gunasekara et al., 2022	blockchain	smart contracts	cryptocurrencies				Invoice & Payment	Risk Management	Others		3	3	• Use of BCT in the post-award phase to reliably and accurately monitor payment transactions without involving a third party and to record a public transaction history • Use of BCT in payment execution of the post-award phase, by using smart contracts to enable immediate automatic electronic payments while solving the risk of non-payment without third-party verification • Use of BCT in the post-award phase to execute financial transactions using cryptocurrencies and thereby ensuring a secured monetary system, which not only improves operational efficiency but also reduces dependence on banks
104	Hallikas et al., 2021	internet of things	sensors					Demand Planning & Purchase Requisition	Strategic Demand & Spend Management			1	2	Use of IoT solutions and sensor data to gain transparency about customer operations, allowing needs to be anticipated
105	Haoud & Hasnaoui, 2019	rfid	autoid					Tracking & Tracing				2	2	Use of AutoID technology, particularly RFID, for product tracing across various locations
106	Herold et al., 2023	artificial intelligence						Negotiation				3	3	Use of Artificial Intelligence to autonomously conduct negotiations based on game-theoretic insights
107	Hofbauer & Sangl, 2019	blockchain	smart contracts					Contracting & Onboarding	Tendering	Negotiation	Approval & Ordering	3	3	Use of BCT to connect the supply chain and automate the purchasing of standardized materials (e.g., raw materials) through smart contracts. These contracts automatically search for sales offers based on suppliers' created blocks. In the case of a successful match, the contract comes into force immediately, eliminating the need for requests for quotations or negotiations.
108	Hofbauer & Sangl, 2019	blockchain						Tracking & Tracing	Goods Receipt	Claim Management		2	3	Use of blockchain in automated delivery monitoring and incoming goods inspection by recording damage to the goods in the blockchain for verification purposes
109	Hofbauer & Sangl, 2019	blockchain						Controlling & Reporting	Claim Management	Supplier Relationship Management & Partnering		1	3	Use of Blockchain Technology (BCT) to evaluate the logistics performance of suppliers based on data stored in the blockchain, which also facilitates the easy identification of the source of failure in production or transportation if a complaint arises. Additionally, this enables the identification of opportunities for performance improvement.
110	Hofbauer & Sangl, 2019	blockchain	smart contracts					Invoice & Payment	Approval & Ordering			3	3	Use of BCT and smart contracts for the independent legitimization of financial transactions in fulfilling agreed terms, while also enabling logistics objects in the supply chain network to make autonomous decisions and place orders with the support of decentralized control units
111	Hofbauer & Sangl, 2019	blockchain	smart contracts					Sustainability & Compliance	Organizational Development & Process Management	Others		1	3	Use of blockchain as a distributed data store to ensure that all relevant data from the smart contract is accessible to all networked partners, that the contents of the contract are safeguarded, and that compliance with the contract contents is maintained
112	Jahani et al., 2021	big data	blockchain	internet of things				Sustainability & Compliance	Demand Planning & Purchase Requisition	Category & Sourcing Strategy Definition	Approval & Ordering	1	3	Use of BDA to reduce carbon emissions by providing a reliable database for forecasting climate conditions in the supplier delivery process, as well as minimizing energy consumption and making waste disposal more efficient through the further integration of BCT and IoT for resource planning
113	Jahani et al., 2021	virtual reality	internet of things	drones				Supplier Relationship Management & Partnering				2	3	Use of virtual reality or IoT devices, such as drones equipped with sensors, to support the audit process

114	Jahani et al., 2021	internet of things	sensors	real-time information				Demand Planning & Purchase Requisition	Approval & Ordering				3	3	Use of the IoT in the determination of requirements and in the ordering process, where sensors detect material shortages in real-time and forward this information to computers. These computers, based on replenishment contracts and pricing decisions, calculate order quantities and send orders to suppliers.
115	Jahani et al., 2021	artificial intelligence	algorithm	multiple regression	case-based reasoning			Strategic Demand & Spend Management	Tendering	Supplier Selection	Controlling & Reporting		2	3	Combined use of AI, metaheuristic algorithms, multiple regression, and case-based reasoning (CBR) models in price forecasting and bidding decisions because AI is suitable for solving complex problems as it can learn algorithms based on previous data and compare historical with validation data
116	Jahani et al., 2021	artificial intelligence						Supplier Identification & Prequalification					1	2	Use of AI in supplier identification by analyzing patterns to gain a better understanding of supplier behavior
117	Jahani et al., 2021	big data						Supplier Identification & Prequalification	Controlling & Reporting				1	2	Use of BDA to analyze supplier performance to improve sourcing
118	Jahani et al., 2021	robotics						Tracking & Tracing					1	1	Use of robotics to efficiently track material
119	Jahani et al., 2021	internet of things	sensors	rfid	bluetooth	wi-fi	smartphone	Organizational Development & Process Management	Others				1	3	Use of IoT and its components, such as sensors, RFID technology, and smartphones to enable communication and information exchange between stakeholders via Internet communication protocols, Bluetooth and Wi-Fi
120	Jahani et al., 2021	big data	internet of things					Tendering					2	2	Combined use of IoT and BDA considering all aspects of resource allocation in auctions to determine the optimal price
121	Jahani et al., 2021	internet of things						Supplier Identification & Prequalification	Controlling & Reporting	Supplier Relationship Management & Partnering			2	3	Use of the IoT to monitor changes in material, price, and quality from suppliers, updating static information with a unique identifier to facilitate the selection of suitable suppliers for collaboration
122	Jahani et al., 2021	internet of things						Tracking & Tracing					1	2	Use of the IoT to trace products based on their tags
123	Jahani et al., 2021	big data	decision support system					Supplier Relationship Management & Partnering	Supplier Identification & Prequalification				2	2	Use of a BDA decision support system in supplier evaluation and selection based on a measured satisfiability degree
124	Jahani et al., 2021	cloud manufacturing	platform	cloud computing				Approval & Ordering	Supplier Selection				2	2	Use of of a cloud manufacturing platform to regulate the sequence of ordering resources from different suppliers by monitoring all placed orders, resulting in an improvement in supplier selection
125	Jahani et al., 2021	cyber-physical production network	cps					Supplier Selection	Approval & Ordering				3	2	Use of a cyber-physical production network (CPPN), which can lead to an autonomous production system that focuses on the selection of suppliers through mathematical optimization
126	Jahani et al., 2021	internet of things	internet	cloud computing				Supplier Relationship Management & Partnering	Organizational Development & Process Management				2	3	Use of the IoT by labeling goods with an identification tag and connecting information from these tags via the internet to the cloud, making uploaded data easily accessible worldwide and allowing associated suppliers to be connected for purchase
127	Jahani et al., 2021	artificial intelligence						Negotiation					3	2	Use of AI in negotiations, such as in preparation or even for the automatic execution of negotiations without expert interference
128	Jahani et al., 2021	artificial intelligence						Strategic Demand & Spend Management	Demand Planning & Purchase Requisition	Approval & Ordering			2	3	Use of AI to diagnose (raw) material price patterns by accessing databases that provide detailed information on the suppliers' cost structure, allowing the optimal time and price for purchasing to be determined
129	Jahani et al., 2021	artificial intelligence						Negotiation	Others	Supplier Relationship Management & Partnering			2	3	Use of AI in the purchasing or engineering stage to identify product changes that do not impair functionality and/or quality to reduce costs and avoid over-engineering, which also allows breakdown costs caused by suppliers to be systematically and intelligently recognized and assessed to reduce the imposition of hidden costs
130	Jahani et al., 2021	internet of things	operations research models	meta-heuristic networks	supported vector machines			Controlling & Reporting	Sustainability & Compliance	Organizational Development & Process Management			2	2	Use of IoT techniques such as operations research models, meta-heuristic networks and supported vector machines to provide metrics for evaluating procurement processes and reduce opportunities for corruption
131	Jahani et al., 2021	artificial intelligence	algorithm					Sustainability & Compliance	Risk Management	Controlling & Reporting			2	3	Use of AI techniques learning different algorithms to detect destructive behavior in the supply chain based on transaction patterns
132	Jahani et al., 2021	blockchain						Invoice & Payment					2	3	Use of BCT to simplify procurement finances through a paperless cash flow system recording movements and allowing contractors to securely recognize and regulate transactions
133	Jahani et al., 2021	internet of things	machine learning					Organizational Development & Process Management	Others				2	3	Use of IoT technologies to facilitate communication and information sharing between stakeholders, for example by sharing performance information gathered through machine learning, enabling engineers to provide faster feedback to purchasing
134	Jahani et al., 2021	artificial intelligence						Strategic Demand & Spend Management	Demand Planning & Purchase Requisition				1	2	Use of AI in forecasting techniques to learn demand patterns for items
135	Jahani et al., 2021	smart contracts						Invoice & Payment	Organizational Development & Process Management	Tracking & Tracing			3	3	Use of Smart Contracts to track changes in the process status of various supply chain parties and automatically trigger subsequent processes such as payment transactions
136	Jahani et al., 2021	internet of things	cps	cpps	real-time information	sensors		Controlling & Reporting					2	3	Use of IoT technologies such as CPS, CPPS and wireless sensor networks that enable the activities, operations and processes of machines, materials, workers and products to be monitored in the virtual world allowing real-time decision-making
137	Jahani et al., 2021	blockchain	artificial intelligence	smart contracts				Contracting & Onboarding	Approval & Ordering	Others			3	3	Combined use of AI and BCT for data exchange in the logistics chain as well as for calculating customer-specific transport options and creating smart contracts between the logistics and procurement departments that can be executed risk-free by autonomous programs without human intervention
138	Jahani et al., 2021	cloud manufacturing	cloud computing					Supplier Identification & Prequalification	Supplier Selection				2	3	Use of cloud manufacturing in pricing to analyze the effects of different factors (e.g., manufacturing conditions, variety of items, delivery conditions) in order to determine an optimal price in a supplier selection problem
139	Jahani et al., 2021	blockchain	erp	smart contracts				Supplier Relationship Management & Partnering					2	3	Application of blockchain technology in the ERP system to utilize smart contracts for supplier evaluation and decisions regarding further communication
140	Jahani et al., 2021	cloud computing						Sustainability & Compliance	Supplier Selection	Controlling & Reporting			2	3	Use of cloud systems to develop sustainable procurement by considering factors such as carbon footprint (environmental), waste disposal costs (economic), and social aspects, leading to optimized supplier selection and a reduction in carbon emissions
141	Jahani et al., 2021	blockchain						Supplier Relationship Management & Partnering	Contracting & Onboarding	Tendering	Controlling & Reporting	Others	2	3	Use of BCT for data exchange with suppliers and managing issues or challenges related to quality, quotations, ownership, and contracts. The technology enables companies to quickly identify delivery incompatibilities through dynamic data extraction during the ordering process.
142	Jain et al., 2024	big data						Supplier Identification & Prequalification	Supplier Selection	Supply Market Monitoring			2	2	Use of big data analytics to access market intelligence and scout for potential innovation in the supplier search and selection process
143	Jain et al., 2024	platform						Controlling & Reporting	Risk Management				3	3	Use of an automated monitoring platform based on performance-based contracts and software solutions to enhance the visibility of supply risk indicators, thereby minimizing the likelihood of supply disruptions caused by supplier performance issues
144	Jain et al., 2024	blockchain	smart contracts					Tendering					3	2	Use of blockchain-enabled smart contracts for efficient and secure bidding
145	Jonen, 2023	3d printing						Strategic Demand & Spend Management	Category & Sourcing Strategy Definition				1	1	Consideration of the use of 3D printing for the efficient production of small batches in the context of make-or-buy decisions

146	Jonen, 2023	robotic process automation				Demand Planning & Purchase Requisition	Approval & Ordering	Organizational Development & Process Management			3	2	Use of RPA to automate the ordering process by continuously analyzing it (demand and reordering), allowing software robots to execute the process
147	Jonen, 2023	predictive analytics				Demand Planning & Purchase Requisition	Approval & Ordering				3	3	Use of predictive analytics in operational demand forecasting to generate purchase requisitions, where forecasts for procurement needs are created based on historical data, current inventory, order information, and relevant external data. This approach enables the automated initiation of purchase orders.
148	Jonen, 2023	prescriptive analytics				Controlling & Reporting	Demand Planning & Purchase Requisition	Approval & Ordering			1	3	Use of prescriptive methods to calculate commodity price forecasts based on a value driver model in the form of testable hypotheses. From these forecasts, key procurement insights such as price ceilings, optimal order quantities, the best time to purchase, and strategies like natural hedging can be derived.
149	Jonen, 2023	real-time information				Controlling & Reporting					2	1	Use of real-time data to perform ad hoc analyses quickly and easily
150	Jonen, 2023	artificial intelligence				Supplier Relationship Management & Partnering					3	1	Use of AI to automate supplier evaluation
151	Jonen, 2023	agent technology	simulation			Risk Management	Category & Sourcing Strategy Definition				2	2	Use of agent-based models in supply security analysis, simulating the decisions and actions of suppliers to provide corresponding estimates
152	Klünder et al., 2019	3d printing				Category & Sourcing Strategy Definition	Strategic Demand & Spend Management				1	3	Use of 3D printing as an in-house production alternative in make-or-buy decisions in the course of procurement strategy development
153	Klünder et al., 2019	big data	predictive analytics			Demand Planning & Purchase Requisition	Strategic Demand & Spend Management				1	2	Use of BDA and Predictive Analytics in the demand planning process to determine near-optimal demands based on historical data
154	Klünder et al., 2019	internet of things	cybersecurity	cloud computing		Others					3	3	Use of the IoT including cybersecurity in supplier communication, with material processing machines automatically generating relevant data and sending it to suppliers via the IoT or sharing it via cloud services
155	Klünder et al., 2019	internet of things				Tendering	Negotiation	Contracting & Onboarding			2	2	Use of the IoT in bid negotiations by building on existing data analytics results and transferring the supply contract via the IoT and making it available to all cloud services
156	Klünder et al., 2019	predictive analytics				Demand Planning & Purchase Requisition					1	2	Use of Predictive Analytics in the determination and scheduling of order quantities
157	Klünder et al., 2019	advanced robotics	internet of things			Demand Planning & Purchase Requisition					3	3	Use of advanced robotics to measure data in outgoing goods and in the warehouse to determine the optimal order quantity before placing the purchase order directly via the IoT
158	Klünder et al., 2019	virtual reality	augmented reality	data glasses		Goods Receipt	Human Resource Management & Training				2	3	Use of virtual or augmented reality, for example with data glasses, to support employees with instructions during goods inspection in the goods receipt process
159	Komdeur & Ingenbleek, 2021	blockchain				Tracking & Tracing	Sustainability & Compliance				1	3	• Use of BCT to track and trace products and provide an open record of transactions, allowing the origin as well as the legitimacy of the sustainability of the product (timber) to be validated • Use of BCT to strengthen trust in certification systems and reinforcement of their use through the registration of certificates in the blockchain
160	Křenková et al., 2021	robotic process automation	software robot	sap		Approval & Ordering					3	2	Use of software robots to automatically convert a purchase requisition into an SAP purchase order
161	Křenková et al., 2021	robotic process automation	software robot			Supplier Identification & Prequalification	Tendering	Approval & Ordering			3	3	Use of software robots to send RFQs when no supplier or price is available, or if the price is over a year old. The purchaser sends an email with an Excel attachment, following strict guidelines, to a software robot that processes the requests multiple times a day.
162	Kuruvilla et al., 2023	blockchain	cryptography			Tracking & Tracing	Others	Sustainability & Compliance	Organizational Development & Process Management	Negotiation	2	3	Use of BCT to trace supply chain activities. The decentralized database secures an expanding list of blocks against alterations and interruptions. Through cryptographic technology, ownership is made transparent, enabling parties who do not know each other to reach agreements. Additionally, blockchain technology organizes and stores purchase orders and data transfers between parties.
163	Lee et al., 2022	big data	artificial intelligence	neural networks		Strategic Demand & Spend Management	Demand Planning & Purchase Requisition	Controlling & Reporting			1	2	Use of BDA, AI and a recurrent neural network to create a price forecast model based on previously collected data (historical prices, contract prices, capacity operating rate, etc.)
164	Lorentz et al., 2021	social media				Organizational Development & Process Management	Human Resource Management & Training	Others			1	3	Use of social media platforms to support internal communication across the organization and stakeholders, for example to inform about system updates and procurement policies
165	Lorentz et al., 2021	robotic process automation				Invoice & Payment	Contracting & Onboarding	Supplier Selection	Others		3	2	Use of RPA to automate data transfer between systems, invoice processing, contract implementation and supplier validation
166	Lorentz et al., 2021	robotic process automation				Organizational Development & Process Management	Others				3	3	Use of RPA to delete unused supplier data from databases in compliance with the GDPR regulation
167	Lorentz et al., 2021	social media				Supplier Relationship Management & Partnering					1	1	Use of social media for rating suppliers
168	Lorentz et al., 2021	prescriptive analytics	artificial intelligence			Controlling & Reporting	Supplier Relationship Management & Partnering				2	2	Use of prescriptive analytics or AI applications for intelligent anomaly alerts regarding supplier performance
169	Maedche, 2019	machine learning				Supplier Identification & Prequalification	Tendering	Category & Sourcing Strategy Definition			3	3	Use of machine learning for automated document analysis, for example for quotations in indirect purchasing that contain data on supplier competencies, allowing to predict supplier competencies for certain requirements in future projects based on this historical data
170	Maheshwari et al., 2023	digital twin	real-time information			Demand Planning & Purchase Requisition	Strategic Demand & Spend Management	Organizational Development & Process Management			2	3	Use of a digital twin to enhance procurement decision-making by offering real-time data on the accessibility of raw materials and the demand for finished products, enabling more effective planning and optimization of procurement processes
171	Miehle et al., 2019	blockchain	smart contracts	platform		Demand Planning & Purchase Requisition	Approval & Ordering	Invoice & Payment			3	3	Use of a blockchain-based industrial marketplace where machines have an identity and an account and automatically select, order and pay for materials using smart contracts
172	Miehle et al., 2019	blockchain				Controlling & Reporting	Organizational Development & Process Management				1	3	Use of BCT to reliably record the entire procurement process, creating a tamper-proof audit trail and to securely store data in an audit-proof manner
173	Miehle et al., 2019	cryptocurrencies	digital currency	bitcoin	ether	Invoice & Payment					1	2	Use of digital currencies or cryptocurrencies such as Bitcoin or Ether to make micropayments (due to volatility, low acceptance and lack of regulation, the authors point out that the use of existing digital currencies is not recommended)
174	Mukherjee & Ahmad, 2023	artificial intelligence	natural language processing	robotic process automation		Human Resource Management & Training	Organizational Development & Process Management				3	3	Use of AI/NLP and RPA to enhance work efficiency in procurement by automating and streamlining the process landscape. This approach impacts job allocation and fitment by intelligently routing the right job type to the appropriately skilled person. It improves job transparency through a holistic tracking mechanism for the entire job management process. Finally, it enhances the meaningfulness of work by automating mundane tasks, allowing employees to focus on value-adding activities.

175	Nicoletti, 2020	artificial intelligence	app	smartphone	ibm	social media		Supply Market Monitoring	Controlling & Reporting	Category & Sourcing Strategy Definition	Others		2	3	Use of an AI-based system by IBM to provide supplier information via an app that buyers can use on their smartphones to view spend, compare themselves with the competition and gauge market sentiment towards the organization based on social networks
176	Nicoletti, 2020	artificial intelligence	watson	ibm	dashboard			Contracting & Onboarding	Supplier Relationship Management & Partnering	Controlling & Reporting	Risk Management		3	3	• Use of an AI-based system to support the management of contracts, such as IBM Watson's Contract Analyzer, which can read hundreds of millions of pages per second from a database of digital contracts and scanned contracts and search for specific clauses • Use of an AI solution to evaluate contracts with regard to procurement risks, which are calculated on the basis of certain metrics and presented visually on a dashboard that shows the partners for whom it makes sense to improve the contractual conditions
177	Nicoletti, 2020	big data	algorithm					Supplier Relationship Management & Partnering	Organizational Development & Process Management	Controlling & Reporting	Strategic Demand & Spend Management	Supply Market Monitoring	3	3	Use of algorithms to enhance knowledge about partners, markets, and customers, predict market trends through big data analysis (large volumes of data from diverse heterogeneous sources), and support better decision-making. This enables the implementation of measures to improve processes and, ultimately, allows for automated operational procurement decisions.
178	Nicoletti, 2020	predictive analytics						Demand Planning & Purchase Requisition	Risk Management	Controlling & Reporting			2	2	Use of predictive analytics for predictive defect detection to optimize maintenance and spare parts availability
179	Nicoletti, 2020	cognitive procurement	mobile devices	natural language processing				Demand Planning & Purchase Requisition	Approval & Ordering				2	3	Use cognitive procurement via mobile phones and tablets to navigate through multiple channels and procurement systems, recommend products optimally meeting demands or preferred partner catalogs based on user requests, and interact in natural language for an enhanced user experience
180	Nicoletti, 2020	cognitive procurement	robotic process automation					Supplier Identification & Prequalificatio n	Supplier Relationship Management & Partnering	Controlling & Reporting	Organization al Development & Process Management	Others	3	3	Use of cognitive procurement to support the acquisition of new partners, automatically provide prices, evaluate suppliers, manage emergencies (e.g. difficulties with procurement from a specific partner) and integrate automated solutions such as RPA to support processes
181	Nicoletti, 2020	artificial intelligence	robotics	cognitive procurement	natural language processing			Organizational Development & Process Management	Others				3	3	• Use of a system of AI and robotics for a congnitive procurement assistant that uses natural language processing to answer questions about procurement processes • Use of cognitive procurement processes to suggest best practices based on context and respond to partner requests made via email, chat or voice
182	Nicoletti, 2020	robotic process automation						Approval & Ordering	Controlling & Reporting				3	2	Use of RPA to automate simple repetitive tasks, such as checking whether the order has been approved and all necessary steps have been completed
183	Pause & Blum, 2018	sensors	gps	real-time information				Tracking & Tracing					1	3	Use of tracking technologies, such as GPS, for real-time order tracking via location determination, combined with sensor technologies for monitoring the order status as it progresses through different steps in the procurement plan using real-time routing
184	Pirrone & Meyer, 2021	machine learning						Category & Sourcing Strategy Definition					1	2	Use of semantic analyses or machine learning in strategic procurement processes such as plan-to-strategy or source-to-contract supporting commodity group managers in implementing their procurement strategies
185	Pirrone & Meyer, 2021	algorithm						Supplier Relationship Management & Partnering	Supply Market Monitoring	Risk Management	Controlling & Reporting		2	2	Use of intelligent technologies or algorithms to aggregate, process and analyze large volumes of data from many heterogeneous sources in order to understand suppliers, markets, customers and trends or to investigate machine or product faults
186	Pirrone & Meyer, 2021	blockchain						Invoice & Payment					3	2	Use of BCT for secure payment transactions as part of the automation of financing processes
187	Pirrone & Meyer, 2021	real-time information						Others					1	3	Use of real-time sales and customer usage data from field applications to provide insights to suppliers, generating additional revenue opportunities for procurement while enabling suppliers to develop more cost-effective and functional products through tailored specifications. This strategic use of data enhances procurement’s role from a cost center to a profit center.
188	Rejeb & Appolloni, 2022	cps	platform					Tendering					2	2	Use of cyber-physical systems involving several computational platforms to solicit bids and select the best offer based on the data received
189	Rejeb & Appolloni, 2022	cps	sensors	smart bins				Demand Planning & Purchase Requisition	Controlling & Reporting				3	3	Use of cyber-physical systems in the automated material requirements planning by using sensor-driven shelves and smart bins to monitor stocks and thus recognize when replenishment is necessary
190	Rejeb & Appolloni, 2022	cloud computing						Supplier Relationship Management & Partnering	Organizational Development & Process Management	Others			2	3	Use of cloud computing to connect different businesses, factories, and procedures, enabling companies to transform their supply chains into value networks, simplifying collaboration with suppliers and enabling the agility and flexibility that is key to procurement in the age of Industry 4.0
191	Rejeb & Appolloni, 2022	cloud computing						Sustainability & Compliance	Organizational Development & Process Management	Others			2	3	• Use of cloud computing to carry out several planning and execution operations, streamline processes, save costs and facilitate the sharing of information in the management of upstream suppliers for green purchasing and the eco-design of products • Use of cloud computing in the context of circular procurement to calculate the carbon footprint of a product during its life cycle
192	Rejeb & Appolloni, 2022	additive manufacturing						Others	Category & Sourcing Strategy Definition	Sustainability & Compliance			1	3	Integration of additive manufacturing within the framework of circular procurement at an early stage of the product life cycle. This approach enables components to be manufactured on-site (insourcing) based on design files provided by suppliers, creating a new supply network (onshoring). By leveraging in-house production, this method reduces supply risks, minimizes waste and inventory, lowers transportation costs, and promotes sustainable green ecosystems.
193	Rejeb & Appolloni, 2022	big data						Sustainability & Compliance	Controlling & Reporting	Risk Management	Supply Market Monitoring	Category & Sourcing Strategy Definition	2	3	• Use of BDA in the pricing of raw materials, business and environmental risk minimization of suppliers as well as for data collection for more informed green procurement decisions across the product life cycle. • Use of big data in the context of circular procurement to predict disruptions by evaluating suppliers and market trends
194	Rejeb & Appolloni, 2022	big data						Supplier Selection	Approval & Ordering				3	2	Use of big data to automate the selection of sustainable suppliers by optimizing the purchasing operations of standardized and circular parts
195	Rejeb & Appolloni, 2022	blockchain	smart contracts					Tracking & Tracing	Sustainability & Compliance	Controlling & Reporting			2	3	• Use of BCT to strengthen information security, ensure transparency and traceability throughout the entire product life cycle. • Use of BCT to overcome supply chain sustainability issues such as theft, fraud or corruption through the ability to improve data integrity and authenticate transactions as well as guarantee compliance with environmental requriements by increasing traceability and transparency. • Use of smart contracts coded on blockchain systems to monitor corruption, sustainability concerns and social aspects such as subcontracting, making circular procurement more transparent and traceable.
196	Rejeb & Appolloni, 2022	blockchain						Supplier Relationship Management & Partnering	Sustainability & Compliance	Others			2	2	Use of BCT to quickly verify documents from suppliers such as licenses, certifications and record proofs, resulting in robust integration between supply chain partners
197	Rejeb & Appolloni, 2022	smart contracts						Supplier Selection	Contracting & Onboarding	Supplier Identification & Prequalificatio n	Negotiation	Tendering	3	2	Use of smart contracts for automation to eliminate weaknesses in circular procurement processes and transform the entire supplier selection process into a flexible smart contract
198	Rejeb & Appolloni, 2022	smart contracts						Tracking & Tracing	Organizational Development & Process Management				1	3	Use of smart contracts in auditing circular procurement processes, as they provide a legal basis that can ensure the traceability and auditability of information

199	Rejeb & Appolloni, 2022	internet of things	wi-fi	bluetooth	real-time information			Supplier Relationship Management & Partnering	Organizational Development & Process Management	Others			3	3	• Use of the IoT to automate data collection and transmission for a continuous, unrestricted flow of data through a unified interface and facilitating the interconnection and sharing of relevant information between organizations using internet connection protocols, Wi-Fi and Bluetooth • Use of the IoT to create data in real-time and make it available to buyers and suppliers
200	Rejeb & Appolloni, 2022	internet of things						Supplier Selection	Negotiation				2	3	Use of the IoT within an ecosystem in which suppliers can change previously static data by assigning unique identifiers to products sold at different locations, allowing the IoT system to support the selection of suitable suppliers for collaboration based on parameters such as prices, materials and quality changes
201	Rejeb & Appolloni, 2022	internet of things						Tracking & Tracing					1	2	Use of the IoT to track products using tags
202	Rejeb & Appolloni, 2022	internet of things	meta-heuristic networks	operations research models	supported vector machines			Controlling & Reporting	Sustainability & Compliance				2	3	Use of IoT techniques, such as meta-heuristic networks, operations research models and supported vector machines, to derive metrics to evaluate circular procurement processes in order to reduce corruption
203	Rejeb & Appolloni, 2022	internet of things						Controlling & Reporting	Sustainability & Compliance				2	3	Use of IoT to monitor fuel consumption, emissions and mileage of trucks to improve transportation infrastructure and routing strategies
204	Rejeb & Appolloni, 2022	internet of things						Supplier Relationship Management & Partnering	Controlling & Reporting	Sustainability & Compliance			2	3	Use of IoT networks to track suppliers' performance and environmental effects, allowing suppliers' environmental performance to be monitored through a long-term partnership
205	Rejeb & Appolloni, 2022	simulation	algorithm					Organizational Development & Process Management	Controlling & Reporting				1	3	Model earnings and operating expenses to account for the effects of random factors such as order quantities and delivery times through the use of simulations, and using simulation models that accurately portray system dynamics to assess process changes based on their algorithms
206	Rejeb & Appolloni, 2022	simulation	platform					Sustainability & Compliance	Others				2	3	Use of simulation in the context of a smart supply chain to enable digital platforms with suppliers and customers to optimize green performance, for example by conducting tests virtually rather than on physical prototypes
207	Rejeb & Appolloni, 2022	artificial intelligence						Supplier Identification & Prequalification	Supplier Selection	Supply Market Monitoring			2	3	Use of AI to gather and evaluate market data in supplier selection and to analyze certain supplier behavior patterns in order to identify suitable potential suppliers
208	Rejeb & Appolloni, 2022	artificial intelligence						Sustainability & Compliance					2	2	Use of AI in remanufacturing operations by using the data collected at the end of the product's life to guide remanufacturing processes and reduce pollution
209	Rejeb & Appolloni, 2022	artificial intelligence	machine learning	deep learning				Risk Management					2	2	Use of AI techniques such as machine learning and deep learning to analyze circular procurement data to achieve better pricing protecting against economic and ecological harms
210	Rejeb & Appolloni, 2022	artificial intelligence	algorithm	case-based reasoning				Negotiation	Tendering	Contracting & Onboarding			2	3	Use of AI and various methods such as multiple regression, meta-heuristic algorithms and case-based reasoning models to speed up and improve the accuracy of the pricing process for various suppliers as well as using AI to learn from data and compare historical with real-time data to estimate optimal price in procurement contracts and bidding decisions
211	Ruel et al., 2023	digital twin	artificial intelligence					Risk Management	Others				1	1	Use of digital twin models and AI to provide visibility and reduce uncertainty along the supply chain
212	Ruel et al., 2023	blockchain						Risk Management	Tracking & Tracing				1	2	Use of BCT to improve the transparency and traceability of supply information, thereby aiding in the mitigation of upstream supply chain risks
213	Sahoo & Jakhar, 2024	blockchain	internet of things	cloud computing	real-time information	sensors		Sustainability & Compliance	Controlling & Reporting				2	3	Use of blockchain technology, combined with the sensing power of the IoT and the computing power of cloud technologies, to enable the implementation of a real-time, technology-enabled monitoring and collaboration strategy for the entire value chain, enhancing compliance, resilience, and the transition to a circular economy. This approach ensures that all participants in both the upstream and downstream network adhere to corporate policies and adopt a strategic focus on social sustainability.
214	Sahoo & Jakhar, 2024	internet of things	blockchain	cloud computing	dashboard	h2m		Controlling & Reporting	Organizational Development & Process Management	Demand Planning & Purchase Requisition	Strategic Demand & Spend Management		2	3	Use of a human-machine interface or dashboard that integrates IoT, cloud computing, and blockchain technologies (and potentially others) to specify and monitor manufacturing lead times, component-wise, supplier-wise, and in-house process-wise. This approach facilitates continuous transparency of supplier performance, more accurate planning, and effective monitoring of lead times, thereby reducing bottlenecks and optimizing the remanufacturing process.
215	Sai et al., 2022	chatbot	python					Human Resource Management & Training	Organizational Development & Process Management	Others			2	2	Use of chatbots developed with Python to provide users with the information they need to simplify the procurement process
216	Sai et al., 2022	robotic process automation						Demand Planning & Purchase Requisition	Others				3	2	Use of RPA for optimization in areas such as data management, bill of material preparation, inventory management, and stock optimization
217	Sai et al., 2022	big data						Risk Management	Demand Planning & Purchase Requisition	Negotiation			2	2	Use of big data to analyze raw material prices, lead times and geographically related business risks
218	Shetty et al., 2023	big data						Supplier Identification & Prequalification	Supplier Selection	Risk Management	Controlling & Reporting		2	3	Use of BDA to improve information processing and optimize the supplier selection process both prior to and during disruptions, thereby enhancing predictive capabilities. Alongside intelligent systems and linked ecosystems, BDA aids in forecasting disruptive events. Additionally, it can assess the risk exposure of each component throughout the supply chain, ensuring end-to-end transparency and allowing for the prioritization of risks accordingly.
219	Shetty et al., 2023	drones	robotics					Demand Planning & Purchase Requisition	Approval & Ordering				3	3	Use of drones and robots to count inventory, reducing manual errors, increasing accuracy and improving operational efficiency. This enables systems to generate alerts and automatically reorder items when stock levels drop below a specified threshold, thereby freeing up time and human resources.
220	Shetty et al., 2023	big data	real-time information					Risk Management	Controlling & Reporting	Demand Planning & Purchase Requisition			1	2	Use of BDA to enhance supply chain visibility and enable rapid identification of disruptions. Advanced analytics and expertise allow for real-time understanding of demand fluctuations and their impact on inventory and operating capital, supporting flexible adjustments from manufacturing to raw material sourcing.
221	Shetty et al., 2023	blockchain						Others	Approval & Ordering	Controlling & Reporting	Supplier Relationship Management & Partnering	Invoice & Payment	3	3	Use of BCT to establish direct connections between buyers and suppliers to potentially close gaps, reduce inefficiencies, automate audits, enable instant orders, payments and reporting of process-related activities, and thus develop more robust systems.
222	Shetty et al., 2023	blockchain	real-time information					Risk Management	Sustainability & Compliance	Tracking & Tracing	Controlling & Reporting		1	3	Use of BCT to minimise self-serving behaviour (e.g. rationing and shortage gaming) during crises and enable more effective supply chain responses when supplies are tracked in real time using immediate, traceable and verifiable techniques.
223	Shetty et al., 2023	augmented reality	real-time information					Supplier Relationship Management & Partnering	Others	Tendering	Negotiation	Contracting & Onboarding	2	2	Use of Augmented Reality to transform buyer-supplier interactions by facilitating collaborative procurement meetings, enabling real-time bidding, negotiations, and contract signing
224	Simões et al., 2023	blockchain	erp					Organizational Development & Process Management	Others				2	3	Use of blockchain technology to limit access to data in ERP systems to authorized users and establish monitoring permissions to enhance data security by tracking access activities
225	Sjödin et al., 2023	load-weighing solutions						Supplier Relationship Management & Partnering	Tracking & Tracing	Controlling & Reporting			1	3	Use of load-weighing solutions in trucks to obtain and exchange information about the tons transported and derive possible optimizations that can be managed throughout the duration of the contract between customer and supplier

226	Spreitzenbarth et al., 2024	artificial intelligence					Supplier Identification & Prequalification	Supplier Selection	Approval & Ordering		3	2	Use of AI to recommend alternative suppliers for indirect procurement
227	Spreitzenbarth et al., 2024	artificial intelligence					Supplier Identification & Prequalification	Tendering			3	3	Use of a bundling generator within a comprehensive AI module, adjunct to the tendering system, to recommend potential bidders for projects, thereby enhancing process efficiencies
228	Spreitzenbarth et al., 2024	algorithm	mini batch k-means	erp			Strategic Demand & Spend Management	Tendering	Demand Planning & Purchase Requisition		2	3	Use of clustering algorithms, such as Mini Batch K-means, as a bundling analytics model in the requisition modules of ERP systems in order to bundle purchase requisitions and thus create a better decision-making basis for setting up RFQs and realizing savings potential
229	Srai & Lorentz, 2019	additive manufacturing					Others	Category & Sourcing Strategy Definition			1	3	Use of additive manufacturing technology to manufacture products in-house using data provided by suppliers for designs and plans, which can reduce transportation of bulky items
230	Srai & Lorentz, 2019	cloud computing					Goods Receipt	Controlling & Reporting			1	2	Use of a cloud-based "watch tower" to monitor the supply chain in real time and improve inbound procurement scheduling
231	Srai & Lorentz, 2019	algorithm	genetic algorithm	cloud computing	cloud manufacturing		Supplier Selection	Approval & Ordering			1	1	Use of genetic algorithms to facilitate supplier selection and order allocation in cloud-based manufacturing
232	Srai & Lorentz, 2019	big data					Controlling & Reporting	Risk Management			2	1	Use of intelligent big data analyses in supplier performance controlling and disruption prediction
233	Srai & Lorentz, 2019	blockchain	cognitive computing				Tracking & Tracing				2	2	Use of BCT and a cognitive computing-powered system for managing product information records to trace and authenticate items
234	Srai & Lorentz, 2019	cognitive computing	decision support system				Negotiation	Category & Sourcing Strategy Definition	Strategic Demand & Spend Management		3	2	Use of cognitive computing and various decision support systems for intelligent supplier segmentation, intelligent price negotiations and global outsourcing
235	Srai & Lorentz, 2019	intelligent agent	e-procurement				Category & Sourcing Strategy Definition	Organizational Development & Process Management	Tendering		3	2	Use intelligent agent-based systems to handle e-procurement exceptions, determine the optimal bundle of received offers based on business rules, and develop effective procurement strategies
236	Srai & Lorentz, 2019	intelligent agent					Human Resource Management & Training	Organizational Development & Process Management	Others		2	2	Use of intelligent agents to support and advise internal customers on procurement decisions
237	Srai & Lorentz, 2019	augmented reality					Organizational Development & Process Management	Human Resource Management & Training			2	2	Use of augmented reality applications to make object- or process-related and analytics-based information usable by looking at it
238	Srai & Lorentz, 2019	virtual supplier room	platform	social media	cloud computing		Supplier Relationship Management & Partnering	Organizational Development & Process Management	Category & Sourcing Strategy Definition	Others	1	3	Creation of a virtual supplier room based on collaboration-oriented social media and cloud platforms that enables the exchange of information (costs, risks, technologies, ...) with strategic suppliers and collaboration on product development and open innovation
239	Srai & Lorentz, 2019	virtual reality	digital sense applications	digital twin	telepresence		Controlling & Reporting	Others	Supplier Relationship Management & Partnering		2	3	Use of digital sense applications to remotely assess product features and condition, as well as conduct supplier audits using virtual reality applications in the form of telepresence or digital twins
240	Srai & Lorentz, 2019	social media	platform	cloud computing	virtual category room		Category & Sourcing Strategy Definition	Controlling & Reporting	Supply Market Monitoring	Organizational Development & Process Management	1	3	Establishment of a virtual category room providing a platform for cross-functional category management based on social media and cloud technology, for monitoring ongoing category management projects and exchanging procurement market information
241	Srai & Lorentz, 2019	cognitive computing	algorithm				Controlling & Reporting				3	1	Use of cognitive-computing-based intelligent algorithms to automate reporting
242	Stoykova et al., 2022	intelligent process automation	Intelligent robotic process automation	erp			Organizational Development & Process Management	Others			3	3	Use of intelligent RPA bots for process automation in ERP systems, such as identifying and extracting data, navigating between systems, transferring relevant data across platforms and between users, creating logs of performed operations within a predefined process or workflow or in the creation of business documents
243	Stoykova et al., 2022	intelligent process automation	Intelligent robotic process automation				Approval & Ordering				3	1	Use of intelligent RPA bots to automate purchase order processing activities
244	Stoykova et al., 2022	intelligent process automation	Intelligent robotic process automation				Goods Receipt	Invoice & Payment			3	3	Use of intelligent RPA bots to automate email processing in relation to proof of delivery and payment advice notes by scanning relevant emails, downloading attachments and categorizing documents by document type and company code
245	Taghipour et al., 2022	internet of things	sensors	gps			Risk Management	Supplier Relationship Management & Partnering	Controlling & Reporting		1	2	Use of the IoT and data provided by sensors or via GPS in supplier relationship management and in anticipating on unforeseen events
246	Taghipour et al., 2022	blockchain					Organizational Development & Process Management	Supplier Selection	Goods Receipt	Controlling & Reporting	1	2	Use of BCT to access multitudes of data about suppliers, such as their product or service positioning, agreements, complaints and failures, and to streamline the procurement process from supplier selection to receipt of goods
247	Taghipour et al., 2022	smart contracts	blockchain				Others	Approval & Ordering			2	2	Use of smart contracts in BCT to enable actions such as the release of funds, transfer of information, and the purchase of products through stored scripts
248	Taghipour et al., 2022	smart contracts					Invoice & Payment				2	2	Use of smart contracts to authorize payments only after the goods have been delivered according to predefined conditions
249	Taghipour et al., 2022	artificial intelligence	artificial neural network				Strategic Demand & Spend Management	Tendering			1	3	Use of artificial neural networks that can be flexibly adapted to data or system changes and are part of supervised learning algorithms to compensate for the inaccuracy of forecasts or to predict the supplier's bid prices
250	Taghipour et al., 2022	artificial intelligence	multi-agent system	agent technology			Approval & Ordering	Supplier Identification & Prequalification	Others		2	3	Use of a supply agent in a multi agent supply-chain system seeking to satisfy orders of higher revenues by finding suitable suppliers who can fulfill their delivery obligations with lower operating costs. This approach seeks to create an agent-oriented architecture with distributed artificial intelligence to enhance interoperability among diverse intelligent systems and address challenges beyond the capabilities of centralized system.
251	Tripathi & Gupta, 2021	internet of things	big data	h2m	m2m		Approval & Ordering	Risk Management	Supplier Identification & Prequalification		3	2	Use of IoT to fully automate straight (m2m) and modified (h2m) rebuys as well as big data and h2m communication in new purchases and to reduce uncertainty
252	Tripathi & Gupta, 2021	blockchain	cybersecurity				Contracting & Onboarding	Others			2	2	Use of BCT for record keeping, contract reinforcement and transactions due to cybersecurity issues
253	Tripathi & Gupta, 2021	digital twin	rfid	m2m	agv		Tracking & Tracing				3	3	Utilizing a digital twin of the storage space with an inventory panel that is notified when an order is received, allowing to trace the location of needed items, and communicate their locations and routing to AGVs that pick up the material and deliver it to the issue desk, where the inventory is automatically updated using RFID and M2M communication
254	Tripathi & Gupta, 2021	internet of things	rfid	m2m	platform	real-time information	Tracking & Tracing	Invoice & Payment	Goods Receipt	Controlling & Reporting	3	3	Use of the IoT for real-time tracking during production and delivery through intelligent objects automatically reporting their status, as well as in order follow up by automating receiving and invoicing via objects that register in the system with RFID and M2M communication and processing further invoices with an integrated information platform
255	Tripathi & Gupta, 2021	big data	blockchain				Supplier Relationship Management & Partnering	Controlling & Reporting	Supply Market Monitoring	Risk Management	3	3	Use of big data in the evaluation of suppliers and supply market trends, supporting the procurement strategy and predicting disruptions, with BCT verifying supplier qualifications accelerating and automating supplier evaluation
256	Tripathi & Gupta, 2021	internet of things	big data	simulation			Supplier Selection	Supplier Identification & Prequalification	Supply Market Monitoring		3	3	Use of IoT and big data to automate supplier selection, especially for standardized, non-critical components, as well as automatic prequalification systems and scenario simulation of the supplier market with the help of data analytics to expand the supplier base

257	Tripathi & Gupta, 2021	big data	simulation						Risk Management	Supplier Identification & Prequalification	Category & Sourcing Strategy Definition	Controlling & Reporting	Others	2	3	Use of big data and supplier integration, so that the system can issue early warnings and simulate scenarios for troubleshooting to respond proactively, for example by suggesting alternative suppliers or identifying usable components or routes to maintain the functionality of the production system
258	Tripathi & Gupta, 2021	platform	internet of things						Demand Planning & Purchase Requisition					3	3	Use of an integrated information platform (IIP) based on the IoT to determine material requirements continuously and in real time, including for dynamic requirements of vendor managed inventory systems
259	Tripathi & Gupta, 2021	platform	internet of things						Approval & Ordering	Order Confirmation				3	3	Use of an IoT-based integrated information platform (IIP) to allow an order trigger to generate an order, simultaneously send an approval request to managers and notify the supplier of the preliminary order quantity where, once approved, it is visible to the supplier via an IIP interface, resulting in an overall transparent information flow that allows procurement to be aware of changing customer trends at early stages
260	Tripathi & Gupta, 2021	platform	internet of things	blockchain	cloud computing				Supplier Relationship Management & Partnering	Organizational Development & Process Management	Others			1	2	Utilizing an Integrated Information Platform (IIP) to connect all primary as well as lower tier sub-suppliers through the use of IoT, BC and Cloud
261	Tripathi & Gupta, 2021	platform	rfid	nanotechnology	bluetooth	m2m	real-time information	wi-fi	Others					2	3	Utilizing an integrated information platform (IIP) to connect digital as well as physical objects, using RFID, transducers, M2M communication, nanotechnology (nano-chips embedded in physical objects such as light bulbs, cars and mobile devices) and connectivity systems, so that they can autonomously create, collect, process and transfer data via short-range communications such as Bluetooth or Wi-Fi, enabling real-time information flow
262	van Hoek et al., 2022	robotic process automation							Approval & Ordering	Invoice & Payment	Tendering	Controlling & Reporting	Supplier Relationship Management & Partnering	3	3	Use of RPA in purchase order processing and invoice processing, for transferring price information from spreadsheets to ordering systems or copying request-for-proposal responses to spreadsheets, and in the development of supplier performance scorecards
263	van Hoek et al., 2022	robotic process automation							Negotiation	Tendering				3	3	Use of RPA to automate the negotiation of specific categories via e-auctions, where the trained software robot extracts historical spend data, converts it into a format required for the e-auction platform, creates an e-auction event, invites pre-approved suppliers, and after the negotiation, takes care of all reporting and uploading of the new prices to the catalog solution, thereby ensuring quick access to new prices, with exceptions handled by the employee
264	van Hoek et al., 2022	algorithm							Supplier Selection	Demand Planning & Purchase Requisition	Approval & Ordering			2	3	Use of an algorithm that analyzes a ship's schedule and route, the goods to be purchased, and the lead time for those products to recommend an optimal delivery location. This analysis of incoming purchase requisitions aims to optimize port and supplier selection, as the shipping company's (Maersk's) vessels operate like a moving factory, making the delivery location dynamic. Consequently, determining the optimal delivery location is crucial to the requisition-to-order process.
265	van Hoek et al., 2022	algorithm							Controlling & Reporting	Risk Management				2	3	Use of an algorithm that uses purchasing history, port, supplier and items ordered aiding buyers to predict whether a purchase requisition is likely to be delayed, which is critical since the vessel is moving and a late delivery can cause significant extra cost
266	Viale & Zouari, 2020	robotic process automation							Approval & Ordering	Demand Planning & Purchase Requisition				3	2	Use of RPA to enable buyers to delegate order receipts to software robots or configure the software robots to place orders automatically based on stock levels
267	Viale & Zouari, 2020	robotic process automation							Invoice & Payment					3	3	Use of RPA to automate the payment process by having a software robot mimicing the manual process of paying supplier invoices by copying and pasting data from one source to another
268	Wehrle et al., 2022	big data							Supplier Identification & Prequalification	Supplier Selection	Risk Management	Supply Market Monitoring		2	2	Use of big data analyses in supplier selection and evaluation, procurement risk management and supply market analysis by generating valuable knowledge
269	Wehrle et al., 2022	artificial intelligence							Supply Market Monitoring					3	2	Use of AI for autonomous, continuous monitoring of supplier markets
270	Wehrle et al., 2022	artificial intelligence							Supplier Identification & Prequalification					2	1	Use of AI in the pre-selection of suppliers
271	Wehrle et al., 2022	artificial intelligence	platform						Organizational Development & Process Management	Category & Sourcing Strategy Definition	Others			2	3	• Use of AI in develop-or-buy decisions of new product development, which are based on procurement guidelines as well as to support new product development by taking cost parameters into account in the design phase • Use of digital collaboration platforms as a standard project management tool for supplier interaction in new product development
272	Wehrle et al., 2022	social media							Supplier Relationship Management & Partnering	Supplier Identification & Prequalification	Others			1	3	Use of social media to attract and interact with potential suppliers by using influencers to increase visibility in the supplier network and at that same time highlight the company as an attractive partner
273	Wehrle et al., 2022	artificial intelligence	platform						Supplier Identification & Prequalification					2	2	Use of AI and collaboration platforms to gather information to identify and evaluate potential partners, which can reduce search costs
274	Wehrle et al., 2022	social media	platform	instagram	facebook				Others	Supplier Relationship Management & Partnering				2	3	• Use of social media platforms for interaction with suppliers in new product development, for example via an internal group on Facebook or Instagram, which has a positive impact on supplier engagement in new product development projects and as a source of innovation development • Use of digital collaboration platforms for interface management between external and internal stakeholders during new product development projects, where digital platforms enable to speed up transactions and improve end-to-end collaborations
275	Wehrle et al., 2022	artificial intelligence							Supplier Relationship Management & Partnering	Supplier Identification & Prequalification	Negotiation			2	2	Use of AI to support complex decision-making processes, cataloging and evaluating suppliers or during negotiations