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PhD Thesis

Navigating the Theory–Practice–Potential Gap: A Multi-Method Exploration of Procurement 4.0 Automation in the Manufacturing Sector

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Abstract

Procurement 4.0 marks a transformative shift driven by advanced Industry 4.0 technologies. Despite growing academic interest and recognised benefits, particularly through process automation, implementation in practice remains slow. This delays the realisation of opportunities such as productivity gains. To support the transformation of procurement in the manufacturing industry, where it typically makes a significant contribution to corporate success by managing the largest cost block, this PhD thesis adopts an exploratory multi-method approach.

As a first step, the thesis presents a systematic literature review, analysing 58 references and mapping 275 Procurement 4.0 applications onto an extended procurement process model, visualised as a heatmap. This serves as a practical and academic reference point. Building on this, a multiple case study of five Austrian manufacturing firms explores the real-world implementation and impacts of Procurement 4.0 applications, identifying 169 factors aligned with a conceptual research framework. Finally, a Delphi-based expert study involving 35 procurement professionals assesses the current level of adoption, perceived benefits, and prospects of Procurement 4.0 applications across 15 projections.

Findings reveal a notable gap between academic debate, practical implementation, and perceived potential—termed the Theory–Practice–Potential gap. While advanced and even futuristic applications are widely discussed in the literature, their adoption lags, despite acknowledged benefits. Expert ratings further suggest that augmentation and automation are seen as more relevant than autonomisation, indicating that fully autonomous procurement may remain an aspirational goal rather than an operational reality, even beyond 2035.

This research offers novel insights through its explorative design and focus on practitioner-informed applications. It is, to the author's knowledge, the only recent Delphi-based expert study explicitly examining automation within a Procurement 4.0 context.

In summary, the results provide researchers with a systematic and up-to-date overview of key applications and open research areas, while offering practitioners in the manufacturing industry a structured foundation for navigating the implementation of Procurement 4.0 applications. However, due to the study's exploratory nature, limited case sample, and regional focus, the generalisability of the findings remains constrained.

Keywords: Procurement 4.0; Process Automation; SLR; Multiple Case Study; Expert Study

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List of Abbreviations

AI	Artificial Intelligence
BCT	Blockchain Technology
BDA	Big Data Analytics
BPA	Business Process Automation
CAQDAS	Computer-Assisted Qualitative Data Analysis Software
CPS	Cyber-Physical System
CSDDD	Corporate Sustainability Due Diligence Directive
CRM	Customer Relationship Management
CSR	Corporate Social Responsibility
EDI	Electronic Data Interchange
EMS	Electronic Manufacturing Services
ERP	Enterprise Resource Planning
ESG	Environmental, Social and Governance
GDPR	General Data Protection Regulation
IoT	Internet of Things
IQR	Interquartile Range
LLM	Large Language Model
NGOs	Non-Governmental Organisations
NPD	New Product Development
P2P	Purchase-To-Pay
POs	Purchase Orders
PR	Propositions
PSM	Purchasing and Supply Management
PMLC	Process Management Lifecycle
RFID	Radio-Frequency Identification
RPA	Robotic Process Automation
RQs	Research Questions
S2C	Source-to-Contract
S2P	Source-to-Pay
SAQs	Self-Assessment Questionnaires
SCM	Supply Chain Management
SLR	Systematic Literature Review
SMEs	Small and Medium-Sized Enterprises
SRM	Supplier Relationship Management
TOE	Technology–Organisation–Environment

1. Introduction

The digital revolution in Supply Chain Management (SCM) (Waller and Fawcett, 2013) remains incomplete, with procurement—one of its key processes—highlighting this gap. While digitalisation 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, pp. 2 & 34; Bigliardi et al., 2022, p. 1809; Klünder et al., 2019, p. 10).

Historically, procurement[1] has evolved significantly, transitioning from an administrative support function to one of strategic importance. This transformation gained recognition with Kraljic's (1983) highly acclaimed article 'Purchasing must become supply management', which emphasized the strategic orientation of procurement. Building on this foundation, numerous scholars have highlighted procurement's critical contributions to organisational competitiveness.[2] Today, procurement plays a vital role in the entrepreneurial success of industrial firms, particularly as it influences, on average, approximately 60% of total supply chain costs (Tschandl et al., 2016, p. 29).[3]

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).

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., 2022, p. 9; Jahani et al., 2021, p. 2). These new technologies can positively impact supply chain

[1] The functional integration of procurement in the narrower sense—that is, all activities related to the supply of an organisation with materials, commodities, spare parts, and services—is often referred to in practice using various terms, including Purchasing and Supply Management, Materials Management, and Purchasing. As there is no universally accepted definition in the literature and the terms are frequently used interchangeably, the term *Procurement* is used throughout this study (Kummer, 2013, pp. 90–93; Schulte, 2013, p. 1f; Tschandl and Schentler, 2008, p. 3ff).

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

[3] The cost of materials ratio is a key indicator in this context. It is calculated as the ratio of material costs to sales revenue and serves as a measure of material cost intensity (Binder, 2021; Müller, 2019).

performance (Govindan et al., 2022, p. 34), mitigate risks (Bag et al., 2020b, p. 4), enable seamless and tamper-proof supply chain monitoring (Saberi et al., 2019, pp. 2117 & 2122f.), and allow employees to focus on strategic tasks (Flechsig et al., 2022, p. 6). This shift is particularly relevant given labour 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, p. 5; Ng and Johnson, 2015, p. 121f).

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, p. 10308). The concept of Procurement 4.0 began emerging in 2016 through grey literature (Geissbauer et al., 2016; Pellengahr et al., 2016) and saw its first scientific publication indexed in Scopus in 2018. Bag et al. (2020, p. 2) 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 the relevance of this thesis (Bueno et al., 2024, p. 2; Jain et al., 2024, p. 10295f.).

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, pp. 3–4, 33; Bigliardi et al., 2022, p. 1809). 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 at a relatively low level. Furthermore, procurement—along with sales—lags behind other functional areas in the use of AI, reflecting a delay in technological advancement (Bakir and Borozan, 2023, p. 10).

Consequently, the digitalisation[4] of procurement remains insufficiently developed, with organisational adoption of advanced technologies failing to keep pace with the rapid progress driven by Industry 4.0 (Althabatah et al., 2023, pp. 2 & 34; Bigliardi et al., 2022, p. 1809; PricewaterhouseCoopers, 2024). This gap, amplified by evolving technologies and the growing

[4] The terms digitisation and digitalisation refer to distinct concepts. According to Gartner (n.d.), 'digitization' is *"(...) the process of changing from analog to digital form (...) Digitization takes an analog process and changes it to a digital form without (...) changing the process itself."* In contrast, 'digitalization' refers to *"(...) the use of digital technologies to change a business model (...); it is the process of moving to a digital business*."

diversity of tools, creates significant challenges in decision-making processes, underscoring the necessity for further research in this domain.

1.1. Scientific questions

Motivated by these unresolved issues, this thesis addresses several critical research gaps in the field of procurement digitalisation. One significant challenge, as noted by Bienhaus and Haddud (2018, p. 979), is the uncertainty that companies face in identifying which technologies can effectively support their digital transformation efforts. Althabatah et al. (2023, pp. 14 & 33) substantiate this by emphasizing that implementing Industry 4.0 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, p. 84) 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, p. 154), is the absence of systematic frameworks for 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, p. 91) underscore this requirement, advocating for a broader, more unified approach to applying advanced technologies in procurement.

To address these gaps, this study first investigates the current landscape of Procurement 4.0 applications and their technological underpinnings, leading to the following research questions (RQs) that guide this investigation:

RQ 1: What are the Procurement 4.0 applications[5]*described in the current literature?*
RQ 2: What procurement processes can be supported by technologies or technology bundles, forming an application?

The integration of advanced technologies in procurement can generally be understood as occurring across three stages: augmentation (human acts – machine supports), automation (machine acts – human supports), and autonomisation (machine acts independently) (Herold et al., 2022, p. 6). This progression to substitute manual processes is particularly relevant in the

[5] The term ‘application’ here refers to the use of a technology or technology-related concept in procurement (Cambridge Dictionary, 2024).

context of Procurement 4.0 (Bag et al., 2020b, p. 2), where it warrants closer attention as a central area of research.

On the one hand, automation, when combined with augmentation, has the potential to enhance the strategic functions carried out by procurement professionals (Colombo et al., 2023, p. 10). Considering the challenges outlined, this development could offer procurement the flexibility and scope it requires for long-term success.[6] On the other hand, technologies associated with Procurement 4.0, such as AI, are increasingly expected to facilitate autonomous decision-making and, ultimately, a fully autonomous supply chain (Kleemann, 2024, p. 4; Nicoletti, 2020, p. 227; Wehrle et al., 2022, p. 13).

Kleemann (2024, pp. 11–12, 17) assigns particular importance to intelligent, learning-based autonomisation capable of independent decision-making, and predicts a shift from eProcurement towards fully autonomous systems. He argues that, in principle, digital technologies could take over all procurement tasks—including strategic ones—up to end-to-end process handling in real time, if IT systems are sufficiently advanced. At the same time, Kleemann emphasises that significant challenges remain, noting that automation still rarely exceeds 50% even in operational areas.[7]

In the academic debate, some scholars express scepticism regarding the extent to which strategic decision-making processes can be technologically integrated. Instead, they anticipate a continued emphasis on human–machine collaboration in the form of augmentation or automation (Trunk et al., 2020, p. 903; Wehrle et al., 2022, p. 13). These contrasting views give rise to the focus of this work, which is to further explore the research question concerning the extent to which automation is reflected in Procurement 4.0 applications.

In addition to reviewing the academic literature in the field of Procurement 4.0, scholars frequently call for the investigation of real-world applications of advanced technologies—such as artificial intelligence—and emphasise the need for further exploratory studies in procurement practice to deepen understanding (Althabatah et al., 2023, p. 33; Bruzzi et al., 2019, p. 114; Bueno et al., 2024, p. 16; El Asri and Benhlima, 2022, p. 4575; Gottge et al., 2020, p. 735; Guida et al., 2023, p. 3; Hallikas et al., 2021, p. 641; Spreitzenbarth et al., 2024, p. 1).

In response to these calls, the following case study research questions are formulated:

[6] For example, freeing up employees from time-consuming day-to-day operations and redirecting their focus to strategic tasks is enabled by process standardisation and the use of flexible automation tools, which are key strategies for managing workload (Addicoat et al., 2023, p. 14).

[7] This benchmark is reinforced later in this thesis, where experts were also asked to assess the current degree of automation in their own procurement functions.

RQ3: What are the defining characteristics of Procurement 4.0 applications currently implemented in practice?
RQ4: What effects do these applications have, particularly regarding process automation?

While there is some evidence suggesting that procurement has generally lagged behind the technological advancements stemming from the Industry 4.0 wave (Althabatah et al., 2023; Bigliardi et al., 2022; PricewaterhouseCoopers, 2024), no comprehensive assessment currently exists regarding the prevalence of specific Procurement 4.0 automation applications. Such an assessment could provide valuable insights into whether current practice is still falling short of its potential—and into the extent to which procurement is oriented towards Industry 4.0 technology adoption (Kleemann, 2024, p. 17; Zafari and Teuteberg, 2018, p. 2078). When complemented by the development of a forward-looking scenario, this could offer practitioners a foundation for defining the necessary strategies, objectives, and organisational mechanisms—such as roadmaps—for guiding the transformation towards Procurement 4.0 (Bueno et al., 2024, p. 10; Joseph Jerome et al., 2022, p. 219; Karumsi and Prokopets, 2023, p. 19; Kleemann, 2024, p. 39; Viale and Zouari, 2020, p. 7).

This leads to the final two research questions. However, given the current nature of the topic and the lack of historical data on which to base future projections, expert judgements are sought within the framework of consensus building (Brady, 2015, p. 1; Döring and Bortz, 2016, p. 420; Rowe et al., 1991, p. 236; Rowe and Wright, 1999, p. 353). The corresponding research questions are therefore formulated as follows:
RQ5: How do experts perceive the current level of adoption of specific Procurement 4.0 automation applications in practice?
RQ6: How is this adoption expected to develop over the next ten years?

The research questions presented are examined in this study from the perspective of the private manufacturing industry, which has been identified as the focus of this study based on four five considerations:

1. *Strategic Importance of Procurement:* Given that material costs typically constitute 50–60% of total expenditures (Barth and Barth, 2013, p. 56; Tschandl et al., 2016, p. 29), procurement is a key driver of business success in the manufacturing industry (Schulte, 2013, p. 283; Schweiger, 2017, p. 2; Tschandl and Bäck, 2008, p. 3ff).
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., 2020a, p. 1).
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 and Zühlke-Robinet, 2000, p. 44f; Hauptverband der Deutschen Bauindustrie e. V., n.d.; Pekrul, 2006, p. 20).

4. *Regulatory Environment:* The manufacturing industry, being predominantly privately organized, faces fewer regulations compared to the public sector, resulting in unique procurement dynamics (Weele and Eßig, 2016, p. 554).
5. *Sector-specific conclusions:* To enable sector-specific conclusions, Jain et al. (2024, p. 10307) explicitly recommend that the significance of Procurement 4.0 in private-sector organisations be examined separately.

1.2. Objective of this thesis and methodology

The overarching objective of this study is to apply a multi-method exploratory approach tailored to the research questions, integrating theoretical, practical, and prospective perspectives on Procurement 4.0 automation applications. In doing so, the thesis seeks to provide guidance for navigating adoption within the manufacturing industry and to support broader implementation.

The first two research questions are examined through the development of a comprehensive and structured conceptual framework. This framework is presented as a heatmap[8] and integrates Procurement 4.0 applications identified in the literature with an extended procurement process model, specifically tailored to the context of the private manufacturing industry. It provides a concise overview of critical applications, offers systematic guidance for integrating advanced technologies, and highlights areas requiring further research. To ensure an unbiased, objective, and evidence-based analysis of the literature, this initial research phase adopts a Systematic Literature Review (SLR) methodology (Tranfield et al., 2003, p. 208f.). While prior studies, such as those by Jahani et al. (2021) and Althabatah et al. (2023), have conducted SLRs on the application of Industry 4.0 in procurement processes, this review differs in several key aspects. First, it incorporates the latest 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 analysis of specific applications, further advancing the understanding of Procurement 4.0 implementation.

Building on the findings of the literature review, research questions three and four are explored through a multiple-case study analysis in the private manufacturing industry. The study comprises five companies that have already implemented Procurement 4.0 applications, including those identified in the first research phase. This part pursues two core objectives: first, to investigate the practical manifestation of theoretical concepts; and second, to gain in-depth insights into the real-world impact of Procurement 4.0 approaches. The results are

[8] A heatmap uses colour coding to visually highlight key clusters of technologies and related concepts, revealing significant patterns (Bojko, 2009, p. 30; insightsoftware, 2022).

systematically organised and presented in alignment with a conceptual research framework that underpins this study.

Finally, to explore research questions five and six, an expert survey is conducted as part of the first round of a Delphi study. This phase aims, on the one hand, to assess the current level of adoption and the perceived benefits of Procurement 4.0 automation applications from a practical perspective, and, on the other hand, to examine the prospects for Procurement 4.0 process automation.

As a foundation for the methodological phases of this thesis, the theoretical background to Industry 4.0 will first be outlined, including the development of a comprehensive definition of Procurement 4.0 and the elements of the research framework underpinning this study. This leads to the structure of the thesis as outlined below.

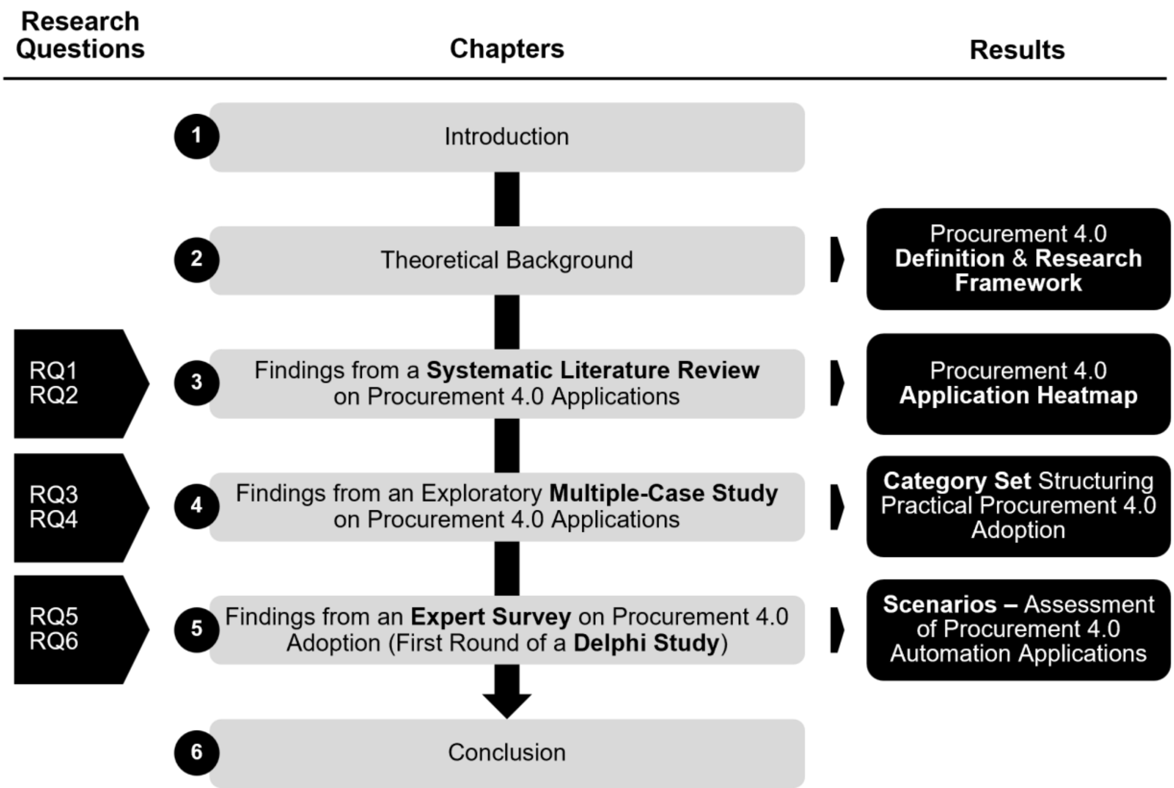


Figure 1: Research procedure model followed within this study

2. Procurement 4.0 – Theoretical Background

This chapter defines the term Procurement 4.0, along with other key concepts relevant to the study, presents a reference model of procurement processes and tasks, and introduces the conceptual research framework. These preliminary considerations provide the basis for the multi-method approach employed in the main body of this thesis (Chapters 3 to 5).

The literature lacks a uniform definition and a clear conceptualization of Procurement 4.0 (Bueno et al., 2022, p. 154). Therefore, this section aims to formulate a comprehensive definition by comparing existing definitions from the scientific literature and analysing their key conceptual elements followed by the introduction of an expanded process model guiding this study.

2.1. Development of a Procurement 4.0 definition

Based on an analysis comparing sources offering an explicit Procurement 4.0 definition , 16 core elements are identified, forming the basis of the proposed Procurement 4.0 definition. These elements are presented in Figure 2, 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 2 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 Supplier Relationship Management (SRM) system functionalities (Herold et al., 2022, p. 3).
- *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, p. 17; Joseph Jerome et al., 2022, p. 222).
- *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, Sjodin et al. (2021, p. 2) 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 associated with Procurement 4.0.
- *Novelty:* This attribute refers to the introduction of new ideas, 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 and Meyer, 2021, p. 706).
- *Agility or flexibility:* Several references explicitly discuss the aspects of responsiveness, resilience, agility, and flexibility in the context of Procurement 4.0.
- *Autonomy:* 'Autonomous' refers to processes carried out without human intervention (Tripathi and Gupta, 2021, p. 441). 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, p. 14). Accordingly, 'Autonomy' is included in the definition as the most advanced form of automation. As (Herold et al., 2022, p. 7) 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 discussed in Procurement 4.0 definitions include sustainability and transparent procurement (Bueno et al., 2022, p. 151), as well as circular economy aspects (Bueno et al., 2024, p. 2). Procurement 4.0 is also recognized as a precursor to Procurement 5.0 (Nicoletti, 2020, p. 211). Furthermore, the evolving role of buyers is highlighted, exemplified by the transition from buyer to consultant (Pirrone and Meyer, 2021, p. 706).

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		
	∑	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 2: Elements with strong reference Procurement 4.0

As a result of the elaboration summarized in Figure 2 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'*, or *'digital procurement'* could be used interchangeably by other authors referring to the integration of advanced digital technologies in procurement processes (Herold et al., 2022, p. 3).

2.2. Advanced technologies and Procurement 4.0 automation

Based on the definition of Procurement 4.0, it remains to be clarified which technologies or technology-related concepts can generally be considered 'advanced' in the context of Industry 4.0 applications in procurement. This distinction is particularly important in view of the planned identification of Procurement 4.0 applications and practical cases, to assess whether they can be categorised as part of the Procurement 4.0 landscape.

At the outset of this study, six authors were identified who proposed various technologies or technology-related concepts considered 'advanced' or 'enabling' in the context of Industry 4.0. These sources were retained throughout the research project, as their content remained relevant and up to date. Table 1 presents a summary of those authors' perspectives, ranked by the frequency of mentions.

	Bag et al. (2020, p. 3)	Bueno et al. (2022, pp. 152–154)	Bruzzi et al. (2021, pp. 85–90)	Govindan et al. (2022, p. 30)	Jahani et al. (2021)	Srai & Lorentz (2019, p. 83)
Artificial Intelligence (AI)	✓	✓	✓	✓	✓	✓
Big Data Analytics (BDA)	✓	✓	✓	✓	✓	✓
Internet of Things (IoT)	✓	✓		✓	✓	✓
Blockchain Technology (BCT)	✓	✓	✓		✓	✓
Cloud Computing		✓	✓	✓		✓
Cybersecurity		✓	✓	✓		
Simulation		✓	✓		✓	

	Bag et al. (2020, p. 3)	Bueno et al. (2022, pp. 152–154)	Bruzzi et al. (2021, pp. 85–90)	Govindan et al. (2022, p. 30)	Jahani et al. (2021)	Srai & Lorentz (2019, p. 83)
Cyber-physical System (CPS)		✓	✓		✓	
3D Printing / Additive & Advanced Manufacturing	✓	✓				✓
Machine Learning	✓		✓			
Augmented Reality / Virtual Reality		✓				✓
Horizontal Integration			✓	✓		
Vertical Integration			✓	✓		
Cognitive Computing			✓			✓
Industrial Internet			✓			
Robotic Process Automation (RPA)			✓			
Cloud manufacturing					✓	
Smart Contracts					✓	
Smart Manufacturing					✓	
Social Media						✓
Mobile Technologies						✓
Internet of Services		✓				
Advanced Robotics		✓				

Table 1: Advanced technologies or technology-related concepts adopted in Procurement 4.0

This illustrates the broad acceptance of technologies traditionally associated with Industry 4.0 (Culot et al., 2020a, p. 7), as indicated by four or more tick marks. Additionally, concepts such as social media and advanced robotics are mentioned, albeit only in isolated cases. While this provides a structured starting point for the Systematic Literature Review (SLR) presented in the following chapter, the analysis deliberately remains open to the inclusion of other relevant technologies and emerging concepts that may not yet be widely recognised but are nonetheless of practical or theoretical relevance in the Procurement 4.0 context.

In order to subsequently assess the degree of automation in Procurement 4.0 applications, a clear definition of the term ‘automation’ is required—particularly given its widespread use in everyday language. For this reason, definitions from two established business dictionaries are compared with those provided by two recognised IT solution providers for business process automation SAP and IBM, to derive a working definition suitable for the context of this study.

	Cambridge Dictionary (n.d.)	Gabler Business Dictionary[9] (Voigt, n.d.)	SAP (n.d.)	IBM (n.d.)
Automation definition	*"the **use** of **machines** or **computers instead** of **people** to do a **job**, especially in a **factory** or **office**"*	*"**Transfer** of **production process** functions, in particular process **control** and **regulation tasks**, from **humans** to **artificial systems**."*	*"**Process automation** is defined as the use of **software** and **technologies** to **automate business processes** and **functions** in order to **accomplish** defined organizational **goals**."*	*"Automation is the use of **technology** to **perform tasks** with where **human input** is **minimized**. This includes enterprise applications such as **business process automation (BPA)**, IT automation, network automation, automating integration between systems, **industrial automation** such as robotics, and **consumer applications** such as **home automation** and more."*
Key elements	▪ Use of machines or computers ▪ People are relieved of a job ▪ Relevant both in the factory and in the office	▪ Focused on production ▪ Humans are relieved from certain tasks ▪ Control and regulation tasks highlighted	▪ Circular reasoning: "Automation is to automate" ▪ Use of software and technology is emphasised ▪ The term process automation is used ▪ Earmarking is emphasized: *"accomplish goals"* ▪ No focus on specific tasks/processes	▪ Use of technology ▪ Humans are relieved from certain tasks ▪ Humans play a certain role: *"human input is minimized"*. This implies different levels of automation. ▪ Specific examples are given, which reveals a broad interpretation: BPA in general but also *"industrial automation such as robotics"* are included ▪ Private consumer area is supplemented

Table 2: Comparison of different definitions of the term "automation"

Apart from the production-related definition in the Gabler Business Dictionary, the contrasting definitions of automation make it clear that automation relieves people of certain tasks rather than full business processes—whether in the factory or in the office. This is achieved using hardware (machines or computers), software and 'technology' in general. The IBM definition understands automation in the sense of partial automation, which, in contrast to full automation, has a degree of automation of less than 1 according to DIN 19233, because it refers to a *'minimization of human input'* (Spath et al., 1999, pp. 10–33). This is also evident in the fact that full automation is not always desired or feasible. Precht (2022, pp. 98–108), for example, argues that, in addition to tasks requiring technical creativity—such as the development of advanced AI systems—there are several types of work that are unlikely to be automated. These include tasks involving creative problem-solving in highly complex, though not exclusively technical, contexts that require collaboration with others, such as planning an airport. He also refers to manual or craft-based activities that rely on artisanal creativity, such as laying stone flooring, as well as roles that depend on social creativity and empathy—such as authentic human interaction in nursing professions. Beyond these examples, certain tasks must legally be carried out by humans or cannot yet be fully automated due to regulatory constraints. One such

[9] *Gabler Wirtschaftslexikon* in German.

case is autonomous driving, which—apart from system testing—is currently not permitted without human oversight in Austria (ÖAMTC, n.d.; Österreichs digitales Amt, n.d.).

Thus, for the purposes of this study, the following concept of automation is derived—one that incorporates aspects of technology (hardware and software), the minimisation of human input, and applicability to any type of task, irrespective of the degree of automation:

Automation is the use of technology, hardware, and software to minimize the human element in any existing task, regardless of the degree to which this is implemented.

When combined with the Procurement 4.0 definition developed above, the concept of automation is extended as follows:

Automation is the use of ***advanced technology, hardware, and software*** *to minimize the human element in any existing* ***procurement task****, regardless of the degree to which this is implemented.*

In terms of the degree of automation, a distinction is made between the three stages introduced earlier: augmentation (human acts – machine supports), automation (machine acts – human supports), and autonomization (machine acts independently) (Herold et al., 2022, p. 6).

In order to systematically identify potential Procurement 4.0 applications in the subsequent chapters, a process and task map is required and is presented below.

2.3. Reference framework of procurement processes and tasks

The process and task map used in this study is based on the work of Bals et al. (2019), Büsch (2013), Schentler (2008), and Weele and Eßig (2017), and was further developed within the research group to provide a structure that enables a more targeted approach to procurement-related initiatives. It is divided into three main areas: the strategic source-to-contract (S2C) process, the procurement system and non-procurement-related tasks, and the operational purchase-to-pay (P2P) process.

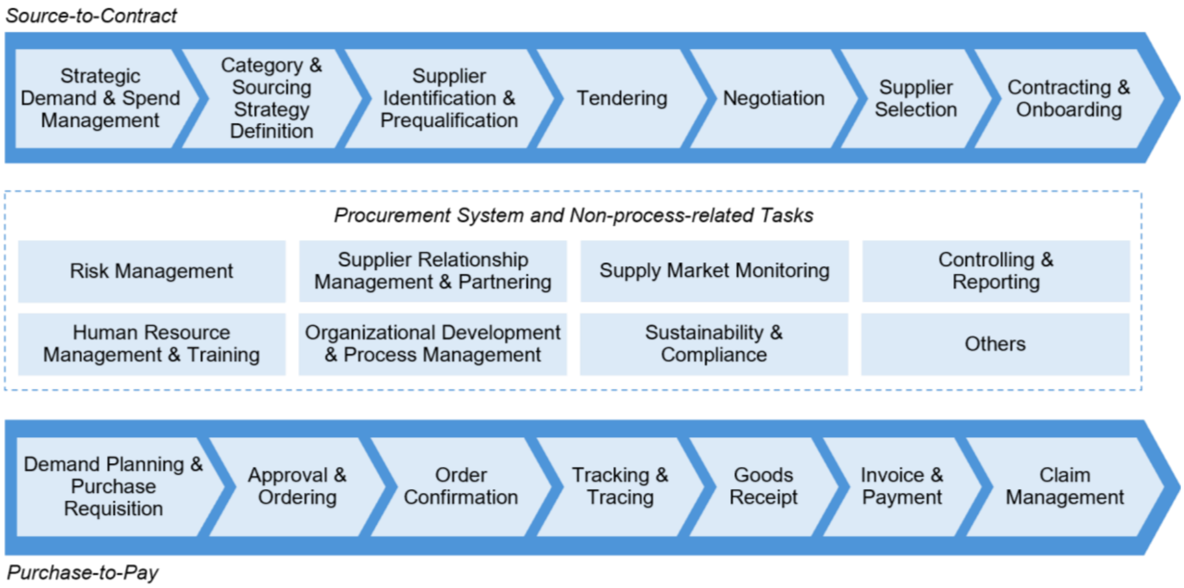


Figure 3: Reference framework of procurement processes and tasks adapted from Bals et al., 2019, p. 5; Büsch, 2013; Schentler, 2008; Weele and Eßig, 2017.

The *Source-to-Contract* process starts with a strategic demand analysis. Based on that differentiated category and sourcing strategies can be derived. In order to implement the intended strategy, the 'right' supplier short-list needs to be identified. Within the tendering and negotiation process the short-list will be narrowed down to the final supplier selection. The process ends with the fixation of a supplier contract, the final approval and onboarding of the suppliers.

The *Purchase-to-Pay* process is initiated with a concrete primary demand defined by a purchase requisition or an automated demand planning procedure. To meet the demand, the creation, approval, and delivery of orders are the next steps. After suppliers confirm the orders, the fulfilment and shipment of orders needs to be tracked until they are finally delivered (Goods receipt). The Purchase-to-Pay process ends with handling and clearing the invoices from the suppliers before a claim needs to be handled or new orders are created. Apart from those two core process-streams, 8 cross-transactional tasks can be added in order to complete a holistic procurement process portfolio: (1) Risk Management, (2) Supplier Relationship Management & Partnering, (3) Continuous Supply Market Monitoring, (4) Controlling & Reporting, (5) Human Resource Management (e.g. search for employees, onboarding and training of the personnel), (6) Organizational Development & Process Management (e.g. Continuous Improvement, restructuring of teams), (7) Sustainability & Compliance (e.g. work on new legal regulations or requirements from customers, CO2 Tracking, create and implement Code of Conducts) and (8) Others.

The elements outlined above are subsequently synthesised within the research framework underpinning this study.

2.4. Conceptual research framework

The foundational elements of Procurement 4.0, as outlined in Chapter 2.1 and culminating in the comprehensive definition presented there, are integrated here into a conceptual research framework that forms the basis of this study (see Figure 4). The bottom arrow represents the ongoing transformation towards Procurement 4.0. The procurement function is shown in grey within the broader company context. At its centre is an arrow symbolising automation enabled by Industry 4.0 technologies—reflecting the technological basis defined as a key element of Procurement 4.0. This automation, represented by the medium-grey arrows pointing upwards, is intended to serve two key purposes: first, to enhance procurement's overarching strategic relevance as a corporate function by freeing up resources for strategic tasks—an aspect discussed in detail in the introduction; and second, to contribute to the characteristic benefit dimensions of Procurement 4.0: agility, performance, innovation, and value proposition. The factors that need to be considered or overcome within these connections are indicated by numbers, explained below, and addressed throughout the remainder of this thesis.

Before presenting the individual elements, two fundamental considerations must be outlined:

(1) The implementation of Procurement 4.0 involves a range of internal and external challenges and barriers, while also entailing certain risks associated with the adoption of technological solutions (Althabatah et al., 2023, p. 31; Flechsig, 2021a, pp. 16–17; Jain et al., 2024, pp. 10305–10306).

(2) The widely adopted Technology–Organisation–Environment (TOE) framework was considered in the development of the conceptual research framework and subsequently used to structure the various influencing factors (Flechsig, 2021a, p. 10; Kosmol et al., 2019, pp. 4–5; Zafari and Teuteberg, 2018, p. 2047). Originally proposed by Tornatzky and Fleischer (1990) and described by DePietro et al. (1990), the TOE framework explains how technological, organisational, and environmental contexts within firms shape adoption decisions and drive technological innovation (Baker, 2011, p. 232). It captures the three key dimensions Technology, Organization, and Environment.

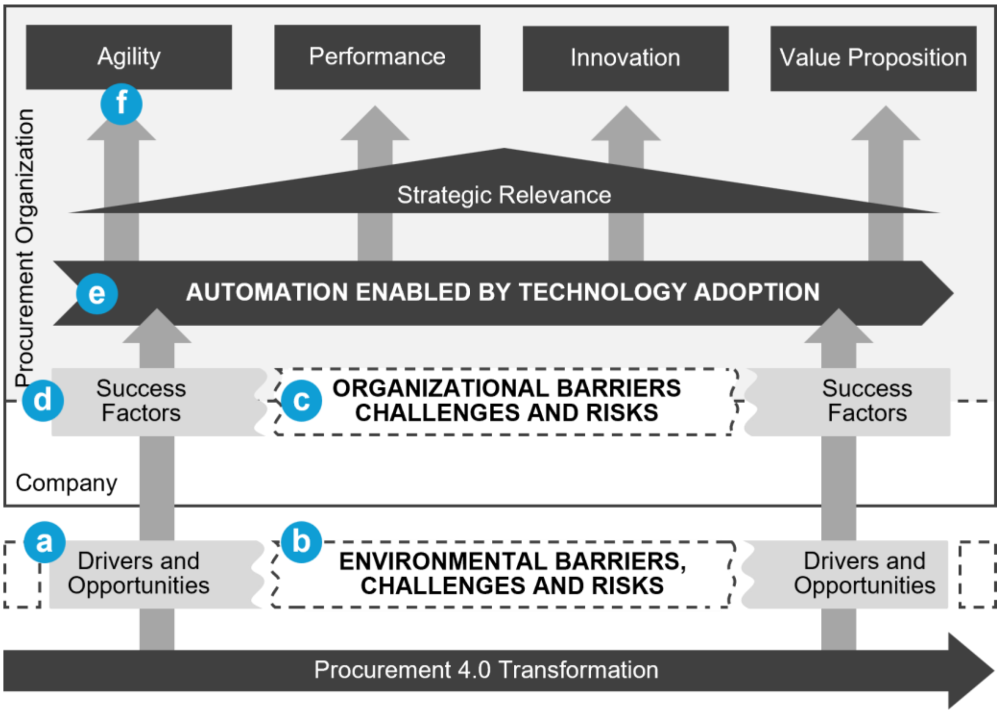


Figure 4: Conceptual research framework

The conceptual research framework is structured to reflect the ongoing transformation towards Procurement 4.0. It posits that environmental factors initially influence the adoption of advanced automation technologies within firms. Subsequently, internal organisational factors further shape this adoption process, which must be navigated before the benefits promised by Procurement 4.0 can be realised.

a) As part of the qualitative exploratory phase of this study, drivers and opportunities emerging from the external environment are to be systematically documented and analysed. The aim is to identify factors that encourage firms to adopt advanced automation technologies, while also providing researchers with valuable entry points for future investigations.

b) In addition, external barriers, challenges, and risks that may hinder the adoption process must be considered.

c) Within the organisational context, internal barriers[10], challenges, and risks may also affect the implementation of Procurement 4.0 automation applications.

d) These internal constraints should be addressed and mitigated through the identification and application of success factors[11] that support and facilitate technological adoption.

e) At the core of the research framework are the Procurement 4.0 automation applications themselves, which impact procurement processes, sub-processes, and tasks (as illustrated in Figure 3). These applications must first be identified and analysed through the SLR, as they represent potential means to realise the benefit dimensions described in section f).

[10] *'Something that prevents something else from happening or makes it more difficult'* (Cambridge Dictionary, 2023).

[11] *'Factor, circumstance that contributes significantly to success'* (Duden, n.d.), translated into English.

f) Procurement 4.0 (as defined) promises both a more strategic orientation of procurement activities and the achievement of specific target dimensions, which are prominent in current academic debate on the topic. Accordingly, in the qualitative multiple case study analysis, selected examples of the Procurement 4.0 applications identified in section e) will be examined in relation to their impact on these target dimensions.

Prior to this, however, it is essential to identify the specific use cases that define Procurement 4.0—this forms the focus of the following Systematic Literature Review (SLR) chapter.

3. Findings from a Systematic Literature Review on Procurement 4.0 Applications

This chapter presents the design, execution, and results of the Systematic Literature Review on Procurement 4.0 applications within procurement processes and tasks.

Building on the theoretical foundations of Procurement 4.0 and the effort to establish a comprehensive definition in Chapter 2, this Section follows the three-stage SLR framework proposed by Tranfield et al. (2003), with the aim of developing a conceptual framework intended to guide both practitioners and researchers. The resulting framework is presented as a heatmap that employs colour coding to visually highlight key clusters of technologies and related concepts, thereby revealing significant patterns (Bojko, 2009, p. 30; insightsoftware, 2022). To this end, Section 3.1 outlines the SLR methodology, detailing phases *(I) Planning* and *(II) Conducting*, while Section 3.2 presents the results corresponding to phase *(III) Reporting and dissemination*. These findings are further analysed in Section 3.3 *(Discussion)*, before concluding remarks and avenues for future research are provided in Section 3.4.

3.1. Methodology

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. (2022).

3.1.1. 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 and Paul-Hus, 2016, pp. 214 & 226). To identify the literature corpus, the next step is to define the search terms and the search period (Culot et al., 2020a, p. 2; Herold et al., 2022). The search covers the academic Procurement 4.0 literature from the start until October 2024. The keywords used in the query, along with their justifications, are presented in Table 3.

'4.0' related		*Procurement related*	
Keyword	Comment	Keyword	Comment
'industry 4.0'	Procurement 4.0 emerged from the fourth industrial revolution transforming procurement (Bag et al., 2020a, p. 1).	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

'4.0' related		Procurement related	
Keyword	Comment	Keyword	Comment
'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').		the search to procurement-related publications that have been published using the term 'supply management'.
digitalization	Procurement 4.0 is a concept enabled by digitalization (Sjodin et al., 2021, p. 2),		
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.		

Table 3: Structure of the search query

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 behaviour 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 were published in a Q1 journal.

(4) *Application description:* Papers explicitly describing Procurement 4.0 applications will be included in the analysis.

(5) *Additional paper:* Papers missed in the initial search but found relevant during literature analysis, such as through citations, are added to the literature corpus.

The final step of the SLR involves systematically analysing the content of the identified references (Culot et al., 2020a, p. 3; Herold et al., 2022). Given that the selected publications consist of textual data, a qualitative data analysis approach is employed (Saunders et al., 2019, p. 638). A key technique in this process is the categorization of qualitative, unstructured text data, enabling the systematic extraction of textual characteristics (Diekmann, 2004, pp. 487 & 512f.; Kuckartz, 2018, p. 100; Saunders et al., 2019, p. 653).

To achieve this, coding is used to categorize relevant text passages (Kuckartz, 2018, p. 100). Each piece of extracted data is analysed and assigned the same code if it conveys a similar meaning (Saunders et al., 2019, p. 653). Codes can be defined before analysis (theory-driven) or developed during analysis (data-driven) (Gläser and Laudel, 2006, p. 43; Saunders et al., 2019, p. 655). This study follows a hybrid approach, starting with predefined categories (‘application’ and ‘technology’) and refining them inductively based on the text (Reichertz, 2016, p. 232). The process follows Thematic Analysis, as described by Braun and Clarke (2006) to identify key patterns within the dataset (Saunders et al. 2019, pp. 650–660).

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, pp. 692–694).
For this study, MAXQDA—a widely used CAQDAS tool—was 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.

3.1.2. Conducting the SLR

The SLR was conducted in accordance with the previously outlined planning phase. Figure 5 presents the applied procedure.

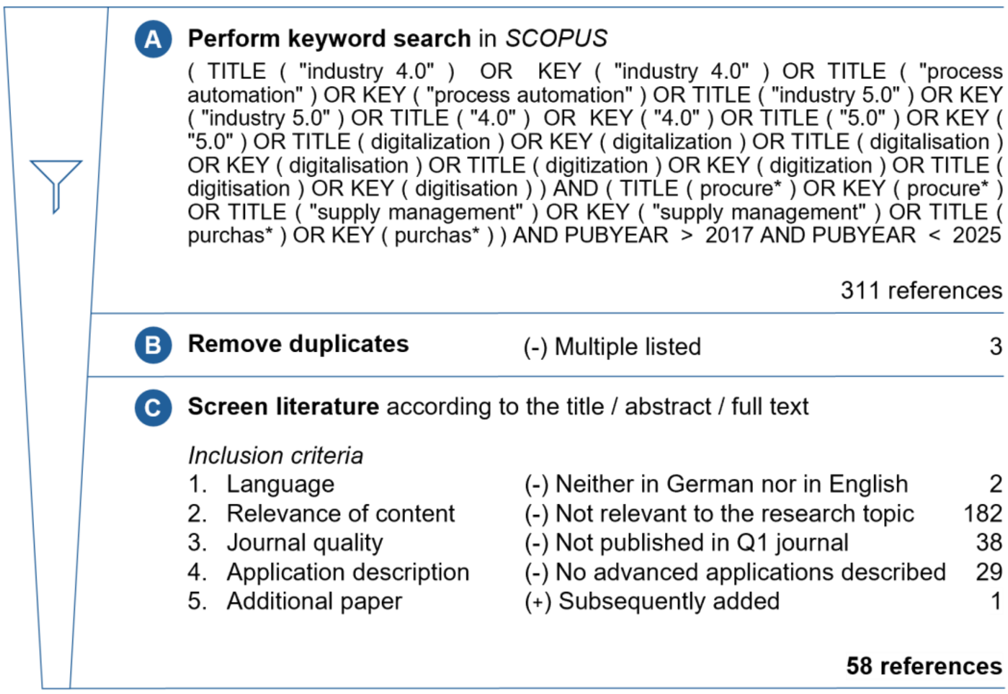


Figure 5: SLR selection funnel

This funnel-shaped approach results from the inclusion criteria, which classified 58 out of the 311 references originally identified through the search query as highly relevant for this study. These 58 references encompass 275 identified applications, systematically documented in an analysis table (see Table 54) developed during the qualitative analysis. This table serves as the foundation for presenting all findings. Figure 6 presents an overview of composition of applications, while Table 53 provides the complete list of references included in the SLR.

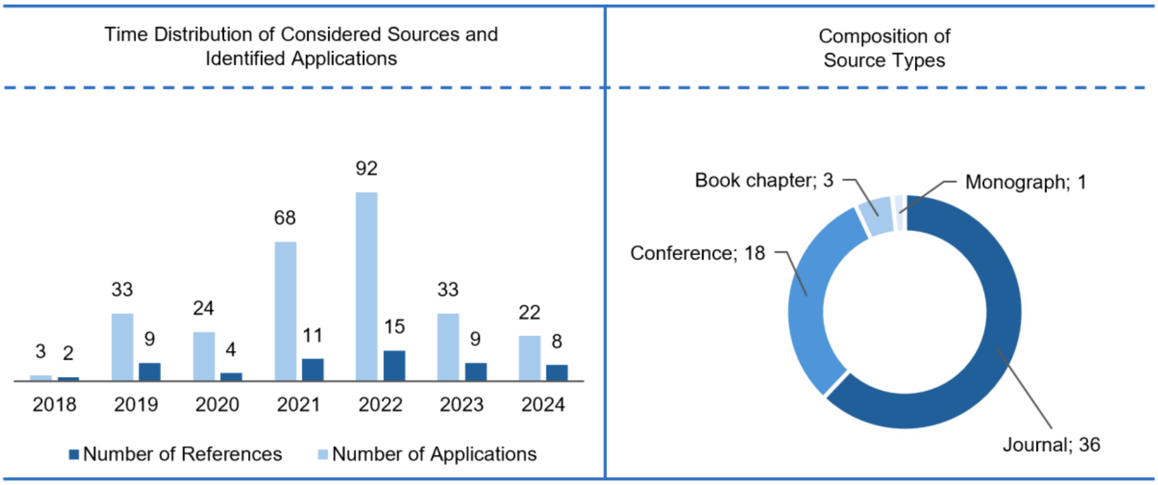


Figure 6: Sources considered in the SLR

Figure 6 highlights two key trends: first, the debate on technological applications in procurement has expanded since the advent of Procurement 4.0 in 2018, peaking in 2022 before stabilizing (data for 2024 extends until October). This aligns with the ongoing challenges of implementing advanced technologies in procurement, underscoring both the complexity and relevance of the topic. Second, the predominance of academic journal sources provides a strong scholarly foundation, while the inclusion of conference papers—usually reflecting more recent advancements—further reinforces the timeliness and relevance of the findings (Islam and Agarwal, 2023, p. 105).

3.2. Results – Conceptual Heatmap Framework for Procurement 4.0 Applications

In accordance with the SLR approach outlined in the previous section, all sources were analysed 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 this analysis, the extended procurement process and task model (see Figure 3) presented in Chapter 2.3 was applied.
The qualitative content analysis identified 275 applications incorporating 100 distinct technologies, related concepts or solutions, referenced 673 times across procurement processes and non-process-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 and Van Rensburg, 1998, p. 483) to identify and categorize the most prevalent technologies and related concepts within the analysed applications. Applied to this study, 18 out of the 100 identified technologies, related concepts, and solutions account for 70%[12] of total mentions across applications. Table 4 serves as a dashboard, providing an overview of the distribution of applications across sub-processes and task areas. It also presents the 18 'A' technologies and related concepts, detailing their occurrence frequency, relative and cumulative[13] percentages, which form the basis for 'A' classification up to 70%. For transparency, all 275 applications, along with the referenced technologies, processes, and task areas, are detailed in Table 54 in the Appendix.

Table 4 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 non-process-related tasks, particularly Controlling and Supplier Relationship Management and Partnering, while various other procurement tasks are also considered.

The applications were further categorized by degree of automation and information content (low, medium, high)[14] 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 7 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 8) 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.

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

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

[14] Applications with limited or no evidence of automation were rated '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 rated 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

Table 4: Dashboard displaying application counts by processes and task areas, along with 'A' technologies or concepts they employ

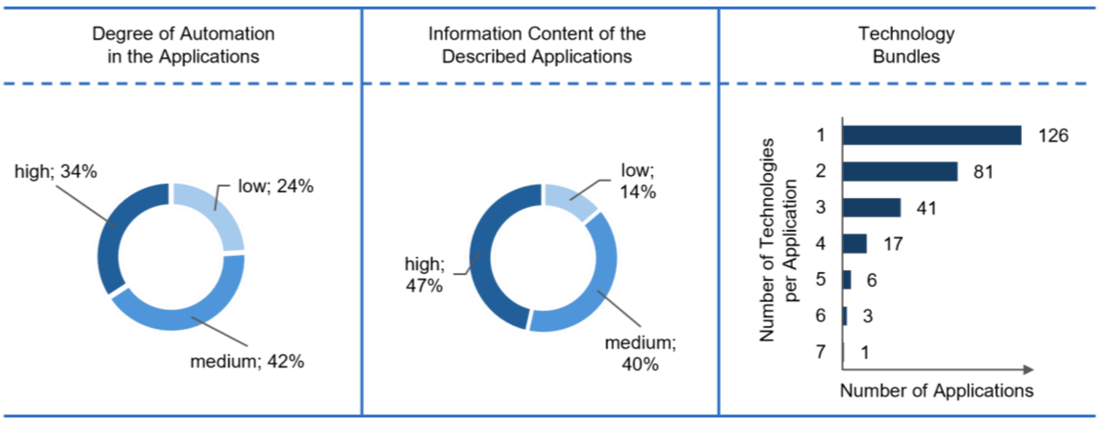


Figure 7: Characteristics of the 275 applications identified

3.2.1. Heatmap Structure

The heatmap visualises the thematic analysis results, with the full dataset available in the *Appendix – B) Procurement 4.0 Applications – Analysis Table*. 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 colour 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 6, column D, rows 6-27) represents procurement processes and tasks (as outlined in Figure 3), 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 Table 4). While E-Procurement was frequently referenced in the context of advanced technologies and was therefore included in Table 4, it is excluded from the heatmap, as Procurement 4.0 extends beyond traditional E-Procurement (Herold et al., 2022, p. 3). Technologies and related concepts not classified as 'A' (82 in total) are grouped under *Others,* visually distinguished by an orange colour code. This category is listed separately, as it represents a collective classification that is not directly comparable to 'A' technologies and related concepts.

3.2.2. Procurement 4.0 Application Heatmap

The Procurement 4.0 Application Heatmap, developed as a conceptual framework in this study, is presented in Figure 7. 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, p. 30):

- *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 3.3.

3.3. 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.

3.3.1. 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 including 73 times, such as Real-time Information, Cloud Computing, RPA, Platforms, Smart Contracts, Algorithms, and IPA. The third and least prominent cluster in the heatmap includes technologies and related concepts that are mentioned 9 to 21 times, comprising 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, p. 431). 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 and Benhlima, 2022, p. 4574; Govindan et al., 2024, p. 10; Gunasekara et al., 2022, p. 456; Jain et al., 2024, p. 10306). 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, p. 457; Raj et al., 2022). As these capabilities extend to Purchase-to-Pay sub-processes, particularly within 'Invoice & Payment'—a 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, p. 16) its adoption rate among German companies remains low, with only 7% reporting current or planned implementation (Bunde and Wolf, 2024, p. 37). 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.

Applications of the Internet of Things (IoT) are predominantly concentrated in the domains of Supplier Relationship Management and Partnering, as well as Controlling & Reporting. In Supplier Management, IoT is expected to enhance data exchange (Rejeb and Appolloni, 2022, p. 10) 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, p. 741). 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, Intelligent Process Automation (IPA) (100%) and Robotic Process Automation (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., 2022, p. 11), in combination with Blockchain, Smart Contracts (Hofbauer and Sangl, 2019, p. 32; Jahani et al., 2021, p. 17), and IPA (Flechsig et al., 2022, p. 14) 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 is still in the early 'innovation trigger' phase and is expected to reach the 'plateau of productivity' only in 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, p. 6). 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, p. 7) 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, p. 1). 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. However, ensuring the effectiveness and process integrity of these technologies should remain a central priority in their implementation.

A notable gap in the literature is the limited discussion of AI, Algorithms, and Simulations in the context of operational procurement processes. Likewise, Sensors and RFID are seldom examined within the strategic Source-to-Contract process. This lack of focus is particularly noteworthy, given that these technologies and related concepts have been explored in various contexts but not explicitly in relation to operational or strategic procurement processes, despite their potential benefits. For instance, AI has been studied as a question-answer assistant (Nicoletti, 2020, p. 162), while simulation models have been used to assess the impact of factors such as delivery times and to optimize procurement-related decision-making (Rejeb and Appolloni, 2022, p. 11). These models integrate embedded algorithms to evaluate process changes and improve system dynamics (Rejeb and Appolloni, 2022, p. 11). Moreover, while data collection via Sensors and RFID (ElAmmari et al., 2024, p. 3f; Govindan et al., 2022, p.

15) has been discussed in relation to decision-making, it has not been explicitly examined within the strategic Source-to-Contract process. A similar pattern emerges with Social Media, as the process section of the heatmap (U6-U19) remains largely unmarked. While Social Media platforms are discussed in the context of enhancing both internal and external collaboration (Lorentz et al., 2021, p. 172), explicit applications within the strategic and operational procurement process are largely absent. 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: while practitioners can leverage it to identify potential use cases, academics can utilize it to explore avenues for future research.

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 54), illustrating the complexity and dynamism 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 cultivate the necessary implementation expertise.

Finally, futuristic applications are also emerging in procurement. Tripathi & Gupta (2021, p. 447) 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, p. 457; Miehle et al., 2019, pp. 433 & 435). These developments highlight the transformative potential of advanced technologies in reshaping procurement practices in the future.

3.3.2. Procurement Processes and Tasks

Among the identified procurement tasks, *Controlling & Reporting* and *Supplier Relationship Management & Partnering* emerge as particularly significant, alongside the category labelled *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 2)—it is anticipated that advanced technologies intersect significantly with controlling and reporting functions. The heatmap analysis reveals a particularly strong intersection, with 16 instances of overlap between Big Data, Blockchain, and Controlling & Reporting. This finding highlights the critical role of data availability and analytics in optimizing procurement management and decision-making. The real-time availability of vast datasets, enabled by technologies such as Big Data, IoT, and AI, presents significant opportunities for enhancing controlling processes. These innovations facilitate the further development of planning, management, and information systems, strengthening procurement's role in organizational decision-making (Eisl et al., 2023, pp. 42–47). As a result, Controlling is increasingly positioned as a target-oriented and decision-supporting subsystem within procurement management (Schentler and Tschandl, 2016, p. 32f). Key applications include price forecasting, optimized price identification, supplier performance measurement, enhanced information transparency, and real-time procurement process monitoring.

Supplier management is another critical domain in procurement, encompassing activities such as supplier selection, development, and performance monitoring (Lysons and Farrington, 2012a, p. 8). 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, p. 7f). 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, termed 'high-resolution supplier management' (Fleisch et al., 2014, pp. 816 & 820), enhances supply chain resilience by enabling firms to anticipate and respond to disruptions effectively (Herold et al., 2022, p. 13; Nicoletti, 2020, p. 93). Furthermore, as discussed in Section 3.3.1 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, p. 741).

Another key observation is the prevalence of procurement system-related and non-process-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, p. 96f). However, successful implementation requires a high degree of process transparency and understanding (Brunnhofer, 2021, pp. 203–205; Dumas et al., 2018, p. 75). From a process management perspective, achieving this transparency remains a persistent challenge (Opitz et al., 2024, p. 14). 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 labour market dynamics, including workforce shortages and evolving generational expectations. However, while academic discussions on Procurement 4.0 primarily emphasize strategic and tactical applications, the heatmap analysis reveals that comparatively less attention is given to the operational Purchase-to-Pay (P2P) process. This discrepancy may partly be explained by Gartner's Hype Cycle for Procurement, which suggests that source-to-pay (S2P) suites are approaching the 'plateau of productivity' in the near future (Gartner, 2024; Zip, 2024). Conversely, emerging strategic applications—such as Predictive Analytics and Smart Contracts—are still in their early 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., 2023, p. 3). 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 3.3.1 above (Eulerich et al., 2022, pp. 1 & 7; Flechsig, 2021b, p. 4f; Ng et al., 2021, p. 1). 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, p. 5f).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	
1						Technologies and Technology-related Concepts																								1
2						**Blockchain**	**IoT**	**Artificial Intelligence**	**Big Data**	**Real-time information**	**Cloud Computing**	**RPA**	**Platform**	**Smart Contracts**	**Algorithm**	**IPA**	**Sensors**	**Business Intelligence**	**RFID**	**Simulation**	**Social Media**	**Cyber-physical systems**	**Others**	∑ **Row** Frequency, Including Technology Bundles ↓	**% Change** Due to Bundle ↓	∑ of Column X per Process or Task Area ↓	# Applications: High Degree of Automation (3) ↓	# Applications: Medium Degree of Automation (2) ↓	# Applications: Low Degree of Automation (1) ↓	2
3				**Number** of **Sources** Referring to Technology Application →		22	12	18	18	20	8	12	12	10	10	3	8	1	6	6	4	5	44							3
4				**Number** of **Applications** Referencing the Technology →		47	47	41	38	30	23	22	22	18	15	13	11	9	8	8	7	7	112							4
5			↓ ∑ **Category**	Frequency of Specific Applications | **per Process/Task** ↓																										5
6	**Procurement Processes and Tasks**	Source-to-Contract	187	Strategic Demand & Spend Management	27	1	3	7	7	3	4	1	3		3	2	1			1			12	47	74	262	6	12	9	6
7				Category & Sourcing Strategy Definition	22	1	1	2	6		3		4			1		1		1	3		12	34	55		4	9	9	7
8				Supplier Identification & Prequalification	34	2	4	11	9		1	2	1	1	1	2		1		2	1		11	47	38		14	17	3	8
9				Tendering	32	9	2	5	2	1		5	1	3	5	4						1	10	39	22		17	12	3	9
10				Negotiation	25	4	3	8	3	1		1		2	2	2		2		1			6	31	24		13	11	1	10
11				Supplier Selection	27	3	3	6	6		4	1	1	1	5	1		1		1		1	10	41	52		10	15	2	11
12				Contracting & Onboarding	20	6	1	7		1		1		5	1	2							5	23	15		11	9	0	12
13		Purchase-to-Pay	144	Demand Planning & Purchase Requisition	42	5	7	5	9	6	4	4	5	2	2	1	4		1			2	14	66	57	206	16	16	10	13
14				Approval & Ordering	39	7	5	5	4	2	3	10	3	5	2	3	1	1				1	10	55	41		29	7	3	14
15				Order Confirmation	3		1			1		1	1			1							0	5	67		3	0	0	15
16				Tracking & Tracing	29	11	7		1	8	1	1	1	4		1	3		5			1	8	41	41		8	8	13	16
17				Goods Receipt	10	2	1			2	1	2	1			2			2				3	14	40		6	2	2	17
18				Invoice & Payment	18	8	1			2		4	2	7		2			1				5	24	33		14	3	1	18
19				Claim Management	3	3								1									0	1	-67		1	1	1	19
20		System & Non-process-related Tasks	342	Risk Management	36	7	6	4	15	4	2	1	2	2	3	1	1	2		3			8	54	50	528	8	20	8	20
21				Human Resource Management & Training	6			1				1									1		4	7	17		1	4	1	21
22				Supplier Relationship Management & Partnering	57	10	12	7	9	8	9	5	7	2	2	2	1	1		1	4		21	91	60		14	28	15	22
23				Organizational Development & Process Management	50	10	9	4	1	7	8	6	9	3	4	1	1		1	2	3		24	83	66		14	21	15	23
24				Supply Market Monitoring	21	1	2	5	8	2	2		1		2	4		1		1	2		4	34	62		9	10	2	24
25				Sustainability & Compliance	29	15	7	2	3	3	3		1	5	3		1		1	1			6	36	24		2	20	7	25
26				Controlling & Reporting	80	16	14	12	16	12	6	4	4	3	7	2	6	2	3	4	2	3	22	122	53		16	42	22	26
27				Others	63	11	8	7	3	10	7	10	9	4		3	1	1	2	3	5		28	101	60		20	27	16	27
28				***Total Frequency*** *of Process or Task Support in each Column* →		132	97	98	102	73	58	60	56	50	42	37	20	13	16	21	21	9	223							28
29				***Total Frequency*** *of Process or Task Support Across Columns F to W* →		905																								29
30				***% Share*** *of Applications by Technology/Concept with a High Degree of Automation (3)* →		28	26	37	18	17	9	91	23	56	33	100	18	44	38	13	0	43	14							30
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	

Figure 8: Procurement 4.0 application heatmap

3.4. Concluding remarks

Based on the outlined challenges regarding the conceptualization of Procurement 4.0, this study 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 Procurement 4.0 applications discussed in current literature (RQ1) and (2) analyse the procurement processes and tasks supported by these applications (RQ2). Both objectives were addressed by systematically developing the heatmap (Figure 8), 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. As a result, research efforts must remain dynamic and evolve in tandem with these advancements. Furthermore, this study identifies several critical research gaps that warrant further exploration.

First, a persistent gap between academic debate and practical implementation is evident, as exemplified by Blockchain applications. While Blockchain is widely analysed in procurement research, its practical adoption remains significantly limited. This trend extends to the broader digitalization of procurement, where substantial potential for process improvement remains unrealized. 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 enable seamless integration across diverse organizational contexts, thereby accelerating adoption and allowing firms to fully leverage the potential of emerging technologies.

Beyond the gaps identified in Chapter 3.3, this study finds that the majority of procurement applications leveraging technologies from the most widely discussed cluster exhibit only a moderate level of automation. This suggests that research continues to position technology primarily as an enabler of human decision-making (augmentation), while full automation remains limited to supervised tasks. Although early use cases involving AI (Herold et al., 2022, p. 11), Blockchain and Smart Contracts (Hofbauer and Sangl, 2019, p. 32; Jahani et al., 2021, p. 17), and IPA (Flechsig, 2021b, p. 14) indicate a gradual shift toward autonomization, fully autonomous procurement processes remain an aspirational goal. This presents an opportunity for further research to systematically examine the autonomization of procurement workflows.

Thus, looking forward, a critical question emerges: At what point does the Procurement 4.0 paradigm become obsolete in light of rapid advancements in AI, and how will procurement evolve beyond this framework? Based on the results and discussions presented in this study, future research should explore these developments, offering additional insights into the evolution of procurement practices in a post-Procurement 4.0 environment.

Finally, the Procurement 4.0 transformation extends beyond technological advancement, encompassing environmental, organisational, and human factors that influence its adoption. Although the findings of this study—presented as a heatmap and complemented by a filterable spreadsheet in Table 4 in the Appendix— may serve as a foundation for stimulating academic debate and informing practitioners about promising technologies and concepts for specific applications, they do not account for these broader dimensions.

To address the context of change from the perspective of adopting companies, the following chapter, which explores practical Procurement 4.0 applications, is structured around the TOE framework according to DePietro et al. (1990) in Tornatzky and Fleischer (1990). This framework captures the three key contextual factors that influence technology adoption and implementation within firms: Technology, Organization, and Environment.

4. Findings from an Exploratory Multiple-Case Study on Procurement 4.0 Applications

This chapter presents the design, implementation, and findings of the qualitative multiple case study analysis on automation in the context of Procurement 4.0, drawing on the conceptual research framework.

The discussion of the heat map presented in Chapter 3 clearly highlights the gap between theory and practice. Given this gap, the literature frequently calls for investigating real-world applications of advanced technologies, such as AI, in procurement practice to enhance understanding (Bruzzi et al., 2019, p. 114; Bueno et al., 2024, p. 16; El Asri and Benhlima, 2022, p. 4575; Gottge et al., 2020, p. 735; Guida et al., 2023, p. 3; Spreitzenbarth et al., 2024, p. 1).

This chapter responds to this call by examining the implementation of advanced technologies in the procurement practices of five companies using a qualitative multiple-case study. The aim is twofold: to investigate the practical manifestation of theoretical concepts and to gain in-depth insights into the real-world impact of Procurement 4.0 approaches. Specifically, the study focuses on the relevance of automation and seeks to identify practice-based factors, including success factors, opportunities, potential benefits, challenges, risks, barriers, and actionable practical recommendations. To this end, the chapter first outlines the design of the qualitative multiple case study analysis, then describes its implementation, and finally presents and discusses the findings.

4.1. Design of the multiple-case study

Advanced technologies have not yet been widely adopted in practice, and relatively few cases have been scientifically investigated and documented. Furthermore, existing case studies in this domain exhibit inherent methodological limitations, such as restricted generalizability (Křenková et al., 2021, p. 200). Consequently, this study applies an exploratory research approach, which in turn leads to a qualitative research (Döring and Bortz, 2016, pp. 192–193). This approach is particularly recommended when exploring realities that have been scarcely researched (Flick et al., 2010, p. 25).

Qualitative research is highly application-oriented in its inquiry, seeks to describe phenomena from the perspective of those involved, and helps highlight structural characteristics (Flick et al., 2010, pp. 14–15). Qualitative research typically adopts an open approach to the phenomena under investigation, emphasizing the specific characteristics of the research object (Flick et al., 2010, p. 17). The objective is to derive insights from a limited number of cases, for which comprehensive data is collected in a non-structured manner (Döring and Bortz, 2016, p. 25). Rather than testing theories through statistical analyses, qualitative research contributes to an in-depth understanding by generating new hypotheses and theories based on an interpretive, detailed analysis of multiple aspects of a few (individual) cases or deliberately small samples (Döring and Bortz, 2016, pp. 14, 32, 185).

Flick et al. (2010, pp. 22–23) further highlight that qualitative research encompasses a diverse spectrum of methods, each of which can usually be traced back to specific research topics for which they were originally developed. They emphasize that the object of investigation and the research questions serve as the primary reference points for selecting and evaluating appropriate methods.[15] Since this study examines the implementation of advanced technologies in the context of Procurement 4.0 process automation, with the objective of collecting detailed insights into Procurement 4.0 applications within organizations, these research aims serve as the basis for the methodological approach and method selection.

A suitable research method for this purpose is the case study approach (Yin, 2003, pp. 22–26, 56), as it is particularly effective for examining contemporary developments within a real-world context (Eisenhardt and Graebner, 2007, p. 25). Case studies can be conducted as either single or multiple-case studies, with the latter enabling comparisons and the identification of cross-case patterns (Yin, 2003, pp. 39–53). To explore the practical application and potential for the dissemination of advanced technologies in procurement, this study adopts a holistic multiple-case study approach, in which a specific use case is examined within each participating company (Yin, 2003, pp. 40–45, 52–53). This decision is based on three central theses that this study seeks to examine:

(1) *Success factors in practice:* The first thesis asserts that the successful implementation of advanced technologies in procurement is driven by specific factors that have not yet been sufficiently analysed and documented in the academic literature. By examining concrete case examples, this study aims to identify these factors.

(2) *Similarities and differences between companies:* The second thesis suggests that, although there are shared patterns in how companies introduce and use advanced technologies in procurement, there are also important differences. The aim is to explore both the commonalities and the variations, and to identify a set of key factors, which will be presented in tabular form. These insights may also offer practical guidance for companies that have not yet adopted

[15] Among the examples they provide, they refer to the narrative interview, which was developed for the analysis of municipal power processes (Flick et al., 2010, p. 22).

advanced procurement technologies, helping them anticipate and overcome potential risks and barriers.

(3) *Future perspectives on technological developments:* The third thesis states that companies that have already implemented advanced procurement technologies and thus exceed the industry average have previously engaged with technological advancements. It follows that these companies are likely to continue doing so, making them valuable sources of insight into current and future developments in the field.

Stuart et al. (2002, p. 420)—who are widely cited in case study research in the fields of digitization, process management, and supply management (Dirnberger-Wild and Roth, 2024, p. 3; Flechsig, 2021a, p. 8)—propose a five-step process for conducting case study research consisting of the following steps: (1) defining research questions, (2) developing instruments, including case selection, (3) data gathering, (4) data analysis, and (5) dissemination.
Yin, 2003 (pp. 49–51) outlines a similar sequence of steps specific to the multiple-case study method, with some occurring in parallel, a feedback loop between steps (3.n) and (2.n), and an explicit distinction between conducting the initial case studies before proceeding with the remaining ones to ensure theoretical replication. The process consists of the following steps: (1) develop theory, (2.1) select cases, (2.2) design data collection protocol, (3.1) conduct the first case study, (3.2) conduct the second case study, (3.3) conduct the remaining case studies, (4) write individual case reports, (5) draw cross-case conclusions, (6) modify theory, (7) develop policy implications, and (8) write the cross-case report.
These frameworks broadly align with typical schematic descriptions of qualitative research processes such as outlined by Döring and Bortz (2016, p. 27) consisting of the following steps, where steps (4) to (7) are performed in a cycle and feedback loops exist between step (3) and (4) as well as the cycle and step (8): (1) Research Topic and Research Problem, (2) State of Research and Theoretical Background, (3) Research Design, (4) Sampling, (5) Data Collection, (6) Data Processing, (7) Data Analysis, (8) Hypothesis and Theory Development, (9) Presentation of Results. The following sequence (see Figure 9) is derived from these three approaches.

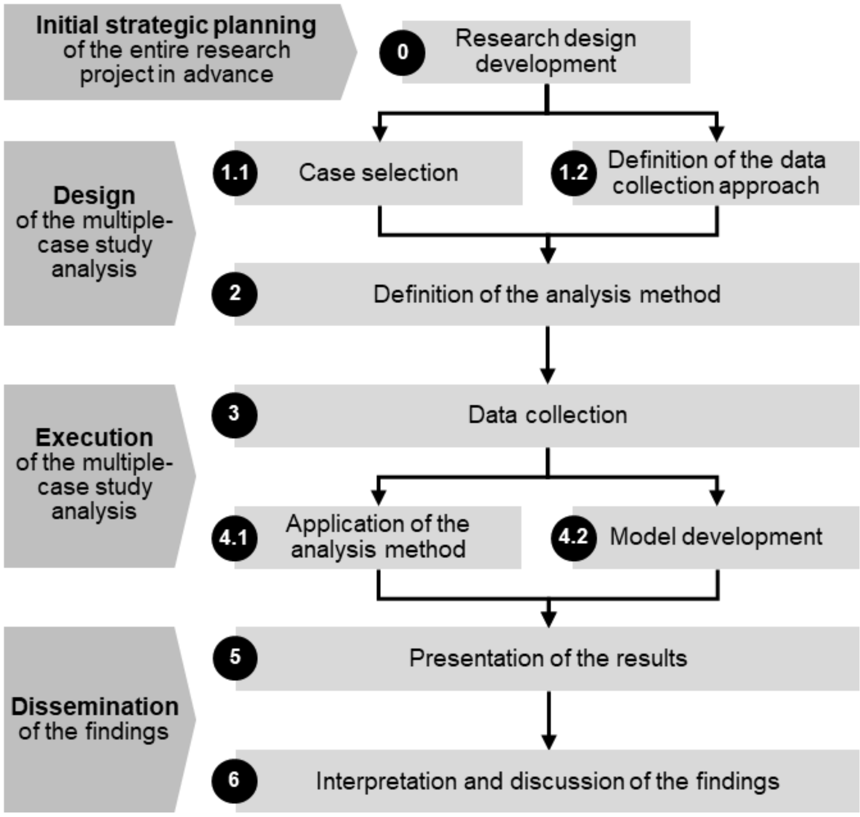


Figure 9: Multiple-case study analysis procedure

While the overall research design (0) has been developed and introduced in the introduction (Chapter 1), serving as a guiding framework for the entire study, the subsequent multiple-case study-specific steps (1) to (6) are outlined in this chapter. A distinction is made between steps (1) and (2), which are part of the case study design, and therefore presented in Chapter 4.1, the steps (3) and (4), which belong to the case study implementation included in Chapter 4.2, and steps (5) and (6), which are part of the results Section 4.3.

4.1.1. Case selection

There are various approaches to case selection, which Saunders et al. (2019, pp. 296–297, 315–324) categorize into probability and non-probability sampling techniques, further distinguishing within the latter between quota sampling, purposive sampling, volunteer sampling, and haphazard, namely convenience sampling. They recommend probability sampling for research aimed at drawing statistical conclusions about a population, such as in survey studies. This approach is explicitly confirmed by (Yin, 2003, p. 48), who emphasizes the distinction between survey research—aimed at drawing statistical conclusions, such as determining the prevalence of a phenomenon—and case study research. Therefore, a non-probability sampling approach is adopted.

This study employs a purposive sampling approach. In purposive sampling, the selection of cases is guided by the research questions to ensure that they best contribute to answering them and achieving the study's objectives (Saunders et al., 2019, p. 321). In this case, the objective—

to examine Procurement 4.0 use cases in practice—supports the application of the primarily homogeneous sampling technique (Saunders et al., 2019, p. 321). This entails selecting cases in which industrial companies have implemented advanced technologies or solutions in procurement, as defined in Chapter 2. Consequently, the selected group is homogeneous regarding the maturity of technology adoption in procurement. However, to ensure broader insights, the study also incorporates elements of maximum variation sampling by including diverse use cases that apply different advanced technologies (Saunders et al., 2019, p. 321). The study thus adheres to the recommendation that case selection should be guided by its variety and potential contribution to the research objectives rather than by random selection (Stuart et al., 2002, p. 426).

Döring and Bortz (2016, p. 30) emphasize that, in practice, potential participants may decline involvement due to a lack of willingness, posing both ethical and practical challenges in the recruitment process. They stress that research participation must always be voluntary for ethical reasons, which inherently leads to trade-offs, such as a degree of self-selection in all empirical studies.[16] Case studies conducted in the context of Procurement 4.0 confirm that the willingness of companies to participate is a practical factor influencing case selection (Flechsig, 2021a, p. 8; Lorentz et al., 2021, p. 164). Beyond these considerations, constraints related to resource availability significantly influence case selection. Stuart et al. (2002, pp. 426–427) discuss their implications in case study research and outline practical strategies. They:

- Propose initially selecting cases based on geographical proximity to enhance feasibility.
- Recommend using the 'popular press' and 'best practice practitioner conferences' to identify organizations suitable for developing innovative theories.
- Advocate for establishing a broad set of 'corporate-level criteria' for selecting potential companies, considering the various limitations involved.
- Suggest collaborating with well-known companies with strong performance histories, which enhances the likelihood that the collected information will be perceived as representative by reviewers.
- Advise considering opportunities within the immediate case researcher's environment 'to ground the research in normative practice' and refine the study design.

Against this backdrop, the study aims to secure access to cases identified through purposive sampling, while considering feasibility constraints. Thus, companies were selected and approached through a network of procurement experts in which the author is actively engaged.

A key challenge during case selection was the limited adoption of Procurement 4.0 applications in practice. Several companies withdrew from participation, citing a lack of advanced

[16] Self-selection does not involve the targeted recruitment of participants but instead relies on general calls for participation. As a result, the sample is more likely to be overrepresented by motivated individuals who choose to participate, for example, due to their interest in the study topic (Döring and Bortz, 2016, p. 306).

technologies in their procurement processes as a reason for their inability to contribute effectively to the study. Ultimately, five companies were successfully engaged. These firms were selected based on criteria relevant to the research, specifically being manufacturing enterprises that incur a high proportion of material costs or procurement expenditures, thus conducting procurement processes typical for this type of business. Furthermore, they already employ advanced procurement technologies and are geographically proximate, facilitating on-site visits.

Initial contact was established either in person or via telephone, depending on which method proved successful first. During this initial interaction, the purpose of the case study was explained, including the background, status, and scope of the research (see step 1.2, 'Define the data collection approach'), as well as the benefits of participation. Participants were assured of receiving a summary of the findings, opportunities for joint publications, and potential unforeseen advantages, such as networking possibilities with other participating firms. Notably, two companies were successfully connected, each expressing interest in the other's use case. The five selected companies are presented in the following.

voestalpine Metal Engineering GmbH (voestalpine, n.d.)**:** The Metal Engineering Division of the voestalpine Group is active in the business units 'Railway Systems' and 'Industrial Systems' and serves industry segments such as railway infrastructure, automotive and energy. With its Railway Systems business unit, the division is, among other things, a global market leader in railway infrastructure systems and signalling technology. With its Industrial Systems segment, it is also the European market leader in high-quality wire and a global provider of complete welding solutions.

> *Procurement 4.0 Application:* The company is currently implementing AI-supported analysis of supplier self-assessment questionnaires (SAQs) as part of its ESG risk management process. This procurement use case aligns with the Procurement 4.0 Application Heatmap due to its integration of AI technology to enhance sustainability and achieve efficiency gains through the automated analysis of documents.

RHI Magnesita GmbH (RHI Magnesita, n.d.): Refractory products are used globally in industrial high-temperature processes and are essential for industries such as steel, cement, glass, and chemicals. They remain strong and stable under extreme conditions at temperatures of 1,200°C and above, safely containing materials during processing and protecting furnaces and kilns from thermal, mechanical, and chemical stresses. RHI Magnesita provides solutions for these extreme challenges, making over 120,000 products ranging from bricks and lining mixes to flow control devices such as slide gates, nozzles and plugs. Their service life ranges from a few cycles within a day to ten years. Their base materials used are magnesite and dolomite, with fused magnesia exhibiting a melting point of over 2,800°C.

Procurement 4.0 Application: The company utilises a cloud-based procurement platform to standardise and automate supplier-related processes. This procurement use case aligns with Procurement 4.0, as it incorporates the platform concept and cloud computing technologies to further optimise and automate supplier management and collaboration processes.

KNAPP AG (KNAPP AG, n.d.): The company develops and manufactures intelligent warehouse systems using the latest digitalisation, software, automation and robotics solutions. The company offers everything needed for efficient warehouse logistics from a single source. Since its foundation in 1952 with 2 employees in Graz, the company has grown into an international group with around 8,300 employees and 49 locations worldwide.

Procurement 4.0 Application: The company employs algorithm-driven software in its category strategy development process, systematically guiding the creation of category strategies and thereby facilitating global standardisation and transparency. This use case aligns with the heatmap due to the application of algorithm-based technology within a strategic procurement process (category strategy development), and the automated compilation of the material group dossier.

Company 4 (Comp4): In this case, the company's name may not be disclosed, and therefore no further details can be provided; however, it can be stated that the company examined in this case study is the Austrian production site of a global Electronic Manufacturing Services (EMS) Provider.

Procurement 4.0 Application: The company utilises an internally developed real-time information system for its supply chain to enhance transparency and provide visual decision-making support in procurement. This use case aligns with Procurement 4.0, as real-time data facilitates various procurement processes (e.g., negotiations), and the information processing has been automated.

Siemens Mobility Austria GmbH (Siemens Mobility, n.d.): The company provides mobility solutions. The portfolio includes digital solutions, rail infrastructure (trams, metros, urban, regional and high-speed trains) including related services, vehicles (trains, locomotives), components and systems such as traction systems, bogies, and braking systems, as well as turnkey and customized rail solutions.

Procurement 4.0 Application: The company employs a combination of IT- and AI-based systems to evaluate risk information and conduct N-tier assessments within its supply chain risk management. This procurement use case aligns with Procurement 4.0 due to the integration of AI technology in risk management and sustainability, automating aspects of the information collection process.

Table 5 below summarises the five cases examined, providing pseudonymised abbreviations (in brackets) for ease of reference throughout this study, alongside additional details on each procurement organisation gathered during the case study analysis. These details were collected to assess the context of each case and ensure compliance with the selection criteria outlined previously. Specifically, all the companies operate within the manufacturing sector, incur significant procurement expenditures (spend) both in absolute terms and relative to revenue, and consequently maintain sizeable procurement organisations as reflected by employee numbers.

		Case 1	Case 2	Case 3	Case 4	Case 5
Com-pany		voestalpine Metal Engineering GmbH (Comp1)	RHI Magnesita GmbH (Comp2)	KNAPP AG (Comp3)	Austrian production site of a global Electronic Manufacturing Services (EMS) Provider (Comp4)	Siemens Mobility Austria GmbH (Comp5)
Core Business		Railway infrastructure systems, signalling technology, wire, and complete welding solutions	Refractory products and solutions, ranging from bricks and lining mixes to flow-control devices such as slide gates, nozzles, and plugs, as well as raw materials including dolomite and magnesite	Intelligent warehousing systems, including software, automation, and robotic solutions	/	Rail infrastructure (trams, metros, urban, regional and high-speed trains), components and systems such as traction systems, bogies, and braking systems
Examined P4.0 Application		AI-supported analysis of supplier SAQs (Self-Assessment Questionnaires) as part of ESG risk management	Use of a cloud-based procurement platform to standardize and automate supplier-related processes	Algorithmically driven category strategy development to facilitate global standardization and transparency	Use of a supply chain real-time information system to create transparency and visual decision support in procurement	IT- and AI-based risk information and N-tier assessments in the supply chain within the scope of risk management
Procurement Organization	Employees	This is a staff position without direct reports. There are decentralised organisational units and a divisional steering committee that coordinates the business units via the purchasing department, which acts as an interface to group purchasing	Procurement without the supply chain consists of 10 employees; including the Supply Chain and Commercial, the total is 150 The entire procurement organization consists of 130-150 employees	50 (direct reporting line), 80 (including matrix structures)	35 purchasing employees in Austria, plus 14 people in a team in India supporting the Austrian site, making a total of 49 employees	90 employees in Austria; operational purchasing (call-off orders) not part of strategic purchasing; 400-450 employees worldwide in strategic purchasing (incl. Supplier Quality Engineers)
	Spend	Spend excluding raw materials in the metal engineering division at ~1.1 billion euros	The regional procurement is responsible for 400 million euros; 700 million euros procurement volume incl. investments and raw materials (procured globally) for the region	~1 billion euros	>100 million euros per year	700 million euros project procurement volume in Austria
	Material/Cost Ratio	Approx. 75 %, relates to energy (gas, electricity) and raw materials as well as various additive materials	/	35 % direct material; 50 % total procurement volume in relation to revenue	> 50 %	Product-specific material cost ratio between 50 and 75%

Table 5: Overview of the analysed cases

4.1.2. Definition of the data collection approach

The Interview, as the primary method for data collection, is widely recognised as particularly effective in case studies, which commonly investigate phenomena involving human behaviour and interactions (Eisenhardt and Graebner, 2007, p. 28; Yin, 2003, pp. 89, 92). Interviews facilitate the targeted collection of case-study-specific data, providing valuable, in-depth insights and enabling the identification of perceived causal inferences (Eisenhardt and Graebner, 2007, p. 28; Yin, 2003, p. 86). Depending on the degree of structure involved, a fundamental distinction is drawn between unstructured and semi-structured interviews. This distinction hinges upon whether a catalogue of questions (interview guide) is developed in advance by the researcher or if the interview structure emerges primarily from the narratives provided by the interviewees (Döring and Bortz, 2016, pp. 369, 372).

The semi-structured interview method—in contrast to unstructured interviews—involves a predetermined catalogue of open-ended questions (interview guide) without predefined response options (Döring, p. 372). This approach is particularly prevalent within Procurement 4.0 case study research and frequently employed either as the primary data collection technique (Colombo et al., 2023, p. 3; Flechsig, 2021a, p. 9; Lorentz et al., 2021, p. 164; Sjodin et al., 2021, p. 5) or exclusively (Gottge et al., 2020, pp. 735–736). The advantage of semi-structured interviews is that they establish a fundamental framework for analysis and cross-interview comparability, while still allowing sufficient freedom for spontaneity and flexibility, such as the exploration of unanticipated topics (Döring and Bortz, 2016, p. 372).

With regard to semi-structured interviews, the methodological literature further identifies several distinct sub-types. Döring and Bortz (2016, pp. 372–379) distinguish between the focused interview[17], the problem-centred interview, and the expert interview. Given that Procurement 4.0 use cases serve as the units of analysis to explore their characteristics and associated factors, and considering that expert interviews explicitly target respondents' practical, behavioural, and structural expertise (Döring and Bortz, 2016, p. 375)—which are clearly also relevant to case study research—established best practices from the expert interview approach are incorporated into the semi-structured case study interview to enhance its effectiveness.

Consistent with theoretical recommendations (Yin, 2003, p. 92) and the practical approaches adopted by the previously mentioned authors, relevant documents and supplementary sources of information—such as websites identified during the interviews—will be considered in order to enhance academic rigour and corroborate the findings.

[17] The focused interview is also described by Yin, 2003 (pp. 90–91) as an example of a guideline-based interview.

After selecting the semi-structured interview as the primary data collection method, two subsequent steps are necessary: *identifying suitable respondents* and *developing the interview guideline.*

4.1.2.1. Identification of the interview participants

In addition to the willingness and availability of interviewees, it is essential to determine in advance who possesses the relevant knowledge and is best positioned to provide accurate information (Gläser and Laudel, 2006, p. 113).

Therefore, the objective was to identify and approach suitable experts with particular know-how (Gläser and Laudel, 2006, p. 10) within the selected companies for each specific use case. Alongside comprehensive knowledge of the respective application derived from direct responsibilities, selection criteria included extensive professional experience (Gottge et al., 2020, p. 735) and managerial positions within the organisation (Lorentz et al., 2021, p. 164) as these are indicators of expertise (Döring and Bortz, 2016, p. 375). It was assumed that individuals meeting both criteria would possess the most comprehensive understanding of all relevant aspects. Consequently, interviews targeted experienced managers directly responsible for the respective use cases.

In Comp1, the appropriate respondent—the division's Purchasing Manager, who originally proposed the use case under evaluation—immediately confirmed participation. This manager has 18 years of procurement experience, including more than 15 years in managerial roles, and is actively engaged in advancing further AI use cases in procurement. In Comp2, the initial respondent, a Senior Supply Chain Executive with 20 years of procurement experience—including more than nine years in managerial positions and current responsibility for approximately 150 employees—invited a colleague to join the interview. This colleague, a Procurement Analyst with over 20 years of experience, held a lead role in the SAP Ariba implementation project and was therefore directly involved. Consequently, this interview involved two respondents. In Comp3, the selected respondent—the Vice President Global Supply Chain & Facility Management, who has over 20 years of managerial experience in procurement, currently has responsibility for approximately 50 employees, and actively leads digitalisation initiatives in purchasing—was also immediately available. In Comp4, the initially approached manager referred the interview to another purchasing manager (with 10 years of procurement experience, including the last 6 years in management, currently responsible for 8 employees), indicating that this individual was best positioned to discuss all relevant Procurement 4.0 digitalisation solutions and supply chain applications. Finally, in Comp5, information regarding the use case was provided directly by the Head of Procurement, who has more than 13 years of procurement experience—including 10 years in managerial roles—and currently has responsibility for approximately 90 employees. Additionally, this individual holds global responsibility for sustainability within the division and serves as the interface for digitalisation topics.

Interviewees were offered the option to remain anonymous, firstly because this is standard practice, and secondly to encourage greater willingness to participate (Döring and Bortz, 2016, p. 128). As three of the six respondents preferred not to disclose their identities, anonymity is consistently maintained for all respondents, who are identified by job titles in relation to their respective cases. This information, along with the interview dates, is summarised in Table 6.

Case Study	#	Respondent	Expert status	
			Procurement experience in years	Procurement position and further aspects
Comp1	1	Purchasing Manager-ME Division	18	▪ 15 years of experience in managerial procurement position ▪ Proposed the use case under evaluation ▪ Active role in development of further AI procurement use cases
Comp2	2	Senior Supply Chain Executive	20	More than 9 years in managerial roles, currently responsible for ~150 employees
	3	Procurement Analyst	20	Leading role in the implementation project for the relevant use case
Comp3	4	Vice President Global Supply Chain & Facility Management	20	▪ Over 20 years of managerial experience in procurement ▪ Currently responsible for ~50 employees ▪ Actively leading digitalisation initiatives in purchasing
Comp4	5	Purchasing Manager	10	6 years in management position, currently responsible for 8 employees
Comp5	6	Head of Procurement	13	▪ 10 years in managerial positions, currently responsible for ~90 employees ▪ Global responsibility for sustainability within division ▪ Interface function for digitalisation topics

Table 6: Overview of interview respondents

4.1.2.2. Development of the interview guideline

In order to conduct the semi-structured interview, it is necessary to develop an interview guide consisting of questions derived from the overall research design (Döring and Bortz, 2016, p. 372; Yin, 2003, p. 90). All steps involved in constructing the interview guide must be documented to ensure maximum transparency in the operationalisation process (Gläser and Laudel, 2006, p. 111). This documentation is provided subsequently.

According to Hopf, 1978 (pp. 99–100), there are four fundamental requirements for qualitative interviews, all of which should be applied both to the interview guide developed here and to the interview execution itself:

(1) *Scope*: The interview guide does not solely address predetermined factors but encourages discussion of a wide range of aspects to examine the reconstruction process from multiple perspectives. Thus, it aims to facilitate descriptions of complex interrelationships.

(2) *Specificity*: The interview guide is designed to elicit specific rather than standardised responses from interviewees. Capturing detailed and individualised answers is crucial for understanding the background context.

(3) *Depth*: The interview guide assists interviewees in elaborating on the meaning and significance of particular situations they have experienced.

(4) *Personal context*: It is necessary to understand the contexts surrounding interviewees' responses in order to accurately interpret any unanticipated reactions.

In a semi-structured interview, open-ended questions are employed to uphold the principle of openness (Gläser and Laudel, 2006, p. 111). This principle, alongside three additional considerations, is reflected in the minimum requirements for formulating interview questions, which according to Patton (1990, p. 295) should be open-ended, neutral, singular, and clear. Additionally, simple ‘why’ questions should be avoided due to their inherent ambiguity (Patton, 2002, p. 363). Different question types should also be clearly distinguished: facts from opinions and real from hypothetical questions, as each provides distinct and valuable insights for case-study research (Gläser and Laudel, 2006, pp. 118–126; Yin, 2003, p. 90). Furthermore, narrative-stimulating questions and detailed questions (for managing responses), as well as filters or follow-up questions (for guiding the direction of the interview), must be considered (Gläser and Laudel, 2006, pp. 118–126). To ensure interview quality, these criteria—summarised in Table 7—were systematically integrated into the development of the interview guide.

Requirements	*Description*
Functional aspects	▪ Typically, open-ended questions are employed to stimulate the respondent's narrative, accompanied by detailed follow-up questions. ▪ Closed or filtering questions (e.g., yes/no) are used strategically to exclude irrelevant topics and ensure efficient use of interview time. ▪ Potential areas for follow-up questions are identified in advance, though their actual use must be decided situationally. ▪ Leading questions, which explicitly or implicitly suggest a particular response, have to be avoided.
Clarity and simplicity	▪ A simple question should address only a single aspect of information; questions containing multiple queries should therefore be avoided. ▪ To enhance clarity, a question may begin with a statement that establishes common ground or shared knowledge, thus removing the need for further explanation within the question itself.
'Why' questions	'Why' questions often prompt interviewees to spontaneously mention aspects that immediately come to mind, potentially leading to superficial or unfocused answers. Questions should therefore be formulated with greater specificity. For example, rather than broadly asking 'why', interviewees might instead be asked to identify specific economic reasons for a particular decision or outcome.
Content-related aspects	▪ Regarding content, interview questions may address either facts or opinions. Although distinguishing clearly between these two categories can be challenging, a key difference is that factual questions yield verifiable information. ▪ Additionally, a distinction must be drawn between reality-based questions and hypothetical questions (stimulus questions).

Table 7: Requirements for formulating guiding questions (Gläser and Laudel, 2006, pp. 118–141)

For the construction of the interview guide, Gläser and Laudel (2006, pp. 140–145) outline key preliminary considerations that are presented in Table 8.

Key aspects			Sequence of the Interview		
Recommendation from the Literature		Implementation	Recommendation from the Literature		Implementation
Interview scope	Given the typical interview duration of 1 to 2 hours, it is realistically feasible to cover approximately 8 to 15 questions.	14 questions were posed regarding the case itself and the interviewee's evaluations and opinions.	**Informed consent**	The interview should begin with a statement ensuring informed consent by explaining the research topic and how the interview contributes to the study's objectives.	✓
Question formulation	Each question should be clearly defined in advance[18]	✓	**Clarification of recording and anonymisation**	The interviewer should clarify the process of tape recording and reassure the respondent regarding anonymisation procedures.	✓
Tape recording	From a methodological perspective, recording interviews is recommended[19]; however, explicit consent must be obtained beforehand	Four of the five interviews were permitted to be recorded. At one company, recording was not allowed due to internal regulations; therefore, detailed notes were taken as accurately as possible and later sent to the interviewees for review.	**Logical progression of topics:**	The interview should be structured so that related topics are addressed consecutively.	✓
			Warm-up and closing questions	The first question should serve as a warm-up to establish a positive atmosphere, while the final question should also be engaging and non-sensitive to leave a favourable impression.	✓

Table 8: Preliminary considerations for the construction of the interview guide (Gläser and Laudel, 2006, pp. 140–145)

Table 8 presents key aspects that need to be considered before developing the interview questions. To ensure the transparency of the interview guide—aligned with the research design—and to maintain its quality by avoiding design flaws, the four quality criteria defined by Ullrich (1999, pp. 436–437) are followed:

(1) *Theoretical relevance:* Why is the question being asked?

(2) *Content:* What does the question address?

(3) *Question type:* Why is the question formulated in this specific way rather than differently?

(4) *Coarse and fine structure:* Why is the question or question block positioned at this specific point in the guide?

The formulation in (3) is derived from the aspects presented in Table 7. The arrangement (4) follows the aspects outlined in Table 8, with explanations provided after the table to enhance understanding. The points (1) theoretical relevance and (2) content are presented directly within

[18] While there are differing views on whether questions should be explicitly formulated, Gläser and Laudel (2006, p. 140) advocate for clearly defining each question in advance to ensure that all respondents receive them in a consistent manner, thereby enhancing comparability. Furthermore, this approach enables interviewers to revisit topics in challenging interview situations. However, a potential drawback is reduced flexibility, as it may result in excessive adherence to the interview guide.

[19] For evaluation purposes alone, it is essential that qualitative interviews are recorded, making it necessary to address and mitigate potential barriers to acceptance in advance (Döring and Bortz, 2016, p. 366).

the guideline overview in Table 9. This structured approach is intended to ensure the rigour and clarity of the interview guide.

The interview guide is divided into four sections. The first serves as an introduction, while the final section provides the closing. The third section, which focuses on company-specific Procurement 4.0 applications, forms the core of this multiple case study analysis. An additional section was included to elicit the interviewees' expert perspectives on the practical application of AI in procurement and to explore broader views on the future of the field. AI was addressed in a dedicated section to reflect the recent surge of formal interest in this technology within the procurement domain, as evidenced by several recent surveys (Addicoat et al., 2023; EY, 2025; Karumsi and Prokopets, 2023; PricewaterhouseCoopers, 2024; Tandler and Bose, 2025). As all the interviewees speak German, the interviews were conducted in German. Therefore, the original German questions are also included in the guidelines presented.

Sect-ion	English question (translated)	German question (verbatim)	Content: What does the question address?	Relevant aspects	Theoretical relevance: Why is the question being asked?
Introduction	**Organisational** conditions	**Organisatorische** Rahmenbedingungen	Preliminary considerations	Recording; quoting; mentioning name; mentioning company	**Checklist** for ensuring academic rigour
	Objectives of my **research** & key **research questions**	**Zielsetzung** meiner **Forschung &** relevante **Forschungsfragen**	Explanation of the research topic and its relevance to the study's objectives	Research area procurement 4.0 and automation as well as the research questions 1 to 5 shaped by the case study	Ensuring **informed consent**
	Please provide an overview of your **career path**.	Bitte geben Sie einen Überblick über Ihren **Werdegang**.	Description of the respondent's educational and professional background	Education and experience in years (field-specific, within the company)	Verification of **expert status**.
	Please provide an overview of your **role**, your **area of responsibility**, and the **structural characteristics** of your **procurement organisation**.	Bitte geben Sie einen Überblick über Ihre **Funktion**, Ihren **Verantwortungsbereich** und die **strukturellen Merkmale** Ihrer **Beschaffungsorganisation**.	Organisational case study characteristics	Role; area of responsibility (number of employees, managed spend in EUR); procurement organisation (total number of employees, interfaces – centralised vs. decentralised); material cost ratio (material costs as a percentage of revenue), alternatively classified as: >25%, >50%, >75%	Identification of the **case study framework**
AI in Procurement and Outlook	When did you start engaging with **AI** in **procurement**?	Wann haben Sie im **Einkauf** damit begonnen, sich mit **KI** auseinander zu setzen?	Temporal AI starting point in the company	Time aspect, reasons, who was the initiator, how it differs from other functional areas	Assessing **relevance** in **procurement**, identifying motivation, **driving factors**, and **opportunities** for AI engagement
	Which **AI-based use cases** are you currently implementing?	Welche **KI-basierten Anwendungsfälle** setzen Sie derzeit um?	AI use cases currently being implemented in the company	Practical AI use cases, how was it learned about?; who made the decision?; AI technology (LLM, ML, …); timeline: when was it started, what is the current status, and when is the solution planned to go live?; application areas	Identification of **practical AI use cases**, key **application areas**, and **decision-making structures**; collection of **proposals** from practice; and determination of the **maturity level** of such solutions
	Are there any **additional AI use cases** in the **pipeline**?	Gibt es **weitere KI-**Anwendungsfälle in der **Pipeline**?	Planned AI implementations	Planned AI implementations; if yes, which ones?	Exploration of **near-future practical AI focus areas**
	Which **AI applications** do you foresee in procurement in the **future**?	Welche **KI-Anwendungen** sehen Sie in der Beschaffung in **Zukunft**?	Expert opinion on future AI applications in procurement	Future AI applications in procurement; reasons	Identification of **potential future applications** and associated **opportunities**, outline of **AI development**, and **outlook** on **AI use** in **procurement**
	Is there **another** emerging **technology** that you plan to use or intensify its	Gibt es eine **andere**, neuere **Technologie**, die Sie planen, **zukünftig** in der Beschaffung	Other, yet-to-be-discussed technologies relevant to procurement practice	Other practically relevant Procurement 4.0 technologies; if yes, which ones?	Discovery of **additional practical Procurement 4.0 technologies**

Sect-ion	**English question** (translated)	**German question** (verbatim)	**Content:** What does the question address?	**Relevant aspects**	**Theoretical relevance:** Why is the question being asked?
	application in procurement in the **future**?	zu nutzen oder zu intensivieren?			
	When you look ahead to the year 2034, how will **procurement** of the **future** differ from today?	Wenn Sie in das Jahr 2034 blicken – inwiefern wird sich der **Einkauf** der **Zukunft** von heute unterscheiden?	Expert opinion on the long-term procurement future and its characteristics	Long-term procurement future; terminology for advanced procurement or ‘procurement of the future’; company-internal terms	Exploration of a **potential long-term vision** for **procurement**, identification of **additional terminology** for Procurement 4.0
Company-specific Procurement 4.0 Application	Please **describe** the **use case**.	Bitte **beschreiben** Sie den **Anwendungsfall**.	Practical, company-specific Procurement 4.0 use case = Unit of analysis in the case study	Practical Procurement 4.0 use case; technological background; labour-intensive or manual steps that have been automated or partially automated	Understanding of the **Procurement 4.0 application** and deployed **technology**(ies), identification of **automation potential**
	For what **reasons** are you **implementing** this use case?	Aus welchen **Gründen** setzen Sie diesen Anwendungsfall um?	Implementation reasons for the Procurement 4.0 application	Reasons	Identification of **driving factors**, **opportunities**, and **potential benefits**
	What are your **future expectations**?	Welche **Erwartungen** haben Sie in **Zukunft**?	Future expectations for the Procurement 4.0 use case	Future expectations; how will it be determined that these have been fulfilled?	Exploration of the **future vision** for the application to **evaluate** its **progress level** and derive a **target state**
	Who is the **provider** of this **solution**?	Wer ist der **Anbieter** dieser Lösung?	Solution provider	Solution provider; why was this provider chosen?	Identification of **potential providers**, and selection criteria as a **reference** for other companies; facilitation of the subsequent **collection** of **additional** accessible **information** (e.g., websites) related to the case
	Please reflect on the **implementation** of the solution up to its current status.	Bitte reflektieren Sie die **Einführung** der Lösung bis zum jetzigen Status	Applied implementation approach	What was the procedure?	Understanding of the **implementation steps** and derivation of **key factors** (e.g., success factors) for **model development**
			Positive experiences, successful aspects	What went well?	Identification of **success factors** in the **implementation**
			Negative experiences, challenges encountered, and solutions	What problems were encountered? How were they solved?	**Identification** of **barriers**, **challenges**, **risks**, and **success factors** in the **implementation**
			Employee reactions, possible approaches, and solutions	Reactions of employees involved with the solution. How was/is this handled?	Identification of **barriers** and **challenges**, as well as **solution approaches** and **recommendations** in the implementation and execution

Sect-ion	**English question** (translated)	**German question** (verbatim)	**Content:** What does the question address?	**Relevant aspects**	**Theoretical relevance:** Why is the question being asked?
			Impacts on suppliers	Does the solution also affect suppliers? If so, how?	Identification of **environmental factors** (e.g., risks) related to the **supplier**
			Planning recommendations and underlying reasons	Which considerations should, based on experience, be made in advance of implementation in procurement? And why?	Derivation of **recommendations** for **planning**
			Usage risks	What risks are associated with its use?	Identification of **risks** regarding the **application**
	What **benefits** have you gained from this solution in procurement?	Welchen **Nutzen** haben Sie von dieser Lösung im Einkauf?	Benefits	Benefits (at the procurement level and company-wide); measurable results; satisfaction on a scale of 1–10	Identification of **benefits** for **case evaluation** and assessment of **potential advantages**
	Which **expectations** have **not** yet been **met**?	Welche **Erwartungen** haben sich **noch nicht** erfüllt?	Unmet expectations	Why?; what is the prognosis in this regard?	Identification of **gaps**, their **causes**, and the derivation of **challenges**
Closing	What do you **recommend** to **other procurement organizations** that want to implement this use case?	Was **empfehlen** Sie **anderen** Einkaufs-organisationen, die diesen Anwendungsfall einsetzen möchten?	Recommendations	Recommendations; what to pay attention to?; what to avoid?	Derivation of recommendations for similar cases
	May I **follow up** with you **afterward**?	Darf ich mich im **Nachgang melden**?	Further contact	Further contact for questions or for the Delphi study	Obtaining **consent** for **further contact**
	What would you like to **share** with me in **conclusion**?	**Was** möchten Sie mir **abschließend mitgeben**?	Respondents' questions and feedback	Any questions or feedback for me?	Complete **clarification** of **questions**, **satisfaction** of the **respondent**, and **collection** of **feedback** for the **improvement** of subsequent interviews

Table 9: Interview guideline for collecting information on cases

The column *Theoretical Relevance* in Table 9 presents the categories that were deductively derived from the research design, serving as the basis for pre-coding the text material in the analysis. The corresponding method is outlined in the following Chapter 4.1.3.

4.1.3. Definition of the analysis method

Since the source material for this multiple-case study analysis primarily consists of transcribed interview texts, qualitative content analysis is applied (Gläser and Laudel, 2006, pp. 188–191). The principles of qualitative content analysis, such as coding, have already been outlined in Chapter 4.1.3 and 4.2.2. However, specialised approaches exist for analysing interview texts.

Kuckartz's (2018, p. 97f) content-structuring qualitative content analysis method guides the analysis process. This approach is chosen for its established methodological validity and its capacity to enhance the depth and explanatory power of the analysis (Kuckartz, 2018, p. 97f). Initially, categories are deductively derived from the guideline questions and used to perform a preliminary coding of the text material. Subsequently, the text material is reviewed again, during which subcategories are inductively developed, enabling the extraction of specific factors within each category. Subsequently, the information is categorized, and the companies are evaluated comparatively, with the results prepared for inclusion in this PhD thesis. The findings also serve as the foundation for the next methodological Phase 4, the Delphi study, of the underlying research endeavour. This analysis process, as proposed by Kuckartz, is illustrated as a flowchart in Figure 10.

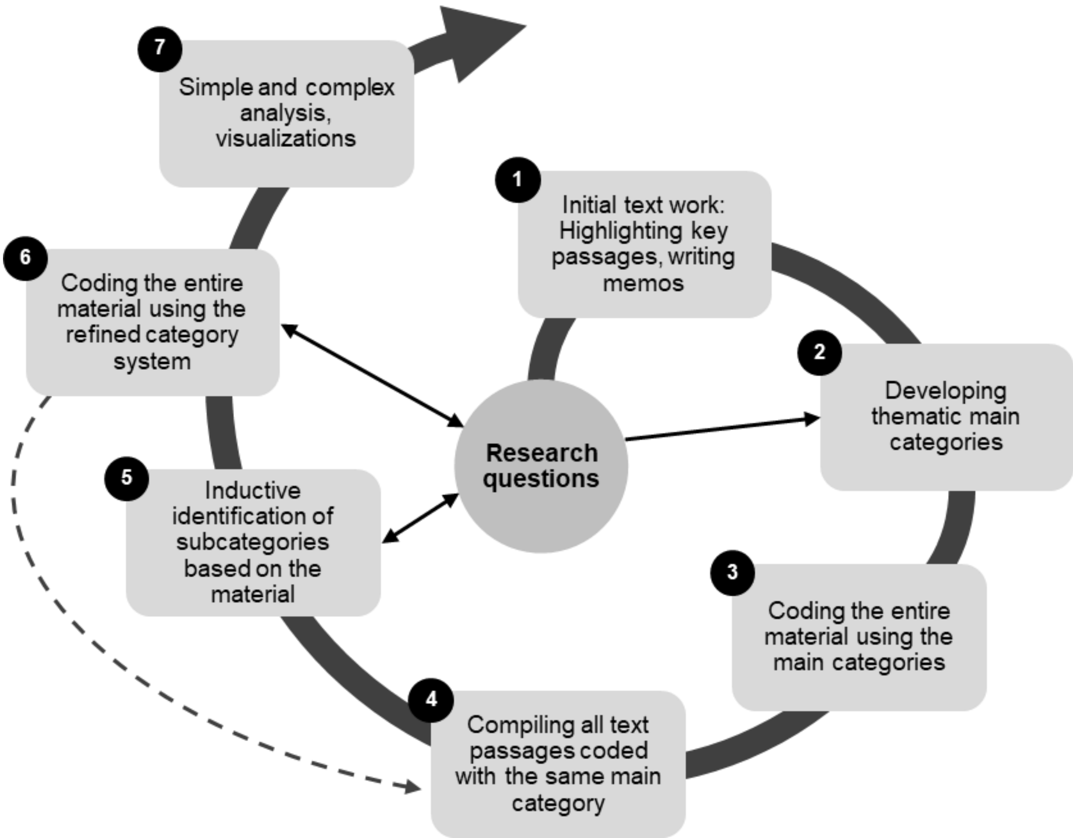


Figure 10: Phases of content-structuring analysis adapted from Kuckartz (2018, p. 100), translated into English.

The seven phases and their interrelationships, visualised with arrows according to Kuckartz, (2018, pp. 100–121), are presented in sequential order:

(1) *Initial text work:* Texts must be carefully examined, with particularly relevant information highlighted, evaluation ideas documented, and memos recorded. Finally, an initial concise case summary is produced.[20]

(2) *Developing thematic main categories:* In this qualitative content analysis method, data are structured using categories and subcategories, with themes serving as overarching categories. The main themes are typically derived from the research question and therefore guide the data collection process, as they are reflected in the guiding questions. For instance, a question regarding risks associated with the application of a technology directly leads to responses within the main category *Risks*. Additionally, in accordance with open coding from Grounded Theory, new themes may emerge, which—like all salient and relevant aspects—should be documented. As the analysis progresses, the distinction between isolated and significant themes becomes increasingly evident. In general, the main categories for the initial coding process should not be too detailed or extensive and should be formulated in a way that allows the research report to be structured accordingly. It is also recommended to test the categories on a sample of the text.

[20] The initial brief case summaries can be found in Table 5 and Table 6.

(3) *Coding the entire material using the main categories*: In the initial coding process, each text is examined line by line, and text passages are assigned to categories based on their thematic relevance. Passages that are not relevant to answering the research question are excluded. In cases of uncertainty, category assignment is determined based on an overall assessment of the text. A text passage does not necessarily have to be linked to a single category. Particularly in thematic coding, it is common for a passage to encompass multiple themes, resulting in overlaps and nested structures within the category system. Coded text passages may consist of a single sentence or multiple paragraphs and must be sufficiently comprehensible on their own, without reliance on the surrounding text. Therefore, it may be necessary, for instance, to include the interviewer's question in the coding process.

(4) *Compiling all text Compiling all text passages coded with the same main category and* ***(5)*** *Inductive identification of subcategories based on the material*: Passages assigned to the same categories are compiled in a table and further differentiated in the next step by developing new subcategories. This process involves the following steps:

- Inductive and unstructured development of subcategories
- Organisation, systematisation, and consolidation of subcategories
- Formulation of definitions for subcategories

(6) *Coding the entire material using the refined category system*: At this stage, the text material is coded a second time using the refined category system. This process may also involve the retrospective consolidation of subcategories. A pragmatic approach is recommended when determining the number of categories, taking the sample size into account. When analysing multiple cases, individual cases should not be treated as exceptional cases, ensuring that both similarities and differences can be systematically identified.

The steps outlined thus far provide the foundation for the core analysis. Additionally, when working with particularly extensive material, it may be advisable to introduce an intermediate step by constructing tabular case overviews in a grid format. These overviews should include original quotations and serve as a reference point. The quotations are then paraphrased, synthesised into case-specific thematic summaries, and systematically compared in tabular form.

(7) *Simple and complex analysis, visualizations*: Kuckartz (2018) dedicates a separate subchapter to the core analysis and presents six forms of evaluation (Kuckartz, 2018, pp. 117–121), which are summarised in Table 10.

#	Form of evaluation	Description	Imple-mented
1	Category-based evaluation along the main categories	The results for each main category should be elaborated and presented in the results section. The analysis should address what is extensively discussed on the topic and what is only mentioned in passing. While numerical data can be reported, the primary focus should be on qualitatively presenting the substantive findings and discussing the details. Prototypical examples should be cited where appropriate.	✓
2	Analysis of the relationships between the subcategories of a main category	Thematic relationships can be analysed both within main categories (through the simultaneous mention of subcategories) and between them. Furthermore, the aim is to identify patterns or clusters. In this context, specific formulations may also be of interest.	✓

#	Form of evaluation	Description	Imple-mented
3	Analysis of the relationships between categories	Relationships between main categories are generally explored on a broader scale, which may extend to complex interconnections involving multiple categories.	✓
4	Cross-tabulations – qualitative and quantifying	Cross-tabulations enable the systematic identification of connections between grouping characteristics and themes. They also facilitate clustering and frequency analyses.	✓
5	Examine configurations of categories	The aim is to investigate the frequency of code combinations, including those involving more than two codes, within the data. This approach enables the analysis of multidimensional relationships.	x [21]
6	Visualization of relationships	Where appropriate (e.g., in the case of a large number of respondents), diagrams can be used to visualise relationships. Concept maps may also be employed to examine the connections between codes and subcodes or to graphically compare selected individuals (in this context, cases).	~ [22]

Table 10: Forms of evaluation in a content-structuring qualitative content analysis according to Kuckartz (2018, pp. 117–121). Translated into English.

In addition to the aspects presented in Table 10, the analysis needs to conclude with a summary addressing the research questions, identifying gaps, and providing an outlook for future research. Furthermore, the evaluation process should be documented by outlining its phases and explaining the category development. The category system should also be made transparent by providing coding rules and examples for selected categories (Kuckartz, 2018, pp. 120–121).

The categories, subcategories, and factors identified inductively in Step 5 are further structured during the qualitative content analysis according to the Technology-Organisation-Environment (TOE) framework, originally proposed by Tornatzky and Fleischer (1990). The TOE framework model explains how the technological, organisational, and environmental contexts within a corporate setting influence adoption decisions and drive technological innovation (Baker, 2011, p. 232). This overarching structure aims to identify key areas for alignment with the perspectives outlined in the conceptual research framework.

4.2. Execution

All interviews were conducted in person and on-site between July 2024 and November 2024. A summary of the cases examined and the individuals interviewed is presented in Table 5 and Table 6.

Following the approach outlined by Yin (2003, p. 50), feedback loops were implemented by incorporating lessons learned from the initial interviews into the remaining interviews.[23]

[21] Code combinations were not analysed separately.

[22] Given the limited number of companies included in the multiple-case study, diagrams are not used; instead, key insights are conveyed through a range of tabular visualisations.

[23] For instance, the MS Word dictation function was initially used in two interviews. However, it was found to provide no significant added value for transcription, whereas automatic transcription directly in MAXQDA yielded better results.

One interview lasted 60 minutes, while all others lasted 90 minutes. With the exception of one interview, all were transcribed. The transcription process is outlined below, followed by an explanation of the application of coding rules and category development and further measures implemented to ensure academic rigour.

4.2.1. Transcription of the interviews

To prevent distortions or loss of meaning due to interviewer summarisation—such as those that may arise from merely listening to and summarising audio recordings—it is essential to fully transcribe the interviews (Gläser and Laudel, 2006, p. 188). In line with the preliminary considerations (Table 8), participants were asked in advance to consent to audio recording. With the exception of one company, all participants granted permission for recording.

For the company that did not consent to audio recording, notes were taken during the interview following the interview guide, with direct quotations documented as accurately as possible. These notes were subsequently sent to the company for review and confirmation to minimise potential misinterpretations. The company then revised the document, returned it, and granted final approval.

All the other interviews were transcribed using the automatic transcription functions in MS Word and MAXQDA[24] in a first step. In a second step, the transcripts were manually checked and revised according to the recordings in MAXQDA using the transcription function. In the German-language transcripts, for example, errors occurred mainly due to the spoken dialect, which had to be manually corrected. Table 11 presents an overview of the volume of transcribed text material, documented and managed in MAXQDA.

Case Study	#	Respondent	Transcribed text material[25]	
			Words	Signs[26]
Comp1	1	Purchasing Manager-ME Division	9,765	62,263
Comp2[27]	2	Senior Supply Chain Executive	3,561	25,203
	3	Procurement Analyst		
Comp3	4	Vice President Global Supply Chain & Facility Management	7,442	47,249
Comp4	5	Purchasing Manager	11,138	70,193
Comp5	6	Head of Procurement	12,587	79,509
			∑ 44,493	∑ 284,417

Table 11: Transcribed text material

The 90-minute interviews comprise between 9,765 and 12,587 words and based on the mean value of these two figures, fall within a margin of approximately ±12.6%. The 60-minute

[24] The study revealed that MAXQDA provides better results in transcription, which is why the paid premium feature of MAXQDA was used in the end.
[25] These values also include speaker references within the transcripts.
[26] Including spaces.
[27] This refers to the interview documented in the notes.

interview falls below this range, while the interview that was documented through notes rather than transcription cannot be meaningfully compared. In total, 44,493 words and 284,417 characters were recorded and incorporated into the analysis.

4.2.2. Application of the coding rules

The categorisation carried out in this study follows Kuckartz's (2018) content-structuring qualitative content analysis, applying a deductive-inductive mixed-method approach (Kuckartz, 2018, pp. 95–96). Accordingly, the categories derived from the research questions serve as a search grid, while the actual category formation occurs directly within the text material. This process involves coding units of meaning, which may span multiple paragraphs and, depending on their relevance, include the interviewer's questions to ensure that the text passage can be understood independently of its surrounding context (Kuckartz, 2018, p. 104).

In forming categories, Kuckartz (2018, pp. 86–88) approach of category development through summarisation is followed. The transcribed original text, structured based on the deductively defined categories, is systematically examined category by category. Relevant information is documented in tabular form alongside the original quotation and summarised in paraphrased form. Finally, new subcategories are inductively generated, with the key factor[28] addressed in the summary also documented. When paraphrasing and summarising, care is taken to ensure that the individual characteristics of the case are preserved and not inadvertently removed or lost, as can occur with particularly detailed approaches (Kuckartz, 2018, p. 78).

This coding procedure ensures that the source of the information remains traceable while adhering to the principles of qualitative content analysis. The analysis is not confined to the text but instead involves extracting information and processing it separately from the original text (Gläser and Laudel, 2006, p. 44). Subsequent analytical steps are therefore conducted using the extracted information.

To develop a well-structured framework of coded text material that supports further analysis, two aspects should be considered when defining the underlying categories (Saunders et al., 2009, p. 493):

(1) *Internal:* categories *"(...) must be meaningful in relation to the data".*

(2) *External:* categories *"(...) must be meaningful in relation to the other categories."*

The deductive pre-coding is conducted in MAXQDA, while the inductive refinement and the step-by-step development of the category set are carried out in MS Excel. As recommended by Yin (2003, pp. 101–102), this approach ensures a transparent and comprehensible research database in which the original statements are recorded and connections remain traceable.

[28] A factor represents an important aspect in the analysis (Holland et al., n.d.).

To clarify the coding rules and ensure the transparency of the analysis, as recommended by Kuckartz (2018, p. 121), three examples that aim to capture the different facets of the analysis are provided in Table 12. These follow the analysis process for inductively forming categories based on the considerations outlined above and illustrated in Figure 11.

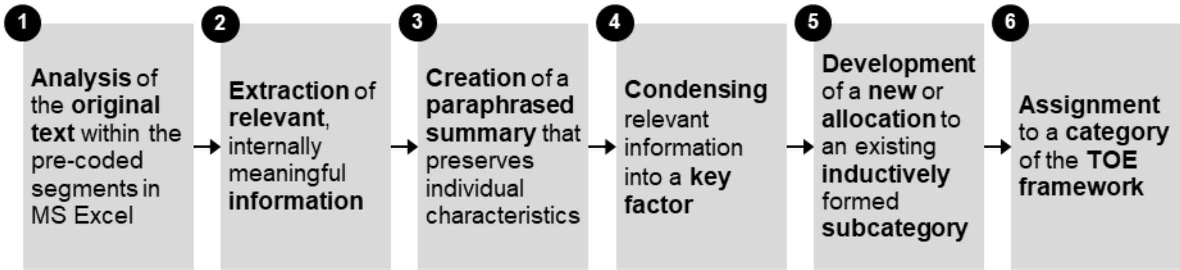


Figure 11: Inductive approach to category formation based on the text material

Steps →			1 & 2		3	4	5	6
#	**Source**	**Deductive main category**	**Coded German original quote**	**Original quote, translated into English**	**Paraphrased summary**	**Key factor**	**Inductive subcategory**	**TOE category**
1	Comp1	Opportunity	„(...) man könnte schon theoretisch Unmengen von Ressourcen aufbauen, damit man so eine Bürokratie quasi abarbeitet. Aber die Frage ist, ist man als Unternehmen dann noch wettbewerbsfähig? Und deswegen, glaube ich, muss man Automatisierungsthemen, Optimierungsthemen einfach nutzen."	'(...) you could theoretically build up vast amounts of resources to deal with such a bureaucracy. But the question is, are you still competitive as a company? And that's why I think you simply have to make use of automation and optimization issues.'	To address bureaucratic challenges, organisations could allocate extensive resources at the expense of corporate competitiveness; hence, they adopt optimisation and automation.	Automation sustains competitiveness	Technological Benefits	Environment
2	Comp3	Challenge	„Man muss wirklich einen sehr guten strategischen Einkauf (...) ausbilden und haben und (...) diese Leute kann man dann auf das System geben und sagen okay das hilft euch jetzt dabei."	'You really have to train and have very good strategic purchasing (...) and (...) you can then put these people on the system and say, okay, this will help you now.'	A highly skilled strategic procurement team must be trained and in place for the system to effectively support users.	Highly skilled strategic procurement team	Skills and Competences	Organization
3	Comp1	Success Factor	Comp1: „Aber ich glaub' das Wichtige ist, dass man sich damit einmal beschäftigen beginnt." Interviewer: „Und in Ihrem Unternehmen gibt es eine Kultur, die das zulässt?" Comp1: „Wir haben zum Glück diese Kultur, die das zulässt. Wir haben, wie gesagt, auch in unserer Division diese Digital Agency."	Comp1: 'But I think the important thing is to start dealing with it.' Interviewer: 'And in your company, is there a culture that allows that?' Comp1: 'Fortunately, we have this culture that allows it. As I said, we also have this digital agency in our division.'	A corporate culture open to innovation motivates employees to embrace new technologies.	Technology-openness	Corporate Culture	Organization
					An organizational unit called "Digital Agency" focuses company-wide on advanced technologies.	Organisational unit for digitalisation	Institutionalization	Organization
4	Comp3	Barrier	Interviewer: „Und das heißt, das Potenzial wird nicht ausgeschöpft?" Comp3: „Nein, noch bei weitem nicht schnell genug. (...) weil, ich sage, die technischen Lösungen noch immer sehr komplex sind und eine starke IT-Unterstützung brauchen und da die Ressourcen fehlen, um Lösungen schnell und unkompliziert umsetzen zu können. (...) ein Projekt, das Ressourcen verschlingt und über ein Jahr dauert, wo man sagt, im Prinzip ist die Idee eine simple (...) Und das ist nur der Beginn, deswegen, das zeigt, wie komplex dann doch die technische Umsetzung ist, wo man immer sagt, im privaten Bereich geht das alles so schnell und man kriegt Antworten von KIs und alles geht, geht das im Geschäftsumfeld nicht so rasch und nicht so leicht."	Interviewer: 'And that means the potential is not being fully exploited?' Comp3: 'No, not nearly fast enough. (...) because, I say, the technical solutions are still very complex and need a lot of IT support and since the resources are lacking to be able to implement solutions quickly and easily. (...) a project that devours resources and takes over a year, where you say, in principle, the idea is a simple one (...) And that's just the beginning, so that shows how complex the technical implementation is, where they always say, in the private sector it's all so fast and you get answers from AIs and everything works, it doesn't work that quickly and easily in the business environment.'	Technical solutions continue to pose significant complexity, and even the implementation of simple ideas in AI projects can extend beyond a year while consuming significant resources. What is quick and straightforward in the private sector may become considerably more time-consuming and challenging in a business environment.	Complex technical solutions	Technology Readiness	Technology

Table 12: Exemplary descriptions of inductive category formation steps

The categorisation of the four examples presented by Table 12 is explained below to ensure methodological clarity.

In the first example, Comp1 discusses the need for automation to manage bureaucracy and maintain competitiveness. In other words, Company 1 highlights automation as being driven by external factors—in this case, bureaucracy—to sustain its market position. This represents an *Opportunity* to leverage advanced technology to achieve a tangible benefit, categorised under *Technological Benefits*, specifically by reducing workload in managing administrative tasks. Since the issue of bureaucracy is mentioned in the context of pending regulations, this information is assigned to the *Environment* category within the TOE framework, as the impetus originates from outside the company (Baker, 2011, p. 235).

In the second example, Comp3 highlights the challenge that a highly trained strategic purchasing team is required for the effective use of the system. This *challenge* arises from the necessary *Skills and Competences*, which are defined as a subcategory. Since this challenge relates to corporate resources, it is assigned to the *Organization* category (Baker, 2011, p. 233).

The third example, again from Comp1, within the main category *Success Factors*, demonstrates how a coded segment can encompass multiple factors. On the one hand, the interviewee emphasises the importance of engaging with technology and highlights the presence of a company culture that facilitates this process. In other words, the company fosters a culture that promotes *openness to technology*. On the other hand, the interviewee refers to the *digital agency* within the cultural context, which systematically explores new technologies in an *institutionalised* manner. Consequently, this aspect is documented and assigned separately. Both factors reflect company-specific (culture) and structural (agency) characteristics, leading to their classification under the ***Organisation*** category within the TOE framework (Baker, 2011, p. 233).

The fourth and final example of a coded *Barrier*, as described by Comp3, highlights that *technical solutions*—in this case, AI—remain highly *complex*, preventing the full exploitation of technological potential in procurement, particularly in a timely manner. The interviewee also refers to an AI project he is familiar with, which is taking a long time and consuming substantial resources, despite being a relatively simple use case. The respondent further states that what applies to the private sector does not necessarily apply to the business sector. Since this factor relates directly to technology, it is assigned to the *Technology* category within the TOE framework (Baker, 2011, pp. 232, 238).

During the coding process, the distinct assignment of certain factors to a specific TOE category proved challenging. For example, well-documented concerns related to attitudes toward Procurement 4.0 such as the perception of transparency as surveillance or concern of AI job replacement (see Table 17) were identified as challenges, reinforcing perspectives found in the literature. Assigning such ambiguous factors—the same accounts for barriers such as ‘resistance to change’ (see Table 21)—is particularly challenging, as they can stem from both organizational factors, such as inadequate communication and limited employee involvement, and individual-level factors, including prior experiences, psychological responses, and perceived injustices, which exist independently of the organization’s direct influence (Canning and Found, 2015, p. 277ff; Nadim and Singh, 2019, p. 516ff). For classification purposes, aspects that originate from company-driven processes are categorized under the organizational dimension, whereas those linked to inherent human tendencies and personal backgrounds is attributed to the environmental dimension.

4.2.3. Measures to ensure academic rigour

The following table summarises 14 measures implemented to ensure academic rigour in the interview-based multiple case study analysis conducted in this study. It indicates whether, to what extent (fully, partially, or not at all), and, most importantly, why the quality criteria for qualitative case study research, as outlined in the literature, are met or not met.

#	Source	Recommendations to ensure academic rigor		Check	Implementation
1	Döring and Bortz (2016, p. 7)	Systematic, transparent, and verifiable application of recognised scientific methods.		✓	The entire research process presented here has been described and explained in detail to ensure intersubjective traceability and verifiability. This encompasses the selection of scientific methods, case selection, the application of data collection techniques and qualitative content analysis, as well as the explicitly discussed quality criteria.
2	Yin (2003, pp. 33–39)		Establish chain of evidence	✓	The tabular structure of the results makes them traceable from the paraphrased statements to the case study procedure and the research questions. The presented paraphrased summaries can also be traced in the original case study database back to the coded segments in the transcripts (Yin, 2003, pp. 105–106).
3			Use multiple sources of evidence	~	During data collection, additional sources were used to validate the results, including the homepages of the tool providers mentioned—one of whom was even heard live at a supply management conference—and the internal market intelligence report that was made available. Further details on construct validity, as discussed by Yin (2003), could have enhanced the validity of the results. However, the length of the interviews allowed for the collection of comprehensive information. Moreover, some documents were highly sensitive and internal, preventing companies from disclosing them. Finally, all interviews were conducted in person, with four of the five interviews taking place on-site at the respective companies, providing additional insights and impressions. Furthermore, the interview method aligns with the primary approach used in the methodologically comparable studies referenced earlier.
4			Have key informants review draft case study report	~	The overview of the case study context information (see Table 5 and Table 6) was sent to all interview partners for review and approval to ensure that the data was assessed within the correct context. The interview notes, taken for the one interview that was not permitted to be recorded and therefore could not be transcribed, were also revised through a feedback and approval process to minimise documentation errors. All other interviews were recorded in audio format and transcribed. Once these interviews were available in their original audio format, the information could be extracted and processed directly.
5		**Internal validity**	Do pattern-matching	x	Yin (2003, p. 34) explicitly states that this aspect is only relevant for explanatory and causal case studies and not for descriptive or exploratory studies such as the one conducted here.
6			Do explanation-building		
7			Address rival explanations		
8			Use logic models		

9		**External validity**	Use replication logic in multiple-case studies (Yin, 2003, pp. 47–48)	✓	The multiple case study analysis is based on a purposive sample aligned with the conceptual research framework. The first three case studies were defined and conducted in a timely manner in July and August 2024. To expand and consolidate the results, two additional cases were requested, acquired, and data collected in August (with the interview conducted in November) and September (with the interview conducted in October). One case (Company 5) was selected for literal replication, as it explicitly mentioned the use of AI in procurement upfront—just as in Company 1—thereby confirming prior findings. The other case (Company 4) was selected for theoretical replication, as it featured a completely different Procurement 4.0 application, allowing for an exploration of variations.
10		**Reliability**	Use case study protocol	✓	The procedure presented (see Figure 9) was derived from the literature and systematically followed.
11			Develop case study database	✓	The raw database is stored in MAXQDA. To individualise the analyses (see Chapter 2), the coded segments were exported to MS Excel, where the database was expanded during the analysis.
12	Gläser and Laudel (2006, p. 197)	Apply a systematic, rule-based approach to qualitative content analysis.		✓	The analysis method follows the content-structuring qualitative content analysis approach by Kuckartz (2018) as presented by Figure 10.
13	Saunders et al. (2019, pp. 692–694)	Use CAQDAS software.		✓	CAQDAS enhances research transparency and facilitates the precise application of methodological approaches. MAXQDA is used in this study.
14	Kuckartz (2018, pp. 120–121)	Ensure transparency of the category system and provide coding rules.		✓	The category system is made transparent by presenting all categories and explaining the coding rules, accompanied by examples for selected categories.
Legend			*✓ fully applies | ~ partially applies | x does not apply*		

4.3. Dissemination of the findings

In this chapter, the Procurement 4.0 applications under examination are first introduced, followed by the presentation and discussion of the results from the qualitative content analysis. The perspectives of the interviewees, as procurement experts from practice, on the application of AI—explored in the interview section preceding the company-specific Procurement 4.0 application (see interview guideline in Table 9)—are presented separately in Chapter 4.3.4.

4.3.1. Examined Procurement 4.0 applications

All examined Procurement 4.0 applications are presented based on the *initial situation*, *problem definition and motivation*, a description of the *solution*, and current application *status* to ensure transparency and facilitate comparability for readers. A summary table is provided in Chapter 4.3.1.6 to enhance clarity.

4.3.1.1. AI-supported SAQ analysis in ESG risk management (Comp1)

Initial situation: As part of its ESG commitment, Comp1 requires suppliers to align with its sustainability values, providing guidance through a code of conduct that suppliers must sign. In addition, anticipated future developments, as indicated by the German Supply Chain Act "Lieferkettengesetz" and the European Corporate Sustainability Due Diligence Directive (CSDDD), highlight the key risk management activities for ESG issues in the supply chain.

To this end, a risk management process has been introduced to identify suppliers with potential risks. The company actively engages with suppliers, requiring them to provide substantive evidence—such as certificates and supporting documents—rather than mere verbal assurances. Suppliers must prove that their code of conduct effectively addresses key ESG concerns, such as child labour. To facilitate this, Comp1 requires suppliers to complete a self-assessment questionnaire (SAQ), with responses and supporting documents reviewed via a structured feedback process.

Several communication channels are available for this process. As part of the current use case implementation, an email-based solution serves as a pragmatic approach. This system ensures that all communication, including attachments, remains traceable within an email communication stream with the supplier. It provides an overview of verified and pending responses. Moreover, this email-based solution offers flexibility, allowing partially completed SAQs to be returned to suppliers iteratively, without requiring integration into the existing IT landscape or supplier onboarding, until the process is finalised.

If all questions are answered satisfactorily and no risk is identified, the information process is considered successful. Otherwise, further action—such as audit measures—must be initiated.

Problem definition and motivation: Conducting a manual review of supplier responses and supporting documents is highly labour-intensive. Given the volume of responses, number of documents, and page count (potentially several hundred pages per response), analysing a single submission can take up to one hour. The interviewee describes this as a 'lengthy' process.

However, if the pre-selection of critical text passages or identification of missing evidence is automated—for example, through AI-powered labelling—the verification process becomes significantly more efficient.

Solution: This filtering process, which verifies supplier responses against submitted documents, can be effectively addressed using a Large Language Model (LLM). The challenge of multilingual responses—such as an answer in English accompanied by a Chinese certificate—can also be resolved, as the system automatically translates documents as needed. Since the SAQs in this use case are handled via email, the process can be executed without integration into the existing IT landscape or the onboarding of suppliers.

Status: The use case was initiated at the end of Q2 2024, two months before the interview in July 2024, and is currently in implementation. At the time of the interview, however, the solution provider had not yet been selected.

4.3.1.2. Cloud-based procurement platform SAP Ariba (Comp2)

Initial Situation: The company previously used both a catalogue system and an SRM solution; however, these were inadequately configured and less robust than SAP Ariba (SAP, n.d., n.d.).

For instance, SAP Ariba offers greater efficiency in catalogue management, as catalogues are directly integrated within SAP. Additionally, Ariba's user interface and overall user experience are superior. Another key advantage is that, as a cloud-based solution used by numerous customers, SAP Ariba undergoes continuous optimisation—an improvement that was not feasible with the previous system.

A further challenge was the lack of standardisation. For example, tenders were conducted inconsistently, contracts were stored in different ways, and orders were frequently placed without the purchasing department's knowledge. Additionally, supplier data transfer into the ERP system was previously performed manually.

Communication with suppliers during the ordering process was primarily conducted via emails with PDF attachments. Similarly, supplier onboarding involved sending Word questionnaires via email, which suppliers completed, returned, and had to be entered manually.

Problem definition and motivation: The primary reasons for implementing the platform were to standardise and automate processes while enhancing transparency. The objectives included improving efficiency, increasing transparency, and reallocating freed-up resources to strategic activities, thereby adding value and achieving cost savings through successful negotiations.

Solution: Currently, all SAP Ariba modules are in use: Supplier Lifecycle Performance (Onboarding), Risk and Contract Management, Sourcing, Commerce Automation, and Buying. Comp2 refers to this as 360-degree coverage in a single solution, encompassing registration, tendering, contract and catalogue management, and risk management. This ensures that all procurement-relevant information is accessible within one system.

Every supplier is onboarded via SAP Ariba. Suppliers register in response to an invitation (shared service) on Ariba, where they enter data based on questionnaires. This data is then automatically transferred to the SAP ERP backend. In Europe, there are currently 1,350 fully registered suppliers via Ariba, who are prepared for the transition to S4/HANA. Globally, 3,000 suppliers are fully registered, which will be necessary for performance measurement in the future (2025/2026). Additionally, sourcing tenders are issued via Ariba: there were 450 in

Europe in 2023, and these are gradually being incorporated into catalogues and framework contracts.
E-auctions are also conducted via SAP Ariba, resulting in additional unexpected savings. Furthermore, more orders are placed via catalogues with discount rates. There are currently 60 catalogues in use featuring Guided Buying. Low-value materials are ordered directly from the factory via catalogue. Invoices are also sent automatically via the Ariba Network. Additionally, numerous catalogue and other suppliers receive automatic purchase orders (POs) processed through standard Ariba. Orders are transmitted via the Ariba Network through EDI from SAP ERP.
Moreover, certificates and key figures, such as the LTIFR (lost time injury frequency rate), are collected. Standardised questionnaires are requested from suppliers and stored in SAP Ariba and then, currently still selectively, considered in supplier evaluations. Additionally, ratings from *EcoVadis*, a partner in sustainability issues, are imported into Ariba and considered in bid comparisons in a standardised manner.

A key advantage is that the system operates in the cloud and is continuously optimised, as it is connected to many SAP customers—something that was not possible with the previous system. Furthermore, SAP Ariba enhances efficiency and transparency, for example, by replacing email-based PDF exchanges with direct data transfers. Previously, supplier onboarding was conducted via email using a Word questionnaire, which had to be manually completed and entered into the system. While several alternative solutions were briefly considered, the process is now automated, providing a 360-degree solution that integrates registration, tendering, contracting, catalogue management, and risk management—all within a single system.

SAP Ariba is generally accepted by suppliers, as many large suppliers were already using Ariba.

Status: The project to implement the Source-to-Contract platform commenced in 2019 with a market survey to identify available cloud SRM solutions. The tender was issued based on a requirements specification, and SAP Ariba was awarded the contract. The pilot region began in 2020, and Europe went fully live in 2021. Except for two non-SAP countries, all regions were live in Ariba by 2023, with the solution undergoing further development.

The next step involves optimising an intermediate step that still exists. Currently, the order is sent from Ariba to the suppliers, and only a copy is created in the SAP ERP backend. In the future, the process will run in SAP S4/HANA. Then, the purchase requisition is generated in Ariba, and the PO is created directly in S/4HANA and sent to the supplier via Commerce Automation. Incoming goods will also be processed via S4/HANA, which should mitigate sources of error.

In the long term, AI is also expected to contribute to procurement tenders by providing insights such as identifying additional suppliers who may offer more competitive pricing. For instance, Ariba promotes this capability through its "Ariba Discovery" feature.

In summary, respondents in Comp1 are satisfied with the Source-to-Contract platform and noting significant improvements through the introduction of SAP Ariba. Supplier registrations and tenders were explicitly mentioned as positive. However, they believe that the objectives have not yet been fully met and anticipate further progress with the S4/HANA implementation. In the contract area, for example, they are not yet where they aspire to be. With end-to-end coverage, satisfaction would even increase in the future.

4.3.1.3. Algorithmically driven category strategy development in Cirtuo (Comp3)

Initial Situation: The company places a strong emphasis on process digitisation, with a particular focus on SAP, as full digitisation and automation are essential for ensuring that data is quickly accessible and analysable, given the about 15,000 purchase order items per month. Additionally, RPA is of interest and is actively monitored within the company. Big Data, particularly data accumulated over the years within the organisation, also plays a role. The company is exploring the application of data mining and corresponding tools to leverage this data effectively. Currently, quantitative data is analysed, while qualitative data, such as verbalised information from correspondence, remains unexamined. The company's vision is to scan supplier correspondence for process anomalies in the future, enabling the derivation of strategic insights from the findings.

Problem definition and motivation: Historically, the category strategy development process was conducted using MS Office tools (Word and PowerPoint), with data compiled via screenshots. Cirtuo (Cirtuo, n.d.) was introduced to achieve global transparency regarding procurement strategies, necessitating a global spend analysis that would have been challenging to perform manually without appropriate tools. Cirtuo was the sole system available at this level, with no comparable solutions previously existing.

Solution: The system was developed in collaboration with Cirtuo, evolving from an initial Excel list of the 100 most important questions for purchasing employees to a web-based cloud software solution. Today, the system is based on a database and corresponding algorithms. Strategic recommendations for action are derived for direct material categories through predefined questionnaires as part of the Guided Strategy. These recommendations follow the principle: 'If certain answers are provided and the spend volume falls within a specific range, it is advisable, for example, to open up the market, bundle, introduce new technological aspects, renegotiate, or involve stakeholders.'

To achieve this, the entire spend data for a category—structured uniformly with the same categories worldwide—is first merged from SAP and non-SAP systems into Cirtuo. Non-SAP systems include local ERP systems, from which Strategic Procurement receives monthly files with data at the category or supplier level, depending on system options. SAP is the ERP system used in most cases.
Based on this data, spend analyses are conducted at the category level, from which strategies are derived. For categories with a high purchase volume, a more detailed analysis is performed, whereas for those with a lower volume, bundling is carried out, and the strategy is determined at a higher level.

The system guides the purchasing employee through a webpage to answer specific questions and enter data. The system provides evaluations for compiling a material group dossier and generates algorithmic strategy suggestions based on the question lists.

The material group dossier addresses key questions, such as the function, purpose, and benefits of the category, and how it differs from other material groups. It also considers the company's plans for new technologies in this area and movements within the category. A classification in the Kraljic matrix and analysis of potential risks are included. Furthermore, the key strategic suppliers are identified, and Porter's Five Forces are applied to the category. The leverage opportunities for both the company and its suppliers are addressed. Finally, the most critical hotspots within the category are highlighted and the most significant pain points and areas of potential are identified.

Based on this information, a category strategy is derived to define the key actions required over the next three to five years. This includes major projects that need to be initiated, aimed at cost reduction or quality improvement within the category, for example.

In addition, a supplier dossier for the most critical suppliers in a category from a global perspective is also created within the same system. This dossier is similar and includes the spend, the spend of competitors, and strategies with the supplier. Currently, however, the category strategy and supplier management are still two separate areas in Cirtuo, although their interlinking is considered beneficial by Comp3.

The implementation of the system has enhanced the quality of strategy development. Despite some handling issues, the system's results in terms of presentation and explanation options are exceptionally good, and it offers an unmatched depth in the depiction of a category strategy. Additionally, the significant manual effort previously required to compile the 30-page dossier has been reduced, as it now only requires updates rather than regular rewrites. Today, only a few parameters (e.g., risk) need to be adjusted, significantly accelerating the process.

Status: Comp3 has long been using Cirtuo for the development of category strategies, ensuring satisfaction. However, the report outlines specific areas for improvement. In the future, the system's relatively static data analysis could be enhanced by adopting a more dynamic approach to spend analysis. Additionally, improvements could be made in data handling, security, and audit integrity. With the next release, AI will be integrated into the system, enabling independent strategy formulation, rather than merely relying on predefined standard sentences generated by the algorithm.

4.3.1.4. Cloud-based real-time supply chain information system (Comp4)

Initial situation: In a complex landscape with hundreds of thousands of item numbers and over 10,000 direct suppliers, transparency throughout the digital supply chain is vital for Comp4.

Problem definition and motivation: Traditionally, meetings such as the Inventory Management Review involved a protracted process of collecting and merging data across various company departments and preparing it using MS Excel or PowerpPoint. This approach was not only time-consuming but also rendered the data outdated by the time of the actual meetings due to the dynamic nature of supply chains. The need for a big picture view of the supply chain and the inability to conduct comprehensive, cross-location performance analyses of suppliers further motivated the development of a cloud-based, real-time supply chain information system.

Solution: Implemented in the 2010s, the supply chain real-time information system was developed in-house as part of a global initiative. It facilitates global supply chain visibility and supports decision-making at all organisational levels. The system is accessible securely from various devices and locations, with robust data protection measures in place. Data from multiple sources, including ERP, shop floor, and CRM systems from factories worldwide, is integrated into this system. Particularly relevant for procurement are, for example, spend data, supplier data, supplier evaluations, process quality, delivery times, ordering behaviour, price information, and minimum order quantities.

Information is visualized on dashboards according to a standard developed internally by the company, while filtering options allow for easy customization of analyses. These dashboards are actively used across all hierarchical levels for data-driven decision-making and to monitor operational measures. Supply chain decisions are considered end-to-end, from customer order to fulfilment, with data generated and utilised at each step. Five specific examples illustrating applications and associated benefits in procurement are outlined below.

(1) *Inventory Management Review:* An example of an application that impacts not only planning and operations but also purchasing activities is the Inventory Management Reviews. A standard has been established where dashboards and filters are pre-configured, allowing all pertinent information to be accessed online in real time during meetings. Depending on the type of data, 'real time' means updates every hour or, for instance, twice weekly updates concerning delivery times. This eliminates the need for all the previously required preparation work, and employees are no longer involved in data preparation, allowing them to focus on their core activities. As a result, the entire process of information collection, preparation, presentation, and visualisation has been automated.

(2) *Supplier meetings:* On designated supplier days, the strategically most important key suppliers for a project are invited to the site in coordination with the client, having been briefed on relevant issues beforehand. These might include discussions on impediments to enhancing supply chain flexibility. Workshops with each supplier are conducted where, traditionally, the effort to collate logistics and performance data would be considerable and likely outdated by the time of the meeting. This could lead to significant discussions based on incorrect, outdated information. However, the current approach allows for immediate, fact-based discussions and decision-making on actions, supported by visually prepared data presentations using colour coding.

(3) *Trade fair visits and business trips:* A similar efficiency is observed during trade fair visits, where the company might conduct 40 meetings with suppliers at a single venue over three days, thus addressing potential cooperation areas without the need for extensive global travel. The same applies to business trips in Asia, where numerous supplier meetings can be conducted in just a few days without the burden of outdated information or the need to prepare presentations en passant. Upon accessing the dashboard, all real-time information is instantly available.

(4) *Broad analysis spectrum:* The system facilitates a broad spectrum of analytical scenarios for procurement, including cross-location, supplier-specific analyses tailored for negotiations. For instance, the delivery times from a supplier at one location can be benchmarked against their performance at other locations to evaluate their overall efficiency. The system again eliminates the typical effort of collecting information via email or phone. Additionally, a market intelligence report is shared quarterly among customers, incorporating inputs from the cloud-based, real-time supply chain information system to analyse market trends.

(5) *Crisis management:* Finally, the digitalisation of the supply chain plays a critical role in crisis management. Signals indicating potential disruptions, such as natural disasters, strikes, or geopolitical events, are monitored. The system allows for the tracking of impacts, activation of various mechanisms, and adherence to protocols, potentially extending to product redesign in response to component shortages. Following analysis at the team leader level and the accumulation of necessary information, standardised communication processes are maintained until normal business operations can resume.

Status: The system has been live for several years and continues to evolve. The latest system update incorporates advanced machine learning models to analyze ordering behavior and supplier flexibility. This enhancement supports the assessment of which suppliers or regions can adapt to upcoming changes in the next quarter.

Satisfaction with the current solution is described as very high, as the efficiency achieved today would not be possible without the system. Room for improvement exists for the system to achieve even better performance, particularly in terms of speed when using filters in the dashboard.

4.3.1.5. IT- and AI-based N-tier supply chain assessment (Comp5)

Initial situation: In-depth knowledge of the supply chain is pivotal to developing convincing arguments in strategic purchasing and thus achieving optimal negotiation outcomes, such as improving conditions. Moreover, numerous economic sanctions impact procurement activities. Likewise, organizations such as non-governmental organisations (NGOs) or universities can raise allegations of misconduct that may affect the supply chain and, in turn, pose a risk not only to suppliers but also to customers.

Finally, legal regulations on sustainability are gaining importance, necessitating the expansion of related measures. In this context, consulting firms take two approaches. Some argue that companies must be capable of fully tracing the entire N-tier supply chain. The other perspective argues that processes and tools must be in place to prevent this issue and identify any emerging problems.

This does not imply that companies have not previously implemented measures to address this issue; however, they are now being challenged to adapt to the new situation. The signing of the Code of Conduct, for example, is already a prerequisite for business cooperation. However, this document cannot guarantee that issues will not arise within the entire supply chain. Therefore, Comp5 has established a process with appropriate means and tools to ensure responsiveness and to examine the supply chains as thoroughly as possible. This process is being further developed, which is why the tools used are also being reviewed.

Problem definition and motivation: Acquiring knowledge about the entire N-tier supply chain is inherently complex. While tracing the second-tier supplier or the raw material supplier of the first tier via material certificates linked with delivery notes is relatively manageable, the complexity escalates from the third-tier supplier onwards, particularly towards the N-tier supplier. Additionally, accessing certain information, such as domestic Chinese shipment data, presents significant challenges.

Solution: No singular tool suffices to address all questions related to N-tier supply chains. Consequently, Comp5 relies on a combination of IT- and AI-based solutions in procurement. Prewave (n.d.), which provides AI-driven risk and sustainability monitoring, is one of the tools employed to automatically alert stakeholders via email about potential risks (e.g., financial risks at suppliers, sanctions) and developments. At this point, it is necessary to act and delve into the details. For this purpose, information from further databases and systems is utilised. In addition to proprietary databases, Sayari (n.d.), a browser-based risk intelligence platform, can serve as a supplementary tool in N-tier checks, providing access to global sanctions lists, risk data, and extensive databases tracking worldwide shipment information. Sayari is connected to other systems and also facilitates graphical representation of supply chain relationships and deep insights into the supply chain. Utilizing business information, Sayari further aids in identifying supply chain branches in Asian corporations.

Moreover, a proprietary tool was also deployed in N-tier management, linking to Prewave and an internal SCM system for onboarding suppliers, processing electronic tenders, and evaluating suppliers. This tool gathers comprehensive data, including economic data, and serves as a resource for company information.

Ultimately, the AI-based Copilot is used for research and information gathering on companies. It transparently discloses its sources, which must then be individually assessed.

All these systems support the process by providing information or enabling detailed verification of retrieved data, allowing supply chains to be traced and situational recommendations to be developed for management.

Status: In the current evaluation of systems, the integration of AI is being considered. AI can support the N-tier verification process by, for example, providing indications of whether a supplier should be classified as problematic due to allegations made by a non-governmental organisation (NGO), such as those related to forced labour. However, AI is not yet capable of independently deciding the appropriate corporate response, as such decisions require careful consideration. Hastily made decisions might lead to adverse outcomes, including reputational damage to both the supplier and the company. Consequently, at this point a manual process is initiated where the perspectives of various departments—including compliance, legal, and communications—are coordinated, and a decision from top management is sought. Ultimately, it is the human who must moderate this decision-making process across various hierarchical levels.

Satisfaction with the current solution is high. However, it would be even better, if the solution delivered a comprehensive response immediately upon entering a set of facts. Currently, achieving this requires multiple steps, although both Copilot and Prewave are already showing commendable performance and are undergoing continuous enhancements.

4.3.1.6. Summary of examined procurement 4.0 applications

To summarise the examined Procurement 4.0 applications, Table 13 provides an overview of the cases presented according to their contexts and the solutions used.

	Comp1	Comp2	Comp3	Comp4	Comp5
Examined P4.0 Application	AI-supported analysis of supplier SAQs (Self-Assessment Questionnaires) as part of ESG risk management	Use of a cloud-based procurement platform to standardize and automate supplier-related processes	Algorithmically driven category strategy development to facilitate global standardization and transparency	Use of a supply chain real-time information system to create transparency and visual decision support in procurement	IT- and AI-based risk information and N-tier assessments in the supply chain within the scope of risk management
Case Context	Comp1 mandates suppliers to adhere to its sustainability values and sign a code of conduct as part of its ESG commitment. A risk management process identifies suppliers with potential risks, requiring evidence like certificates to prove compliance with ESG criteria. Manually reviewing supplier responses and supporting documents during SAQ collection is highly labour-intensive.	Comp2 previously used a catalogue system and an SRM solution, but both were inadequately configured and less robust. SAP (n.d.) Ariba was introduced to standardise and automate processes, enhance efficiency and transparency, and enable cost savings and a shift to strategic tasks.	Historically, category strategy development was conducted using MS Office tools, with data compiled through screenshots. To enhance transparency in global procurement strategy, Comp3 adopted and further developed the system Cirtuo (n.d.) in collaboration with the solution provider.	Comp4 developed an in-house, cloud-based real-time system to enhance supply chain transparency, addressing the complexity of managing thousands of item numbers and direct suppliers. The time-consuming process of preparing data in MS Excel or PowerPoint—often outdated by completion—further motivated this use case.	In strategic purchasing, in-depth supply chain knowledge is essential for effective negotiation and risk management, highlighting the importance of technological support for information gathering and decision-making. Due to the complexity of N-tier supply chain assessment, no singular tool suffices to address all questions related to N-tier supply chains.
Solution	Comp1 implements a **solution** that uses **AI-powered labelling** to **automate** the **pre-selection** of **critical text passages** and the **identification** of **missing evidence** during the **collection of SAQs** from suppliers. Comp1 found out that the filtering process, which verifies supplier responses against submitted documents, can be effectively addressed using a Large Language Model (LLM).	**All SAP Ariba modules** are in use: Supplier Lifecycle Performance (Onboarding), Risk and Contract Management, Sourcing, Commerce Automation, and Buying. Comp2 refers to this as 360-degree coverage in a single solution, encompassing registration, tendering, contract and catalogue management, and risk management. This ensures that all procurement-relevant information is accessible within one system.	Comp3 uses **Cirtuo** in the **guided category strategy development**. The system guides the purchaser through the process, generates algorithmic strategy suggestions and provides analyses to compile a material group dossier, which addresses strategic key questions. Based on this information, a category strategy is derived, including main projects that need to be initiated within the category. A dossier for the most critical suppliers in a category from a global perspective is created too.	Comp4 uses an **internally developed supply chain real-time information system** that facilitates global supply chain visibility and supports data-driven decision-making and action tracking at all organisational levels. Data from multiple sources across factories worldwide is integrated and information is visualized on dashboards according to an internally developed standard. Procurement use cases include cross-functional meetings, supplier meetings and business trips, specific reports and analyses, as well as crisis management.	Comp5 **employs a range of IT- and AI-based tools** such as **Prewave**, (n.d.), **MS Copilot**, and **proprietary databases** to gather and analyse information across the N-tier supply chain. This knowledge is valuable for several reasons: it supports strategic purchasing negotiations, enables an informed response to potential allegations of supply chain misconduct by organisations such as NGOs, and addresses growing sustainability regulations.

Table 13: Summary of examined procurement 4.0 applications

4.3.2. Factor set

The conceptual research framework from the introduction is revisited here (Figure 12) to explain the systematic factor survey approach in the qualitative multiple case study.

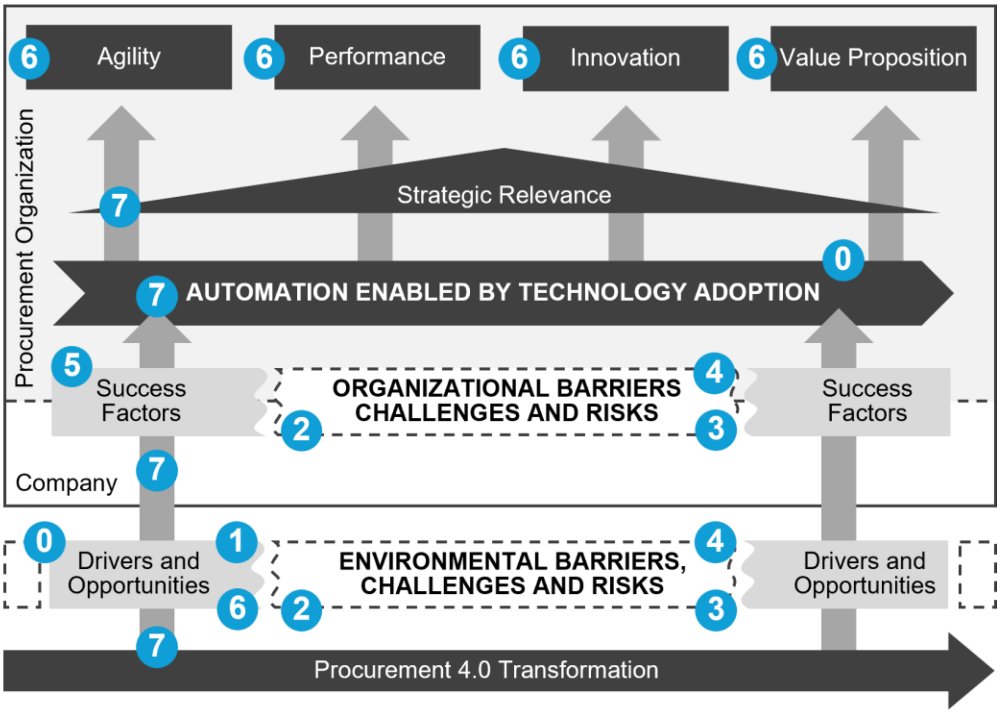


Figure 12: Conceptual research framework

The aspects highlighted in blue in Figure 11 indicate where the multiple case study analysis connects, and which findings are subsequently presented.

(0) *Drivers and technology adoption:* The respective drivers were discussed in the Procurement 4.0 use case descriptions in the previous chapter 0 under *Initial situation* and *Problem definition and motivation*. These represent the driving and motivating factors for companies to implement advanced technologies as part of the respective use cases, whose functionalities were also outlined in the previous chapter.

(1) *Opportunities:* Opportunities represent potential additional benefits arising from the implementation of the presented use cases, for example, as planned steps or as aspects that emerged during the discussion. These are examined first. However, the achieved benefits presented later (5) also serve as opportunities for companies with a lower maturity level in terms of Procurement 4.0 adoption. These, however, have been discussed in a different context and are therefore presented separately.

(2) *Challenges:* The challenges associated with adopting advanced technologies in procurement are then described.

(3) *Risks:* The risks associated with adopting advanced technologies in procurement are then described.

(4) *Barriers:* Next, the barriers observed in practice, which companies may need to overcome when adopting these technologies, are addressed.

(5) *Success factors:* The success factors—aspects that have contributed to successful implementation and may be valuable for other companies—are then presented.

(6) *Benefits:* Finally, the reported benefits are discussed. These real-world achievements may serve as incentives to promote the adoption of advanced procurement technologies.

(7) *Actionable practical recommendations:* In the interviews, questions were also posed concerning the organizational implementation of advanced technologies, as well as general recommendations for other procurement organizations, including key considerations and potential pitfalls. In this context, several practitioner insights were gathered, which may contribute to a more structured approach, supporting the entire process from technology adoption to the realization of its benefits. These findings are presented in the final section

A total of 169 factors were identified across these seven main categories through the previously described qualitative content analysis approach. Their frequencies are presented in the following table, which provides an overview by categorising the factors according to the cases in which they were identified, their classification within the TOE framework, and the inductively derived categories.

Cases ↓ | ∑→	**∑**	**169**	**Procurement 4.0 Application**
Comp1	32	■■■■■■■■■■ 32	AI-supported analysis of supplier SAQs (Self-Assessment Questionnaires) as part of ESG risk management
Comp2	35	■■■■■■■■■■■ 35	Use of a cloud-based procurement platform to standardize and automate supplier-related processes
Comp3	31	■■■■■■■■■■ 31	Algorithmically driven category strategy development to facilitate global standardization and transparency
Comp4	51	■■■■■■■■■■■■■■■■■ 51	Use of a supply chain real-time information system to create transparency and visual decision support in procurement
Comp5	20	■■■■■■ 20	IT- and AI-based risk information and N-tier assessments in the supply chain within the scope of risk management
TOE (Tornatzky and Fleischer, 1990)			**Context**
Technology	27	■■■■■■■■■ 27	Since, according to the TOE framework, these represent the technologies relevant to the company, all factors directly related to the underlying technology are categorised accordingly.
Organization	129	■■■■■■■■■■■■■■■■■■■■■■■ ■■■■■■■■■■■■■■■■■■■■ 129	This includes all characteristics and resources of the company, as well as the associated structures.
Environment	13	■■■■ 13	This category encompasses general industry structures, market developments, other stakeholders, and regulatory aspects.
Categories [exkluding Benefits/Advantages]			**Aspects…**
Project Management	14	■■■■ 14	... related to the planning and execution of implementation projects, as well as other factors explicitly referring to projects.
Solution	14	■■■■ 14	... concerning the technological dimension, specifically the tool-related aspects of the use case linked to the technical solution.
Process Management	13	■■■■ 13	... related to the management of recurring processes, from their design to their optimisation.
Data Management	7	■■ 7	... addressing data-related and data management elements.
Communication	7	■■ 7	... dealing with communication methods and practices.
Leadership	6	■■ 6	... concerning leadership, leadership style, or aspects related to managerial roles.
Attitude	5	■ 5	... pertaining to the attitudes, values, and mindset of the individuals involved.
IT Security	5	■ 5	... addressing IT security considerations.
Organisational Structure	5	■ 5	... concerning organisational structure, particularly in terms of responsibilities and task distribution.
Project Organization	5	■ 5	... specifically related to project organisation within the implementation project.
Strategic Management	5	■ 5	... of strategic significance or involving strategic management considerations.
Technology Readiness	5	■ 5	... addressing the maturity of the technologies or technical solutions employed or discussed.
Education and Training	3	■ 3	... concerning training and professional development in relation to the discussed topics.
Prioritization	3	■ 3	... focusing on prioritisation, ensuring that key elements are given prominence.

Innovation	3	■ 3	... related to innovation, understood as the introduction of novel and advanced solutions, excluding process innovation.
Corporate Culture	2	2	... reflecting corporate culture, including the organisation's values and principles.
Infrastructure	2	2	... addressing the existing infrastructure, such as the available IT systems.
Procurement Complexity	2	2	... associated with the complexity of procurement challenges and decisions.
Risk Management	2	2	... concerning risk prevention and risk-based decision-making.
Skills and Competences	2	2	... focusing on the skills and competences of employees.
Solution Provider	2	2	... related to the provider of the implemented or discussed solutions.
Supplier Relationship	2	2	... concerning relationships and cooperation with suppliers.
Tech Vigilance	2	2	... highlighting the need for technological vigilance to remain up to date with developments.
Finance	2	2	... addressing the financial implications of adopting advanced technologies.
Responsiveness	2	2	... concerning the responsiveness and agility of the supply chain.
Others	7	■■ 7	…concerning evolving technologies, implementation, IT resources, over-engineering, technological benefits, …

Table 14: Factor frequency analysis illustrating the key focal points in the examined cases

The factor frequency analysis shows a balanced distribution of factors across the cases. The notably high number of aspects derived in the case of Comp4 can be explained by the fact that the use case is already established and deeply embedded within the company's structures, thereby revealing the potential to address numerous different facets. In the case of Comp5, although the smallest number of factors was prepared, this can be accounted for by the subsequent detailed explanations, as these factors were described with thoroughness and appropriately documented.

From a content perspective, the frequency patterns observed within the Technology-Organization-Environment (TOE) framework already indicate a key conclusion of this study—one that is also reflected in the existing literature and further reinforced here: The introduction of new technologies is primarily an organisational matter. While environmental factors present both challenges and opportunities, the key success drivers in the examined cases are predominantly internal, making them subject to organisational influence. The remainder of the study will therefore also explore the extent to which companies may be obstructing their own use of advanced technologies in procurement.

Regarding the inductively identified subcategories, four distinct clusters emerge in terms of quantity. The first three stand out: (1) from project management to process management, (2) from data management to technology readiness, and (3) from education and training to responsiveness. The final cluster consists of other subcategories that were assigned only once.

To account for the theoretical and methodological considerations outlined in Chapter 4.1, highlight the nuances of qualitative research, and leverage the TOE framework’s classification at a higher level of aggregation, excessive generalisation of subcategories was deliberately avoided. While critics might perceive this approach as overly fragmented, this level of detail is intentional. It is designed to engage companies seeking to derive insights from the examined cases in specific areas of interest.

The factors identified in the case study interviews are presented and discussed in detail below, structured according to the seven main categories that were deductively derived. For each main category, an overview is provided in the form of a dashboard, offering a summarised visual representation of the findings. This is followed by a detailed analysis presented in table form and further examined in the body text. This structured approach aims to enhance clarity and facilitate a comprehensive understanding of the key insights derived from the case studies.

4.3.2.1. Opportunities

The opportunities represent potential additional benefits associated with the Procurement 4.0 application examined or derived from complementary discussions during the case study interview. Companies that have not yet attained the same level of technological maturity as those examined in this study may also perceive the achieved benefits as opportunities; these are presented in Chapter 4.3.2.6. A total of 13 opportunities—referred to here as *factors*—were identified. Categories frequently mentioned in the interviews are grouped together and presented in descending order in the analysis tables. Table 15 illustrates the frequencies.

(1) Opportunities | ∑ →		**13**	
Cases	Comp1	■■■■ 4	Frequencies
	Comp2	■■ 2	
	Comp3	■■■ 3	
	Comp4	■■ 2	
	Comp5	■■ 2	
TOE	Technology	■ 1	
	Organization	■■■■■■■■■■ 10	
	Environment	■■ 2	
Categories	Process Management	■■■■■ 5	
	Strategic Management	■■ 2	
	Responsiveness	■■ 2	
	Attitude	■ 1	
	Technology Acceptance	■ 1	
	Innovation	■ 1	
	Supply Chain Visibility	■ 1	

Table 15: Dashboard illustrating frequency distribution in the Opportunities category

This main category reflects a balanced distribution across the cases. The predominance of identified opportunities in discussions with Comp1 can be attributed to the fact that the use case is still in its introductory phase, meaning that the actual benefits have not yet fully materialised (see also (6) Benefits). Additionally, it is notable that most factors were expressed and discussed within an organisational context. Furthermore, the heterogeneity of the identified factors is evident, with a cross-case pattern emerging only in process management. The following table presents the detailed analysis, which is subsequently discussed in the body text.

Category	**Factor**		**Description**	**TOE**	**Case**	
Process Management	O01	AI-enabled process conformance	The AI could detect during the ordering process that the item should not be ordered via the catalogue, as it has previously been procured using its material number.	Organization	Comp2	x
	O02	AI-enabled optimisation of the tendering process	In the long term, AI is expected to play a role in tendering processes by providing relevant input. For instance, it could alert users to additional suppliers offering more competitive prices. In this regard, Ariba is already promoting 'Ariba Discovery.' Looking ahead, it seems likely that AI-generated recommendations in procurement will adopt a similar approach to Amazon’s system, where users receive suggestions based on previous interactions, such as 'Customers who viewed this item also bought…'			x

Category	Factor		Description	TOE	Case	
	O03	Productivity enhancements through AI-driven optimisation	Allocating additional staff for every new task is not feasible, making optimisation essential. AI serves as a key tool in this process.		Comp1	x
	O04	Improved analytical transparency through process digitalisation and automation	The full digitalisation and automation of operational procurement, managing 15,000 order items per month—including order confirmations, delivery notifications, and other related processes—ensures that all data is swiftly recorded in the system, making it readily available for further processing and analysis.		Comp3	
	O05	Enhanced and automated decision-making with AI	The system's further development and the integration of AI are anticipated. Decisions made today could potentially be automated by AI in the future, a development actively promoted at the global level within the company. Some dashboards already integrate machine learning models, which may assist in risk decisions and forecasting.		Comp4	x
Responsiveness	O06	Machine learning-based prediction of supplier flexibility	Recently—one specific case has already been implemented—machine learning models have been integrated into the system to analyse supplier flexibility, particularly their responses to shifts and cancellations. These models, based on historical data, can predict which suppliers will be able to handle these changes in the upcoming quarter.			x
	O07	Rapid decision-making and responsive actions driven by supply chain insights	With crises occurring frequently, the company must be able to assess supply chains—including gaining extensive insights into fourth- and fifth-tier suppliers—and respond effectively. By implementing risk-based AI systems and utilising comprehensive supply chain databases, it will be able to swiftly generate recommendations and take appropriate action.		Comp5	x
Strategic Management	O08	Automation sustains competitiveness	To address bureaucratic challenges, organisations could allocate extensive resources at the expense of corporate competitiveness; hence, they adopt optimisation and automation.	Environment	Comp1	x
	O09	Strategic enhancement through qualitative data insights	The company aims to leverage its internally accumulated Big Data through data mining and appropriate tools. While there is already a strong focus on utilising Big Data, the current approach remains centred on SAP-based quantitative analysis. The vision extends beyond numerical data to include qualitative text analysis, such as supplier correspondence, to generate strategic insights.	Organization	Comp3	
Attitude	O10	Employee acceptance through perceived added value	The solution supports operational employees, particularly in carrying out tasks perceived as bureaucratic, which they recognise as adding value and therefore respond positively.		Comp1	x
Innovation	O11	Co-development and customisation through early customer engagement	The system was co-developed with the solution provider as its first customer. What started as an Excel list evolved into a cloud-based software solution.		Comp3	x
Supply Chain Visibility	O12	Deeper supply chain insights enabled by the integration of diverse information sources	The browser-based browser-based risk intelligence platform Sayari provides access to sanction lists and extensive databases that track global shipment information (e.g., freight tracking) and financial data, including shareholder structures. By integrating with numerous other systems, it enables the consolidated provision of information, visualises relationships, and delivers in-depth supply chain insights.	Technology	Comp5	x

Category	Factor		Description	TOE	Case	
Technology Acceptance	O13	External influences enhance technology acceptance and adoption	The situation is similar to the introduction of video conferencing. Without the impact of COVID, such systems might not have gained widespread acceptance. However, the pandemic demonstrated that remote work is possible and provides real added value. In the field of sustainability, operational day-to-day tasks often involve extensive information gathering and dissemination, which can individually be perceived as bureaucratic. In this context, AI is also regarded as a helpful tool.	Environment	Comp1	x

Table 16: Practical perspective on the opportunities of advanced technology use in procurement

The factors are numbered consecutively to ensure clear reference in the discussion. Each description translates, paraphrases, and summarises the interview content associated with the respective factor, along with its underlying subcategory, to enhance comprehensibility and transparency. Additionally, the TOE classification and the case source are provided.

Because two aspects in the main deductive category ‘opportunities’ were not explicitly related to the case, an ‘x’ is additionally included in the outermost column of the table to indicate whether a factor was directly expressed in relation to the case under investigation or emerged during a broader, thematically relevant discussion in the interview.

The initial observation is that the adoption of AI is perceived as an opportunity. In factors O01, O02, O03, O05, O06, O07, and O13—except for Comp3—this is discussed in relation to the use case. However, it is noted that Comp3 also acknowledged the future application of AI, specifically in the formulation of category strategies, which are currently reliant on standard algorithmic approaches.

The potential benefits of AI are diverse, predominantly enhancing employee assistance (O01, O02, O05, O06) at present. Notably, an interviewee from Comp4 suggested that decision-making might eventually be automated through AI, a development actively promoted at the global level within the company (O05). This already points to the intended automation in terms of autonomisation, which, in both the examined cases and the literature, is still not recognised as a tangible and viable opportunity.

The enhancement of competitiveness through AI and the consequent productivity gains, as highlighted in both academic and practical literature, are substantiated by the insights from Comp1. This aspect is revisited in the discussion on realised benefits (refer to Chapter 4.3.2.6).

The discussion also extends to the increased responsiveness enabled by advanced technologies, illustrated through two examples. O06 specifically explores the potential of machine learning to predict supplier responses to forthcoming changes, enhancing the dynamism of procurement practices. Meanwhile, O07 underscores the rapid response capabilities enabled by advanced digital technologies.

Regarding employee acceptance of new technologies like AI (O10), there is an opportunity to enhance this by addressing repetitive and bureaucratic tasks. Reflecting further, modern change management theories, such as Kotter's 8-phase model (Kotter, 2012), affirm that short-term, visible benefits are crucial for driving change. Hence, use cases like that described by Comp1 serve as ideal catalysts for broader technological initiatives.

It is noteworthy that Comp3 co-developed the solution with the vendor (O11). Expanding on this, adopting a similar collaborative approach to a company's key challenges could guide towards genuine innovation.

Lastly, Comp1's mention of the positive impacts of crisis dynamics, such as the COVID-19 pandemic (O13), is intriguing. As demonstrated by the initial situation of Comp5 (refer to Chapter 4.3.1.5) concerning supply chain legislation, external pressures can lead to actions culminating in technological advancements.

4.3.2.2. Challenges

The challenges represent factors discussed in relation to the analysed application as obstructive or complicating, yet surmountable. They should not be understood as barriers in the strict sense. In total, 25 challenges were identified. The frequencies are illustrated by Table 17, followed by a detailed analysis and description as in the previous section.

(2) Challenges		**25**	
Cases	Comp1	■■■ 3	Frequencies
	Comp2	■■■■ 4	
	Comp3	■■■■■ 5	
	Comp4	■■■■■■■ 7	
	Comp5	■■■■■■ 6	
TOE	Technology	■■■■■■ 6	
	Organization	■■■■■■■■■■■■ 12	
	Environment	■■■■■■■ 7	
Categories	Process Management	■■■ 3	
	Attitude	■■ 2	
	Infrastructure	■■ 2	
	Procurement Complexity	■■ 2	
	Solution	■■ 2	
	Supplier Relationship	■■ 2	

(2) Challenges		25
	Technology Readiness	■■ 2
	Data Management	■ 1
	Evolving Technologies	■ 1
	Finance	■ 1
	Leadership	■ 1
	Organisational Structure	■ 1
	Over-engineering	■ 1
	Prioritization	■ 1
	Project Management	■ 1
	Skills and Competences	■ 1
	Tech Vigilance	■ 1

Table 17: Dashboard illustrating frequency distribution in the Challenges category

This category is notably diverse and heterogeneous. Although factors related to process management are once again prominent, the presence of 17 subcategories indicates that there is no single focal topic. Instead, it is the unique aspects of the challenges that must be addressed or resolved within the context of various Procurement 4.0 applications.

Furthermore, it is evident that a significant number of factors in this category are associated with technological and environmental contexts, a point that will be revisited in subsequent discussions.

Category	Factor		Description	TOE	Case
Process Management	C01	Regional process discrepancies	Two years into the global implementation, it became clear that, due to factors such as tax differences, not all regions could operate under a fully standardized process approach (template). As a result, significant modifications had to be made, and custom templates were developed.	Organization	Comp2
	C02	Establishing and maintaining a global standard	The company operates multiple factories and ERP systems globally. To ensure integration and accurate comparisons, key metrics, such as delivery times, must be standardized worldwide. The same applies to the use of color codes for highlighting information. The primary challenge lies in establishing and maintaining this standard over time. Furthermore, new functions must be implemented in accordance with this global standard.		Comp4
	C03	Despite AI, humans remain central to hierarchical decision-making processes	The interpretation of AI-generated information, particularly the subjective assessment of the sources used, remains the responsibility of humans. Depending on the company's size, complexity, and the significance of the issue, this information is synthesized into a recommendation. Ultimately, it is up to humans to guide the decision-making process across various hierarchical levels.		Comp5
Attitude	C04	Perception of transparency as surveillance	Initially, employees perceived the transparency as a form of monitoring. A mindset shift was necessary, involving engagement and clarification that the focus was on the broader supply chain picture, not on surveillance.	Environment	Comp4

Category	Factor		Description	TOE	Case
	C05	Perceived job insecurity	One challenge is to familiarize the workforce with the technology and mitigate the common concern that AI may replace jobs.		Comp5
Infrastructure	C06	Initial integration hurdles	Technical integration issues emerged initially but were later resolved.	Organization	Comp2
	C07	ERP system diversity	Individual regions that do not use SAP also do not utilize SAP Ariba. Therefore, the use of different ERP systems at various global locations can prevent a solution from being implemented on a widespread basis.	Technology	
Procurement Complexity	C08	Strategy formulation for complex items still relies on specialized expertise	The Guided Strategy is effective for direct materials, while strategy formulation for more complex procurement items still relies heavily on the expertise of strategic buyers. Collaborative efforts with the solution provider are underway to improve this in the next version.	Environment	Comp3
	C09	Limitations due to practical complexity	A comprehensive 100% assessment of the global N-tier supply chain is currently unfeasible due to its inherent complexity.		Comp5
Solution	C10	Enhanced data analysis	Enhanced data analysis, resulting in a more dynamic spend analysis, would benefit the global strategy system.	Technology	Comp3
	C11	Audit-proof data storage	Improving the database to include audit-proof data storage within the Guided Strategy System would benefit the company, since data can currently still be overwritten there.		
Supplier Relationship	C12	Lack of supplier participation	While no IT-related issues have arisen to date, a potential challenge lies in the human factor, such as suppliers failing to complete the SAQs. Even the most effective IT solution is rendered useless if it is not actively used.	Environment	Comp1
	C13	Supplier cost-bearing depends on market power	SAP Ariba imposes fees on suppliers for uploading catalogues, often leading to initial resistance to the platform. Whether a supplier participates depends on market power dynamics, as those unwilling to incur these costs choose to stop issuing tenders.		Comp2
Technology Readiness	C14	AI-constraints in crisis-related corporate communication	In the event of supply chain-related allegations, AI cannot independently generate corporate communication for external distribution; it can merely offer recommendations. The underlying process is lengthy and complex, particularly for publicly listed companies, as it involves determining both whether the case genuinely relates to the company's supply chain and if a problem exists, as well as deciding how to respond, for instance in light of potential reputational damage.	Technology	Comp5
	C15	Progressive enhancement of AI-generated responses	A comprehensive response is generated in multiple stages. Ideally, the system would deliver a complete answer immediately upon receiving a set of facts. However, with Copilot, responses gradually increase in detail.		
Data Management	C16	Sufficient data quality	The underlying data, such as spend data, must be of sufficient quality for the Guided Strategy to function effectively.	Organization	Comp3
Finance	C17	High costs of accessing valuable supply chain insights	There is no single tool that offers a comprehensive solution for N-tier assessments. However, a combination of tools, including proprietary solutions, can support the process. Yet, tools that generate valuable insights for large corporations by consolidating information—such as mapping the branching of hundreds of companies across multiple tiers behind a supplier, including their shareholder structures—are associated with significant costs, as they rely on expensive databases.	Environment	Comp5
Leadership	C18	Managerial bypassing of system processes	The adoption of tool usage by employees should be demonstrated at the management level. For example, if relevant information is available within the system, managers are expected to retrieve it themselves rather than requesting employees to provide it separately.	Organization	Comp4

Category	Factor		Description	TOE	Case
Organisational Structure	C19	Responsibility assignment for overseeing the AI solution	Assigning responsibility for overseeing AI solutions in daily operations, including troubleshooting, presents a challenge.		Comp1
Over-engineering	C20	Overengineering-induced information overload	One challenge that emerged at the start of the implementation was the tendency to map every process, even when the information was ultimately unused. This can lead to the creation of multiple dashboards for the same topic, resulting in redundant information. Initial enthusiasm may drive an excessive accumulation of information, necessitating a conscious reduction to the essentials to maintain clarity and prevent employee overload.		
Prioritization	C21	Significant groundwork required for new dashboards	Location-specific processes are visualized through dashboards for management. One challenge is the premature enthusiasm for developing a new dashboard, even though data visualisation with graphics should always be the final step. The first key question is what is needed and what must be controlled. Considerable time is spent identifying necessary data, assessing its quality, and determining the need for a standard, requiring substantial effort and consideration.		Comp4
Project Management	C22	The process of system integration and acceptance is lengthy, demanding significant effort	It can take a considerable amount of time—in this case, two to three years—before employees fully recognize the benefits. Until then, significant effort is required. It is a gradual process, not a system that can be implemented overnight with immediate understanding and acceptance.		
Skills and Competences	C23	Building a highly qualified strategic procurement team	A highly skilled strategic procurement team must be trained and in place for the system to effectively support users.		Comp3
Tech Vigilance	C24	Breaking new ground: learning through engagement vs. business case evaluation	The traditional and familiar approach of calculating a business case and predicting the outcome upfront is not applicable to this technology, as its potential cannot yet be fully assessed. The focus is on learning through engagement, gaining experience, and navigating challenges. Setbacks and failures are inevitable, but they are part of the process.		Comp1
Evolving Technologies	C25	Unforeseen effort for technological adaptation	If background technologies change, adjustments may be required, such as modifications to the data structure, which can be time-consuming.	Technology	Comp4

Table 18: Practical perspective on the challenges of advanced technology use in procurement

The most striking aspect in the area of process management is the focus on standardisation (C01 and C02). However, regional process differences (C01) can lead to a partial reduction in the degree of standardisation. This was observed in the case of Comp2, where, after two years, it became evident that not all regions in which the company operates function according to a uniform process approach, for example, due to tax differences.

The complex use case of N-tier assessment at Comp5 demonstrates that technology—exemplified by AI—encounters limitations in hierarchical decision-making processes. In such cases, it remains the responsibility of humans to prepare recommendations and facilitate decision-making across different hierarchical levels (C03).

Furthermore, well-documented concerns in the theory related to attitudes toward Procurement 4.0 such as the perception of transparency as surveillance (C04) or concern of AI job replacement (C05) were identified as challenges, reinforcing perspectives found in the literature. However, it should be noted that none of the interviewees indicated or suggested that the introduction of technology was aimed at workforce reductions, a point that will be further elaborated under the discussion of benefits (see Chapter 4.3.2.6).

The subsequent challenges identified relate to infrastructural elements that need to be considered and the complexity of procurement. The latter is noteworthy in the context of Procurement 4.0 process automation as it indicates potential technological limitations highlighted by two factors: strategy formulation (C08) and general complexity-related limitations observed in practice (C09). These factors underscore the necessity for human expertise and decision-making under residual uncertainty, even with the deployment of advanced technologies.

In addition to the individual potential of the solution, as exemplified by Comp3, challenges 12 and 13 as encountered by Comp1 and Comp2 relate to the relational dynamics with suppliers. For instance, an AI solution might fail due to inadequate supplier engagement (C12). Additionally, as evidenced in the SAP Ariba case, some suppliers may resist supporting changes, depending on market power dynamics (C13).

The final area of concern addresses the technology readiness itself, connecting back to the limitations within the procurement complexity at Comp5, particularly during the N-tier assessment process (C14). Crisis-related corporate communication cannot be conducted solely by AI due to the multitude of aspects that must be considered and the need to balance diverse stakeholders; rather, AI can only serve as a supporting tool.

With reference to AI, especially the Copilot, there is recognition of the ongoing improvement in AI-generated responses (C15). However, the ideal state of delivering a fully comprehensive answer to a question has not yet been attained. At the same time, the continuous advancements in technology and enhancements in application effectiveness are acknowledged, underscoring the rapid pace at which research must also evolve.

The additional challenges, from C16 to C25, span a wide array of potential hurdles in the implementation of various Procurement 4.0 applications. These range from the need for sufficient data quality (C16) and the potential risk of managers bypassing established processes in Procurement 4.0 applications (C18), to the requirement for technical vigilance (C24). This last point is critical as emerging technologies like AI may challenge conventional procedures (e. g., calculating a business case and predicting the outcome), given the current inability to fully assess their potential (Comp1). Comp1 highlights the necessity of learning about the topic, engaging with it, and gaining experience. Finally, ongoing adaptation efforts throughout an application's lifecycle need to be considered to remain current and effective, as unforeseen effort for technological adaptation may occur (C25).

4.3.2.3. Risks

The risks include all aspects mentioned in the interviews that could potentially lead to negative consequences, disadvantages, or even losses (Duden, n.d.). Table 19 provides an overview before the factors are discussed in detail.

(3) Risks		13	
Cases	Comp1	■■■■■■■ 7	Frequencies
	Comp2	■ 1	
	Comp3	■■■ 3	
	Comp4	■ 1	
	Comp5	■ 1	
TOE	Technology	■■■■■■ 6	
	Organization	■■■■■■ 6	
	Environment	■ 1	
Categories	IT Security	■■■ 3	
	Solution	■■■ 3	
	AI-driven Business Interactions	■ 1	
	Communication	■ 1	
	Data Management	■ 1	
	Implementation	■ 1	
	Risk Management	■ 1	
	Solution Provider	■ 1	
	Tech Vigilance	■ 1	

Table 19: Dashboard illustrating frequency distribution in the Risks category

Risks constitute the second smallest category, with a total of 13 identified factors. Similar to the challenges category, it is heterogeneous, as eight of the ten subcategories were assigned only once.

Notably, more than half of the risks were discussed in the case of Comp1 alone. This may be because Comp1 is still in the testing phase, unlike the other companies where a solution has already been implemented and potential risks are less prominent. Consequently, this observation may provide organisations in analogous circumstance with guidance, particularly when it comes to identifying important factors to consider when implementing an AI solution in collaboration with a startup.

Moreover, it is evident that, compared to the opportunities and challenges, the factors are more technology related. The individual aspects are discussed following Table 20.

Category	Factor		Description	TOE	Case
IT Security	R01	Company data leakage	Highly sensitive data is hosted on third-party software, presenting a significant risk in the event of data loss or leaks.	Technology	Comp3
	R02		Data privacy is a well-recognised challenge, and ensuring its protection remains complex. As solely company-related data is utilised, IT security becomes a critical concern, particularly regarding system access to data and the risk of data leakage.		Comp1
	R03	Cyber-attacks	Cybersecurity risks arising from cyber-attacks are a major concern in industrial environments. With every machine and system connected to the internet, the threat of compromise or extortion remains significant. In this context, even vehicles performing 'over-the-air updates' represent a potential threat. This raises the question of to what extent such vehicles, when operating on company premises and potentially connecting via Wi-Fi to company products, might be exploited as entry points for cyber-attacks.	Organization	
Solution	R04	System reliability	The system requires initial monitoring and assessment to verify its reliability. During subsequent operations, random checks will be conducted. As the solution demonstrates its robustness, the need for such oversight will gradually diminish.	Technology	
	R05	System failure	For operations, it is also essential to determine what happens if the system fails or malfunctions.		
	R06	System quirks leading to user dissatisfaction	System quirks complicate operation, leading to user dissatisfaction.		Comp3
AI-driven Business Interactions	R07	Data exploitation and unintended disadvantages in negotiations caused by AI involvement	Concerns exist regarding the possibility that companies might find themselves negotiating with a supplier's AI rather than with the supplier directly. This raises the issue that the AI could collect extensive information about the customer and potentially use it to gain an advantage in negotiations.	Technology	Comp1
Communication	R08	Impact of supplier-related communication on reputation and litigation	The approach to handling an allegation requires careful consideration. For instance, engaging a first-tier supplier regarding a potential violation by a sub-supplier entails the risk of reputational damage for both the supplier in question and the company itself. Uncertainty arises from the unpredictable manner in which the first-tier supplier may address the issue within its supply chain. Even when a suspicion is substantiated by a credible source, such as an NGO or a university, it does not equate to an official sanction. If, as a result of the company’s communication, the first-tier supplier terminates its contract with the implicated sub-supplier, the latter may accuse the company of reputational harm and demand substantiating evidence, potentially leading to legal disputes. This intricate risk assessment in compliance cases cannot be fully handled by any system. Companies must carefully determine what risks exist, which measures should be taken, and how communication should be managed. Otherwise, they risk negative consequences such as a lower rating, a downgraded index, or a loss of market position.	Organization	Comp5

Category	Factor		Description	TOE	Case
Data Management	R09	Incorrect category classification ('garbage in, garbage out')	Large-scale entry of incorrect categories in the ERP system results in irreversibly misclassified revenues, leading to erroneous outcomes and strategies during the development of the Guided Strategy. This poses a significant risk, adhering to the 'garbage in, garbage out' principle, and must be closely monitored.		Comp3
Implementation	R10	System non-utilization despite investment	The only risk lies in the potential underutilization of the solution, meaning that investment is made in something that ultimately remains unused.		Comp2
Risk Management	R11	Absence of a fallback scenario	There is a risk that the AI could hallucinate or fail. Without a fallback scenario in place, the collapse of the system would leave the organization incapacitated. This issue is also applicable to other IT solutions, such as the ERP system.		Comp1
Solution Provider	R12	Dependency on an external solution provider	The long-term use of a system requires a redesign of processes and working methods. Relying on an external provider for implementation presents a significant risk, as discontinuation by the provider would make the system unavailable, creating challenges for the company that has aligned its processes with it. This is one reason why Comp4 opted for in-house development.	Environment	Comp4
Tech Vigilance	R13	Technological advancement lag	One potential risk is to fall behind in various technological topics.	Organization	Comp1

Table 20: Practical perspective on potential risks of advanced technology use in procurement

The first three risks identified pertain to aspects of IT security. On the one hand, there is the risk of data leakage (R01 and R02), which arises when sensitive company data is handled by third parties while utilising the technology. On the other hand, the increasing interconnection of machines via the Internet results in the threat of cyber-attacks (R03). This underscores why cybersecurity has been a prominent topic accompanying the Industry 4.0 debate for years (Rüßmann et al., 2015), and why it remains on the agenda (PricewaterhouseCoopers, 2025). Evidently, robust security concepts are essential, particularly when even each vehicle on company premises represents a potential security threat (R03).

Risks R04 to R06 relate to the solution itself and are particularly relevant because, although they are technology-related, they affect the organisational processes that accompany new technologies and systems. They concern system monitoring (R04), the definition of failure scenarios (R05), and the handling of system quirks (R06). These aspects should therefore be included in the value-added analysis of such solutions to provide a realistic view of the difference between the actual and target situations.

R07 is so unique that it has been assigned its own subcategory. From a purchasing perspective, it addresses a risk that also represents an opportunity for suppliers on the sales side: a negotiating advantage through AI. This is another perspective that can be considered when applying technology in a supplier–customer relationship. Extending this idea, a futuristic scenario could be that, due to full transparency and the capabilities of AI, negotiation tactics become less relevant.

In relation to R08 the discussion revealed that this intricate risk assessment in compliance cases cannot be fully handled by any system. Companies must carefully determine what risks exist, which measures should be taken, and how communication should be managed. Otherwise, they risk negative consequences such as a lower rating, a downgraded index, or a loss of market position.

Risks R09 to R12 stand alone and are largely self-explanatory. However, it is worth noting that Comp2 explicitly refers to only one risk (R10): namely, that a system in which investments have been made remains unused and lies idle. Given that systems such as SAP entail both financial and organisational effort (Baecke, 2025), his point illustrates that, for such comprehensive solutions, the implementation project must be particularly well prepared and executed. This is reflected later in the success factors at Comp2 (see Table 24).

The final risk (R13) indicates that, in the category of technological vigilance, there is a risk of falling behind if this is not ensured. Considering the number of technologies mentioned in this paper that can be applied in procurement, companies need a way to monitor the emerging technologies, concepts, and solutions relevant to them to mitigate this risk.

During the interview with Comp4, one additional aspect emerged that may be seen as a potential risk. Although not discussed in direct relation to the specific case, the interviewee noted, from an expert perspective, that if employees are not involved in the project from the outset and the system is simply finalised and handed over once fully operational, acceptance is likely to be low. It may therefore be assumed that, from a project management perspective, involving employees early in a Procurement 4.0 project could help mitigate the risk of low acceptance due to insufficient involvement. This observation aligns with Kotter's eight-step model, which emphasises the importance of securing commitment to change when enlisting a volunteer army (Kotter Inc., n.d., p. 19). According to the model, this can be achieved by generating excitement around the opportunity and fostering a sense of personal willingness to contribute, both of which require early involvement.

4.3.2.4. Barriers

The barriers include the factors mentioned in the interviews that may complicate or even prevent use (Cambridge Dictionary, 2023). Table 21 provides an overview of these factors before they are discussed in detail.

(4) Barriers		7		
Cases	Comp1	2	■■ 2	Frequencies
	Comp2	1	■ 1	
	Comp3	1	■ 1	
	Comp4	2	■■ 2	
	Comp5	1	■ 1	
TOE	Technology	4	■■■■ 4	
	Organization	1	■ 1	
	Environment	2	■■ 2	
Categories	Solution	3	■■■ 3	
	Attitude	2	■■ 2	
	IT Security	1	■ 1	
	Organisational Structure	1	■ 1	

Table 21: Dashboard illustrating frequency distribution in the Barriers category

The fewest factors were identified in relation to barriers. One possible explanation for this is that general organisational barriers within the companies played a minor role in the cases examined and were therefore not mentioned. The fact that this is also the area in which most factors have a technological context, particularly in relation to the solution itself, supports this interpretation. In general, it is difficult to draw a clear line between risks and barriers. For this reason, during the qualitative analysis, category assignment involved considering which factors might potentially become showstoppers; these were assigned to the barrier category. The limited number of factors that were identified are distributed relatively evenly across the cases examined. The individual aspects are discussed following Table 22.

Category	Factor		Description	TOE	Case
Solution	B01	Perceived usefulness of system features	Certain features, such as Risk Alerts, are not yet considered useful and are therefore not utilised.	Technology	Comp2
	B02	System complexity and challenging usability	The system exhibits inefficiencies at the database and handling levels, making consistent use difficult. Tasks such as data entry and analysis are cumbersome. While the system delivers high-quality results, including excellent presentation and explanation options, its overall usability remains demanding due to its complexity.		Comp3
	B03	Technical Performance Limitations	Initially, the system exhibited technical performance deficiencies, including prolonged loading times, slow dashboard rendering, and extended refresh intervals, which impeded efficient tool usage.		Comp4
Attitude	B04	Employee resistance and scepticism	Some employees are hesitant to adopt new solutions and occasionally raise unfounded concerns about minor issues, such as non-functional filters (e.g., initially claiming something does not work, only for it to function later). This increases the support workload.	Environment	Comp4

Category	Factor		Description	TOE	Case
	B05	Resistance and acceptance spectrum among employees	The rapid advancement of technology often triggers fear, particularly concerns about AI replacing jobs. Employees respond differently: tech-savvy individuals, already familiar with AI in their personal lives, adapt more easily in professional settings. Conversely, risk-averse employees resist change, adhering to the mindset of 'Never change a running system,' which is increasingly impractical in today's fast-evolving and volatile world. Between these extremes, some remain undecided. To ensure successful AI adoption, each group requires tailored engagement.		Comp5
Organisational Structure	B06	Internal organisational dynamics shaping the decision-making process	A central department for digitalisation matters plays a role in the selection of the solution provider.	Organization	Comp1
IT Security	B07	IT security and data protection requirements	Ensuring data protection and IT security is particularly challenging when adopting new digital technologies. In a corporate setting, secure system access is essential to prevent data leaks. This use case requires addressing processes, protocols, certifications, storage, and access rights. Digitalization has made previously unaddressed concerns critical, such as cyber-attacks—due to the near-universal connectivity of machines—and legal frameworks like the EU's AI Act.	Technology	Comp1

Table 22: Practical perspective on potential barriers to the adoption of advanced technology in procurement

The first three barriers indicate that potential barriers to using the solutions may arise if certain system functions are not perceived as useful (B01), the systems are overly complex and therefore challenging to use (B02), or there are technical performance limitations (B03). In reference to the Technology Acceptance Model (Davis, 1985, pp. 109–110), this suggests that, when developing solutions for use in Procurement 4.0, particular attention should be paid to usefulness and usability in order to encourage actual use.

When it comes to employee attitudes, potential barriers B04 and B05 suggest that different groups require tailored initiatives to address scepticism and overcome resistance. These factors reveal potential hidden motives when a new technology or solution is implemented. They reinforce the importance, particularly in the context of Industry 4.0, of actively engaging people in the process, something which, as Comp4 demonstrates, also results in an increased support workload (B04). Moreover, the observation from Comp5 that tech-savvy individuals who already engage with AI in their private lives tend to adapt more readily in professional contexts could lead to the conclusion that such employees are especially well positioned to form a 'volunteer army' in the sense proposed by Kotter Inc. (n.d., pp. 19–21), helping to build momentum for change.

Barrier 06, *Internal organisational dynamics shaping the decision-making process* was not explicitly described as a barrier by the interviewee. However, the literature identifies internal bureaucratic decision-making processes as a barrier (Flechsig et al., 2022, p. 8). For this reason, the aspect B07 was coded as a potential barrier to illustrate that similar dynamics may also arise in practice, where the involvement of multiple stakeholders could potentially present a challenge. This reasoning is based on the consideration that if additional stakeholders influence the decision about a solution provider, throughput times may be prolonged or the ‘experimental nature’ of a Procurement 4.0 application project may be compromised. In this case it should be noted, however, that this central department for digitalisation matters is identified as one of the success factors in the following chapter (see S38 in Table 24).

The final barrier (B07) relates to IT security risks R01–R03 in Table 20. It highlights that necessary IT security and data protection requirements may pose an obstacle to digitalisation projects, as ensuring compliance with these standards can be difficult.

During the interview with Comp3, two additional aspects emerged that may be seen as potential barriers. Although not discussed in direct relation to the specific case, they were introduced from an expert perspective during an exchange on the potential of digitalisation in industrial procurement. The interviewee stated that, in industrial procurement, master data is insufficiently digitised, resulting in the potential of digitalisation not being fully realised. It was further noted that the swift and seamless implementation of advanced, often complex, digital solutions such as AI requires strong IT support, yet there is a lack of IT resources and support. These two aspects—insufficient master data digitisation and limited IT resources and support—may represent additional barriers to realising the full potential of digitalisation in industrial procurement. It may therefore be assumed that these areas form a foundational basis for Procurement 4.0 applications and should consequently be prioritised for evaluation in the early stages of procurement digitalisation initiatives.

4.3.2.5. Success Factors

The constraints outlined in the preceding chapters could be addressed and mitigated through specific factors that contribute significantly to success to support and facilitate technology adoption. These 49 success factors (Duden, n.d.), identified across the analysed cases, are presented in Table 24, following the overview provided in Table 23.

(5) Success Factors		**49**	
Cases	Comp1	■■■■■■ 6	Frequencies
	Comp2	■■■■■■■■■■■■■■■■ 16	
	Comp3	■■■■■■ 6	
	Comp4	■■■■■■■■■■■■■■■■■ 17	
	Comp5	■■■■ 4	
TOE	Technology	■■■■■■ 6	
	Organization	■■ 42	
	Environment	■ 1	
Catego.	Communication	■■■■■■ 6	

(5) Success Factors		49
	Leadership	■■■■■ 5
	Project Management	■■■■■ 5
	Project Organization	■■■■■ 5
	Process Management	■■■■ 4
	Solution	■■■■ 4
	Data Management	■■■ 3
	Education and Training	■■■ 3
	Corporate Culture	■■ 2
	Organisational Structure	■■ 2
	Strategic Management	■■ 2
	Technology Readiness	■■ 2
	Innovation	■ 1
	Prioritization	■ 1
	Risk Management	■ 1
	Skills and Competences	■ 1
	Solution provider	■ 1
	Technological Benefits	■ 1

Table 23: Dashboard illustrating frequency distribution in the Success Factors category

The evaluation indicates that most success factors emerged in the Comp2 and Comp4 cases, which involved the largest and longest-running implementation projects, where substantial experience with the solution was accumulated. These results can therefore serve as a guiding list of factors that may support the successful implementation of similar Procurement 4.0 applications, although they cannot be generalised. Furthermore, the TOE evaluation suggests that the success of the cases presented is significantly influenced by organisational context. This may be interpreted as a positive indication that companies retain control over the transformation to Procurement 4.0 and can actively shape its course.

In addition, an analysis of the identified categories reveals recurring patterns when compared with the previously established deductive main categories: opportunities, challenges, risks, and barriers. Notably, two-thirds of the categories were assigned multiple times, with one-third appearing four to six times in the qualitative data.

The prominence of the first five categories—communication, leadership, project management, project organisation and process management—suggests that Procurement 4.0 initiatives are not fundamentally different from other IT projects in terms of their management approach. Similar critical success factors for project success can be observed. For example, key factors include effective organisational communication, team competence, and the use of appropriate methodologies, tools and techniques, as highlighted by the more recent source Yohannes and

Mauritsius (2022, pp. 61–62). Similarly, communication, top management support, project mission, and planning were identified by the earlier work of Pinto and Slevin (1987, pp. 25–26). The individual aspects identified in this study are presented in Table 24 and discussed in the following.

Category	Factor		Description	TOE	Case
Communication	S01	Making success visible	No employees are made redundant; rather, the savings generated through procurement performance are highlighted, measured by comparing the best offer with the actual order value. The achieved savings were demonstrated through tracking and evaluation in SAP Ariba, as well as the presentation of negotiation successes for each material group as part of benefit tracking process.	Organization	Comp2
	S02	Project marketing	Promoters were integrated into the team to perform marketing activities and to train employees, thereby facilitating effective change management.		
	S03	Highlighting the quick wins	Quick wins were highlighted.		
	S04	Adoption of a multi-channel communication strategy	The intranet and an employee app were leveraged to address potential resistance by ensuring broad communication. Additionally, numerous meetings and training sessions were conducted, complemented by user documentation and instructional videos.		
	S05	Using and demonstrating the system in daily business	The system was integrated into daily work and team meetings. It was not just presented and advertised, but actively used by the group leaders, thereby demonstrating it to the employees.		Comp4
	S06	Presenting the application	On-site, there is a control room where the solution is utilized, dashboards are displayed on screens, meetings are conducted, and it also functions as a showroom.		
Leadership	S07	Celebrating success	Successes were celebrated, emphasized, and showcased, serving as a source of motivation.		Comp2
	S08	Mandatory system use	Cirtuo must be used for material group reviews, as this is where they are accessed by the management. While errors may occur in the system and are addressed, this should not deter its extensive use.		Comp3
	S09	Engaging employees and explaining benefits	Initially, employees expressed concerns about being monitored due to the system's complete transparency. To address this, employees were engaged, and the benefits of the system were clarified in face-to-face meetings, weekly meetings, work meetings, and training sessions. It was explained that the system's purpose is to provide a comprehensive view of the supply chain and to utilize supply chain data in supplier meetings, rather than monitoring employees.		Comp4
	S10	Top management commitment	The project was initiated by the CEO, ensuring the availability of an appropriate budget. Furthermore, the management presented the initiative and its intended goals to address employee concerns.		
	S11	Presentation of technological advantages in workshops	To address common concerns regarding AI, employees are introduced to the technology through case studies and department-specific use case presentations in voluntary mini-workshops. This approach highlights practical applications and enhances acceptance by demonstrating benefits while preventing employees from feeling overwhelmed.		Comp5
Project Management	S12	Testing straightforward requirements	Successful tests can boost acceptance, as demonstrated here, where straightforward and clear requirements were tested with the AI solution, exceeding expectations.		Comp1

Category	Factor		Description	TOE	Case
	S13	Hypercare phase	It was important to evolve the solution to be error-free in the hypercare phase.		Comp2
	S14	Multiple information sources to establish a clear goal	Surveys, early stakeholder involvement, feedback loops in the solution selection process and reference discussions with other companies using the shortlisted vendors' solutions helped to clearly define the goal.		
	S15	Measurement and monitoring of savings	The strategies developed result in initiatives being implemented. These initiatives are evaluated using a degree of implementation method, and the actual savings are measured and monitored.		Comp3
	S16	Gradual tool introduction	Employees are gradually introduced to Copilot, starting with a selected group who receive the full version. As they experience its benefits, colleagues begin to recognize the advantages, leading to a rise in interest.		Comp5
Project Organization	S17	Diverse project team	The implementation progressed rapidly due to the formation of a diverse team of up to 15 people, led by two project managers (global and regional). It included key users for each material group, regional members, and representatives from procurement, IT, Shared Services, and Accounting. An implementation partner joined during the implementation phase.		Comp2
	S18	Procurement as the key implementation driver	The key to successful implementation was the purchasing department's role as the driving force behind the solution, actively advocating for and guiding its implementation.		
	S19	Operational employees as decentralized intermediaries	When the solution was handed over to the line organisation, 'Ariba Champions' were the effective link. The team included not only purchasers, but also employees from the plants who had used the previous purchasing solution.		
	S20	Integrating opinion leaders	The opinion leaders were integrated in the team to address potential resistance.		
	S21	Monitoring by IT department	IT was an integral part of the project, overseeing the implementation process, ensuring that data protection and similar concerns were adequately addressed.		
Process Management	S22	Ensuring objective decision-making	Suppliers are aware that tendering processes involving e-auctions are more stringent yet fairer, with less priority given to emotional or relationship-based factors, resulting in increased savings.		Comp2
	S23	Continuous improvement	As part of close support, all issues, including bugs and suggestions for improvement, are carefully addressed, documented, and incorporated into quality discussions with the solution provider.		Comp3
	S24	Process integration	The benefits and user acceptance are ensured due to the integration of the tool into routine processes and daily tasks, making certain activities no longer feasible without it.		Comp4
	S25	Use of a unified information source	All stakeholders access the same data, visualised uniformly on a shared dashboard, ensuring that the data remains unaltered and cannot be manipulated or selectively presented in an overly favourable light, as it is available in real time and transparently reflects the actual situation.	Technology	
Solution	S26	User-friendliness	SAP Ariba provides an improved user experience and interface compared to the company's previous SRM and catalog solutions, some of which were poorly configured.		Comp2
	S27	Effective visualisation in dashboard design	The design of the dashboards, which incorporates the psychology of color, has proven effective. The visual aids provided by the dashboards are utilized to highlight areas requiring attention, such as using the color red to signal prolonged delivery times.	Organization	Comp4

Category	Factor		Description	TOE	Case
	S28	In-house development	The system was developed in-house, leveraging globally available expertise and know-how, thereby mitigating the potential risks associated with external development.		
	S29	Ongoing and transparent optimisation of the tool	Issues or concerns raised with group leaders or Subject Matter Experts were demonstrated directly within the system by the employees, often revealing user errors, as the system was functioning as intended. Conversely, legitimate issues were escalated to the development team, enabling the identification of solutions and the continuous improvement of the tool.		
Data Management	S30	Ensuring secure data access	Whether in a local control room, on a desktop PC or on a mobile device, secure data access is guaranteed.	Technology	Comp4
	S31	Establishing a global data standard	A global standard was established to consolidate data from various ERP systems worldwide, enabling the analysis and comparison of key metrics. Although standardisation was a long process, it proved successful and continues to be beneficial.	Organization	
	S32	Centralization and controlled data access	To maintain standards, master data is updated centrally, ensuring the information is consistently processed in the same manner. For ERP data updates at the sites, access to the necessary fields is restricted.		
Education and Training	S33	Key users in procurement	A key user approach leverages experts within the procurement department who have in-depth knowledge of specific modules to address enquiries directly. This reduces the involvement of IT staff, often seen as a barrier, and ensures immediate support within the functional area.		Comp2
	S34	Extensive training program	An extensive training program, also offered in cooperation with the solution provider, equips strategic buyers with the required theoretical knowledge.		Comp3
	S35	Staff training	Employees were trained in the system on the PC by group leaders and subject matter experts to address concerns, issues, and complaints related to the tool.		Comp4
Corporate Culture	S36	Technology-openness	A corporate culture open to innovation encourages employees to embrace new technologies.		Comp1
	S37	Implementing employee feedback	Problems raised by employees were addressed with appropriate solutions. Rather than allowing these concerns to go unheard, improvements were implemented. This approach enhanced employee acceptance. The commitment to this must be ingrained within the organization.		Comp4
Organisational Structure	S38	Organisational unit for digitalisation	An organizational unit called "Digital Agency" focuses company-wide on advanced technologies.		Comp1
	S39	Establishing subject matter experts	In every department, subject matter experts serve as points of contact for employees who require assistance with unfamiliar topics. If there were only one expert per location, it could prove to be impractical. However, this approach ensures that the necessary level of system expertise is disseminated across the broader workforce.		Comp4
Strategic Management	S40	Clear vision	It is essential to clearly define the objectives to be achieved in advance. This includes identifying which aspects of the process should be made transparent using specific key figures, determining the necessary information and data, and specifying what should be managed based on this information, along with the anticipated benefits.		
	S41		The goal to be achieved is paramount. Implementing a platform just because it is a trend would be a misguided approach.		Comp2

Category	Factor		Description	TOE	Case
Technology Readiness	S42	Technological maturity	The solution's LLM was highly advanced, enabling it to achieve complete accuracy in error detection across all test cases.	Technology	Comp1
	S43		Recently, sophisticated tools such as Prewave and Copilot have significantly reduced the basic effort required to obtain answers concerning the N-tier assessment of supply chains. This enhancement has increased satisfaction with this Procurement 4.0 application.		Comp5
Innovation	S44	Networking	Opportunities can arise through networks, such as here, the contact to a startup that already offers an innovative and compelling solution.	Organization	Comp1
Prioritization	S45	Focus on key elements	The initial enthusiasm led to the creation of multiple dashboards to visualize the same information, resulting in data overload. To maintain clarity, it is essential to consciously focus on key elements by reducing non-essential ones.		Comp4
Risk Management	S46	Risk assessment and compliance in tool selection	The solution is considered low risk, as it requires various internal and external certifications. The security of the applied tools is ensured, particularly regarding data protection, confidentiality, and protection against industrial espionage. Additional security aspects, such as data storage and server locations, are evaluated through questionnaires and serve as key decision criteria.		Comp5
Skills and Competences	S47	Profound procurement expertise	The guided strategy solution cannot substitute the required expertise. Thus, prior to implementation, strong expertise in procurement strategies is essential, including knowledge of methodologies (e.g., spend analysis) and a deep understanding of the supplier market and external as well as internal technological developments.		Comp3
Solution provider	S48	Competent solution provider	The solution provider, leveraging its expertise in procurement, thoroughly prepared the implementation. As a result, the application was smoothly adopted, allowing the company to use it relatively quickly and effectively.	Environment	Comp3
Technological Benefits	S49	Visible added value	When technology visibly adds value, it is perceived as a helpful tool. This alleviates employees' fears regarding the technology. In this case, it aids bureaucracy by efficiently gathering, compiling, and transmitting information.	Technology	Comp1

Table 24: Practical perspective on success factors for the adoption of advanced technology in procurement

Notably, aspects of leadership (4), project management (4), process management (3) and education and training (3), are addressed in more than two cases and will therefore be discussed first.

Regarding leadership aspects, three points emerge as particularly noteworthy, in addition to well-established factors in any change project such as top management commitment (S10) and the celebration of successes (S07).[29] In Comp3 the use of the system is mandatory for strategic category management, as it serves as the primary information source accessed by management (S08). The interviewee notes that although errors may occur within the system and are addressed, this should not deter its extensive use. Process compliance is thereby ensured by management. Similarly, in Comp4 the tool was integrated into routine processes and daily tasks, making certain activities no longer feasible without it, thereby ensuring benefits and user

[29] On this, see for instance Kotter's 8-Step Model to accelerate change (Kotter Inc., n.d.).

acceptance (S05). Furthermore, in Comp4 employees initially expressed concerns about being monitored due to the system's complete transparency. To address this, employees were engaged, and the benefits of the system were clarified in face-to-face meetings, weekly meetings, work meetings, and training sessions (S09). It was explained that the system's purpose is to provide a comprehensive view of the supply chain and to utilize supply chain data in supplier meetings, rather than monitoring employees. Similarly, Comp5 addressed common concerns regarding AI, by introducing employees to the technology through case studies and department-specific use case presentations in voluntary mini-workshops (Comp5). This approach highlighted practical applications and enhanced acceptance by demonstrating benefits while preventing employees from feeling overwhelmed.

These examples show how management influences both the design and enforcement of processes supported by Procurement 4.0 applications, and how diverse communication channels, particularly face-to-face interaction, remain essential. Altogether, they underscore the importance and complexity of the organisational context in the implementation of such technologies.

Furthermore, aspects of project management and project organisation proved particularly influential in the successful implementation. Regarding project management, in the Comp1 case, where simple and clearly defined requirements were tested using the AI solution and expectations were exceeded, it became evident that successful testing of straightforward requirements can enhance acceptance. Since ‘exceeding expectations’ implies that a benefit was perceived, this factor (S12) can be seen to support the TAM construct of perceived usefulness as a determinant of behavioural intention (King and He, 2006, p. 751). This suggests that, in comparable contexts, projects introducing Procurement 4.0 applications may benefit from an early focus on demonstrable benefits, either through testing, as in this case, or through dedicated workshops (S11). In the communication category, factors S01 (making successes visible) and S03 (highlighting quick wins) point in a similar direction, namely towards improving transparency and broad awareness of benefits, thereby offering an indication of the ‘how’ in Procurement 4.0 projects.

Additionally, Comp2 emphasized the importance of multiple information (S14) sources to establish a clear goal for the application and the ‘hypercare phase’[30] (S13) to evolve the solution to be error-free. Comp3 mentioned that the strategies developed result in initiatives being implemented (S15). These initiatives are evaluated by measuring the degree of implementation and monitoring the actual savings achieved. At Comp5, in turn, a particular approach to tool introduction emerged in reflections on success factors. Employees are gradually introduced to MS Copilot, starting with a selected group who receive the full version (S16). As they

[30] ‘Hypercare’ refers to the period following go-live during which additional support and monitoring are provided to ensure that the new solution functions as intended and to address any issues that may arise (Atlassian, n.d.).

experience its benefits, colleagues begin to recognize the advantages, leading to a rise in interest.

In terms of project organisation, all five identified success factors originated from Comp2, where the interviewees provided detailed responses. The first key to successful implementation was the purchasing department's role as the driving force behind the solution, actively advocating for and guiding its implementation. Second, a diverse project team including key users, regional members, representatives from IT, shared services, and accounting as well as an implementation partner joining during the implementation phase, ensured rapid implementation progress. Opinion leaders were also integrated in the team to address potential resistance. The IT was an integral part of the project, overseeing the implementation process, ensuring that data protection and similar concerns were adequately addressed. Finally, when the solution was handed over to the line organisation, operational 'Ariba Champions' were the effective link as decentralized intermediaries.

In the process management category, the Comp2 case shows that IT-supported processes based on clear rules, such as e-auctions, lead to more stringent yet fairer decisions, which suppliers are also aware of (S22). The interviewees pointed out that e-auctions have occasionally produced unexpected additional savings. From a process management perspective, increased standardisation is both expected and welcomed. It is well established that a lack of process standardisation leads employees to improvise, which can hinder consistent quality due to the absence of learning curve effects (Best and Weth, 2010, p. 87).

The Comp3 case highlights the importance of continuous improvement from a process management perspective (S23), supported by close and ongoing operational involvement, through which all issues, including bugs and suggestions for improvement, are addressed. This in turn emphasises the relevance of considering the total cost of ownership across the full life cycle of a Procurement 4.0 application, including the costs associated with ongoing system use (Weber, 2018).

In the Comp4 case, the emphasis is placed on process integration (S24), which supports both the realisation of benefits and the achievement of user acceptance. The level of integration into day-to-day operations is such that certain activities can no longer be performed without the system. This potentially helps to mitigate Risk 10 (system non-utilisation despite investment), as previously discussed. Additionally, the greater standardisation achieved using a unified information source with real-time visualisation (S25) helps to prevent the manipulation or embellishment of information. Considering that knowledge workers spend considerable time searching for information[31], this application demonstrates the potential for productivity gains solely through the standardised provision of information that is broadly accessible.

As far as the solution itself is concerned, most of the relevant factors (S27 to S29) are reported by Comp4. This can be attributed to the fact that the company developed the tool in-house, thereby avoiding risks typically associated with external development (S28). The visualisation is considered effective, as it is specifically tailored to the company's needs and helps to highlight critical areas (S27). In addition, both system-related and user-related errors are addressed to enable the continuous development of the tool (S29). Regarding data management (S30 to S32), the Comp4 case also provided insights, through which factors based on the in-house development experience were identified and documented.

In the category education and training, Cases Comp2 to Comp4 reflect different focal points that contributed to success. These range from the involvement of key users in procurement (S33), to the provision of an extensive training programme (S34), and to practical, tool-focused staff training (S35).

In terms of corporate culture, openness to technology plays a particularly important role at Copm1 (S36), as does the implementation of employee feedback at Comp4 (S37). Comp1 has also established its own organisational unit, the 'Digital Agency', which focuses on advanced technologies across the company (S38). This institutionalisation may serve as an example for companies that are less advanced in their digitalisation efforts, illustrating how future developments (see category 'Tech Vigilance' and factors C24 and R14) could be addressed.

In the area of strategic management, both Comp2 and Comp4 emphasise the importance of a clear vision (S40 and S41) when introducing a Procurement 4.0 application, identifying it as a key factor for success. This aligns with Kotter's 8-step model, which posits that a strategic vision can motivate people to act in a shared direction (Kotter Inc., n.d., p. 18).

Within the Technology Readiness category, two factors were mentioned by different companies (Comp1 and Comp5), both relating to AI, indicating that a certain level of technological maturity is critical to the success of a Procurement 4.0 application using an emerging technology (S42 and S43). In Comp1, the solution's Large Language Model (LLM) was highly advanced, enabling complete accuracy in error detection across all cases during the testing phase. At Comp5, tools such as Prewave and Copilot significantly reduced the basic effort

[31]Various studies suggest that knowledge workers spend between one-fifth and one-quarter of their working time searching for information. According to a study by APQC, knowledge workers spend an average of *'(...) 8.2 hours each week looking for, recreating, and duplicating information and expertise'* (Trees, 2022). The McKinsey Global Institute estimates that nearly 20% of their working time is devoted to such activities (Chui et al., 2012). Atlassian (2025) reports similar figures in its State of Teams Report 2025, suggesting that 25% of working time is spent solely on searching for answers.

required to obtain answers regarding N-tier supply chain assessments, thereby increasing satisfaction with the Procurement 4.0 application. Consequently, a cautious transformation strategy could involve an initial focus on more mature technologies, which appear more likely to result in a successful application than highly experimental approaches. However, as shown in Chapter 4.3.2.2 (C24), a more exploratory approach may also be advisable when dealing with novel technologies. This reveals a potential tension that may warrant further investigation in procurement practice.

Categories that appear only once include innovation at Comp1, where the opportunity to implement the application arose through a network contact with a start-up already offering an innovative and compelling solution (S44). In the case of Comp1, the technological benefit was also coded as a success factor within the technological context (S49). The interviewee explained that when a solution such as AI provides visible added value—as in the application discussed, where the task may be perceived as bureaucratic—it is regarded as a helpful tool, which in turn fosters acceptance.

In the organizational context, Comp3 noted that the guided strategy solution cannot substitute required expertise. Thus, prior to implementation, strong expertise in procurement strategies is essential, including knowledge of methodologies (e.g., spend analysis) and a deep understanding of the supplier market and external as well as internal technological developments (S47). Furthermore, the presence of a competent solution provider—identified as the only factor assigned to the environmental context within the TOE framework—proved beneficial at Comp3 (S48). Drawing on its procurement expertise, the provider thoroughly prepared the implementation, which contributed to the smooth adoption of the application.

Comp4 noted that the initial enthusiasm led to the creation of multiple dashboards to visualize the same information, resulting in data overload. Consequently, to maintain clarity, it was essential to consciously focus on key elements by reducing non-essential ones underscoring the importance of prioritization (S45).

Comp5 contributed a risk management related factor, mentioning risk assessment and compliance in tool selection via required certificates and additional security aspects (data storage, server locations, …) that are evaluated through questionnaires and serve as key decision criteria (S46).

4.3.2.6. Benefits (Advantages)

Procurement 4.0, as previously defined, aims to foster both a more strategic orientation of procurement activities and the achievement of specific targets, which are prominent in the current academic debate. Accordingly, this section discusses the benefits, referred to here as ‘Advantages’ (A) since ‘B’ has been assigned to ‘Barriers’, as identified in the examined cases and considered in relation to predefined objectives. To enhance transparency regarding the benefits of Procurement 4.0 applications, an additional overarching systematisation category was introduced: *procurement objectives*. These are based on Schentler and Tschandl (2016, pp. 33–34), who identify the following seven key procurement objectives: *reduce procurement costs, improve procurement quality, reduce procurement time, mitigate procurement risks, increase procurement flexibility, optimise procurement autonomy,* and, *pursue sustainable procurement objectives*. As sustainability has become a top enterprise priority under the ESG framework (Addicoat et al., 2023, p. 7), it is incorporated as follows: *Enhance ESG standards*. In terms of flexibility, the concept of *agility*—used in Industry 4.0 technologies and the Procurement 4.0 context—is applied as a target dimension to describe a company's ability to effectively manage uncertainty and respond quickly to change (Mrugalska and Ahmed, 2021, pp. 2 & 11). Furthermore, the objectives that were not previously included, pertaining to *supply security* and *working capital management* as outlined by Lysons and Farrington (2012, p. 54), are taken into consideration. The goal dimension *foster innovation* is also incorporated to align with the Procurement 4.0 principle of ‘Procurement as an Innovation Scout,’ as outlined in the definition Chapter 2.1. Additionally, there is inherent pressure to optimise procurement as a department, as is in any other functional area. For this reason, the dimension of *internal support* has been introduced to encompass all potential benefits within this domain. Benefits that cannot be directly classified are grouped under *Other.* Finally, the *Value Proposition* element derived from the definition results from a combination of the stated goals and is therefore not displayed separately.

The further subdivision into subcategories was based on the procurement process landscape presented in Chapter 2, allowing the benefits to be assigned to specific processes or task areas. This, in turn, is intended to provide practitioners with precise and practice-oriented guidance on the processes and tasks in which the examined cases may offer concrete benefits. The TOE framework does not apply in this context, as all benefit aspects pertain to the organisation.

Table 25 provides an overview of the 42 potential benefits identified, before these are presented in detail and discussed in the following.

(6) Benefits (Advantages)		**42**	
Cases	Comp1	■■ 2	Frequencies
	Comp2	■■■■■■■■■■ 10	
	Comp3	■■■■■■ 6	
	Comp4	■■■■■■■■■■■■■■■■■■■■ 20	
	Comp5	■■■■ 4	
Procure ment	Internal support	■■■■■■■■■■■■■■■■■ 17	
	Reduce time	■■■■■■■■■■■■■■ 14	

(6) Benefits (Advantages)		42
	Improve quality	■■■■■■■■■■■ 11
	Reduce costs	■■■■■■■ 7
	Mitigate risk	■■■■■■■ 7
	Enhance agility	■■■■■ 5
	Ensure material supply	■■■ 3
	Enhance ESG standards	■■■ 3
	Optimize working capital	■■ 2
	Others	■■ 2
	Increase autonomy	0
	Foster innovation	0
Procurement processes and tasks	Controlling & Reporting	■■■■■■■■■■■■ 12
	Organizational Development & Process Management	■■■■■■■ 7
	Supplier Relationship Management & Partnering	■■■■■ 5
	Category & Sourcing Strategy Definition	■■■■ 4
	Risk Management	■■■■ 4
	Sustainability & Compliance	■■■■ 4
	Approval & Ordering	■■ 2
	Negotiation	■ 1
	Others	■ 1
	Supply Market Monitoring	■ 1
	Tendering	■ 1

Table 25: Dashboard illustrating frequency distribution in the Benefits (Advantages) category

This overview indicates two distinct types of cases at the company level. On the one hand, there are Procurement 4.0 applications introduced to address a specific purchasing problem, as reflected in the targeted and comparatively lower number of potential benefits (Comp1, Comp3, Comp5). On the other hand, cases Comp2 and Comp4 involve solutions that span a broader range of procurement processes and tasks, which is evident from the larger number of associated benefits.

Regarding the objectives pursued in the five cases studied, internal support (17)—albeit a broad category—time reduction (14), and quality improvement (11) stand out. This suggests that the typical automation potentials of *time savings* and *quality improvements*, as identified in the literature (Flechsig et al., 2022, pp. 5–6), are also evident in this case study analysis of Procurement 4.0 applications. Cost reductions and risk minimisation were likewise observed. The absence of direct evidence for increased autonomy or the promotion of innovation represents a limitation within the selected cases. However, indirect effects may exist, as in the case of Comp3, for example, where such outcomes could emerge over time as a result of an improved category strategy development.[32]

In terms of procurement processes and tasks, the applications examined demonstrate particular relevance to *Controlling & Reporting* (12), *Organisational Development & Process Management* (7), and *Supplier Relationship Management & Partnering* (5). This is consistent with the application potential identified in the theoretical framework (see Figure 8: Procurement 4.0 application heatmap).

All benefits mentioned in the case interviews are listed in Table 26 below, categorised by procurement processes and tasks, as well as by the predefined procurement objectives to which they contribute.

[32] For example, through long-term supply relationships for strategic items or backup plans for bottleneck items (Kraljic, 1983, p. 112).

Category	Factor		Description	Procurement objectives			Case
Controlling & Reporting	A01	Improvement of reporting	AI assistants like 'Joule' enhance analyses and graphical representations, thereby continuously improving reporting significantly.	Internal support			Comp2
	A02	Quantification and monitoring of cost savings realization	Cost savings from each initiative can be accurately quantified retrospectively and are monitored within Cirtuo.				Comp3
	A03	Industry benchmark	The system maps the industry with thousands of suppliers worldwide and numerous sites, providing a comprehensive benchmark.				Comp4
	A04	Supply chain understanding	Various data streams, programs, and processes provide a comprehensive understanding of the supply chain and its overall scope ('big picture').				
	A05	Well-informed decision-making	The system serves as a reliable source, delivering real-time data essential for informed decision-making.				
	A06	Unified data for an unfiltered real-time view	All hierarchical levels have access to the same data, visualization, and dashboard, ensuring transparency and preventing data manipulation or misrepresentation. This guarantees a real-time, unfiltered view of the facts.				
	A07	Workload reduction	Previously, preparing for an Inventory Management Review, which involved procurement, planning, operations, and other teams, required two weeks of collaboration and extensive data collection. However, by the time the meeting occurred, much of the information was outdated. Today, a two-week lead time is impractical due to rapid changes in the supply chain and global landscape. The system standardises this review process by defining key focus areas. With predefined dashboards and configured filters, only an internet connection is needed.	Improve quality	Reduce time	Optimize working capital	
	A08	Internal benchmarking	The system enables global comparisons within the company. For example, a supplier serves 15 sites. Through the system, internal benchmarks can be identified based on key metrics. If a supplier has reduced delivery time by X days at one site, yet it still exceeds delivery times at other sites on different continents, this can be identified within seconds, revealing opportunities for improvement.			Internal support	
	A09	Automatic information visualization	Information visualization, which was previously manually compiled using Excel and PowerPoint after data collection, is now automated. This effort has been eliminated. Data is directly extracted from the ERP system and visualized through individual dashboards, without the need for manual intervention.				
	A10	Supplier performance monitoring	The system offers insights into supplier performance, including how flexibly they adapt to company-driven shifts due to changes. Supplier flexibility and performance are now tracked, a capability that was previously unavailable at this scale—monitoring the global performance of supplier sites and the overall picture.	Improve quality	Ensure material supply	Enhance agility	
	A11	Procurement performance monitoring	The performance of individual groups or at the buyer level can also be monitored. Key metrics, areas of focus, and the reasons preventing the achievement of these metrics are identifiable. The system enables tracking and filtering of this information, ensuring transparency.				

<table>
<tr><th>Category</th><th colspan="2">Factor</th><th>Description</th><th colspan="3">Procurement objectives</th><th>Case</th></tr>
<tr><td></td><td>A12</td><td>Cross-plant inventory monitoring</td><td>Monthly reviews of the inventory situation are conducted in each segment to avoid idle capital. Collecting information from each factory would be a cumbersome task for a segment manager. However, with the system, all factories and key metrics are continuously monitored.</td><td colspan="3">Optimize working capital</td><td></td></tr>
<tr><td rowspan="7">Organizational Development & Process Management</td><td>A13</td><td>Process standardisation</td><td>The use case resulted in emotional aspects and relationship dynamics being deprioritised, making business collaboration more stringent yet fairer, while also increasing savings through SAP Ariba.</td><td>Improve quality</td><td>Mitigate risk</td><td rowspan="2">Reduce costs</td><td rowspan="2">Comp2</td></tr>
<tr><td>A14</td><td>Process conformance</td><td>An increasing number of purchases are now made through catalogues with discounted rates. Previously, procurement processes were frequently bypassed. Even low-value items are now procured via catalogues, contributing to overall cost efficiency.</td><td colspan="2"></td></tr>
<tr><td>A15</td><td>Increase in productivity</td><td>The system’s time-saving benefits enabled a gradual increase in workload per employee. Without these efficiencies, additional staff would have been necessary to manage the workload. Measured results showed an improvement in employee efficiency of up to 25%. Within the same working hours, employees could handle more parts, suppliers, and orders. This allowed the business to support growth without expanding the team. Without this system, the current level of operational efficiency would not be attainable.</td><td colspan="3" rowspan="2">Reduce time</td><td rowspan="3">Comp4</td></tr>
<tr><td>A16</td><td>Focus on core tasks</td><td>Real-time information access eliminates the need for employee involvement in data preparation. Employees can focus on core tasks rather than reports while having access to the required information.</td></tr>
<tr><td>A17</td><td>Real-time collaboration</td><td>An action tracker monitors tasks from initiation to completion, driving progress. Dashboards track results and optimize processes to support continuous improvement. Over time, early issue detection and consolidated data distribution ensure that employees have timely access to critical information. This enables real-time collaboration, preventing costly delays. Ultimately, the system helps the company maintain a responsive, resilient, and secure supply chain.</td><td>Mitigate risk</td><td>Reduce costs</td><td>Enhance agility</td></tr>
<tr><td>A18</td><td>Automated documentation</td><td>5,000 employees in the company use the Pro version of Copilot, which automatically generates meeting minutes and highlights key elements, such as decisions.</td><td rowspan="2">Internal support</td><td colspan="2">Reduce time</td><td rowspan="2">Comp5</td></tr>
<tr><td>A19</td><td>Rapid information gathering and source traceability</td><td>The initial response from Copilot enables immediate action and further progress. Additionally, the sources used are visible, which is beneficial as it allows for an assessment of the information's quality.</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Supplier Relationship Management & Partnering</td><td>A20</td><td>Automated data transfer</td><td>Suppliers enter their data, and the transfer to the ERP backend, previously done manually, is now automated. In Europe, 1,350 suppliers are fully registered via SAP Ariba and ready for S4/HANA integration.</td><td>Reduce time</td><td colspan="2"></td><td rowspan="2">Comp2</td></tr>
<tr><td>A21</td><td>Supplier evaluation</td><td>Questionnaires are collected from suppliers in a standardised manner, stored in Ariba, and considered selectively—but not yet comprehensively—in supplier evaluations.</td><td colspan="3">Internal support</td></tr>
</table>

<table>
<tr><th>Category</th><th colspan="2">Factor</th><th>Description</th><th colspan="3">Procurement objectives</th><th>Case</th></tr>
<tr><td rowspan="3"></td><td>A22</td><td>Guided creation of a supplier dossier</td><td>Globally, 120 critical suppliers are strategically managed. For each, an electronic supplier dossier is created, detailing spend, revenue, competitor spend within the category, and the supplier collaboration strategy.</td><td colspan="3"></td><td>Comp3</td></tr>
<tr><td>A23</td><td>Efficient consolidation of business meetings</td><td>At a major trade fair, meetings can be efficiently consolidated. In just three days, 40 meetings, each lasting 30 to 45 minutes, can be scheduled to address performance issues or similar topics at the CEO level without the need for global travel. This is possible because there is no need to prepare data or worry about prior events, as dashboards automatically update. This allows for immediate focus on discussing key topics instead of preparing and following up on 40 meetings. Similarly, on business trips, where multiple countries are visited over several days to meet with suppliers, time spent traveling between airports, hotels, and meeting rooms makes it impossible to prepare presentations. Even if prepared in advance, the data may be outdated, leading to tedious debates on data reliability.</td><td>Reduce time</td><td>Reduce costs</td><td rowspan="2">Improve quality</td><td rowspan="2">Comp4</td></tr>
<tr><td>A24</td><td>Increased supplier transparency</td><td>The supplier has become more transparent. Previously, a supplier might serve multiple company factories across different locations, but there was a lack of cross-site knowledge, allowing the supplier to conceal certain information. For example, if a supplier was asked whether they could offer Vendor Managed Inventory and declined, the discussion would conclude there. Today, however, it is possible to determine whether a supplier really cannot provide the service, or if it is unavailable at a specific site but offered at others. This enables the negotiation process to be resumed.</td><td colspan="2">Internal support</td></tr>
<tr><td rowspan="4">Category & Sourcing Strategy Definition</td><td>A25</td><td>Generating recommendations for strategy development</td><td>As part of the Guided Strategy, the system generates recommendations such as opening the market, consolidating purchases, integrating new technological aspects, renegotiating terms, and engaging stakeholders based on a predefined set of questions.</td><td colspan="3" rowspan="2">Internal support</td><td rowspan="4">Comp3</td></tr>
<tr><td>A26</td><td>Guided creation of a material group dossier</td><td>The system guides purchasers through a structured process where they answer specific questions and enter data while receiving system-generated analyses. This results in a material group dossier that details the category’s purpose, benefits, scope, latest technologies, risk considerations (e.g., Kraljic Matrix), key strategic suppliers, and relevant levers.
In summary, the dossier highlights critical issues within the material group and defines necessary actions for the next three to five years—outlining projects to reduce costs, enhance quality, and address key pain points and opportunities.</td></tr>
<tr><td>A27</td><td>Accelerated development of high-quality strategy dossiers</td><td>Previously, category strategies were developed in Word or PowerPoint, with data manually gathered from various sources using screenshots. System integration has enhanced strategy quality while reducing the manual effort required to compile 30-page dossiers. Since only a few parameters, such as risk, need adjustment, strategy revisions are now significantly faster.</td><td rowspan="2">Reduce time</td><td></td><td rowspan="2">Improve quality</td></tr>
<tr><td>A28</td><td>Full coverage in strategy development</td><td>Previously, only 25% of strategies at the supplier and category level, including reviews, could be developed. Now, full coverage is possible.</td><td></td></tr>
</table>

Category	Factor		Description	Procurement objectives		Case
Risk Management	A29	Risk mitigation	Insights provided by the dashboards enable risk mitigation before they escalate into major disruptions.	Mitigate risk	Ensure material supply	Comp4
	A30	Structured crisis management	Given the complexity of the global supply chain, a structured crisis management approach has been implemented. Depending on the signal, various scenarios can be activated. For instance, not every part shortage constitutes a crisis, as such shortages are part of daily operations. However, regional or global events—such as natural disasters, strikes, or geopolitical developments (e.g., Russia-Ukraine)—can have a significant impact on the supply chain. In these cases, specific mechanisms are triggered. The company follows a defined protocol, starting with an analysis at the team leader level to assess the affected products, customers, and production lines. Internal and customer-facing communication is standardized through a single channel to avoid fragmented email exchanges. Once the crisis is resolved, operations return to normal. This form of crisis management was not as prominent in the past, but it has gained significance, particularly due to the COVID-19 pandemic.		Enhance agility	
	A31	Identification of cause-and-effect relationships in supply chain disruptions	Geopolitical issues and natural disasters (e.g., typhoon season in Asia) are daily challenges in procurement. Digitalization and the implemented system facilitate oversight by enabling the immediate identification of affected products, customers, production lines, or shifts when a supplier fails. By linking information such as item numbers, purchase orders, or suppliers, it is possible to quickly pinpoint where adjustments or actions are required.			
	A32	Risk alert	The AI-based risk management tool, Prewave, alerts the company to potential risks.			Comp5
Sustainability & Compliance	A33	Workload reduction	The current process is time-consuming, as analysing a response can take up to an hour due to the extensive volume of text—sometimes several hundred pages—that still needs to be translated. This applies to 5,000 suppliers, enabling an extrapolation of potential cost savings.	Reduce time	Reduce costs	Comp1
	A34	Error detection	All errors in the test data were fully identified, and the relevant text passages were highlighted, ensuring easy verification.		Improve quality	
	A35	Sustainability consideration in bid evaluations	Ratings provided by the sustainability assessment partner EcoVadis are integrated into SAP Ariba, readily accessible, and systematically incorporated into bid comparisons.	Enhance ESG standards	Internal support	Comp2
	A36	Workload reduction	The effort required to investigate a supply chain issue arising from allegations and assess the own company's position has been significantly reduced through the use of Prewave and Copilot, with the latter providing information about any firm.		Mitigate risk	Comp5
Approval & Ordering	A37	Automated ordering	In standard SAP Ariba, automatic purchase orders are created for numerous suppliers. Through EDI, suppliers receive orders directly from SAP ERP into the SAP Ariba Network. Previously, orders were sent via email with a PDF attachment, a process that remains in use for suppliers not integrated into Ariba.	Reduce time		Comp2
	A38	Automated pre-filling for catalogue orders	The catalogue solution features a recommendation system that automatically pre-fills certain fields when a material is reordered.		Improve quality	

Category	Factor		Description	Procurement objectives			Case
Negotiation	A39	Successful tender negotiations	No employees are made redundant; savings are achieved through successful negotiations and tracked in SAP Ariba tenders.	Reduce costs			Comp2
Others	A40	Management of complex product and supplier structures	Supply chain digitalization enables the management of thousands of item numbers for customers across diverse market segments, involving thousands of direct suppliers. Advanced data analytics technologies support the operation of a highly complex and resilient supply chain.	Ensure material supply	Internal support	Others	Comp4
Supply Market Monitoring	A41	Market insights	The system enables the creation of a Market Intelligence Report that analyses market developments and is shared with customers on a quarterly basis.	Enhance agility			
Tendering	A42	E-auction savings	E-auctions in Ariba generate additional and unexpected cost savings.	Reduce costs			Comp2

Table 26: Benefits of implementing procurement 4.0 applications in practice

The identified potential benefits support well-informed internal decision-making (A05) by improving reporting (A01), quantifying cost savings (A02), enabling comparisons (A03), and enhancing understanding of the supply chain (A04). Time savings are also explicitly reported whether through a reduction in workload (A07) related to information gathering for meetings, the automatic visualisation of data (A09), or the documentation of meetings (A18) itself. These examples indicate potential for more efficient procurement controlling, which may enhance both the effectiveness and efficiency of procurement by improving the provision of information and, consequently, planning and control (Schentler and Tschandl, 2016, p. 27).

Further examples of time savings include automation in data transfer (A20), accelerated development of high-quality strategy dossiers (A27), and the automatic evaluation of supplier responses as part of the SAQ collection process (A33). Factor A27 (less time, more quality) illustrates how automation can contribute to simultaneous optimisation within the traditional process target triangle, which consists of the equally weighted dimensions of time, cost, and quality (Brunner et al., 2017, p. 11). In contrast, A33 (less time, lower costs) demonstrates that time savings—here, in simplified terms, extrapolated to up to 5,000 hours—can yield substantial cost advantages.

In the area of risk management, Comp4 reports several potential benefits, including risk reduction (A29), structured crisis management enabled by the solution (A30), and the identification of cause-and-effect relationships in supply chain disruptions. Factors A30 and A31 further illustrate how structured, active risk management can enhance agility by supporting the ability to manage uncertainty effectively and to respond rapidly to change (Mrugalska and Ahmed, 2021, pp. 2 & 11). This is also supported by the market intelligence teport in Comp4, which is shared with customers (A41). This introduces an interesting additional aspect to the Procurement 4.0 discussion. It aligns with common themes in Industry 4.0, namely that digitalisation may also provide a foundation for new service offerings (in this case, the market intelligence report), creating opportunities to develop new business models (Kagermann, 2014, pp. 606–609; Kleinemeier, 2014, p. 572). This could strengthen customer relationships and potentially evolve into a monetisable new business model (Schlick et al., 2014, p. 82; Schöning and Dorchain, 2014, p. 548).

The use of technology also contributes to the enhancement of ESG standards. In Comp1, the AI could identify all errors in the test data (A34). In future, this may allow critical suppliers to be preselected automatically through SAQs, thereby supporting the development of a sustainable supply chain. In Comp2, EcoVadis ratings are integrated into Ariba and included in bid comparisons (A35). This allows sustainability considerations to be considered during tendering and supplier selection, thereby facilitating a more sustainable supply chain. In Comp5, tools and AI are used to investigate supply chain issues arising from allegations, which also contributes to the strengthening of ESG standards.

The presented benefits illustrate the diverse and concrete potential that the integration of advanced technologies into procurement can offer through specific Procurement 4.0 applications. Considering that understanding the value of Procurement 4.0 has proven difficult in the past (de la Boulaye et al., 2017) and remains a challenge (Joseph Jerome et al., 2022, p. 224), the clearly demonstrated benefits identified here may support the implementation of such applications (Jahani et al., 2021, p. 2).

4.3.2.7. Actionable practical recommendations

The final set of identified factors pertains to practical recommendations ('P') for the implementation of Procurement 4.0 applications. These 20 recommendations were obtained both through direct inquiry and by analysing responses related to the approach for implementation (see interview guideline in Table 9).

(7) Actionable recommendations		20	
Cases	Comp1	■■■■■■■■ 8	Frequencies
	Comp2	■ 1	
	Comp3	■■■■■■■ 7	
	Comp4	■■ 2	
	Comp5	■■ 2	
TOE	Technology	■■■■ 4	
	Organization	■■■■■■■■■■■■■■■■ 16	
	Environment	0	
Categories	Project Management	■■■■■■■■ 8	
	Data Management	■■ 2	
	Solution	■■ 2	
	Finance	■ 1	
	Innovation	■ 1	
	IT Security	■ 1	
	Organisational Structure	■ 1	
	Prioritization	■ 1	
	Process Management	■ 1	
	Strategic Management	■ 1	
	Technology Readiness	■ 1	

Table 27: Dashboard illustrating frequency distribution in the Actionable Practical Recommendations category

This evaluation shows that most actionable recommendations were identified in Comp1 (8), where the implementation process was still ongoing at the time of the interview, and in Comp3 (7). Both cases focused on a specific, narrowly defined procurement problem.

In the other cases, however, only a quarter of the factors were found. The organisational context (16) also appears to play the most important role in the introduction of Procurement 4.0; no environmental factors were identified. In terms of categories, project management is the most prominent (8), followed by a wide range of areas in which actionable recommendations have emerged. The individual factors are presented in Table 27 and discussed below. Because several aspects in this main deductive category—similar to those in ‘opportunities’—were not explicitly linked to the case, an ‘x’ is included in the outermost column of the table to indicate whether a factor was case-specific or arose during a broader, thematically relevant discussion in the interview.

Category	Factor		Description	TOE	Case	
Project Management	P01	Design a rollout scenario and project setup	A rollout scenario and the project setup will be defined.	Organization	Comp1	x
	P02	Conduct a pragmatic PoC using test cases	During a pragmatic PoC phase, the company created test cases with intentionally incorrect data, which were evaluated by the solution provider. The outcome of these tests was critical for the subsequent process. In this instance, the results were satisfactory, as all embedded errors were successfully detected.			x
	P03	Follow a gradual, step-by-step approach	The supply chain is undergoing significant change in terms of sustainability. While the future direction remains uncertain, progress is being made step by step.			x
	P04	Implement a structured approach to solution selection, including a specification sheet	A systematic selection process, initiated with a call for tenders and a specification sheet, culminated in inviting the top providers to a "beauty contest". They presented their proposals, and the selection was made based on their presentations and pricing.		Comp2	x
	P05	Analyse relevant elements of the as-is situation	Before digitalizing the development of the category strategy, it is recommended to analyse the current situation. This includes assessing the number of strategic buyers, the characteristics of product groups, and the ERP database in terms of homogeneity and data accuracy. The solution should only be implemented after the database has been cleaned up and consolidated.		Comp3	x
	P06	Implement the full scope gradually	The entire project spanned over two years from initiation to go-live. During the preparation phase, main KPIs were defined, and efforts were made to visualize them within the system. This was initially done to a limited extent, with the full scope being developed progressively over time.		Comp4	x
	P07	Analyze the as-is situation and define the necessary requirements and objectives	On the one hand, it is important to determine the requirements for such a solution—such as the necessary data, its intended use, and the objectives to be achieved. This includes identifying the decisions to be made based on the data and the resulting implications, such as whether it will be used to control processes. These considerations are essential.			x

Category	Factor		Description	TOE	Case	
	P08	Follow a structured tool selection process and invite selected providers to pitch their solutions, incorporating the evaluations into the final decision	The selection process follows a structured approach in which the purchasing departments conduct market inquiries based on a predefined catalogue of core requirements. Following the evaluation of received proposals, a decision is made regarding which providers will be invited to present their system. Prior to this, the company identifies relevant stakeholders, informs them about the process, and invites them to participate in the presentations. These stakeholders include end users and individuals in interface functions who will be directly affected by the IT system. The presentations are conducted in tightly scheduled meetings lasting between two and three hours. During these sessions, solution providers showcase their systems and functionalities, while participants engage by asking questions. After the presentations, attendees complete a structured survey to assess each tool based on a predefined evaluation framework. The results of this survey serve as a fundamental component in the final decision-making process regarding the selection of a provider.		Comp5	
Data Management	P09	Clean up and consolidate the database beforehand	The solution should only be implemented after the database has been cleaned up and consolidated.		Comp3	x
	P10	Analyse the current state, with an emphasis on the data infrastructure	Prior to implementation, it is essential to analyse the existing situation, which includes strategic purchasing, the material groups, and the level of engagement with these elements, as well as the ERP database. Most importantly, accurate data is a fundamental prerequisite for the successful implementation of the solution.	Technology		x
Solution	P11	Host a solution demonstration	The solution provider presented the solution and demonstrated its functionality and application. This strongly resonated with the company's expectations, leading to the realization that it aligned well with their envisioned requirements and represented a beneficial solution.			x
	P12	Monitor and assess the system continuously to achieve robustness	The system must be initially monitored and assessed to verify its reliability. In subsequent operations, random checks will be conducted, and as the solution proves its robustness, the need for such oversight will gradually decrease.		Comp1	x
Finance	P13	Establish financial mechanisms for flexible short-term IT investments	The solution was not budgeted, as it is a group-wide solution whose costs are covered by the group rather than the division. Additionally, if budgeting were required first, the purchase could only be made a year later.	Organization		x
Innovation	P14	Organize a digitalization day to identify and develop use cases	The business case was initiated by the interview partner during a company-hosted Digitalisation Day, which centered on the topic of AI and the development of AI use cases. The use cases identified during the event were assessed in a plenary session, leading to the formulation of the business case.			x
IT Security	P15	Perform IT security, data protection and compliance checks to assess solution security	The solution is secured from an IT security and data protection perspective, including a cloud compliance check and a review of all relevant IT aspects. This covers processes, protocols, certifications, storage, and access rights. Digitalization has made previously unaddressed concerns critical, such as cyber-attacks—due to the near-universal connectivity of machines—and legal frameworks like the EU's AI Act.			x
Organisational Structure	P16	Establish oversight responsibility for the solution	The responsibility for overseeing the AI solution needs to be defined and will be managed through the company's digital agency.			x

Category	Factor		Description	TOE	Case	
Prioritization	P17	Focus on advancing and implementing a digitisation initiative while assessing additional technologies	The company is monitoring several technologies, such as RPA, but does not want to tackle everything at once. It is therefore prioritizing the rapid implementation of SAP digitization. Once this is complete, the company will assess which technologies can be integrated at system interfaces.		Comp3	
Process Management	P18	Refine appropriate solutions to address key challenges and ensure continuous improvement	The company already has processes and tools that align with the goals of the presented use case. However, they are being evaluated for potential improvements. During a research and assessment phase, the focus is on identifying the most suitable tools to support the company at a group-wide level.		Comp5	x
Strategic Management	P19	Procurement Excellence strategy	As part of its Procurement Excellence strategy, the company is continuously working to improve training, systems, processes, and the organizational distribution of responsibilities.		Comp3	
Technology Readiness	P20	Test the solution to identify its strengths and weaknesses	The solution was tested with the strategic lead buyers and performed well in direct material. However, its effectiveness in system procurement was limited due to the more complex background knowledge required.	Technology		x

Table 28: Actionable practical recommendations for the adoption of advanced technology in procurement

In the project management category, relevant factors were identified across all five cases, offering guidance in the form of actionable recommendations. One group of recommendations refers to the importance of a step-by-step approach (P03, P06), while another highlights the necessity of conducting concrete analyses (P05, P07). In addition, the value of a structured approach in areas such as tool selection is emphasised (P04, P08).

These elements are consistent with common Industry 4.0 procedure models (Pessl et al., 2017, pp. 193–195), which suggests the potential relevance of developing Procurement 4.0 roadmaps. This gap is also recognised in both the scientific and grey literature on Procurement 4.0 (de la Boulaye et al., 2017; Flechsig et al., 2022, p. 3; Joseph Jerome et al., 2022, p. 219; Karumsi and Prokopets, 2023, p. 19; Viale and Zouari, 2020, p. 7), and the various aspects from different categories presented here may be seen as potential building blocks for company-specific Procurement 4.0 roadmaps. In this context, it is worth noting that Trautmann (2021, p. 102) discusses the agile dimension of digitalisation, which results in a preference for shorter sprints over long-term roadmaps, and proposes integrating this aspect into dynamic roadmaps. A similar perspective is evident in P03 at Comp1, where the respondent stated that, as with other topics, it is not clear where one will be at a defined point in the future with regard to sustainability, and that progress is instead made step by step.

4.3.3. Conceptual typification of the five case studies

In conclusion, this section summarises the results of the multiple case study and attempts to develop a tentative typology of the five cases based on their main characteristics, with the aim of informing a conceptual framework that may be validated in future research.

To this end, the main deductive categories are assigned to two overarching areas. The first comprises the success factors, while the second brings together challenges, risks, and barriers under the label of ‘pain points’. The category of ‘opportunities’ is not included in this evaluation, as it contains aspects that are not directly related to the cases. The actual potential benefits identified within the cases—serving as the opportunities derived from this multiple case study—will be presented separately at a later stage. Similarly, the practical, actionable recommendations are excluded from this section. On the one hand, they include elements that are not case-specific; on the other, they were not analysed with the aim of conceptualising the topic, but rather to derive practitioner-oriented recommendations for similar implementation projects.

This study identified a total of 94 factors across the categories (Table 29). Success factors form the most prominent category with 49 factors, followed by challenges (25), which—together with risks (13) and barriers (7)—are summarised as ‘potential pain points’, representing a similarly prominent area of discussion. While the success factors could be directly derived from the cases, the pain points reflect aspects identified by interviewees as relevant to the implementation and are therefore labelled as ‘potential’ pain points.

TOE-Framework	**Success Factors**	**Potential Pain Points**			Σ
		Challenges	Risks	Barriers	
Technology	6	6	6	4	22
Organization	42	12	6	1	61
Environment	1	7	1	2	11
Σ	49	25	13	7	94

Table 29: Overview of 94 success factors and pain points

Within the TOE categories, the organisational dimension emerges as particularly prominent—especially in relation to success factors—with 42 such factors identified. However, this emphasis shifts when examining potential pain points, where the technological and environmental dimensions gain greater relevance, indicating increased complexity in addressing the challenges, risks and barriers identified.

To categorise the five cases according to their *application profiles*—represented by the identified main characteristics—and to support the development of a conceptual framework for future validation, the analysis is extended in Table 30 through a heatmap based on two additional deductive analytical grids. The first captures the benefits achieved in relation to procurement objectives, indicating *effects* (Lysons and Farrington, 2012b, p. 54; Schentler and Tschandl, 2016, pp. 33–34), visualised in green. The second reflects the procurement processes supported (see reference framework developed in Chapter 2.3), shown in shades of turquoise to indicate *implementation areas*. Evaluation categories are arranged in descending order of frequency. The numbers within the cells show the quantity of distinct factors within the respective category identified per case. In addition, success factors and potential pain points are presented for each case, structured according to the inductively derived categories and their cross-case frequency.

Table 30 highlights the heterogeneity of Procurement 4.0 applications implemented in practice. The greatest application potential emerges in *Controlling & Reporting*, with three cases contributing to this area. Similarly, in line with the *Internal Support* target dimension, three cases show a positive impact on *Organizational Development and Process Management*. The cases also show promise for *Supplier Relationship Management and Collaboration*: examples within the categories include supplier evaluation (Comp2), strategic supplier management (Comp3), and improved efficiency in cooperation (Comp4). The *Sustainability and Compliance* task area is also marked by three blue fields. Comp1 and Comp5 demonstrate the use of technology motivated by sustainability objectives. In addition, Comp2 has integrated sustainability ratings into SAP Ariba and can systematically include them in bid evaluations.
When examining success factors and potential pain points, *Process Management* emerges as a recurring aspect in both, with three mentions each across the cases. *Leadership*, alongside *Project Management* and *Education and Training*, is also more prominent among the success factors. In contrast, regarding potential pain points, the technological *Solution* itself is the most frequently mentioned issue, while the remaining factors appear more scattered and case specific. These findings suggest a tension between the solution, the process, the implementation project, training, and leadership when introducing Procurement 4.0 technologies into an organisation, indicating that successful adoption may depend on more holistic and integrated approaches.

Evaluation Categories		Comp1	Comp2	Comp3	Comp4	Comp5
Targeted Objectives	Internal support		4	4	7	2
	Reduce time	1	3	2	6	2
	Improve quality	1	2	2	6	
	Reduce costs	1	4		2	
	Mitigate risk		1		4	2
	Enhance agility				5	
	Ensure material supply				3	
	Enhance ESG standards	1	1			1
	Optimize working capital				2	
Improved Processes and Tasks	Controlling & Reporting		1	1	10	
	Organizational Development & Process Management		2		3	2
	Supplier Relationship Management & Partnering		2	1	2	
	Category & Sourcing Strategy Definition			4		
	Risk Management				3	1
	Sustainability & Compliance	2	1			1
	Approval & Ordering		2			
	Negotiation		1			
	Others				1	
	Supply Market Monitoring				1	
	Tendering		1			
∑		2	10	6	20	4
Success Factors: Categories discovered in…	…4 cases	• Project Management	• Leadership • Project Management	• Leadership • Project Management	• Leadership	• Leadership • Project Management
	…3 cases		• Education and Training • Process Management	• Education and Training • Process Management	• Education and Training • Process Management	
	…2 cases	• Corporate Culture • Organisational Structure • Technology Readiness	• Communica-tion • Solution • Strategic Management		• Communica-tion • Corporate Culture • Organisational Structure • Prioritization • Solution • Strategic Management	• Technology Readiness
	…1 case	• Innovation • Technological Benefits	• Project Organization	• Skills and Competences • Solution provider	• Data Management	• Risk Management
Potential Pain Points: Categories identified in…	…4 cases	• Solution	• Solution	• Solution	• Solution	
	…3 cases		• Process Management		• Process Management	• Process Management
	…2 cases	• IT Security • Supplier Relationship	• Supplier Relationship	• IT Security • Procurement Complexity	• Attitude	• Attitude • Procurement Complexity
	…1 case	• AI-driven Business Interactions • Organisational Structure • Risk Management • Tech Vigilance	• Implementa-tion • Infrastructure	• Data Management • IT Resources • Skills and Competences • Solution Provider	• Evolving Technologies • Leadership • Over-engineering • Prioritization • Project Management	• Communica-tion • Finance • Technology Readiness

Table 30: Procurement 4.0 application profiles: effects, implementation areas, and key factors

In summary, while each case focuses on different primary objectives, there are clear synergy effects across other tasks and sub-processes. These are more evident in broader applications (Comp2 and Comp4) than in more narrowly focused solutions (Comp1), which nevertheless offer significant added value and support technology acceptance. This evidence allows for the derivation of five tentative (arche)types of technology engagement, based on the observed patterns of overlap and difference, each reflecting a distinct focal point within the cases examined.

(1) *Innovator*: Case 1 demonstrated that Comp1 actively experiments with technologies and possesses the structures (e. g. 'Digitalisation Day' to generate new use cases) and culture necessary to embrace innovative approaches, which is why it is referred to as an *Innovator*. As the case is still in the introductory phase, comparatively few benefits have been documented. Nonetheless, the potential of applying AI in this context became evident at an early stage—the interview was conducted two months after efforts relating to the use case were initiated. As the current process is time-consuming—with the analysis of a single response taking up to an hour due to the large volume of untranslated text—the application to 5,000 suppliers allows for an extrapolation of potential cost savings, thereby demonstrating the value of process automation in this context.

(2) *Organiser*: Case 2 shows that Comp2 has achieved standardisation of a multitude of processes on a global scale through the platform, which is why it is referred to as an *Organiser*. The solution affects a total of seven procurement sub-processes and tasks, thereby having the greatest organisational impact. This has also increased the degree of automation in purchasing; for example, automatic purchase orders are created for numerous suppliers while previously, orders were sent via email with a PDF attachment, a process that remains in use for suppliers not integrated into Ariba.

(3) *Strategist*: Case 3 illustrates that the company was able to optimise its strategic category management through a specific and co-developed solution, which is why it is referred to as a *Strategist*. The solution is particularly noteworthy for the support it provides to employees in strategy development, which falls under the category of 'augmentation'. At the same time, the process itself has been significantly accelerated. Whereas previously only 25% of strategies were developed at the supplier and category level, the system now enables 100% coverage. Previously, category strategies were developed in MS Word or PowerPoint, with data manually gathered from various sources using screenshots. System integration has enhanced strategy quality while reducing the manual effort required to compile 30-page dossiers. Since only parameters, such as risk, need adjustment, strategy revisions are now significantly faster.

(4) *Optimiser:* Case 4 demonstrates the greatest number of improvements, particularly in terms of time and quality, achieved through data-driven supply chain management in procurement, which is why it is referred to as an *Optimiser*. For example, previously, preparing for company internal steering meetings such as the ‘inventory management review’, which involves procurement, planning, operations, and other teams, required two weeks of collaboration and extensive data collection. However, by the time the meeting occurred, much of the information was outdated. The system facilitates standardisation of this process and provides predefined dashboards and configured filters, enabling real-time access to information. Furthermore, the system’s time-saving benefits enabled a gradual increase in workload per employee. Without these efficiencies, additional staff would have been necessary to manage the workload. Measured results showed an improvement in employee efficiency of up to 25%. Within the same working hours, employees could handle more parts, suppliers, and orders. This allowed the business to support growth without expanding the team.

(5) *Protector:* Case 5 highlights the diverse opportunities offered by technology use and process management that contribute to risk minimisation in a preventative manner and enhance responsiveness to sustainability issues. For this reason, it is referred to as a *Protector*. Moreover, the application offers potential to reduce the workload too. For example, the effort required to investigate a supply chain issue arising from allegations and assess the own company's position has been notably reduced.

These five types, derived from the cases, do not imply that the remaining characteristics are absent in other cases. On the contrary, the heatmap shows that 10 of 28 success factor categories and 6 of 26 pain point categories appear in more than one case. Rather, the typology summarises the focal points observed in each case.

4.3.4. Experts’ Perspectives on the Practical Application of AI in Procurement

Due to the limited number of practical examples available on AI, and the lack of documented successful implementations in the literature, case studies on its application are particularly valuable for generating insights (Guida et al., 2023, p. 3; Vial et al., 2023, p. 670). Cases Comp1 and Comp5 already included Procurement 4.0 applications involving the use of AI. During the interviews (see Chapter 4.1.2.2 Development of the interview guideline), the interviewees were also asked to share their expert views on the application of AI in procurement. The main challenges and drivers are outlined below for each of the five companies.

4.3.4.1. Challenges

Comp1: In addition to the use case outlined above, Comp1 is also implementing an AI-powered digital avatar[33] to support purchase requisition creation in SAP. This use case was developed jointly with another company, with the aim of generating a fully accurate, IT-supported purchase requisition at the start of the process, thereby ensuring an error-free and efficient

[33] An avatar is a digital representation of an entity (e. g. specific person) that enables interaction in virtual spaces (Oladokun and Gaitanou, 2024, p. 1f). Recent advancements in AI have facilitated the development of AI-powered avatars (e.g., educational avatars) that exhibit human-like characteristics and interact within virtual environments (Fink et al., 2024, p. 1f). Accordingly, AI-powered Avatars are software programs that use AI to enable human-like digital characters to interact independently in virtual spaces.

process from the outset. However, this initiative was temporarily put on hold at the time of the interview, as the CSDDD issue was demanding more organisational effort than the anticipated benefits of the artificial requisition assistant could justify. This illustrates that the resource requirements associated with advanced technologies may also pose challenges for large companies.

The interviewee also pointed out that the potential of AI cannot yet be fully assessed, for example in terms of where AI functionalities could be made available across administrative areas. This suggests that one key challenge lies in identifying new use cases for AI. Comp1 is addressing this by holding workshops with external partners to explore potential applications and develop them into concrete use cases.

Comp2 already uses AI in production and is interested in procurement tools that go beyond sending alerts by using AI to predict where risks may arise in the supply chain. The company is currently exploring available AI-supported tools on the market; however, the solutions identified so far are not yet considered ready for use. This highlights the category of technology readiness, already addressed in the case studies, as a potential challenge.

In addition, the potential use case of category strategy development, as carried out by lead buyers, reveals that AI is evaluated differently across material groups. One interviewee, for example, considered strategic planning using GPT to be conceivable for metal parts, but stated that this was not a relevant topic for aluminium. As a result, the differing material groups may pose a potential challenge for the use of AI.

Comp3: At Comp3, the Copilot is already in use for software development tasks such as programming. In procurement, however, no AI applications had been implemented at the time of the interview. One planned initiative involves deploying an AI chatbot on the supplier hotline to handle frequently asked questions. Similar to Comp1, Comp3 also emphasised that the use of AI is currently limited only by imagination, with potential applications envisaged across various areas—including negotiations. This further illustrates the challenge that the precise value of AI remains difficult to determine.

A key challenge identified relates to the differing implications of AI errors in private versus business contexts. The identified challenge is that, while incorrect outputs from AI may be acceptable in private contexts, this is not the case in professional settings. In particular, in areas involving numerical data such as budgeting or financial reporting, errors are not permissible. In such contexts, an additional AI layer is needed to validate outputs, which increases complexity. According to the interviewee, LLM-based AI applications, such as drafting emails, work well. However, the application of AI in numerical contexts remains problematic. There is still a lack of AI solutions capable of reliably producing accurate, number-based results. This, similar to Comp2 where relevant tools are considered not yet sufficiently mature, points to a challenge in the area of technology readiness.

Comp4: already uses AI in quality control within production, where the inspection programme evolves by continuously learning from detected error patterns. However, at the time of the interview, Comp4 had not yet implemented any AI applications in procurement. The interviewee attributed this to the company's role as a contract manufacturer, which involves dependence on customer forecast requirements. While AI could potentially be used to predict demand in this context, deviating from customer forecasts would raise compliance concerns due to existing contractual obligations. This could pose a challenge in terms of the business model, as an AI use case (demand planning) that is seen as promising cannot be implemented due to compliance constraints associated with the company's role as a contract manufacturer. Nevertheless, the company is exploring what is technically feasible with AI, as it sees significant potential for its future application.

In addition, due to the high number of orders, there is perceived AI application potential in the full automation of C-parts procurement. This is justified by the argument that, in this area, the low value of the items means that the impact of an error caused by AI operating without human oversight would be less severe than in the case of A-parts. This reflects an underlying challenge: AI is still associated with a risk of error.

Comp5: In the case study on Comp5, several AI solutions had already been outlined. During the broader discussion on AI, the interviewee explained that a publicly available ChatGPT solution was not used; instead, a cloned version was employed due to data protection concerns. This points to a potential challenge: consumer-grade AI products may not offer the level of data protection required for professional or enterprise use.

Moreover, the discussion at Comp5 suggests that routine clerical work related to call-off orders, in its current form, is fully automatable and does not necessarily require AI, as the tasks involved are highly repetitive. However, in cases of process deviation—such as when a supplier initially confirms delivery but later reports issues like increased costs or a delay—AI support is considered useful for resolving such problems. In this context, AI could automatically process the supplier's information, compare it to the ERP system, and evaluate its implications. Nonetheless, communication with suppliers to clarify special cases and complex situations is not expected to be feasible through AI in the near future. As a result, AI will not completely replace human involvement but could free up resources for other tasks. This suggests a challenge in managing complex, exceptional cases using AI.

These challenges discussed in the interviews regarding the use of AI in procurement are summarised in Table 31.

Case	Challenge	Description	TOE
Comp1	Lack of resources	The digital avatar initiative was temporarily put on hold at the time of the interview, as the CSDDD issue was demanding more organisational effort than the anticipated benefits of the artificial requisition assistant could justify.	Organization
	Full potential not yet assessable	The potential of AI cannot yet be fully assessed, for example in terms of where AI functionalities could be made available across administrative areas. This suggests that one key challenge lies in identifying new use cases for AI. Comp1 is addressing this by holding workshops with external partners to explore potential applications and develop them into concrete use cases.	Technology
Comp2	Technology readiness	Comp2 is interested in procurement tools that go beyond sending alerts by using AI to predict where risks may arise in the supply chain. The company is currently exploring available AI-supported tools on the market; however, the solutions identified so far are not yet considered ready for use.	
	Material groups with differing characteristics	One interviewee considered strategic planning using GPT to be conceivable for metal parts but stated that this was not a relevant topic for aluminium.	
Comp3	Full potential not yet assessable	Similar to Comp1, Comp3 also emphasised that the use of AI is currently limited only by imagination, with potential applications envisaged across various areas—including negotiations.	
	Shortcomings of AI tools in quantitative areas	According to the interviewee, LLM-based AI applications, such as drafting emails, work well. However, the application of AI in numerical contexts remains problematic. There is still a lack of AI solutions capable of reliably producing accurate, number-based results.	
Comp4	Compliance-related limitation arising from the business model	While AI could potentially be used to predict demand, deviating from customer forecasts would raise compliance concerns due to existing contractual obligations as a contract manufacturer.	Organization
	Error susceptibility associated with AI	In C-parts procurement, the low value of the items means that the impact of an error caused by AI operating without human oversight would be less severe than in the case of A-parts, indicating that AI is still associated with a perceived risk of error.	Technology
Comp5	Data protection concerns	Consumer-grade AI products may not offer the level of data protection required for professional or enterprise use.	
	Managing complex, exceptional cases	Communication with suppliers to clarify special or complex situations is not expected to be feasible through AI in the near future. As a result, while AI may not fully replace human involvement, it can help free up resources for other tasks.	

Table 31: Summary of AI-related challenges raised during the interviews

The summary, with reference to the TOE categorisation, shows that the challenges discussed in relation to AI differ from the results of the case studies on implemented Procurement 4.0 applications presented in the previous chapter. Whereas organisational TOE factors accounted for the majority of challenges in those cases (12 out of 25), the challenges raised here predominantly concern the technology context (8 out of 10). This may be attributed to the relative novelty of AI. Nevertheless, the findings of the multiple case study suggest that the organisational context should not be overlooked when implementing a Procurement 4.0 application.

4.3.4.2. Drivers

This sub-chapter discusses the drivers[34] identified in the interviews for AI application in procurement, examined on a case-by-case basis.

[34] A driver is *'something that makes other things progress, develop, or grow stronger'* (Cambridge Dictionary, 2025)

Comp1: At Comp1, where Watson[35] was already deployed in procurement, the interviewee began engaging with AI amid the ChatGPT hype of 2023. Since then, interest in AI within procurement has grown as a means of addressing more complex topics. This suggests that technologically advanced companies—exemplified in this case by the use of Watson—may be more likely to recognise rapidly emerging trends, such as ChatGPT, and subsequently evaluate their potential.
One reason for applying AI at Comp1 is to automate routine knowledge work that, while not particularly innovative, demands significant time and human resources—for example, translation. The intention is to redeploy existing resources to value-adding work while assigning non-value-adding activities to AI. In this context, at the time of the interview, a wave of bureaucratisation was expected in connection with sustainability requirements. This was anticipated to create a need for collecting, analysing, and reporting data—an area seen as offering clear potential for automation.

Comp1 had also identified tasks that could be handed over to AI to reduce error rates, such as data entry and data extraction. This insight led to the development of an AI-supported digital avatar to assist in creating requisitions in SAP. The aim was to generate a fully accurate purchase requisition at the start of the process, thereby lowering the risk of subsequent errors.

Another potential use case was identified in the assignment of material groups within the material master data. This issue was being addressed in the context of an ongoing S4 transformation, as material master records require validation. Ensuring the correct material groups are applied—particularly where views may differ between plants—was also seen as a resource-intensive task. The idea was for the system to suggest material groups based on those assigned to the same material at other plants.

These examples point to two central drivers: making more effective use of limited resources and reducing error susceptibility. Both are common motivations for process automation initiatives in procurement, as demonstrated by the recent evolution of RPA (Flechsig et al., 2022, pp. 5–6). However, the interviewee also explicitly referred to engaging with more complex tasks—something that stands in contrast to the rule-based logic of RPA (Flechsig et al., 2022, p. 3). This may indicate that the full potential of AI in knowledge-based work remains difficult to assess.

Comp2: At Comp2, a global digital transformation team coordinates and ensures that procurement progresses towards AI adoption. Furthermore, the energy crisis highlighted that

[35] Nicoletti (2020, pp. 158–161) identifies Watson, developed by IBM, as a solution within the field of cognitive procurement. One practical application he highlights is contract management, where the Watson Contract Analyzer is designed to process extremely large volumes of text and identify the presence of specific clauses.

an AI that analyses big data to detect upward or downward price trends and identify shortages could offer valuable guidance for purchasing decisions.

In addition, the interviewees recognised the potential of AI to increase efficiency. The purchasing organisation typically negotiates amounts of €30,000 or more. For transactions below this threshold, negotiations are either absent or conducted unsystematically, for example by telephone. In such cases, AI could be applied to support negotiations and enhance cost savings.

Finally, areas where employees do not adhere to established processes or occasionally make errors—such as maverick buying or incorrect purchase requisitions—are seen as potential fields of AI application. The next step in optimisation would involve AI capable of learning from past mistakes and reducing recurring problems, for example by correcting input errors. Apparently, even technologically advanced companies—such as Comp2 in this case and Comp1 discussed earlier—continue to face challenges related to purchase requisitions within the operational P2P process. As a result, both are focusing on AI solutions in this area. This suggests that AI, which is rarely addressed in the literature in the context of operational procurement (see Figure 8: Procurement 4.0 application heatmap) compared to strategic procurement, also holds potential in this domain. Moreover, it indicates that the full automation of operational purchasing, as discussed at several points in this paper, has not yet been realised, not even in more digitally advanced companies. This may suggest that the P2P process is less rule-based than previously assumed and that more advanced technologies, such as AI, may be required to achieve full automation.

These findings suggest that engagement with AI is driven, first, by the institutionalisation of digitalisation; second, by strategic considerations such as forecasting price trends and identifying shortages; and third, by the pursuit of greater efficiency in operational tasks.

Comp3: Developments at OpenAI prompted Comp3 to begin exploring AI and its potential benefits for internal business processes approximately two years prior to the interview. As with Comp1, this suggests that the interplay between existing digital maturity and emerging trends may serve as a potential driver for engagement with AI. The company aims to use AI technology to eliminate unnecessary clicks and system duplications for employees. Furthermore, all certificate management tasks currently carried out by humans are viewed as potentially automatable by AI in the future. This also reflects Comp3's intention to relieve employees of non-value-adding activities and represents the second driver.

Comp4 is engaging with AI as it is regarded as a key future technology, and keeping pace with its development is considered essential. Since customers may require support in this regard in the future, early preparation is seen as necessary. This aspect is the first to be classified within the environmental context, as it considers not only the expectations placed on the technology itself but also the role of the customer. This opens up an interesting perspective from a procurement point of view, as the use of AI may offer benefits to customers while also potentially presenting challenges (see Chapter 4.3.4.1).

Furthermore, although C-parts involve low spend, they generate significant workload due to high order volumes. The area of C-parts management is therefore considered well-suited for AI-powered full automation, as the system could autonomously handle orders, and any errors would have relatively limited impact compared to A-parts. This driver is noteworthy as it highlights a specific use case for autonomous demand planning and ordering within the P2P process. In reference to the broader discussion on the autonomisation of procurement, this suggests that research could place greater emphasis on concrete use cases from purchasing, with the aim of exploring their potential for autonomisation and thereby making the topic more tangible.

Comp5 also began to engage with AI when ChatGPT gained widespread public attention. As part of the group's digitalisation initiatives, top management cascades digitalisation topics to its subsidiaries. In this context, foundational automation projects involving AI are being initiated in response to global developments and change. Additionally, the company has large digitalisation departments that develop solutions for external sale, which are also made available for internal use. Consequently, this case also illustrates the interplay between existing digital maturity and emerging technological trends.

Furthermore, possible sanctions, such as those related to the Russia–Ukraine war or to forced labour issues in certain countries, require visibility across multiple tiers of the supply chain and the identification of potential risks. Additionally, action must be taken in response to potential allegations from external parties, such as NGOs. In this context, AI is regarded as a tool to support risk management efforts, for example by providing preventive information and helping to identify potential risks.

Finally, it was suggested that demographic change is reducing the availability of skilled labour and poses a particular challenge for European companies in terms of sustaining growth despite a shrinking workforce. In this context, automation—potentially, but not exclusively, powered by AI—is seen as a requirement for managing business growth in the future. Furthermore, manufacturing companies are no longer regarded as being able to increase their workforce in proportion to sales growth in an economically viable way. Consequently, automation was emphasised as a key factor in maintaining competitiveness, particularly in response to demographic challenges and rising labour costs, thus presenting the final driver for the adoption of AI in procurement derived from the interviews. The key results are summarised in Table 32.

Case	Driver	Description	TOE
Comp1	Interplay between existing digital maturity and emerging trends	At Comp1, the use of Watson in procurement indicated a certain level of digital maturity. Against this background, the interviewee began engaging with AI amid the ChatGPT hype of 2023. This suggests that companies with existing digital capabilities may be more likely to explore AI use cases.	Organization
	Value-creating use of existing resources	One reason for applying AI is to automate routine knowledge work that, while not particularly innovative, demands significant time and human resources—for example, translation. The intention is to redeploy existing resources to value-adding work while assigning non-value-adding activities to AI.	
	Reduced susceptibility to errors	In order to reduce error rates, an AI-supported digital avatar was developed to assist in creating purchase requisitions in SAP, aiming to ensure accuracy at the outset and thereby reduce the risk of subsequent errors.	Technology
Comp2	Institutionalisation of digital transformation	At Comp2, a global digital transformation team coordinates and ensures that procurement progresses towards AI adoption.	Organization
	Strategic considerations	An AI that analyses big data to detect upward or downward price trends and identify shortages could offer valuable guidance for purchasing decisions.	Technology
	Process enhancement	Areas where employees do not adhere to established processes or occasionally make errors—such as maverick buying or incorrect purchase requisitions—are seen as potential fields of AI application. The next step in optimisation would involve AI capable of learning from past mistakes and reducing recurring problems, for example by correcting input errors.	Organization
Comp3	Interplay between existing digital maturity and emerging trends	Developments at OpenAI prompted Comp3 to begin exploring AI and its potential benefits for internal business processes approximately two years prior to the interview.	
	Relieve employees of non-value-adding activities	The company aims to use AI technology to eliminate unnecessary clicks and system duplications for employees. Furthermore, all certificate management tasks currently carried out by humans are viewed as potentially automatable by AI in the future.	
Comp4	AI as a future-oriented technology and anticipated customer expectation	Comp4 is engaging with AI as it is regarded as a key future technology, and keeping pace with its development is considered essential. Since customers may require support in this regard in the future, early preparation is seen as necessary.	Environment
	Full automation of C-parts ordering	Although C-parts involve low spend, they generate significant workload due to high order volumes. The area of C-parts management is therefore considered well-suited for AI-powered full automation, as the system could autonomously handle orders, and any errors would have relatively limited impact compared to A-parts.	Technology
Comp5	Interplay between existing digital maturity and emerging trends	Comp5 has large digitalisation departments that develop solutions for external sale, which are also made available for internal use. The company began engaging with AI when ChatGPT gained widespread public attention. As part of the group's broader digitalisation initiatives, digital topics are cascaded from top management to the subsidiaries.	Organization
	Risk management	Possible sanctions or allegations from external parties require visibility across multiple tiers of the supply chain and the identification of potential risks. In this context, AI is regarded as a tool to support risk management efforts.	Environment
	Automation to maintain competitiveness	Demographic change poses a particular challenge for European companies. Automation—potentially, but not exclusively, powered by AI—is seen as a requirement for managing business growth in the future. Furthermore, manufacturing companies are no longer regarded as being able to increase their workforce in proportion to sales growth in an economically viable way. As a result, automation was emphasised as a key factor in maintaining competitiveness.	

Table 32: Summary of AI-related drivers identified during the interviews

The results show that the organisation, the external environment, and the technology itself all appear to act as drivers for the introduction of AI. The findings indicate that the interplay between existing digital maturity (organisation) and emerging trends (environment) may encourage engagement with AI technology. Three companies directly referred to the strong public response to ChatGPT as a triggering—or at least reinforcing—factor. In addition, as discussed in the case of Comp4, the autonomisation of procurement based on specific use cases could be a subject for future research, in order to make the topic more tangible. Automation in purchasing, including (partially) autonomous P2P processes in specific applications, represent an opportunity for European companies, particularly in view of the competitiveness maintained through automation as highlighted in the Comp5 interview.

4.3.5. Concluding remarks

This study examined the real-world impacts of Procurement 4.0 applications through an exploratory multiple-case study in the private manufacturing industry, identifying a total of 169 factors along the conceptual research framework, based on the five cases examined. Of these, 93 relate to the two overarching categories: success factors and pain points.

The research revealed patterns of overlap and divergence across applications, highlighting key factors influencing technology adoption. The findings were synthesised in Table 30, addressing the two research questions.

In response to RQ3, the analysed cases reveal a broad and diverse range of topics addressed through Procurement 4.0 applications. The organisational context is most consistently emphasised, particularly among success factors, while potential pain points are more strongly linked to technological and environmental dimensions, indicating greater complexity. Success factors are concentrated around *Leadership* (4), *Project Management* (4), *Process Management* (3), and *Education and Training* (3). In contrast, pain points are more dispersed, with only the *Solution* itself (4) and *Process Management* (3) recurring in more than two cases. This fragmentation underscores the diverse challenges associated with the implementation and operation of Procurement 4.0 applications. It further suggests that successful adoption may require more holistic and integrated approaches—considering process requirements (process–solution), resulting effects (solution–process), and organisational implementation (project and leadership–solution/process)—to effectively manage the pressures of transformation. In this context, developing Procurement 4.0-specific procedural models could support managers and promote wider uptake of advanced technologies in procurement.

In relation to RQ4, the five tentative (arche)types of technology engagement derived—*Innovator*, *Organiser*, *Strategist*, *Optimiser*, and *Protector*—offer practical orientation for organisations facing similar challenges. These profiles may serve as a basis for strategic prioritisation, depending on a company's starting point, objectives, and expected benefits. For instance, the AI-supported evaluation of SAQs at Comp1, while limited in scope and comparatively straightforward to implement, yields targeted effects in sustainability and compliance. In contrast, the more far-reaching applications—such as the SAP Ariba platform at Comp2 or the real-time information system at Comp4—are associated with broader, strategic impacts, but also require several years of comprehensive implementation to reach their full potential.

In terms of process automation, all five cases demonstrated tangible gains in productivity, aligning with the notion of 'achieving more with the same'. In particular, the cases presented illustrate opportunities to professionalise and automate traditional administrative processes previously supported by MS Office programmes (Comp3 and Comp4). While no clear tendencies towards autonomisation were observed, the cases instead pointed to augmentation and automation. Nonetheless, as this study draws on a limited sample from the Austrian manufacturing industry, broader and quantitative validation is needed to assess the extent to which the findings may be generalisable.

In addition, the interview section focusing on the interviewees' practical experience with AI provides insights into the challenges and potential drivers for its use in procurement. With regard to challenges, it became apparent that the TOE categorisation reveals a divergence from the findings of the case studies on implemented Procurement 4.0 applications. While organisational TOE factors accounted for the majority of challenges in those cases, the challenges raised in relation to AI predominantly concern the technology context. This may be attributed to the relative novelty of AI, as illustrated by a challenge mentioned by Comp1 and Comp3: that its full potential cannot yet be assessed from today's perspective.

Finally, the organisation, the external environment, and the technology itself act as drivers for the introduction of AI. The findings from the interviews indicate that the interplay between existing digital maturity (organisation) and emerging trends (environment) may encourage engagement with AI. Three companies directly referred to the strong public response to ChatGPT or OpenAI as a triggering factor. In addition, as discussed in the case of Comp4, the autonomisation of procurement based on specific use cases could be a subject for future research, in order to make the topic more tangible. Automation in purchasing, including (partially) autonomous P2P processes in specific applications, may represent an opportunity for European companies, particularly in view of the competitiveness maintained through automation as highlighted in the Comp5 interview.

5. Findings from the First-Round Delphi Expert Survey on Procurement 4.0 Adoption

This chapter presents the design, implementation, and initial findings of an expert survey conducted as the first round of a Delphi study.

Procurement 4.0 has gained traction in the academic discourse (Jain et al., 2024). Moreover, the case studies presented in the preceding chapter demonstrate that Procurement 4.0 has already seen successful real-world application within the manufacturing sector, thereby enhancing the level of automation in procurement. However, there are indications that progress within companies, in general, has not kept pace with the technological advancements stemming from the Industry 4.0 wave (Althabatah et al., 2023; Bigliardi et al., 2022; PricewaterhouseCoopers, 2024). While academic discussions present futuristic scenarios as illustrated in Chapter 3, consultants promote the benefits, and solution providers rapidly introduce new solutions, industrial procurement practice still grapple with traditional digitalization challenges, such as data management (Klee and Janson, 2023; Srai and Lorentz, 2019). Moreover, various obstacles, including resource shortages or technological scepticism, may impede the adoption of modern technologies (Bigliardi et al., 2022; Joseph Jerome et al., 2022).

However, as far as can be determined from the current state of research, evidence on the actual prevalence of Procurement 4.0 applications aimed at increasing automation in the manufacturing industry remains limited. A status assessment could help identify practical areas for action that may serve as starting points for initiatives by various stakeholders, including companies, solution providers, and research institutions. When combined with an outlook on the future of procurement in this context, such insights can enable companies to recognise potential developments and seize emerging opportunities (Stöttner et al., 2025, p. 2), thereby supporting the broader adoption of advanced technologies in line with Procurement 4.0.

One established and pragmatic method for achieving expert consensus and forecasting future developments—while taking into account both qualitative and quantitative data—is the Delphi study, in which experts[36] respond to a structured written questionnaire and are given the opportunity to revise their opinions over the course of at least two rounds, based on the anonymised responses of other participants (Brady, 2015, p. 1; Döring and Bortz, 2016, p. 420; Rowe and Wright, 1999, p. 353). This method is therefore well-suited to the present research.

[36] This explains why the term *'multi-round expert study'* is used in academic literature to describe Delphi studies (Sokolov et al., 2025, p. 1).

It is employed in this study, firstly, because it enables the generation of forecasts based on judgement-based, subjective assessments in the absence of historical data (Rowe et al., 1991, p. 236). Secondly, it is widely recognised as an established approach for conducting structured expert surveys in the fields of Industry 4.0 and procurement research (Culot et al., 2020b; Delke et al., 2023; Gebhardt et al., 2022; Wehrle et al., 2022).

Based on the available literature, this study appears to be the only recent Delphi-based research examining the future of procurement explicitly from a Procurement 4.0 automation perspective, with a particular focus on the manufacturing sector and practitioner viewpoints. While Wehrle et al. (2022) investigated the effects of digitalisation on purchasing and supplier management (PSM) within new product development (NPD), their study does not specifically provide a forecast of procurement's future from a Procurement 4.0 use-case oriented perspective. Ekström et al. (2021) also employed a Delphi approach to develop a purchasing portfolio model specifically tailored for use by defence agencies in the context of arms procurement. However, this study focuses on public procurement and does not explicitly address digitalisation. Similarly, Aristotelis and Dimitrios (2025) used the Delphi method to develop a technology roadmap for the integration of new technologies, aligned with the strategic goals of the European Union—again, within the context of public procurement. Gebhardt et al. (2022), in turn, applied a Delphi study to examine post-Covid supply chain resilience and discussed the role of digital technologies in this context; however, their study does not explicitly forecast the future of procurement from a Procurement 4.0 application-oriented perspective. Moreover, Delke et al. (2023) also adopted a Delphi approach to explore future roles in PSM within the context of Industry 4.0. While relevant, their focus is not on a use case-oriented approach to digital procurement either. Finally, Bueno et al. (2024) applied the Delphi Method at the intersection of Procurement 4.0 and the Circular Economy, aiming to evaluate how Procurement 4.0 can facilitate the transition towards a circular economy and to identify which enabling technologies of Industry 4.0 can support this shift. Moreover, the study is based on a small sample consisting of five procurement and four circular economy experts.

Against this backdrop, the structured written expert survey presented here constitutes the first round of an ongoing Delphi study aimed at aimed at exploring practical perspectives on the future of procurement in the context of Procurement 4.0 (Döring and Bortz, 2016, p. 420). A comprehensive solution proposal and detailed forecast can only be developed upon completion of the full Delphi process (Döring and Bortz, 2016, p. 421). However, written expert surveys are themselves recognised methods of data collection (Döring and Bortz, 2016, pp. 403–404). They may be applied in contexts where expert judgement supports the understanding of phenomena for which only limited knowledge is available, with the number of participants ranging from fewer than ten to well over one hundred (Zhang et al., 2021, p. 19). The literature includes examples of both semi-standardised and fully standardised formats that are not conducted within a Delphi framework (Buhl et al., 2007; Grützner et al., 2025; Owusu et al., 2019; Scheller et al., 2021; Yevu et al., 2023). These considerations provide the rationale for publishing the results of the expert survey derived from the first round of this Delphi process. It is intended to fulfil three key purposes.

Firstly, the survey aims to refine and further develop the category set previously established through multiple case study analyses, based on ten defined Procurement 4.0 applications. These applications are classified as augmentation, automation, or autonomisation, and are complemented by two environmental and three organisational factors, in line with the TOE framework. By involving a broader group of industry experts, the intention is to strengthen and potentially expand this category set.

Secondly, it seeks to identify current gaps, explore future scenarios, and assess the practical benefits associated with Procurement 4.0. In doing so, it evaluates the following propositions (PR) concerning Procurement 4.0 in the manufacturing sector, which are derived from the systematic literature review and multiple case study analysis:

PR1: *Although the perceived benefits are considerable, current procurement practices still lag significantly behind what is technologically possible.*
PR2: *Technology continues to be perceived as a tool that supports human decision-making. Fully autonomous processes, as envisioned at the outset of the Industry 4.0 debate, remain an aspirational goal rather than an established reality.*
PR3: *To date, the adoption of blockchain technology in procurement remains virtually non-existent in practice.*
PR4: *Even in the future, procurement practice is likely to remain cautious towards fully advanced Procurement 4.0 applications aimed at the autonomization of processes resulting in their limited adoption compared to more conventional automation solutions.*

Finally, the expert survey aims to draw preliminary conclusions regarding the future of procurement and to outline avenues for further research.

The structure of this chapter mirrors that of the previous one, beginning with the design of the Delphi study and expert survey, followed by its implementation and analysis, concluding with the dissemination of the findings.

5.1. Design

First, the development of the Delphi items is explained, then the selection of the expert panel.

5.1.1. Development of the Delphi projections

The development of the Delphi projections was guided by the previously presented research framework, with the objective of representing all three contexts of the TOE framework (DePietro et al., 1990).

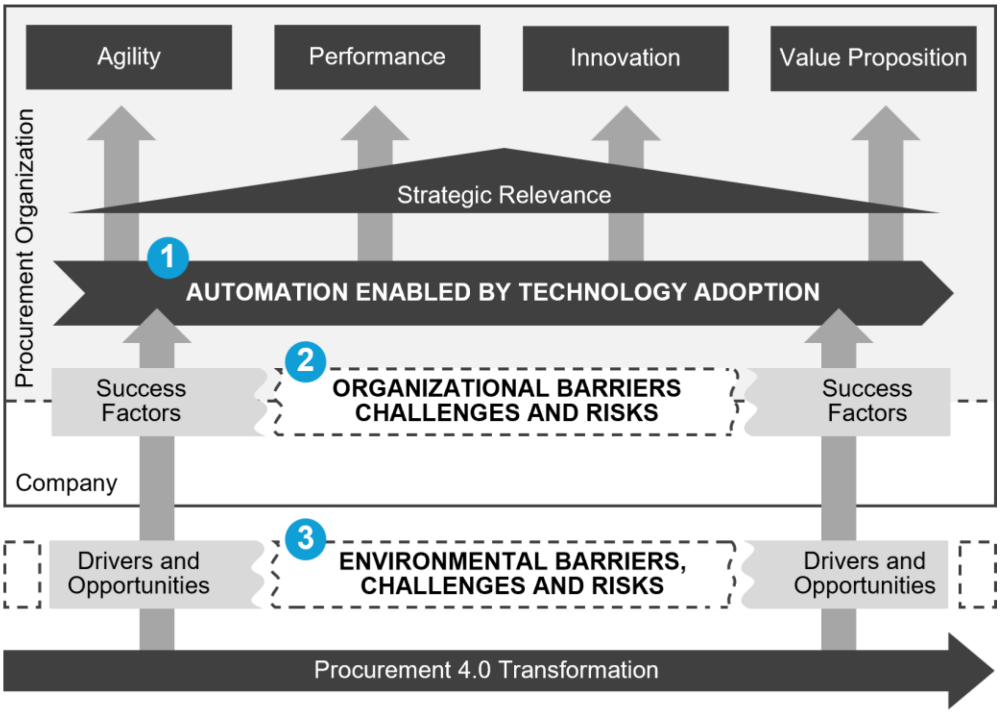


Figure 13: Conceptual research framework

(1) *Technological context:* The majority of the items centre on the Procurement 4.0 applications explored in the previous chapters.

(2) *Organizational context*: As the qualitative multiple-case study analysis indicated that organisational challenges play a dominant role in the introduction of Procurement 4.0 applications, these have been given greater weight than environmental factors.

(3) *Environmental context:* Selected environmental factors are also considered.

Drawing on the previously developed research findings, a set of projections—formulated as short theses, that is, assertive statements serving as a starting point for further argumentation (Duden, n.d.)—was developed for expert evaluation within the study (Culot et al., 2020b, p. 8). This set was further refined through several iterations within the research group, with particular attention given to reducing the number of items. Keeping the number of items manageable is essential to avoid overburdening participants and to minimise the likelihood of dropout (Kluge et al., 2020, p. 4). The literature offers a range of precedents: Wehrle et al. (2022) employed 10 projections, Kluge et al. (2020) 17, and Culot et al., (2020b) 43. For the purposes of this study and informed by the approaches of Wehrle et al. and Kluge et al., 15 projections were ultimately deemed appropriate.

According to Schmalz et al. (2021, p. 5), who share lessons learned from a Delphi study, the core of each projection should be formulated in the present tense, provided that a time horizon is specified. In line with the typical future horizon of 10-15 years, the reference year for this study is 2035 (Culot et al., 2020b, p. 8). In addition, the recommendations of Schmalz et al. (2021, p. 6) to ensure clarity through simple phrasing and the use of examples were considered. While the projections concerning Procurement 4.0 applications were formulated to describe the use of a specific technology in a defined process or task, those relating to organisational and environmental barriers were phrased to suggest that these challenges will have been overcome by 2035. This approach is intended to assess the anticipated long-term significance of these barriers.

All 15 projections were evaluated by the experts across three dimensions using Likert-type items with a five-point ordinal rating scale ranging from 1 (strongly disagree) to 5 (strongly agree) (Culot et al., 2020b; Döring and Bortz, 2016, pp. 240, 245–246, 269; Wehrle et al., 2022). In addition, participants were asked to explain their assessments in a comment, with the note: *‘Your justifications in the form of comments are particularly valuable for the study’*, in order to generate qualitative insights.
Owing to their differing nature, the projections related to Procurement 4.0 applications were assessed using different evaluation statements than those pertaining to organisational and environmental factors. Table 33 provides an overview of the applied evaluation dimensions and statements including their original German wording.

<table>
<tr><th colspan="3">Procurement 4.0 Technology Application</th><th colspan="3">Organisational and Environmental Factors</th></tr>
<tr><th colspan="2">Dimension</th><th>Evaluation statement (rating item)</th><th colspan="2">Dimension</th><th>Evaluation statement (rating item)</th></tr>
<tr><td rowspan="2">Perceived Adoption</td><td>Current Adoption</td><td>EN: This statement describes common practice in 2025.
DE: Diese These beschreibt die gängige Praxis heute im Jahr 2025.</td><td rowspan="2">Perceived Situation</td><td>Current Situation</td><td>EN: This statement describes the situation in the year 2025.
DE: Diese These beschreibt die Situation heute im Jahr 2025.</td></tr>
<tr><td>Future Adoption</td><td>EN: This statement describes common practice in 2025.
DE: Diese These beschreibt die gängige Praxis im Jahr 2035.</td><td>Future Situation</td><td>EN: This statement describes the situation in the year 2035.
DE: Diese These beschreibt die Situation im Jahr 2035.</td></tr>
<tr><td colspan="2">Perceived Benefits</td><td>EN: From today's perspective, this application provides added value in procurement.
DE: Diese Anwendung bietet aus heutiger Sicht einen Mehrwert für den Einkauf.</td><td colspan="2">Desirability[37]</td><td>EN: This situation is desirable from today’s perspective.
DE: Diese Situation ist aus heutiger Sicht wünschenswert.</td></tr>
</table>

[37] This dimension is inspired by Kluge et al. (2020, p. 7)

Table 33: Dimensions and evaluation statements

The final questionnaire was subjected to a pre-test involving two researchers and three practitioners who were not later included in the expert panel. This step led to revisions in wording, the addition of explanatory notes for specific aspects, and adjustments to the final sequence of questions. The final list of projections, including a justification for their consideration and the survey's original text in German, is presented in Table 40.

#	Category	Short version	English statement	Justification based on literature and case evidence	German statement
1	Augmentation Scenario	Big Data Analytics in Risk Management	*Big data analytics support procurement employees in risk assessment (e.g., supply risk).*	According to the evaluation presented in the application heatmap, big data is among the most extensively discussed technologies in Procurement 4.0 research, particularly in relation to its potential for risk management. Moreover, Bueno et al. (2024, p. 9) identify it as the most widely adopted Industry 4.0 technology in procurement. On this basis, and to explore the validity of this claim, the application is considered as a projection.	*Big-Data-Analysen unterstützen die Mitarbeitenden im Einkauf bei der Risikobewertung (z. B. Versorgungsrisiko).*
2	Augmentation Scenario	AI Avatars for Task Assistance	*AI-powered avatars assist procurement employees in completing their tasks.*	The avatar[38] use case originates from the case study in Comp1, where the interviewee introduced this innovative application during the discussion on artificial intelligence.	*KI-basierte Avatare unterstützen die Mitarbeitenden im Einkauf bei der Erledigung ihrer Aufgaben.*
3	Augmentation Scenario	AI Support in Category Strategy Development	*AI-based systems assist procurement employees in the development of category strategies.*	This use case was derived from the case study in Comp3 to assess how it is perceived more broadly within the manufacturing industry. Furthermore, the heatmap documents only two use cases at the intersection of Category & Sourcing Strategy Definition, indicating a low level of academic engagement with this topic. However, the interviewee noted that AI will also be incorporated into their solution, suggesting a potentially broader relevance in practice than currently reflected in the literature.	*KI-basierte Systeme unterstützen die Mitarbeitenden im Einkauf bei der Entwicklung von Warengruppenstrategien.*
4	Automation Scenario	Full P2P Automation with Human Exception Handling	*The operational Purchase-to-Pay process is fully automated; humans intervene only in exceptional cases.*	The heatmap analysis reveals that the operational P2P process receives comparatively limited attention in the academic debate. Indeed, Gartner's Hype Cycle for Procurement suggests that S2P suites are approaching the 'plateau of productivity' in the near future (Gartner, 2024; Zip, 2024). Nevertheless, employees faced difficulties in shifting their focus towards strategic priorities (ivalua, 2019). This paper aims to provide a practitioner-oriented current perspective on this apparent disconnect.	*Der operative Purchase-to-Pay-Prozess ist vollständig automatisiert; nur bei Ausnahmen greifen Menschen ein.*
5	Automation Scenario	Automated Sustainability Compliance Checks	*AI evaluates suppliers' compliance with sustainability criteria in an automated manner, while exceptions are manually reviewed by humans.*	This use case was derived from the case study at Comp1 and reflects the limited attention that AI applications in the field of sustainability have received within the scientific community, as evidenced by only two documented examples in Procurement 4.0 Application Heatmap.	*KI bewertet die Einhaltung von Nachhaltigkeitskriterien durch Lieferanten automatisiert, während Ausnahmefälle manuell von Menschen überprüft werden.*
6	Autonomization Scenario	AI-Driven Supplier Prequalification	*With the help of AI, the identification and prequalification of suppliers is carried out without human intervention.*	This application, in turn, is among the most extensively discussed in academic literature and is therefore included to explore how practitioners perceive its current and future relevance as well as the potential benefits they associate with it.	*Mit Hilfe von KI erfolgt die Suche und Vorauswahl von Lieferanten ohne menschliches Zutun.*
7	Autonomization Scenario	Autonomous Chatbots for Contract Negotiation	*Intelligent chatbots autonomously negotiate contracts with suppliers.*	In the areas of negotiation and contracting, several AI applications were identified, including the one presented here (Flechsig et al., 2022), which is assumed to be somewhat futuristic from a practical standpoint. It was therefore included as part of the autonomisation use cases in order to capture the practitioner perspective on its feasibility and potential relevance.	*Intelligente Chatbots handeln selbstständig Verträge mit Lieferanten aus.*

[38] An avatar is a digital representation of an entity (e. g. specific person) that enables interaction in virtual spaces (Oladokun and Gaitanou, 2024, p. 1f). Recent advancements in AI have facilitated the development of AI-powered avatars (e.g., educational avatars) that exhibit human-like characteristics and interact within virtual environments (Fink et al., 2024, p. 1f). Accordingly, AI-powered Avatars are software programs that use AI to enable human-like digital characters to interact independently in virtual spaces.

#	Category	Short version	English statement	Justification based on literature and case evidence	German statement
8	Autonomization Scenario	Blockchain Smart Contracts for Automated Payments	*Payments are processed fully automatically without any human intervention thanks to blockchain-based smart contracts.*	As blockchain is the most intensively discussed Industry 4.0 technology in procurement, and application potential for smart contracts has also been documented in the heatmap, this use case—linked to both technologies and concepts[39]—has been included as it also reflects the potential for autonomisation.	*Zahlungen werden mittels Blockchain-basierter Smart Contracts vollautomatisch und ohne menschliches Zutun abgewickelt.*
9	Autonomization Scenario	Autonomous Detection of Automation Potential in Daily Tasks	*A monitoring system integrated into procurement processes autonomously detects automation potentials in the daily tasks of procurement employees.*	Although process mining is not among the most frequently cited applications— with only two applications documented in Bahaweres et al. (2022)— it was mentioned in discussions with both Comp3 and Comp4. Given that, alongside process mining, task mining in particular holds significant potential for the automatic data-driven identification of automation opportunities (Dirnberger et al., 2023; Dumas et al., 2022; Leno et al., 2021; UiPath, n.d.), this use case was included without specifying the underlying technology, in order to encourage open-ended responses.	*Ein in die Beschaffungsprozesse integriertes Überwachungssystem erkennt eigenständig Automatisierungspotenziale in den täglichen Aufgaben der Mitarbeitenden im Einkauf.*
10	Autonomization Scenario	AI Agents for Strategic Decision-Making	*Intelligent non-human agents (AI agents) independently make complex decisions, including strategic decisions such as supplier selection, which were still made by humans ten years ago.*	The potential of AI in supplier search and selection—such as the identification of suitable suppliers (Rejeb and Appolloni, 2022) and the generation of recommendations (Spreitzenbarth et al., 2024)—is repeatedly highlighted in the literature. In light of the current prominence of agentic AI, i.e. intelligent, autonomous agents capable of making complex decisions, particularly in the context of process management debates and beyond (Bansal et al., 2025; Ng et al., 2021; Pacher, n.d., n.d.), a use case was developed to gauge expert reactions and explore whether they would consider it plausible for an AI agent to make such decisions.	*Intelligente nicht-menschliche Agenten (KI-Agenten/AI Agents) treffen selbstständig komplexe Entscheidungen, einschließlich strategischer Entscheidungen wie der Lieferantenauswahl, die vor zehn Jahren noch von Menschen getroffen wurden.*
11	Environment	Consulting Support	*Professional consulting firms help procurement unlock the potential of advanced technologies such as AI.*	Collaboration with consulting firms may be critical for the successful implementation of advanced technologies like AI (Vial et al., 2023, p. 670f.). This was also evident in the case studies in Chapter 4, where three of the companies explicitly mentioned the collaboration with the implementation partner positively (Comp1) or cited it as a success factor (Comp2 and Comp3). Therefore, this element is included as a projection in the Delphi study and is formulated following the mission of a North American AI consultancy firm, *'helping organizations leverage the power of AI,'* (Vial et al., 2023, p. 671) to assess how practice perceives the role of business consultancies.	*Professionelle Beratungsunternehmen helfen dem Einkauf dabei, das Potenzial fortschrittlicher Technologien wie KI zu erschließen.*
12	Environment	Shift in Taxation	*The financing of the social system is less dependent on taxes on human labor than it was in the past. Instead, alternative forms of taxation—such as those on value creation generated through automation—are being used more extensively.*	If the potential of automation is fully realized and employment declines, it could impact the national economy, as the financing of the welfare state—primarily dependent on taxes and levies on employees' wages and salaries,	*Die Finanzierung des Sozialsystems ist weniger von Steuern auf menschliche Arbeit abhängig als früher. Stattdessen kommen alternative Steuerformen – etwa auf durch Automatisierung geschaffene Wertschöpfung – stärker zum Einsatz.*

[39] Blockchain technology facilitates instant, automatic electronic payments through Smart Contracts, triggered upon fulfilment of all procurement agreement obligations without the involvement of trusted third parties (such as banks, lawyers, etc.) (Gunasekara et al., 2022, p. 457; Raj et al., 2022, p. 108038). The Smart Contract is a program stored on the Blockchain that represents a digital contract, which is automatically executed based on the fulfilment of predefined rules (e.g., if-then conditions) (Wu et al., 2022, p. 50839ff).

#	Category	Short version	English statement	Justification based on literature and case evidence	German statement
				as seen in Austria—may no longer be sustainable (gpa, n.d.).[40] Whatever the solution for this may look like in the future, as long as the welfare state is funded through taxes and levies on labour, there remains a risk of societal opposition that could hinder automation. This fundamental factor is therefore reflected as a projection in the Delphi study.	
13	Organization	Reduced Internal Bureaucracy	*The implementation of advanced technologies in procurement is free from internal bureaucratic obstacles such as tedious approval processes.*	Flechsig, 2021 (p. 17) highlights that some participants experienced excessive bureaucracy as a key barrier to the implementation of Intelligent Process Automation, citing, for example, the considerable effort required for documentation and justification. As this issue tends to receive comparatively little attention in the academic Procurement 4.0 literature, it was included as an organisational factor to explore its practical relevance in more depth.	*Die Einführung fortschrittlicher Technologien in der Beschaffung ist frei von internen bürokratischen Hindernissen wie langwierigen Genehmigungsprozessen.*
14	Organization	Mutual Understanding of Requirement Specification	*Providers of advanced technological solutions (e.g., AI) and procurement employees share a common understanding of how to specify the requirements for new technologies.*	The topic of requirements specification is frequently addressed in the Procurement 4.0 literature (Joseph Jerome et al., 2022; Sjodin et al., 2021). Drawing on practical experience, it was also deemed relevant by the research group and therefore incorporated into the study.	*Anbieter fortschrittlicher technologischer Lösungen (z. B. KI) und Mitarbeitende im Einkauf verfügen über ein gemeinsames Verständnis zur Spezifikation der Anforderungen an neue Technologien.*
15	Organization	Use Case Identification	*Procurement executives are able to identify suitable use cases where new technologies provide the greatest benefit.*	The topic of prioritisation and use case identification is considered important both in the academic literature on process automation (Flechsig et al., 2022) and in practice, as evidenced by the case study interviews. For this reason, the aspect was included as a projection to enable a broader examination.	*Führungskräfte im Einkauf sind in der Lage, geeignete Anwendungsfälle zu identifizieren, bei denen neue Technologien den größten Nutzen bieten.*

Table 34: List of final Delphi projections

[40] It is therefore unsurprising that barriers such as the ‘fear of job loss’ continue to hinder the advancement of automation (Toshav-Eichner and Bareket-Bojmel, 2022, p. 1553). At the same time, various proposals exist regarding how the taxation on human labour might be reduced without jeopardising the future financing of the welfare state. Precht (2022, pp. 398–407), for example, outlines several such approaches. One possibility involves introducing a tax on the entire value creation process—commonly referred to as a ‘machine tax’ or ‘technology tax’, with the latter covering both hardware and software. Paradoxically, however, such a tax could discourage automation, as companies might slow down technological adoption to avoid additional taxation. An alternative proposal shifts the focus away from taxing profits or labour and instead suggests applying a micro-tax to all monetary transactions, particularly targeting high-frequency financial trading.

Following the description of the content-related Delphi design, the primarily organisational aspect of expert selection is outlined below.

5.1.2. Selection of the expert panel

The Delphi method can be applied in qualitative, quantitative, or mixed-method approaches (J. Skulmoski et al., 2007, p. 9). Given the exploratory nature of this study, the primary focus is initially on the collection of qualitative data. Accordingly, the first guiding criterion for expert selection— Once again, a purposive sampling approach was adopted—is the identification of individuals capable of providing informed insights through detailed textual comments. According to Döring and Bortz (2016, p. 302) a typical number of cases in qualitative doctoral theses is between 20 and 30. Consequently, and in order to increase the significance of the quantitative data, the target was set to reach the upper threshold—namely, to obtain at least 30 experts for the panel—and to postpone the analysis until this number was achieved. As far as the criteria and the acquisition process are concerned, the procedure followed was similar to that used to identify the interview partners for the multiple case study analysis: identifying and approaching suitable experts possessing particular knowledge due to their experience and managerial positions (Döring and Bortz, 2016, p. 375; Gläser and Laudel, 2006, p. 10; Gottge et al., 2020, p. 735; Lorentz et al., 2021, p. 164). In addition to recruiting experts through professional and personal networks, LinkedIn was also used to identify experienced procurement managers from the manufacturing industry and to post calls for participation. Regarding LinkedIn acquisition, the experience can be shared that this proved difficult and only two additional experts could be recruited. However, LinkedIn was useful for re-establishing contact with known experts from personal and professional networks. Each contact received at least a briefing by email—sometimes supplemented by a phone call or in-person conversation—during the process of receiving the formal invitation to participate in the survey. In total, 35 practitioners were successfully recruited for the Delphi study. The characteristics of this panel are outlined below.

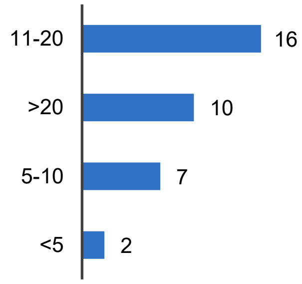
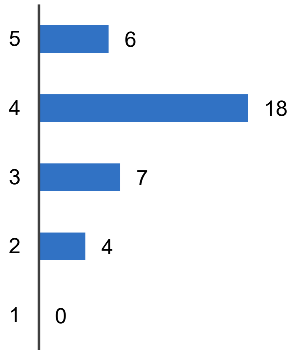
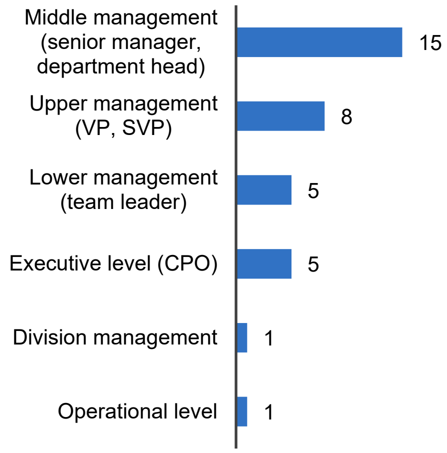
Experience	Topic Familiarity	Position / Role
How many years of experience do you have in procurement/purchasing?	*Please estimate how familiar you were with the topics covered. (1 = not very familiar, 5 = very familiar)*	*What is your current position in the company?*
		
n = 35 | single selection | the bars represent the number of experts per category		

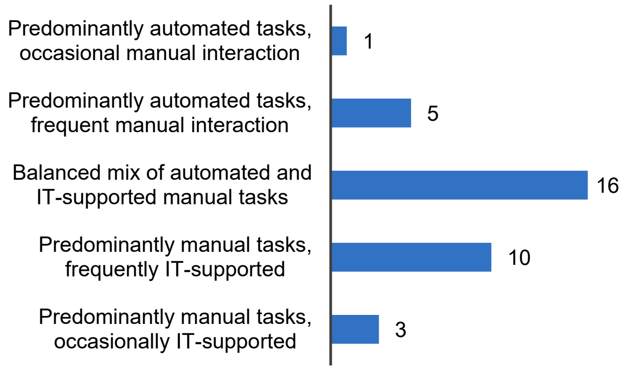
Table 35: Characteristics determining the expert status of panellists

The panellists' significant professional experience—26 of them having worked in the field for between 11 and over 20 years—indicates that the aim of involving experienced practitioners in discussions about the future of procurement was successfully achieved. In addition, 24 experts considered themselves rather to very familiar with the topics, while only four reported lower familiarity, suggesting that the panel was well equipped to evaluate the projections. The distribution across management levels is relatively balanced, with upper and top management somewhat more prominently represented than lower management. Notably, one participant identified with the operational level. However, as this individual reported five to ten years of procurement experience and rated their topic familiarity as relatively high, the response was retained to ensure that this perspective was also reflected—despite the absence of a formal management role.

As the study aims to reflect the practical perspective of the manufacturing industry, the following table presents key information about the companies in which the experts work in procurement. This is intended to clarify the extent to which the findings can be linked to this sector.

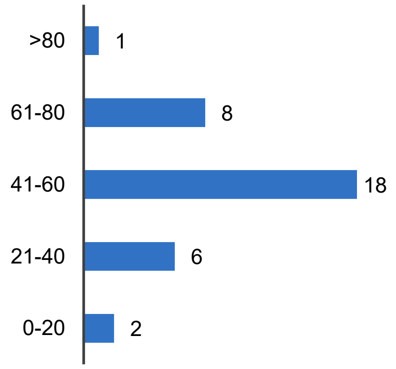
Self-assessed degree of automation

Please assess the degree of automation in procurement at your company.



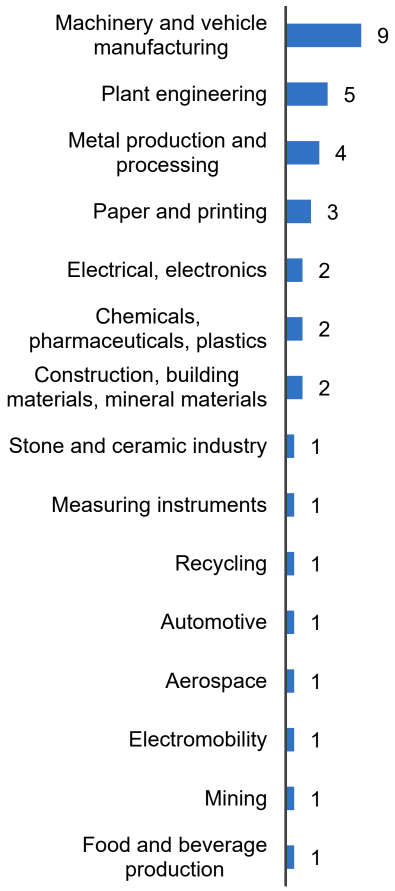
Material cost share (%)

What approximate share of turnover (%) do material costs (raw materials, auxiliary materials, operating supplies, and purchased components) represent in your company?



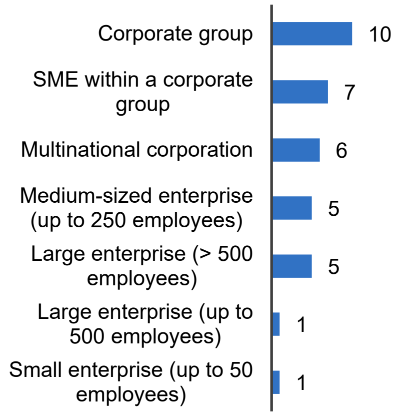
Industry sector[41]

In which industrial sector does your company operate?



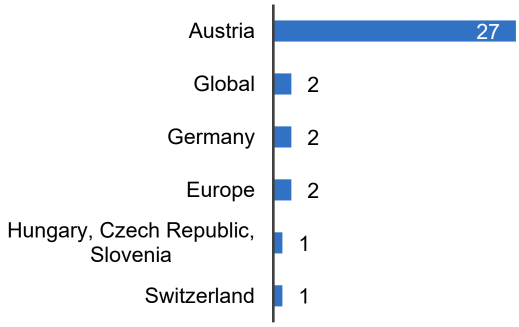
Company type and size

Which company category do you assign your organisation to according to the following overview?



Country

In which country do you carry out your procurement activities?



n = 35 | single selection | the bars represent the number of the experts companies per category

Table 36: Company profiles of the panellists

[41] The industry classification is derived from category *C – Manufacturing* in the *Statistical Classification of Economic Activities in the European Community*, the categories provided by PricewaterhouseCoopers' (2024) Digital Procurement Survey and the industrial sectors into which the Austrian industry association clusters the industry (Industriellenvereinigung Steiermark, n.d.; ShowVoc, n.d.).

The companies represented by the surveyed experts generally exhibit a balanced mix of automated and IT-supported manual procurement processes. While six panellists report a high degree of automation, manual tasks still predominate for thirteen. This diversity is advantageous for the Delphi study, as it ensures the inclusion of a broad range of perspectives.

Regarding the share of material costs, 27 of the 35 companies report figures of 41% or higher, highlighting the economic relevance of procurement in their operations and underscoring its significance for this manufacturing industry-focused investigation. The remaining eight companies fall within a lower range, two of which evidently have a particularly high value-added or service component.

The panel also reflects a broad sectoral spread, with experts representing 15 different industries, including those identified under ‘Other’. The machinery and vehicle manufacturing sector is somewhat overrepresented, which is unsurprising given the concentration of participants from the Styria region, where several panellists were recruited through professional networks.

Geographically, Austria is the most frequently cited country, with 27 mentions. However, this figure should be interpreted with caution. In retrospect, the wording of the question may have led to some ambiguity, as procurement often operates on a global scale due to internationally sourced suppliers. Regarding company type and size, ten panellists report working in a corporation, seven in SMEs that are part of larger corporate structure, and six in multinational corporations. This means that approximately two-thirds of the panellists are affiliated with large corporate entities, suggesting a global orientation in their procurement activities. Only seven panellists represent independent SMEs or companies with fewer than 500 employees, which may introduce a degree of bias in the data. Nevertheless, the overall company sizes indicate that the procurement departments represented are generally of considerable scale and significance.

In summary, the sample as a whole captures a wide range of perspectives. While there is a notable Austrian focus, the corporate affiliations of many panellists suggest that the international dimension of procurement is still well represented. The implementation of the survey is discussed below before the results are analysed and discussed.

5.2. Implementation and analysis

The survey was conducted online using Microsoft Forms. The link was first distributed on 4 February 2025, and responses were collected until 17 March 2025. In addition to email reminders, telephone follow-ups were conducted wherever contact details were available or could be obtained, in order to gradually increase the response rate. In total, 35 experts fully participated in the first round of the Delphi study.

A total of slightly more than 20 individuals[42] were invited to join the expert panel but either did not respond or explicitly declined participation. As a result, they were not sent the survey link. Among those who had expressed initial interest and were sent the link, 11 ultimately did not participate. The primary reason cited for non-participation was a lack of time. One expert stated via telephone that he would not be participating, while another confirmed that he had discontinued the survey due to time constraints. A third expert also mentioned the length of the survey as a reason for not completing it earlier.

This reasoning appears credible, as Microsoft Forms recorded an average completion time of 55.5 minutes. This underlines the considerable commitment demonstrated by the participating experts, who collectively provided 372 written comments, all of which were incorporated into the analysis. With 35 panellists, this equates to approximately 11 text comments per person. These were provided in response to 15 projections, each evaluated across three dimensions, along with additional structural questions, as presented in the previous subchapter. Although this represents only one round of a single Delphi study, these figures may serve as a useful benchmark for researchers planning similar projects.

The completed online questionnaires were downloaded directly from Microsoft Forms as an Excel file for analysis. In one case, the comments provided by an expert in relation to the ratings suggested that the rating scale may have been used incorrectly. This was confirmed through direct communication with the expert, after which the responses were corrected to reflect the intended use of the scale.

The qualitative content analysis followed the approach described in Chapter 4.1.3, with two methodological adaptations. First, coding was conducted from the outset using the category set developed in Chapter 4; however, four additional categories—Maturity Level, Technology Adoption, Human Skills, and Rules and Regulations—were added inductively during the process. Second, the use of MAXQDA was omitted, as the data were already available in tabular form and were analysed question by question.

[42] As direct contact was sought with all prospective experts—alongside the emergence of some spontaneous personal contacts—the total number of individuals approached cannot be stated with complete accuracy.

The original expert opinions were translated from German into English and paraphrased in accordance with Mayring's (2015, p. 72) recommendations regarding the interpretation rules for summarising qualitative content analysis. This involved stylistic adaptation—for example, first-person formulations were neutralised, incomplete sentences were completed based on contextual information, repetitions were removed, and spelling or grammatical errors were corrected. The responses were then categorised using the set of categories and coding principles outlined in Chapter 4. Recurring patterns within each category were identified and summarised for each projection, grouped according to the respondents' rating levels—high (5–4), medium (3), or low (1–2)—with regard to perceived adoption in 2035, in order to more effectively highlight the differing perspectives. Grouping according to the Perceived Future Adoption ratings (2035) was applied to distinguish sceptical from optimistic comments, thereby enabling a more nuanced description of potential future developments.

The wording of the paraphrased statements was based closely on the original comments; however, significant variation in perspectives on the same issue was frequently observed within each agreement group. In such cases, divergent views were included with attribution to the respective experts.

The analysis of the quantitatively assessable data—experts' ratings on Likert-type items using a five-point rating scale[43]—follows established research standards, as applied, for example, by Culot et al. (2020b, p. 16) and Wehrle et al. (2022, pp. 5–6). Consequently, central tendency was assessed using the median, and response variability was measured via the interquartile range (IQR). In addition, the Wilcoxon[44] test was applied in the open statistical software jamovi (n.d.) to identify statistically significant differences between groups. Furthermore, mean values were calculated. While the use of means with ordinal data is generally discouraged (Döring and Bortz, 2016, p. 240), it is not uncommon in empirical research practice (Norman, 2010). In the present study, the mean serves as a secondary criterion for ranking the projections in cases where the median values are identical. Finally, individual visualisations were developed to present the findings in a clear and easily interpretable way.

The findings from the first round of the Delphi study are presented in the following chapter. The second round is scheduled to take place in the fourth quarter of 2025.

[43] To mitigate the problem of ambivalence or indifference, a 'don't know' response option was included; however, it was used only sparingly by participants (Döring and Bortz, 2016, p. 249).

[44] The Wilcoxon test is a non-parametric significance test used for smaller sample sizes where a normal distribution cannot be assumed (Bortz, 1999, pp. 149 and 756). It is applied to determine whether there is a difference in the central tendency of an ordinal variable between two related (i.e. non-independent) groups (Bortz, 1999, pp. 149 and 756).

5.3. Dissemination

Based on the indications outlined in the introduction suggesting that procurement lags behind other functional areas in terms of technology utilisation—such as the use of AI (Bakir and Borozan, 2023, p. 10)—experts were asked, as part of the survey, to assess the degree of automation in procurement compared with other functional areas. This was done using the question: *"Please assess the overall degree of automation in procurement across the industry compared to other functional areas,"* with predefined answer options representing different levels of automation.

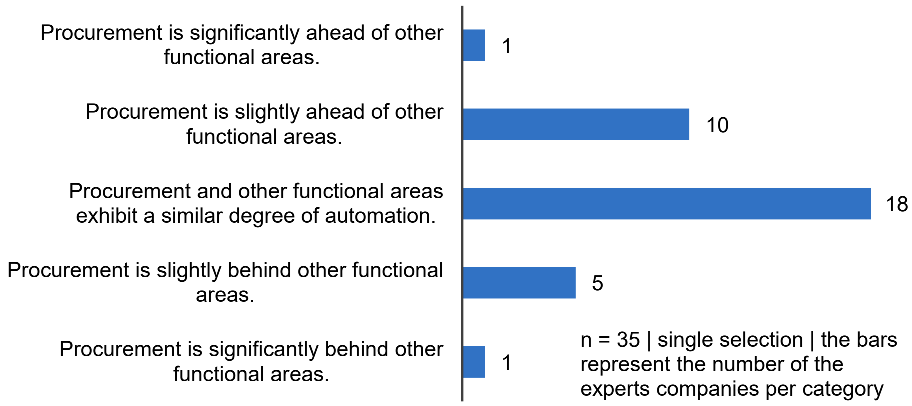


Figure 14: Assessment of the degree of automation in purchasing compared with other functional areas.

The illustration indicates that procurement is not perceived by the experts as lagging behind other functional areas; rather, there is a slight tendency to regard it as comparatively more advanced. The results presented below illustrate the extent to which this perception is reflected in the evaluation of the projections. First, all findings related to technological automation applications are presented and discussed, followed by an analysis of the five organisational and environmental factors.

5.1.3. Scenarios for Automation Application Scenarios

Table 37 provides a summary of the experts' ratings.

#	Scenario	Statement	Short version	This statement describes common practice in **2025**. 1 (strongly disagree) to 5 (strongly agree)			This statement describes common practice in **2035**. 1 (strongly disagree) to 5 (strongly agree)			From today's perspective, this application provides **added value** in procurement. 1 (strongly disagree) to 5 (strongly agree)		
				Median	**IQR**	**Mean**	**Median**	**IQR**	**Mean**	**Median**	**IQR**	**Mean**
1	Augmenta-tion	Big data analytics support procurement employees in risk assessment (e.g., supply risk).	Big Data Analytics in Risk Management	3.00	2.00	2.91	5.00	1.00	4.53	4.00	1.00	4.20
2	Augmenta-tion	AI-powered avatars assist procurement employees in completing their tasks.	AI Avatars for Task Assistance	1.00	1.00	1.71	4.00	2.00	4.03	4.00	2.00	3.94
3	Augmenta-tion	AI-based systems assist procurement employees in the development of category strategies.	AI Support in Category Strategy Development	2.00	1.00	2.20	4.00	1.00	4.26	4.00	1.50	4.11
4	Automation	The operational Purchase-to-Pay process is fully automated; humans intervene only in exceptional cases.	Full P2P Automation with Human Exception Handling	2.00	1.00	2.49	5.00	1.00	4.20	5.00	1.00	4.14
5	Automation	AI evaluates suppliers' compliance with sustainability criteria in an automated manner, while exceptions are manually reviewed by humans.	Automated Sustainability Compliance Checks	1.50	1.00	1.74	4.00	2.00	3.84	4.00	2.00	3.85
6	Autono-mization	With the help of AI, the identification and prequalification of suppliers is carried out without human intervention.	AI-Driven Supplier Prequalification	2.00	1.00	1.77	4.00	1.50	4.00	4.00	2.00	3.89
7	Autono-mization	Intelligent chatbots autonomously negotiate contracts with suppliers.	Autonomous Chatbots for Contract Negotiation	1.00	0.00	1.23	3.00	1.00	2.77	3.00	2.00	2.83
8	Autono-mization	Payments are processed fully automatically without any human intervention thanks to blockchain-based smart contracts.	Blockchain Smart Contracts for Automated Payments	1.00	1.00	1.61	3.00	2.00	3.50	3.50	2.25	3.50
9	Autono-mization	A monitoring system integrated into procurement processes autonomously detects automation potentials in the daily tasks of procurement employees.	Autonomous Detection of Automation Potential in Daily Tasks	1.00	1.00	1.66	4.00	1.75	3.82	4.00	2.00	4.00
10	Autono-mization	Intelligent non-human agents (AI agents) independently make complex decisions, including strategic decisions such as supplier selection, which were still made by humans ten years ago.	AI Agents for Strategic Decision-Making	1.00	0.00	1.14	3.00	1.00	2.53	3.00	1.00	2.71

Table 37: Expert assessment of Procurement 4.0 automation application scenarios

The resulting figure, based on the semantic differential, displays the median values for current adoption (2025), expected adoption (2035), and perceived benefit, highlighting contrasts across these three dimensions.

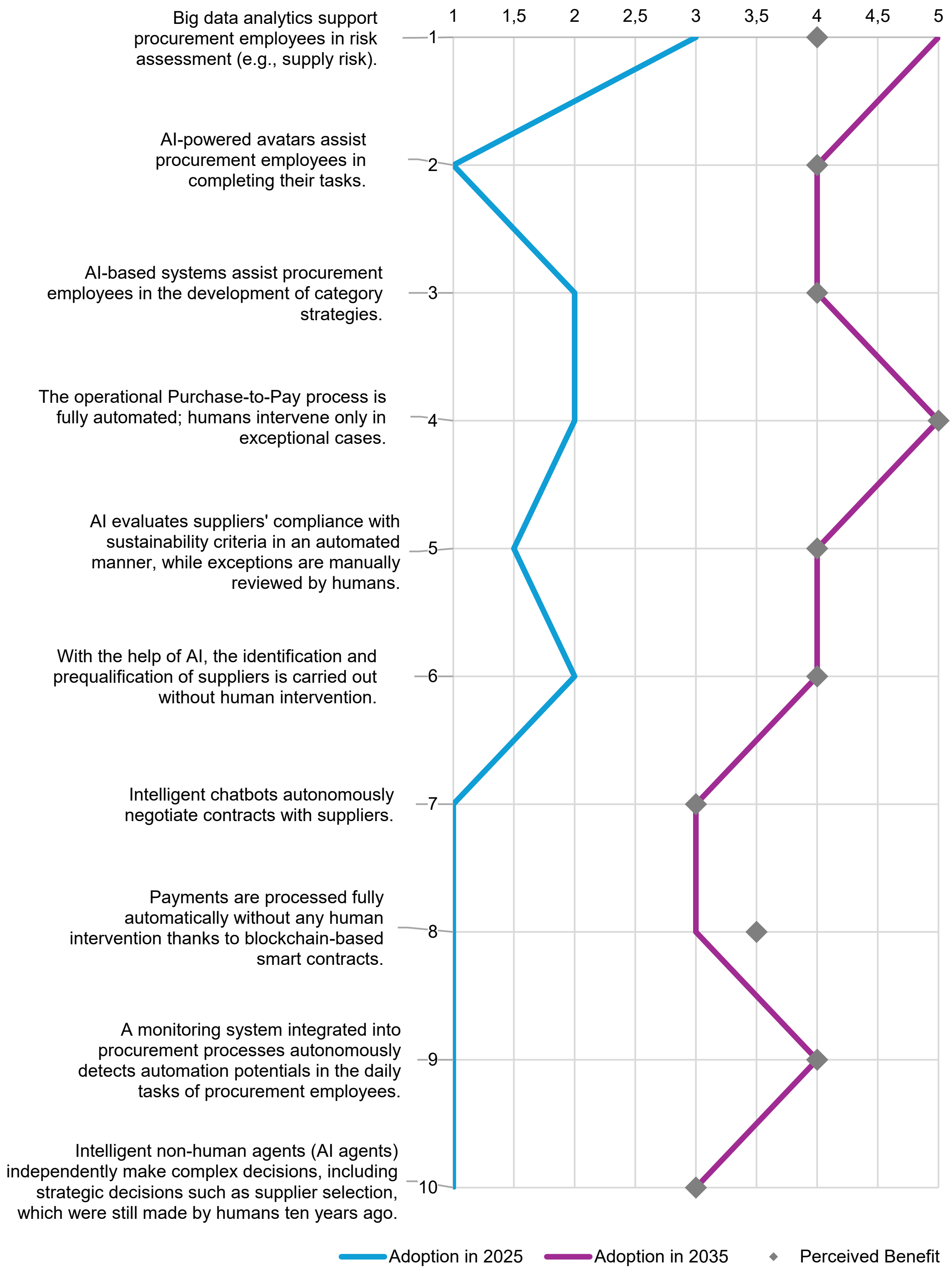


Figure 15: Comparison of the three evaluation dimensions

Figure 15 clearly illustrates the differences between the current state of adoption, the expected development over the next ten years, and the benefits that panellists already associate with the presented applications. Notably, with the exception of a slight deviation between Application 5 and Application 6, a clear distinction emerges between Applications 1–5—representing augmentation and automation scenarios—and Applications 6–10. The former group differs significantly from the latter in terms of current implementation, perceived benefit, and anticipated future adoption.

To test the hypothesis introduced at the beginning of this chapter—that augmentation and automation applications are rated more positively than autonomization applications—a Wilcoxon signed-rank test was conducted. For each participant, median ratings were calculated for both application groups (n = 35 paired observations).

			Statistic	p
Augmentation/Automation Median 2025	Autonomization Median 2025	**Wilcoxon W**	276[a]	<.001
Augmentation/Automation Median 2035	Autonomization Median 2035	**Wilcoxon W**	363[b]	<.001
Augmentation/Automation Median Perceived Benefit	Autonomization Median Perceived Benefit	**Wilcoxon W**	259[a]	<.001

Note. H_a $\mu_{\text{Measure 1 - Measure 2}} > 0$

[a] 12 pair(s) of values were tied

[b] 8 pair(s) of values were tied

Table 38: Results of the Wilcoxon signed-rank test comparing expert ratings

The three Wilcoxon signed-rank tests presented in Table 45 indicate significant differences (all $p < .001$) in expert evaluations across all three dimensions when comparing the medians of individual expert assessments for the five augmentation/automation applications with those for the five autonomization applications. Despite some ties in the data, these results clearly indicate that the panellists perceive augmentation/automation applications more positively and as more likely to shape future procurement practices.

The following chart compares the median ratings and IQR for each application in terms of adoption in 2025 and 2035. The projections are sorted in descending order based on the median ratings. As previously noted, the mean value was used to establish the ranking in cases where the median values were identical. Short version descriptions are used to denote the individual projections.

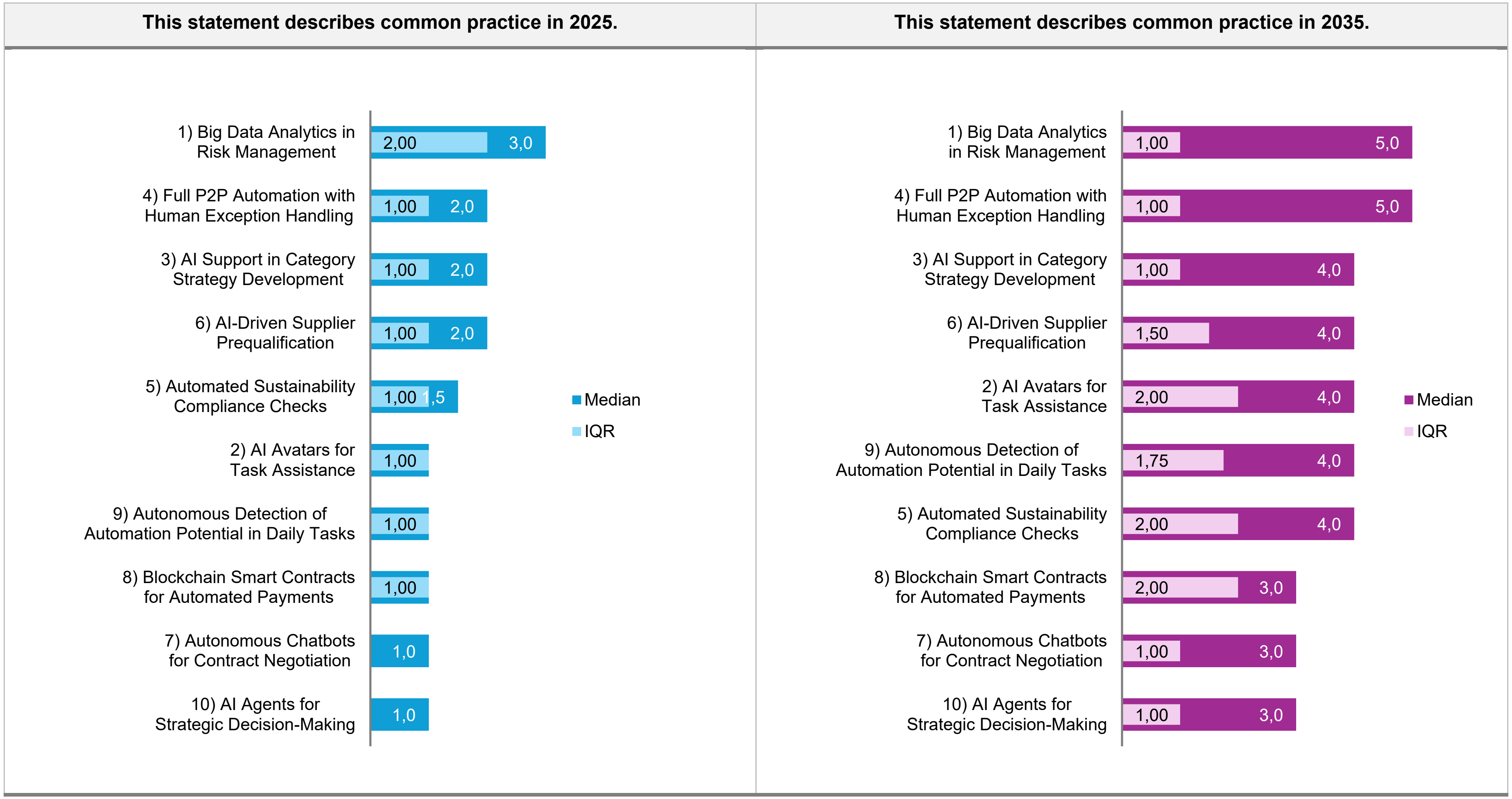


Figure 16: Expert evaluation of Procurement 4.0 automation applications: median and interquartile range by projection

Firstly, it is notable that only one autonomization application appears among the top five ranked applications—namely, AI-driven Supplier Prequalification—reflecting a trend already discussed above. Compared with the autonomization projections (P) 7 and 10, this may be attributed to the fact that prequalification does not represent a final or even strategically relevant decision and is therefore regarded by the experts as more likely to be implemented. Interestingly, in the 2035 projections, Automated Sustainability Compliance Checks (P6) is overtaken by Autonomous Detection of Automation Potential (P9). Apart from this shift, the results suggest that experts largely extrapolate their current assessments into the future.

Secondly, a significant gap is evident between the median ratings for 2025 and those for 2035. The most striking example is operational P2P process, where the median increases from 2 to 5, suggesting that full automation has not been achieved in 2025, but a breakthrough is anticipated thereafter. Strong growth in adoption is also expected for AI Avatars (P2) and Autonomous Automation Potential Detection (P9. In contrast, AI agents—currently a highly discussed topic in the context of process automation—are not expected to play a particularly prominent role in ten years' time. This pattern, along with the other autonomization-related projections, may reflect the influence of Amara's Law, which suggests that the short-term effects of technological innovations are often overestimated, while their long-term impacts tend to be underestimated (Lin, 2024; Precht, 2022). Notably, Blockchain—despite being one of the most intensively discussed technologies in the heat map—only ranks 8th out of 10 in both current and expected adoption levels.

Turning to the IQR, it is notable that—with the exception of Big Data Analytics in Risk Management (P1)—there is already relatively strong expert consensus for most applications, indicated by IQR values ranging between 0 and 1. Given the 5-point rating scale used for the Likert-type items, such low IQR values are generally indicative of consensus in Delphi research (Von Der Gracht, 2012, p. 1531). The divergence in views on big data is surprising, given that it is widely regarded as one of the most established Industry 4.0 technologies in procurement, as discussed throughout this paper. Yet the panellists appear not to have reached agreement on its current relevance. The second Delphi round will be particularly revealing in terms of whether consensus can be strengthened on this point.

As expected, the IQR values vary more widely for the 2035 forecasts. While there is broad agreement on the outlook for big data analytics, significant differences emerge in the evaluations of projections 2, 5, 8, and 9. In the case of autonomous, AI-based applications at a strategic level, there is once again consensus—this time on a moderate level of future relevance.

Finally, it is worth noting the comparatively low level of agreement regarding the future adoption of Automated Sustainability Compliance Checks, which is one of only three applications with an IQR of 2.00. This may reflect the political uncertainty regarding sustainability-related legislation, which leave experts uncertain about the concrete regulatory requirements they may face over the next decade.

The reasons underlying the experts' assessments are examined through qualitative content analysis. Before presenting these findings, however, it is instructive to first consider the perceived benefits of the Procurement 4.0 automation applications. The following chart presents the median ratings and IQR for each application in terms of the perceived benefit from today's perspective. The projections are sorted in descending order based on the median ratings. Again, the mean value was used to establish the ranking in cases where the median values were identical. Short version descriptions are used to denote the individual projections

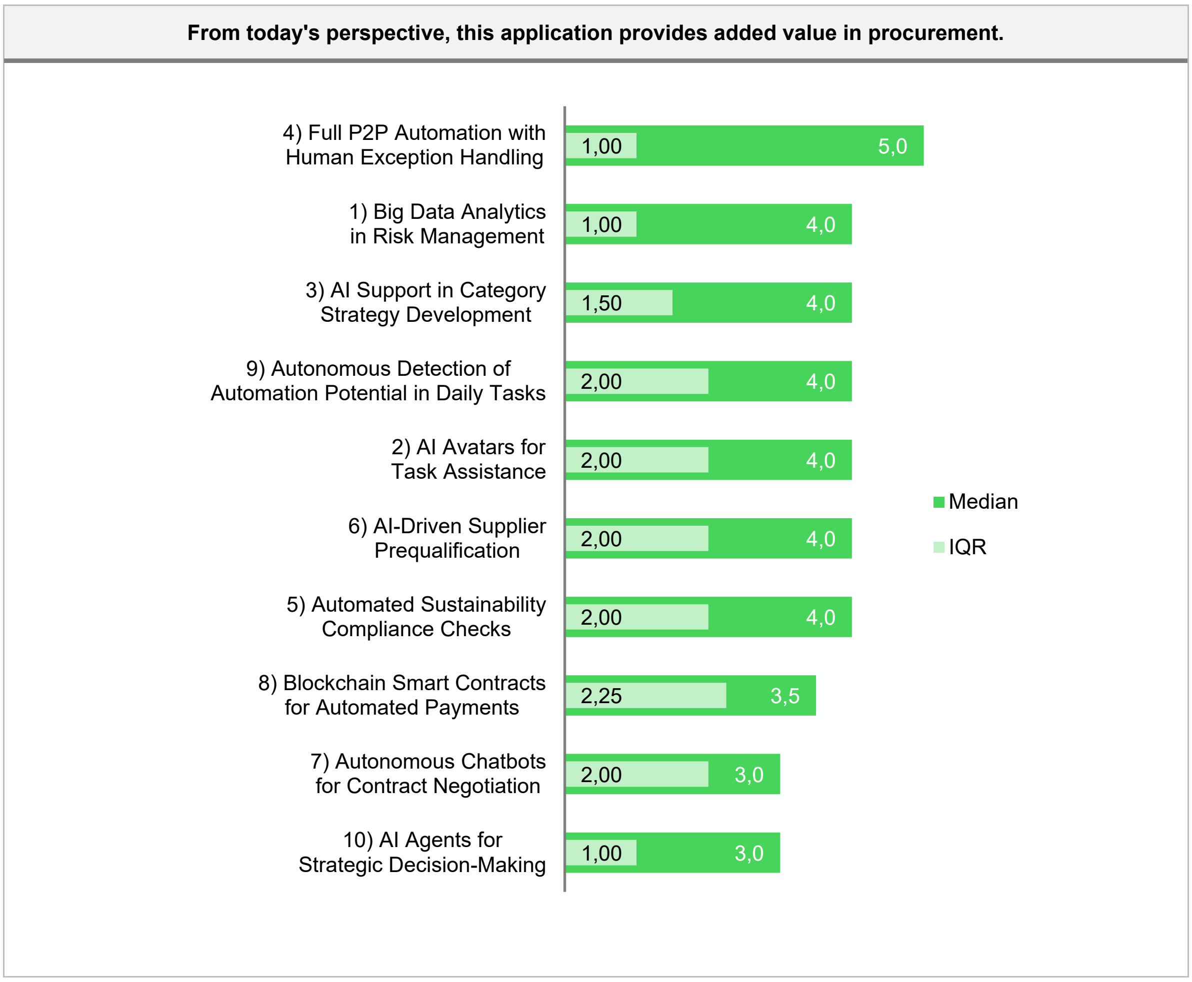


Figure 17: Expert evaluation of the perceived benefits of Procurement 4.0 automation applications

Big Data Analytics ranks first in terms of expected adoption both in 2025 and 2035. However, regarding perceived benefits in prourement, it is positioned behind Full P2P Automation with Human Exception Handling (median = 5.0), with a median value of 4.0. Overall, projections 1, 3, and 4 consistently appear within the top three rankings across all dimensions. Conversely, the perceived benefit of AI-driven supplier preselection lags behind its expected adoption, ranking lower than AI Avatars for Task Assistance and the Autonomous Detection of

Automation Potential in Daily Tasks. Moreover, the bottom four positions in perceived benefit correspond directly to the lowest-ranked applications in terms of expected adoption in 2035.

Overall, the benefit dimension suggests that the top seven applications offer substantial perceived benefits from the procurement experts' perspective. Caution should be exercised with Blockchain Smart Contracts for Automated Payments (P8), given the relatively low expert consensus indicated by an IQR of 2.25—the highest observed in this study.

When comparing perceived benefit with estimated adoption in 2025 (see also Figure 15), the results paint a sobering picture, revealing a clear gap between potential benefits and the currently assessed state of adoption. To test the statistical significance of this 'potential–practice gap', a Wilcoxon signed-rank test was conducted, comparing the median adoption score for 2025 with the median perceived benefit score, both calculated per expert across all ten applications. The results are presented in the following table.

			Statistic	p
Perceived Benefit Median	Perceived Current Adoption 2025 Median	**Wilcoxon W**	630	<.001

Note. H_a $\mu_{Measure\ 1\ -\ Measure\ 2} > 0$

Table 39: Results of the Wilcoxon signed-rank test on the 'potential–practice gap'

The Wilcoxon signed-rank test yielded a test statistic of W = 630 ($p < .001$), indicating that the perceived benefit is significantly higher than the current adoption of the applications. This supports the hypothesis of a gap between perceived potential and current practice, here referred to as the 'potential–practice gap'.

Regarding the IQRs, there is strong agreement on the high perceived benefit of a fully automated P2P process with human exception handling (P4), as well as big data analytics in risk management (P1). There is also consensus on the moderate benefit of AI agents for strategic decision-making (P10).

In contrast, significant disagreement is evident in the case of blockchain-based smart contracts for automated payments. This finding further supports the argument introduced earlier in this thesis that blockchain technology continues to reflect a substantial gap between its theoretical potential, academic debate, and practical implementation. A similar pattern of divergence can be observed across all AI-based applications, apart from AI agents.

This suggests that, despite high expectations for AI technologies, a degree of uncertainty persists among practitioners. Whether AI will soon be used in everyday practice like any other standard software—without attracting particular scrutiny—as recently suggested in a podcast episode on agentic AI[45] (Pacher, n.d.), remains to be seen.

To provide a deeper understanding of the evaluation results, the findings of the qualitative content analysis are presented and discussed in the following by summarising recurring patterns within each category for each projection (P01-P10), grouped according to the respondents' rating levels—high (5–4), medium (3), or low (1–2)— regarding perceived adoption in 2035, in order to highlight differing perspectives.

4.3.5.1. Big Data Analytics in Risk Management

Table 40 presents the aggregated expert justifications for P01.

Big data analytics support procurement employees in risk assessment (e.g., supply risk).		
+	**~**	**-**
• **Evolving Technologies:** Artificial intelligence is assuming an increasingly central role in big data analysis and is expected to see continued growth in its application. • **Maturity Level:** Procurement processes remain at a relatively low level of maturity, with small and medium-sized enterprises lagging behind larger corporations in terms of digitalisation. • **Risk Management:** The use of big data for risk assessment is considered highly valuable, particularly in the context of more frequent crises and heightened risk awareness. It is regarded as a key enabler of more proactive and effective risk identification and management. • **Technology Adoption:** Big data analyses are currently still rarely used and, where they are, primarily in large enterprises. Sectoral differences are also noted (e.g. in serial production). Broader adoption among SMEs is expected by 2035. • **Technological Benefits:** Big data enables a broad spectrum of benefits. Owing to the complexity of procurement, meaningful analyses require substantial resources when performed manually. • **Technology Readiness:** Currently available solutions are too imprecise and fail to adequately cover certain areas of application.		**Data Management and Procurement Complexity:** Big data analyses rely on valid data from the supply chain. However, many aspects—such as disruptions or supplier capacities—cannot easily be captured in data form, which is why this assumption is viewed critically.

Table 40: Explanations of the evaluations for P01

One initial observation is that no comments were recorded for the medium rating category, as none of the respondents assigned a neutral rating for the projected 2035 adoption of the application. Among the experts who expressed optimism about the future of big data analytics, some also offered critical reflections. For example, a comment under the Maturity Level category highlights that processes in general remain at a relatively low level of maturity, while particularly small and medium-sized enterprises (SMEs) continue to lag behind larger companies in terms digitalisation.

[45] This episode of the State of Process Automation podcast was published on 1 March 2025 .

The drivers discussed throughout this thesis—such as the increasing frequency of crises—appear to be contributing to heightened risk awareness, which, in turn, supports the relevance of big data analytics in procurement. A critical perspective in this regard addresses challenges related to data availability and the complexity of procurement. One expert, for instance, notes that many relevant factors—such as supply disruptions or supplier capacities—cannot easily be captured in data form. This comment is another indication that procurement still faces fundamental challenges, such as data integration. Moreover, differences in current adoption levels are also noted, particularly between series production and large companies.

Looking ahead, several respondents anticipate that AI will be increasingly applied to big data analytics and that SMEs will begin to adopt these technologies more widely by 2035. One expert highlights a key benefit that aligns with a frequently mentioned challenge: meaningful data analysis, when done manually, demands significant resources due to the inherent complexity of procurement. This, in turn, supports the case for the use of big data analytics. However, as one expert points out, the current limitations of big data analytics solutions would need to be addressed before these advantages can be fully realised.

4.3.5.2. AI Avatars for Task Assistance

Table 41 presents the aggregated expert justifications for P02.

AI-powered avatars assist procurement employees in completing their tasks.		
+	**~**	**-**
• **Attitude:** Barriers and scepticism toward the use of AI persist. • **Human Skills:** Certain tasks require human interaction, and in areas such as strategic and relationship management, human skills are expected to become even more important. • **Others:** Additional challenges include IT security concerns, the low level of maturity in procurement, and the prevailing use of customised individual tools, while standard tools are often prone to errors. • **Technology Adoption:** Aside from general solutions such as MS Copilot, adoption remains limited at present. However, operational procurement processes are expected to be largely managed by AI in the future. • **Technological Benefits:** The range of potential AI applications in procurement is broad. On one hand, AI is expected to significantly ease repetitive tasks, such as the creation of master data or the processing of order confirmations. On the other hand, AI will increasingly be applied in more complex procurement activities, including supplier selection and evaluation, as well as contract management. Potential use cases for avatars—providing automated data and decision recommendations—include the analysis of supplier evaluations, purchase orders, and contract negotiations. A key advantage lies in the ability to perform complex analyses rapidly, thereby reducing administrative workload and allowing staff to focus on value-adding tasks. This is anticipated to lead to increased productivity and competitiveness.	• **Attitude:** There is currently a lack of openness to new technologies and a general absence of trust. • **IT Security:** Cybercrime is considered a major risk. • **Technological Benefits:** AI is expected not merely to support, but to fully take over certain procurement tasks. Further automation is seen as beneficial, although the added value of avatars remains questionable. • **Technology Readiness:** AI is prone to errors, and issues of liability remain unresolved.	• **Technological Benefits:** On the one hand, the specific tasks that an avatar could take over remain unclear. On the other hand, advantages are recognised in operational procurement, whereas in strategic procurement, only to a limited extent, as tasks such as negotiations are considered to be best left to humans. • **Technology Adoption:** Chatbots are not expected to become widely adopted in the future, as they are perceived to offer limited solutions in the B2B context.

Table 41: Explanations of the evaluations for P02

The comments on AI avatars reveal that, even among experts with optimistic or neutral views, certain reservations persist. A lack of openness and trust towards emerging technologies such as AI remains evident, with concerns also raised around IT security. Several experts emphasise the continued importance of uniquely human skills—a new thematic category—with some suggesting these may become even more important in the future.

It is noteworthy that, aside from general applications such as Microsoft Copilot—which is reportedly already in use—the adoption of AI avatars is not yet widespread. Nevertheless, many panellists anticipate a significant increase in adoption, particularly within operational areas. One expert explicitly mentioned chatbots and expressed scepticism about their future implementation, citing limited solutions in the B2B context.

Regarding the perceived benefits of AI avatars, examples were identified across all three functional areas. In the operational domain, use cases such as master data creation were mentioned, while more complex tasks—such as supplier selection, evaluation, and contract management—were also seen as potential application areas. However, contrasting views were expressed, with some experts suggesting that while AI may offer advantages in operational tasks, its usefulness in strategic domains is limited. For instance, tasks such as negotiations were viewed as inherently human.

Interestingly, one neutral respondent addressed the possibility of AI avatars fully taking over tasks that extend beyond support functions. This viewpoint stands in contrast to the overall position reflected in the panel's responses.

The general value of AI avatars was also questioned, whereas the speed of complex analysis—enabling greater focus on value-adding activities and potentially enhancing productivity and competitiveness—was cited as a key benefit of AI in procurement.

These contrasting perspectives highlight areas of contention and divergence, which may yield valuable insights in the context of the second Delphi round.

4.3.5.3. AI Support in Category Strategy Development

Table 42 presents the aggregated expert justifications for P03.

AI-based systems assist procurement employees in the development of category strategies.		
+	~	-
• **Data Management:** The necessary individual (master) data infrastructure is perceived as a key challenge. • **IT Security:** The use of sensitive company-related data within AI systems is viewed critically, particularly in relation to data protection and security concerns. • **Skills and Competences:** There is a lack of expertise in dealing with emerging technologies such as AI. In terms of the specific application, a strong strategic procurement function with the requisite expertise is essential. • **Solution:** Current AI tools cited in this context include ChatGPT and Cirtuo. From a technological perspective, the combined use of big data and AI is considered beneficial. • **Technological Benefits:** Various potential benefits are identified, including the detection of cost-saving opportunities, more agile responses to market changes, acceleration of the strategy development and presentation process, AI as a decision-support and facilitative tool in the category strategy development process, and the automation of routine tasks. Together, these advantages may allow employees to focus more effectively on value-adding activities. However, questions remain regarding the extent to which AI can contribute meaningfully to strategy development beyond documenting the obvious. • **Technology Adoption:** At present, AI use in this domain—apart from general applications such as employing ChatGPT for structural suggestions—is not yet standard practice. Nonetheless, this is expected to change, as AI is believed to offer added value in this context, even though this value is not always clearly articulated.	• **Data Management:** A sound and accurate data foundation is essential. However, AI systems do not align category strategies with the overarching corporate strategy, as the information required for such integration is lacking. • **Others:** The role of human expertise remains important, particularly with regard to market knowledge and experience. • **Technological Benefits:** While AI is perceived to offer added value, this is difficult to assess. On the one hand, it is recognised as a useful tool for decision support; on the other hand, AI systems may be capable of developing strategic category scenarios without aligning them with the broader corporate strategy.	

Table 42: Explanations of the evaluations for P03

For the AI-based category strategy development use case, no respondents assigned a neutral rating for projected adoption in 2035; as such, no comments were recorded for this category. Among the remaining responses—those expressing high or low expectations—two main areas were discussed in greater depth: data management and technological benefits. The required master data structure was identified as a particular challenge, and the need for a suitable data foundation was emphasised as a prerequisite for implementation. However, one expert noted that aligning the procurement strategy effectively with the overarching corporate strategy is not feasible, as the necessary information is simply lacking.

Cirtuo, the solution previously mentioned in the case study, was cited alongside ChatGPT as one of the first tools being applied in this context. Despite the use of basic applications—such as ChatGPT for structuring proposals—current adoption appears limited. Nevertheless, the expected future value of such tools was frequently acknowledged, albeit not always substantiated in detail.

The potential benefits identified by experts include cost savings, increased agility in responding to market dynamics, and acceleration of the strategy development and presentation process. In line with how the use case is framed, AI is viewed primarily as a tool that supports decision-making and automates routine tasks.

The most critical perspective came from an expert who supported the future relevance of the application but questioned its practical value. This expert suggested that, for many categories, AI might merely document the obvious, and the actual added value could remain limited—unless top management insists on developing formalised strategies for all categories. In such cases, the added value may stem from the speed of development and presentation rather than from strategic insight. This statement leads to the well-known remark attributed to *Peter Drucker (1963): 'There is surely nothing quite so useless as doing with great efficiency what should not be done at all.'*

4.3.5.4. Full P2P Automation with Human Exception Handling

Table 43 presents the aggregated expert justifications for P04.

The operational Purchase-to-Pay process is fully automated; humans intervene only in exceptional cases.		
+	**~**	**-**
• **Data Management:** Data quality is a fundamental prerequisite, although the accuracy of existing data remains an issue. The topic of master data requires further improvement. • **Evolving Technologies:** The use of advanced AI technologies is expected to drive forward the automation of the P2P process. • **Finance:** Investment costs are a barrier preventing SMEs from advancing automation. • **Procurement Complexity:** The P2P process continues to involve numerous variables that result in unexpected exceptions and necessitate human intervention. • **Process Management:** A clear definition of processes and responsibilities is a prerequisite for this use case. At present, a variety of exceptions still occur, requiring human input. Further automation and a shift towards exception management are needed. Comments also suggest that trouble-shooting will continue to be necessary. Additionally, references are made to differing degrees of automation across P2P sub-processes: while payment processes and catalogue-based orders can be fully automated, supplier selection for larger orders still requires human involvement due to relationship management and negotiation requirements. • **Technology Adoption:** Such automation would already be feasible today under certain process-related conditions and is already partially implemented in large enterprises. Based on expert experience, 80–90% of tasks can currently be covered through correct configuration. However, in other companies, numerous exceptions still occur that require human intervention. As a result, procurement processes in many organisations are significantly less automated than assumed. Nevertheless, the automation of operational routine tasks will be essential by 2035 in order to remain competitive. Given the current level of ERP penetration, a certain degree of automation already exists and will become standard practice by 2035. Two experts also refer to the differing automation potentials in indirect versus direct procurement. • **Technological Benefits:** Routine tasks are ideally suited for automation, allowing employees to focus on strategic topics such as supplier relationship management. Furthermore, the digitalisation of the P2P process offers advantages including direct and error-free communication with all relevant stakeholders, complete process documentation, and the ability to generate performance insights (e.g. throughput times).	• **Data Management:** This requires highly accurate, 100% reliable (master) data. • **Human Skills:** Employees' experience and intuition in dealing with others cannot be translated into digital data. • **Process Management:** Sub-processes such as ordering, invoice checks, and payments can be handled seamlessly; however, human intervention remains necessary in cases of complex issues or exceptional requests. Standardised processes are a prerequisite—something companies have struggled with for decades. • **Technological Benefits:** Efficiency is maximised, while the number of errors is minimised. • **Technology Adoption:** SMEs are still lagging behind large enterprises in terms of P2P automation.	• **Data Management:** Automation requires a certain level of master data quality. • **Human Skills:** Personal contact, a collaborative approach, and mutual trust will continue to be important in the future. • **Procurement Complexity:** In low-volume/high-complexity industries, achieving 100% master data quality is hardly feasible. • **Risk Management:** Open questions remain, such as those concerning the consequences of supply shortages when avatars operate in an automated manner on both the buyer and seller sides.

Table 43: Explanations of the evaluations for P04

Experts consider the scenario of fully automating the P2P process to be useful, as routine tasks are well suited to automation, enabling employees to focus on more strategic issues. According to a shared experience, 80–90% of such tasks can already be automated today. However, the presence of numerous exceptions in practice means that procurement processes are often significantly less automated than commonly assumed. Nevertheless, the use of AI is expected to drive further advances in P2P automation.

Neutral and critical comments, meanwhile, highlight the need for accurate (master) data and suggest that employee experience and intuition remain important in the P2P process. The importance of personal contact and mutual trust is also emphasised.

Overall, some comments reflect ambivalent expert opinions—despite a uniformly positive assessment of the use case, indicated by an interquartile range (IQR) of 1.

4.3.5.5. Automated Sustainability Compliance Checks

Table 44 presents the aggregated expert justifications for P05.

AI evaluates suppliers' compliance with sustainability criteria in an automated manner, while exceptions are manually reviewed by humans.		
+	**~**	**-**
• **Data Management:** Questions arise regarding the sources that AI relies on. While this may be feasible in Europe, it is more difficult in regions such as South America or Asia. The reliability of such assessments depends on the availability of supplier-related information. • **Rules and Regulations:** The Supply Chain Due Diligence Act and CBAM are relevant in this context and contribute to technological transformation. Companies may also tighten their sustainability criteria, potentially resulting in increased administrative burden. Currently, the vague nature of some regulations and requirements presents challenges for assessing and verifying compliance with sustainability criteria. Additionally, overregulation and excessive bureaucracy are seen as a serious risk, potentially leading to a significant rise in non-value-adding activities. Beyond Tier 1, supply chain transparency becomes a legal issue, as the contractual partner of one's supplier is not one's own contractual partner. • **Skills and Competences:** Procurement does not necessarily include sustainability experts. • **Strategic Management:** Companies should take responsibility for their Tier 1 suppliers and direct customers. Furthermore, the supplier network represents valuable know-how, which must be protected and not disclosed. • **Technological Benefits:** An AI solution offers added value, as procurement professionals are not necessarily sustainability experts. In the context of global and complex supply chains, effective risk and sustainability management is only achievable through the integration of vast amounts of data—a process that would require significant resources if performed manually. • **Technology Adoption:** In this area, the use of AI is not yet common practice. However, this is expected to change considerably in the coming years due to the implementation of the Supply Chain Due Diligence Act. • **Technology Readiness:** Existing AI-based software solutions claim to ensure compliance. However, current company experience suggests that supplier reports often include very general and only marginally relevant information. While today's systems are strong in data collection, user-specific analysis and interpretation remain significantly underdeveloped.	• **Process Management:** Exceptional cases that require complex assessments will continue to be handled manually by specialists. • **Rules and Regulations:** Sustainability regulations, such as the Supply Chain Due Diligence Act, are considered burdensome, as they result in additional financial and non-value-adding effort. Moreover, political regulations are subject to constant change. • **Skills and Competences:** There are significant gaps in practical knowledge among stakeholders when it comes to managing sustainability. • **Technological Benefits:** Real-time evaluation of environmental and social standards enables the rapid identification of violations or irregularities. • **Technology Adoption:** The digitalisation of sustainability remains a distant prospect, due to a combination of knowledge gaps and a general aversion to technology. • **Technology Readiness:** Verifying compliance with sustainability criteria at the supplier level remains a challenge for AI.	• **Technological Benefits:** Using standardised criteria, AI would be capable of assessing sustainability more easily in the context of regulatory requirements. As this process is expected to become increasingly complex in the future, AI support offers clear added value by simplifying and accelerating the evaluation process. • **Technology Adoption:** At present, application is limited due to the low informational value of corporate sustainability reports and the frequent lack of clearly defined criteria and their weighting in procurement decisions. Further developments in this area remain uncertain in light of current political changes.

Table 44: Explanations of the evaluations for P05

Experts see potential in AI-based automated sustainability checks, particularly in light of expected upcoming regulations in the sustainability domain and the associated bureaucratic challenges. As these regulations are expected to involve significant manual effort, AI solutions are viewed as beneficial in easing this burden. However, a key concern remains: the lack of clearly defined criteria and their weighting in procurement decisions. Furthermore, the trajectory of future developments is uncertain, due to potential political shifts.

4.3.5.6. AI-Driven Supplier Prequalification

Table 45 presents the aggregated expert justifications for P06.

With the help of AI, the identification and prequalification of suppliers is carried out without human intervention.		
+	**~**	**-**
• **Data Management:** Limitations exist due to poor master data quality. Additionally, sufficient data quality is required for this application to function—such as the presence of standardised keywords on supplier websites. At present, a global standard is lacking. • **Process Management:** Human intervention will continue to be necessary, for example, when a new supplier enters the market and is not yet accessible to the AI system, or when technical details need to be clarified. • **Technological Benefits:** Added value arises through potential reductions in personnel and process costs, lower administrative effort, accelerated processes, greater decision transparency, and more objective supplier selection enabled by a 360° view of suppliers. Two experts consider automated tendering for C-parts and applications in indirect procurement to be feasible, while for strategically important components, human involvement is still regarded as indispensable. • **Technology Adoption:** This application is suitable for AI use—moving from a supplier database to an AI-based system is a small step—meaning that partial implementation is already possible or even standard for certain product categories. However, it cannot yet be considered common practice. Pre-selection can already be based on system-derived criteria. By 2035, AI will be a key component of this widely applied practice. One expert limits the scope to supplier search, excluding selection. Two others include initial selection and one foresees future support in additional sub-processes—such as clarifying technical details using training based on technical drawings, from which technologies and potential partners could be identified.	• **Procurement Complexity:** This use case is highly dependent on the material to be procured. A distinction must be made between standard goods and complex modules. • **Process Management:** A certain level of automated interaction with suppliers is a prerequisite for this use case. • **Technology Adoption:** In the context of key technologies and complex modules, AI will continue to play a subordinate role compared to human expertise. • **Technological Benefits:** Advantages arise in the global search for suppliers and in the pre-selection of standard goods.	• **Procurement Complexity:** This use case is highly dependent on the material to be procured. It is conceivable for non-critical parts such as C-parts, but less so for high-value components. • **Skills and Competences:** For high-value components, strategic procurement is essential—drawing on its network, experience, agility, and close collaboration with engineering and quality.

Table 45: Explanations of the evaluations for P06

Limitations related to poor master data quality are mentioned in relation to AI-based supplier identification and prequalification. Some experts still view human intervention as necessary—for instance, when a new supplier has not yet been captured by the AI system, when technical details require clarification, or when dealing with strategically important components.

Experts also see clear added value in AI, including potential savings in personnel and process costs, reduced administrative burden, faster processes, increased transparency in decision-making, and more objective supplier selection due to a comprehensive view of suppliers. Two experts consider automated tenders for C-parts and applications in indirect procurement feasible, further addressing the notion of autonomous C-parts procurement raised in the case study analysis.

By 2035, AI is expected to be an integral part of practice. One expert restricts its use to supplier search, excluding selection. Two others include pre-selection, while another anticipates future support in sub-processes such as clarifying technical details—enabled by training systems to interpret technical drawings and identify relevant technologies and potential partners.
The future application of AI in this context is often seen as highly dependent on the material in question. This suggests a need to differentiate between standard goods and complex modules. For key technologies and complex components, experts emphasise that AI will likely remain secondary to human expertise. Strategic procurement, based on networks, experience, agility, and close collaboration with engineering and quality functions, is considered critical for securing high-quality components.

4.3.5.7. Autonomous Chatbots for Contract Negotiation

Table 46 presents the aggregated expert justifications for P07.

Intelligent chatbots autonomously negotiate contracts with suppliers.		
+	~	-
• **Human Skills:** Latent objectives and compromises based on human judgement are difficult to account for in this application. • **Process Management:** If framework conditions are negotiated in this way, employees can focus on handling exceptions. • **Procurement Complexity:** The relevance of this use case depends on factors such as the industry (e.g. automotive vs. plant engineering), the complexity of components, the specificity of products, and the characteristics of the market environment. • **Technology Adoption:** This use case is feasible with appropriate preparation. In one company, AI is already used in contract management. However, there are doubts as to whether chatbots will be able to successfully conclude contracts given the current legal situation. If so, it is considered possible for small-scale orders or in the automotive sector, where contracts follow a certain standard—but not for more complex components, where details make a significant difference, as is typically the case in plant engineering. • **Technology Readiness:** Contract negotiation is not considered a core competency of AI.	• **Attitude:** This use case is vaguely imaginable, but not desirable. One would not sign a contract with a chatbot when it concerns a critical component. It is also unlikely to become common practice for AIs to negotiate with one another and conclude contracts without human involvement. Ultimately, negotiations take place at the table—not in a virtual space. • **Human Skills:** Even in 2035, personal interaction, face-to-face discussions, and negotiation skills will remain essential to reaching compromises—or even achieving better outcomes. This application would undermine the sense of appreciation between business partners and communication on equal footing. • **Process Management:** Involvement of the legal department will remain necessary. • **Technological Benefits:** With the help of AI assistants, legal departments could accelerate contract negotiations and improve outcomes. For simple, parameterisable goods and services, any negotiated result is better than none. Additionally, the technology could be useful in preparing for negotiations (e.g. agenda setting, calculations). • **Technology Adoption:** Although the use of chatbots in negotiations is not yet standard practice, this application is feasible for simple contracts—such as those involving C-parts and commodities—provided adequate oversight is in place. However, it remains unthinkable for critical components. • **Technology Readiness:** It remains unclear which AI would be responsible for agreeing to a compromise.	• **Attitude:** There is a lack of trust in this application. • **Human Skills:** One reason this is only feasible for standard contracts is the significant interpersonal component involved. Additionally, factors such as current power dynamics, BATNA and ZOPA, and tactical negotiation concessions cannot be effectively handled by a chatbot. The need to find compromises also means agreements must ultimately be made between people. • **Rules and Regulations:** In practice, these matters are often highly complex—particularly in the case of cross-border contracts involving different legal systems. Moreover, different partners have different expectations regarding contract content. It remains unclear who, in the case of chatbot use, decides the relative importance of contract clauses and who bears responsibility in the event of penalties. • **Technological Benefits:** Outsourcing the administrative burden associated with contracts and negotiations to AI is desirable, though limited in practice. Support with contract review and drafting, however, is considered useful. • **Technology Adoption:** This application is feasible for standard contracts, but not beyond that, as an intelligent chatbot cannot replace actual negotiation. At a minimum, the buyer's purchasing terms must be reconciled with the seller's sales termss—an area in which AI will not play a role. One expert anticipates similar outcomes to e-auctions, where systems and tactics quickly became predictable. • **Technology Readiness:** Contract negotiations are rooted in human dynamics and are difficult to automate.

Table 46: Explanations of the evaluations for P07

Intelligent chatbots that autonomously negotiate contracts with suppliers are generally considered less likely in future procurement practice. Experts attribute this to the complexity of procurement processes, highlighting factors such as industry-specific requirements, component complexity, product specificity, and the characteristics of the market environment. A degree of scepticism is evident in the comments. While the scenario is not entirely ruled out, it is viewed as undesirable—particularly for critical components, where contracting with a chatbot is seen as implausible.

Experts also doubt the prospect of AI systems negotiating and concluding contracts independently, without human involvement. Negotiations are perceived as inherently personal, typically taking place face-to-face rather than in virtual environments. In addition, contractual issues—especially in cross-border contexts—are often highly complex, involving differing legal systems and divergent expectations among partners regarding contract content. It remains unclear who would determine the weighting of contract clauses or assume responsibility in the event of penalties when chatbots are involved.

One expert draws a parallel with e-auctions, suggesting that similar use cases may lead to predictable patterns and tactics. Nonetheless, delegating certain administrative aspects of contracting and negotiation to AI is seen as potentially beneficial. In particular, support with contract review and drafting is regarded as useful, although expectations for broader automation remain limited.

4.3.5.8. Blockchain Smart Contracts for Automated Payments

Table 47 presents the aggregated expert justifications for P08.

Payments are processed fully automatically without any human intervention thanks to blockchain-based smart contracts.		
+	**~**	**-**
• **Process Management:** A human control function in payment processing—particularly for high-value invoices—should remain in place, meaning this application will not operate entirely without human involvement. One expert assigns this application to the domain of the finance department. • **Tech Vigilance:** In some cases, no opinion has been formed regarding this application, and the specific role of blockchain technology remains unclear. One expert highlights the general unfamiliarity with smart contracts and draws a similar comparison with cryptocurrencies and blockchains. • **Technological Benefits:** Blockchain technology ensures high efficiency and reduces sources of error, as all contractual terms are digitally recorded and immutable, allowing payments to be made only upon full compliance with the agreed conditions. Early payment discounts are also guaranteed. Through this application, non-value-adding administrative tasks may be eliminated. • **Technology Adoption:** Blockchain technology is still largely unfamiliar but may become standard within the next ten years, similar to M2M communication in connection with M2M payments. According to one expert, it is already in use. Another expert notes that automated payment processing is already possible today within a clearly defined framework, although the role of blockchain in this context remains unclear.	• **Process Management:** Spot checks remain essential, as many companies continue to struggle with data quality. • **Tech Vigilance:** There is a lack of knowledge and experience regarding this technology. • **Technology Adoption:** Provided that data quality is assured, and contract parameters are aligned, this application can already be implemented today. AI is considered useful in this area and is expected to be adopted on a larger scale. In the future, if payments are made in accordance with the contract and goods receipt, no additional human intervention will be required.	• **Finance:** This application is currently too expensive. • **Infrastructure:** From today's perspective, it is difficult to envision this application—unless computational power is significantly enhanced through quantum computing. • **Technological Benefits:** The advantages of blockchain technology lie particularly in the seamless documentation of the lifecycle of components or raw materials. • **Technology Adoption:** The application is considered technically feasible today. However, its relevance is industry-specific—for example, there is no demand in special-purpose machinery. In other sectors, feasibility depends on the supply chain and the countries of origin. Finally, from an economic and practical standpoint, it is questionable whether blockchains—with their high energy consumption—should be used by all companies for simple invoice processing.

Table 47: Explanations of the evaluations for P08

The evaluation of the blockchain application reveals that some experts still view human oversight as necessary in the context of payments, particularly for high-value transactions. In addition, several comments highlight gaps in knowledge regarding blockchain technology. Perceived benefits include reduced sources of error, improved compliance, and the automation of non-value-adding administrative tasks. However, one expert notes that automated payments are already possible without blockchain, casting doubt on the added value of blockchain in this context.

Among those who consider the future applicability of blockchain to be low, several challenges are identified. These include concerns over high costs, high energy consumption, and insufficient computational power—with one expert suggesting that quantum computing could be a more suitable solution in the long term. Industry-specific limitations are also raised, such as the perception that relevance is sector-dependent and that blockchain offers limited added value in special-purpose machinery.

4.3.5.9. Autonomous Detection of Automation Potential in Daily Tasks

Table 48 presents the aggregated expert justifications for P09.

A monitoring system integrated into procurement processes autonomously detects automation potentials in the daily tasks of procurement employees.		
+	~	-
• **Evolving Technologies:** Systems continue to develop, and in the foreseeable future, simple, recurring processes will be automatically identified in this way, with robotic support offered. • **Process Management:** Procurement—illustrated here by the example of special machine construction—is highly complex. Combined with staff turnover and a lack of time for sufficient system and process training, operational procedures are handled inconsistently. • **Rules and Regulations:** Compliance with labour law, GDPR, and agreements with employee representative bodies is relevant in this context. • **Technological Benefits:** Such tools are a solution for making diverse processes more transparent and enabling standardisation. Furthermore, several strategic steps are not yet digitally mapped, so improved integration would be welcomed. This also results in a gain in productivity. • **Technology Acceptance:** The term 'monitoring system' is problematic, as no one wants to feel monitored. However, if referred to as a suggestion system that automatically generates ideas for improving effectiveness, the benefit becomes apparent. • **Technology Adoption:** On the one hand, it is not known whether such systems are already widely adopted. On the other hand, the technology is already in use. Ultimately, this application is expected to gain importance over the coming years and become standard practice in many companies by 2035. Another expert assumes that such solutions will become a standard tool for procurement professionals. Untapped synergies, benchmarks, and similar factors will be identified and likely optimised with AI support.	• **Technology Acceptance:** It is questionable to what extent procurement professionals would accept being advised by a machine on what needs improvement. • **Technology Adoption:** The use of this application depends on factors such as the company or the industry. One expert does not believe such an application is currently in use. Another finds the idea appealing, while two others consider the application difficult to imagine. • **Technological Benefits:** Such a monitoring system would be desirable in the context of continuous improvement. If implemented, it would increase efficiency and enhance the ability to adapt more quickly to process changes.	• **Attitude:** It is unlikely that employees will be open to this topic due to fears of becoming obsolete. • **Corporate Culture:** Department heads tend to resist reductions in headcount or downsizing of their teams. • **Rules and Regulations:** It is assumed that such monitoring systems may conflict with labour law. In addition, concerns around data protection remain.

Table 48: Explanations of the evaluations for P09

The monitoring use case is regarded as more viable for the future. However, several regulatory and organisational barriers are identified, including compliance with labour law, the GDPR, and agreements with employee representatives. In terms of acceptance, doubts remain about whether procurement professionals would be receptive to receiving recommendations from a machine regarding areas for improvement. One particularly critical comment suggests that department heads may resist staff reductions or downsizing—an informal barrier linked to the nature of companies as social constructs, as also discussed in the context of process orientation (Bergsmann, 2012, pp. 117–119). Employee reluctance is also noted, with concerns about potential redundancy cited as a reason for limited openness to such systems.

Nevertheless, while one expert questions whether 'monitoring' is the most appropriate term for such systems, their potential benefits are acknowledged. Value is seen, for example, in the context of continuous improvement. If implemented, these systems could increase efficiency and improve responsiveness to process changes. They may also contribute to greater transparency and the standardisation of diverse processes.

4.3.5.10. AI Agents for Strategic Decision-Making

Table 49 presents the aggregated expert justifications for P10.

Intelligent non-human agents (AI agents) independently make complex decisions, including strategic decisions such as supplier selection, which were still made by humans ten years ago.		
+	~	-
• **Maturity Level:** The current maturity level in procurement is too low for this application in terms of competence and know-how. • **Technology Adoption:** Strategic decisions will continue to be made by humans in the future; however, preparatory work will be carried out by AI-supported solutions.	• **Attitude:** On the one hand, there is clear rejection ("certainly not desirable"); on the other hand, there is a noted lack of trust in the technology—one that is expected to persist through to 2035. • **Human Skills:** Business is conducted between people. In practice, this often proves to be a decisive advantage, outweighing hard facts. • **Technological Benefits:** As a decision-support tool that does not assume full responsibility, the application offers added value. • **Technology Acceptance:** Acceptance of AI in this form has not yet been established. AI is widely viewed as a trend—or even as a marketing buzzword—but decisions are currently not entrusted to AI. • **Technology Adoption:** The assessment is difficult, as the application still seems distant. Nevertheless, a general development in this direction appears realistic, as the strategic domain is indeed well suited for AI agents. However, it seems unlikely that an AI agent will independently make decisions such as supplier selection. One reason is that too many relevant data points lie outside the systems in use. The agent will instead support complex decisions by providing valuable input—for example, by pre-filtering information and preparing suggestions or recommendations. Another expert considers the application feasible but by no means desirable, reinforcing the view shared by other experts that strategic and complex decisions will continue to be made by humans. • **Technology Readiness:** It is assumed that AI is still not sufficiently advanced for this application.	• **Human Skills:** The question arises as to whether the human factor in strategic decision-making is an advantage or a disadvantage—particularly when personal sentiments are weighed against strategic human considerations. This application neglects the relational dimension, social and communicative aspects, as well as subjective supplier assessments conducted on-site. Furthermore, some decisions may initially seem illogical yet prove to be right in the long term. • **Strategic Management:** Even if an AI agent were capable of understanding complex circumstances, many important strategic decisions are still based on information and soft factors obtained through conversations with various internal and external stakeholders. • **Technology Acceptance:** Several questions remain open, such as who guarantees the accuracy of decisions made by non-human agents or who assumes liability for errors made by AI agents. • **Technology Adoption:** It is to be hoped that decisions will not be made autonomously, but rather that AI will provide recommendations. In addition, it remains unclear to what extent AI can reflect individual complexity and derive conclusions accordingly. AI agents are not positioned to make strategic decisions. As such, this application remains difficult to imagine and is only considered potentially applicable in specific areas such as supplier search or supplier comparison.

Table 49: Explanations of the evaluations for P10

Intelligent agents capable of making complex decisions autonomously are regarded as the least likely use case, as reflected in the expert comments. On one hand, there is explicit rejection (e.g. 'definitely not desirable'); on the other, a clear and persistent lack of trust in the technology. While there is some debate over whether the human factor constitutes an advantage or a disadvantage in strategic decisions—particularly when personal judgement interacts with strategic reasoning—it is noted that this application overlooks important social and communicative aspects, including subjective supplier assessments conducted on site.

Overall, acceptance appears comparatively low. Several unresolved questions remain, such as who ensures the reliability of decisions made by non-human actors and who bears liability in the case of errors. Limited value is seen in using such systems as decision-making aids, provided they do not carry full responsibility. In light of ongoing discussions about intelligent agents and agentic AI, which are referenced in the development of the projections, it may be worth revisiting this use case at a later stage.

5.1.4. Organisational and environmental factors

This section presents the diagrams illustrating the organisational and environmental factors identified in the expert study.

When analysing the organisational and environmental factors presented in Table 50, Table 51 and Table 52, a similar pattern emerges to that observed in the application-related projections: experts anticipate an increase between the current state and the future outlook. Particularly striking is the gap between the present situation and the desirability. For example, in Projection 15, the median value projected for 2025 is 2.50, while the same aspect is rated as highly desirable, with a value of 5.00. Comments linked to this projection frequently emphasise the importance of managerial technology affinity—one expert noted, *'Everything stands and falls with the technology affinity of the manager.'* It was further criticised that managers are not always sufficiently aware of the operational areas in which AI could offer meaningful support. Moreover, it was noted that current technological possibilities are not yet fully understood, which supports the relevance and timeliness of the present study.

It is also noteworthy that the majority of 'don't know' responses are associated with Projection 12. This may be attributed to the fact that this is the only projection extending beyond the procurement domain, aiming instead to capture the broader societal implications of automation. Nonetheless, a certain degree of change is still expected by 2035, even though this projection shows the highest interquartile range (IQR = 3.00), indicating a considerable divergence of opinion among the experts.

Regarding the desirability of different scenarios, following the use case identification, the issue of a mutual understanding for the requirements specification ranks ahead of consulting support, which appears to play a comparatively secondary role. With respect to the reduction of internal bureaucratic obstacles, expert responses suggest limited optimism; this aspect is expected to rank lowest in 2035, highlighting a significant discrepancy between the anticipated future and its desirability from today's perspective.

#	Scenario	Statement	Short version	This statement describes the situation in the year 2025.				This statement describes the situation in the year 2035.				This situation is desirable from today's perspective.			
				Median	IQR	Mean	# Don't know	Median	IQR	Mean	# Don't know	Median	IQR	Mean	# Don't know
11	Environment	Professional consulting firms help procurement unlock the potential of advanced technologies such as AI.	Consulting Support	2.00	1.00	2.45	2	4.00	1.00	3.79	2	4.00	2.00	3.88	2
12	Environment	The financing of the social system is less dependent on taxes on human labor than it was in the past. Instead, alternative forms of taxation—such as those on value creation generated through automation—are being used more extensively.	Shift in Taxation	1.00	0.75	1.47	5	3.00	1.00	2.64	10	3.00	3.00	2.76	10
13	Organization	The implementation of advanced technologies in procurement is free from internal bureaucratic obstacles such as tedious approval processes.	Reduced Internal Bureaucracy	1.00	1.00	1.69	0	2.00	1.75	2.50	1	4.00	1.00	3.50	1
14	Organization	Providers of advanced technological solutions (e.g., AI) and procurement employees share a common understanding of how to specify the requirements for new technologies.	Mutual Understanding of Requirement Specification	2.00	1.00	1.80	0	3.00	1.00	3.34	0	4.00	1.00	4.26	0
15	Organization	Procurement executives are able to identify suitable use cases where new technologies provide the greatest benefit.	Use Case Identification	2.50	1.00	2.68	1	4.00	1.00	3.79	2	5.00	1.00	4.56	1

Table 50: Expert assessment of organisational and environmental factors

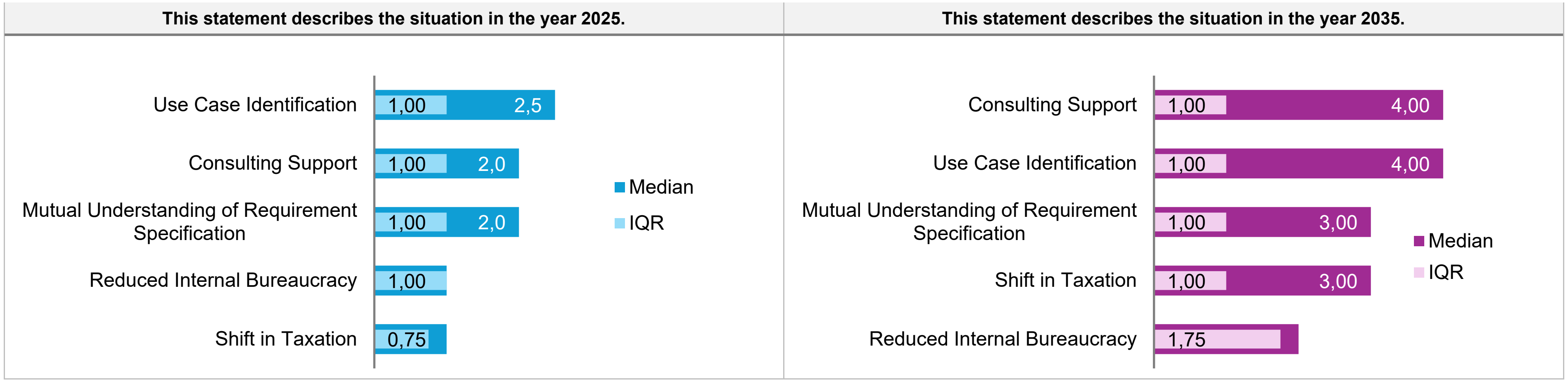


Table 51: Expert evaluation organisational and environmental factors: median and IQR by projection

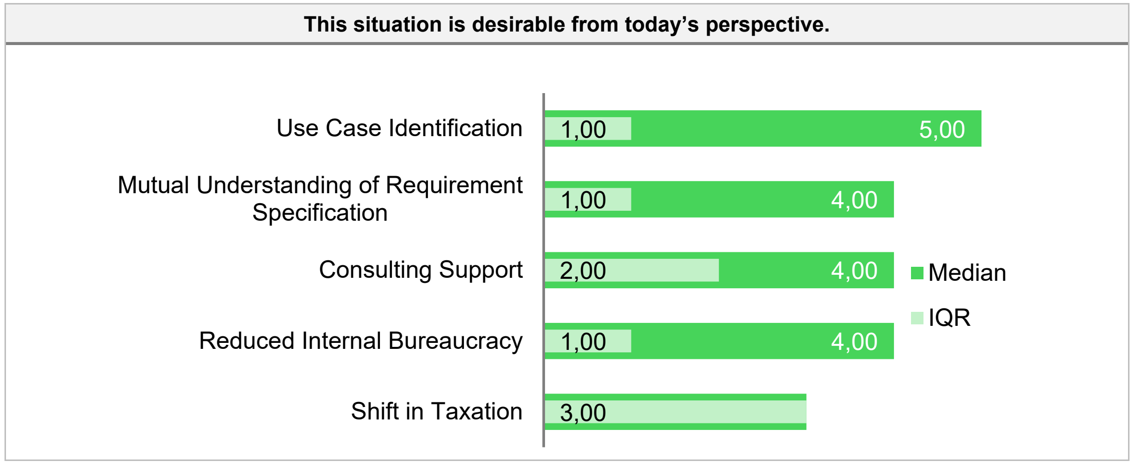


Table 52: Expert evaluation of the desirability of projected environmental and organisational situations

The final evaluation of the contextual factors indicates that barriers remain, some of which appear relatively easy to overcome—such as the identification of use cases. Notably, consulting support is not yet available to the extent considered desirable. There appears to be potential for developing concepts that help organisations better recognise the added value of technology in procurement, offer guidance, and establish a mutual understanding of the associated requirements. Internal bureaucracy is also perceived as a barrier, supporting findings from the literature review and multiple case study analysis. Although change is seen as necessary, significant improvement is not expected. This highlights the ongoing relevance of organisational factors in the adoption of advanced technologies in procurement—factors that lie within an organisation's direct sphere of influence.

5.1.5. Concluding Remarks

The experts' assessments of the current situation in 2025 and their forecasts for 2035 regarding the adoption of the ten applications are summarised in Figure 18. The figure presents a matrix in which the X-axis represents the degree of process automation, categorised into the three predefined scenarios of augmentation, automation, and autonomization, with the latter reflecting the highest level of Procurement 4.0 process automation. Based on the results of the first Delphi round, the following conclusions can be drawn in relation to the propositions formulated at the beginning of this chapter.

PR1: *Although the perceived benefits are considerable, current procurement practices still lag significantly behind what is technologically possible.*
PR2: *Technology continues to be perceived as a tool that supports human decision-making. Fully autonomous processes, as envisioned at the outset of the Industry 4.0 debate, remain an aspirational goal rather than an established reality.*

The assisting applications (P01–P03) are currently perceived by the experts as more widely adopted. According to the panel, this trend is expected to continue through to 2035, with the notable exception of full P2P automation. In this context, it is noteworthy that Frey and Osborne (2013, pp. 44, 72; 2017), in their widely cited 'Oxford Study', ranked 'Procurement Clerks' 680th out of 702 occupations, assigning a computerisation probability of 0.98. 'Order Clerks' were placed even lower, at rank 687, also with a probability of 0.98. Their projection spanned a time horizon of one to two decades.

Now that one of these decades has passed—and given the societal concern prompted by this and similar studies on the future of work in the context of ongoing automation[46]—it is striking that, as of 2025, automation in procurement still appears relatively underdeveloped. Several responses in the first round of the Delphi study highlight persistent structural challenges—such as unresolved issues in master data management—as key barriers to progress. At the same time,

[46] For further discussion on this topic, see, for instance, Precht (2022).

concern over job displacement has been a recurring theme across the academic debate reviewed in this thesis, the case studies examined, and the Delphi study itself. This may suggest that, despite the widespread discourse surrounding automation, its implementation in practice is still approached with caution or ambivalence.

Figure 15 clearly illustrates the differences between the current state of adoption, the expected development over the next ten years, and the benefits already associated with the applications by the panel. The comparison between perceived benefit and current adoption, conducted using the Wilcoxon signed-rank test, reveals a significant difference. This supports the existence of a potential–practice gap (see Table 39). Since the augmentation and automation applications cited by the experts are already technologically feasible and have, in some cases, been applied in practice, Proposition 1 can be supported.

Regarding Proposition 2, the qualitative data reveal a consistent emphasis on the supportive role of Procurement 4.0 applications (P2, P3, P5, P6, P9)—even within the more autonomous use cases (P7, P10). The autonomous decision-making function itself, however, received notably less attention. This reinforces the proposition that technology in procurement continues to be perceived primarily as a tool to support, rather than replace, human decision-making. In this context, an experiment involving the use of various AI tools—*character.ai, Pi.ai, HelloSophia, Fireflies, Sembly, Copilot, Apollo.ai., Sonix, Perplexity AI, Gamma.AI, ChatGPT* and *HeyGen*—to automate routine management tasks, including employee appraisals and team-building activities, demonstrated a notable improvement in personal efficiency (Giesswein, 2024). On average, Giesswein reported that he was able to allocate an additional five hours per week to higher-priority tasks, representing a significant increase in productivity. However, the role of the manager could not be replaced—and, according to Giesswein, this is unlikely to change in the foreseeable future.

PR3: *To date, the adoption of blockchain technology in procurement remains virtually non-existent in practice.*

Notably, blockchain—despite being one of the most intensively discussed technologies in the literature, as highlighted by the heatmap—ranks only 8th out of 10 in both current and expected adoption levels. Furthermore, it is the only application for which a notable number of 'don't know' responses were recorded: four for current adoption, three for expected future adoption, and three for perceived benefit. Finally, expert consensus on this projection is relatively low, with an IQR of 2.25—the highest observed in this study.

To conclude this discussion of Proposition 3, the experts' assessments support this observation, with a median rating of 1.00 for current adoption.

PR4: *Even in the future, procurement practice is likely to remain cautious towards fully advanced Procurement 4.0 applications aimed at the autonomization of processes, resulting in their limited adoption compared to more conventional automation solutions.*

Autonomisation use cases—particularly those involving strategic decision-making or negotiation—are currently perceived as less widely adopted. Apart from *AI-Driven Supplier Prequalification* and *Autonomous Detection of Automation Potential in Daily Tasks*, which are anticipated to experience broader implementation, the other autonomous applications are expected to see only limited uptake.

Given that the Procurement 4.0 debate has now spanned nearly a decade, and that significant importance is attributed to autonomization, it may appear surprising that procurement practice has not progressed further in this area. One possible explanation relates to the observation that applications involving strategic decisions—typically associated with a high degree of strategic responsibility—are perceived as considerably less widespread than those in operational domains such as payment, automation potential detection, and prequalification. The latter is particularly characterised by a high level of preparatory and administrative effort.
This discrepancy could indicate that either the relevant AI technologies are not yet sufficiently advanced to reliably assume such tasks, or that such delegation is not considered feasible by those currently responsible for these decisions—possibly due to their individual motivation.

While a few experts suggest that complex decision-making may eventually fall within the scope of AI, a clear consensus emerged in Round 1 regarding the lower relevance of the two strategic autonomization applications (P07 and P10), both of which had an IQR of 1.00.
To conclude this discussion of Proposition 4, a significant difference between the five augmentation/automation applications and the five autonomization applications was demonstrated across all three evaluation dimensions (see Table 38).

If the expert forecasts prove accurate, procurement may undergo a significant transformation by 2035. This would take place approximately 17 years after the first indexed scientific publication on Procurement 4.0 appeared in *Scopus*. At present, academic debate may already be laying the groundwork for the next stage—potentially termed Procurement 5.0—in reference to the European Commission's 'Industry 5.0', which promotes the *'(...) transition to a sustainable, human-centric and resilient European industry'* (European Commission, 2022).
As of 30 March 2025, however, a *Scopus* search of titles, abstracts, and keywords using the term 'Procurement 5.0' returned no results. Nonetheless, this study has identified numerous areas in which human skills are likely to remain indispensable, with people continuing to play a central role in shaping the future of procurement—an area that may attract increased attention in future research.

Ultimately, it is this very promise of automation that runs as a unifying thread throughout this work, and it was one of the primary motivators for undertaking this research: the ambition to use automation to eliminate repetitive and burdensome tasks that prevent procurement professionals from focusing on value-adding activities.

The organisational and environmental factors also reveal that the item relating to the tax system—an aspect beyond the immediate scope of procurement—received the highest number of ‘don't know’ responses, along with a notable degree of disagreement among the experts. Furthermore, the outlook regarding internal bureaucratic hurdles appears rather pessimistic; experts do not anticipate any significant improvement in this area by 2035.

In any case, because the findings of this expert study derive solely from the first round of a Delphi study, they provide only limited grounds for projecting future scenarios. Nevertheless, they offer preliminary insights into prevailing tendencies among practitioners regarding Procurement 4.0 automation in the manufacturing industry and the adoption of cutting-edge technologies, thereby contributing to an emerging field of research. Accordingly, the second round, scheduled for Q4 2025, is expected to provide further clarity on the future of procurement in the context of Industry 4.0 automation.

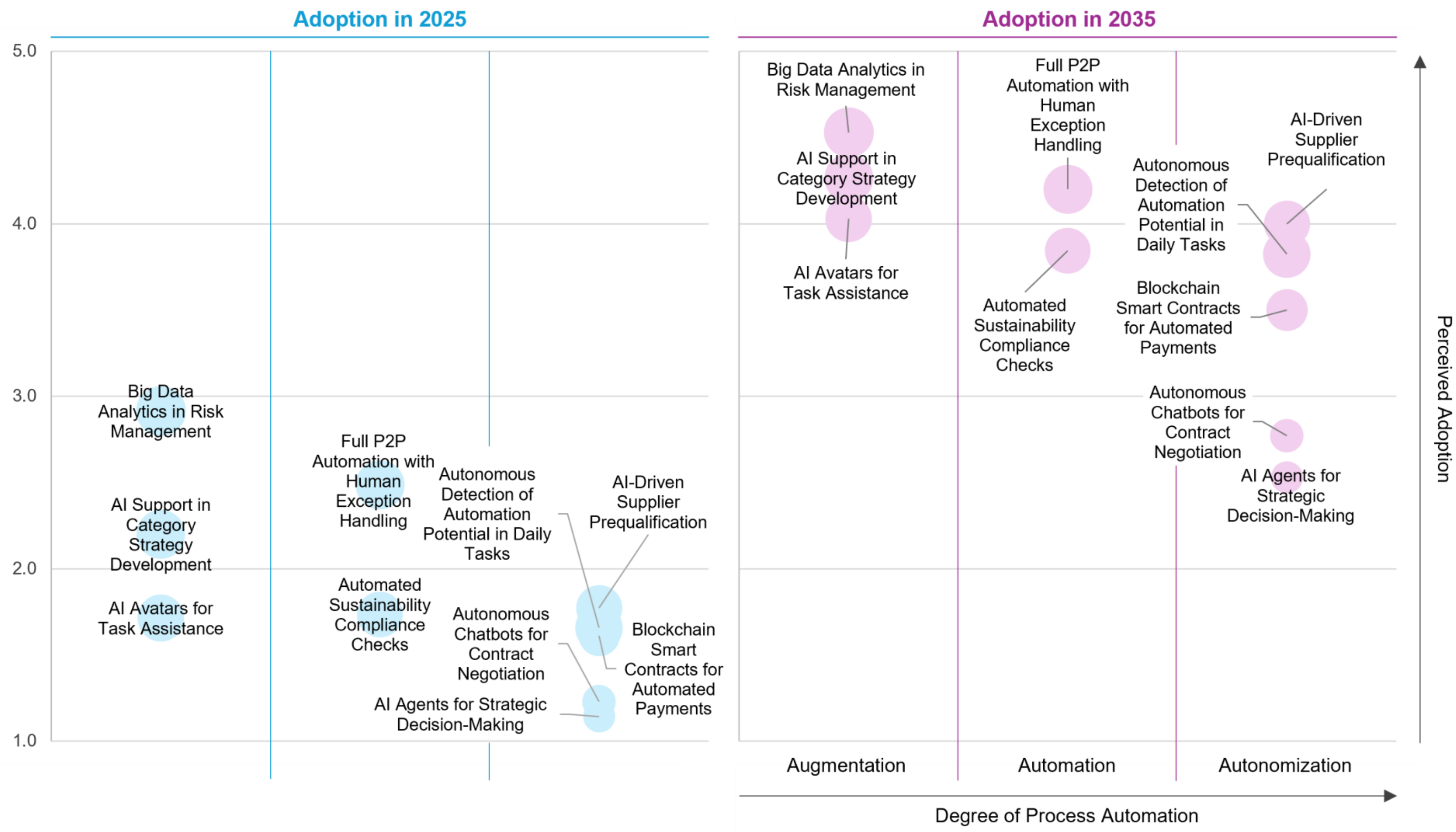


Figure 18: Perceived adoption of Procurement 4.0 applications

6. Conclusion

Procurement 4.0 is the result of a novel transformation enabled by leveraging the technological basis and principles of digitalisation and Industry 4.0. Despite increasing academic interest and widely acknowledged benefits, its practical implementation remains limited, leaving automation potential untapped. This persistent gap hinders the realisation of key opportunities, including improvements in productivity. This is particularly critical in manufacturing, where procurement typically plays a key role in overall business performance by managing the largest cost block.

This thesis addressed these challenges through an exploratory, multi-method research design. It began with a systematic literature review, analysing 58 references and identifying 275 concrete Procurement 4.0 applications mapped onto an extended procurement process model, which is presented as a heatmap serving as both a practical tool and an academic reference. A subsequent multiple-case study analysis of five Austrian manufacturing firms examined the real-world application and impact of these technologies. Finally, a Delphi-based expert survey was conducted with 35 experienced procurement professionals, 28 of whom hold departmental management or higher positions, to assess the current adoption landscape and explore future scenarios for Procurement 4.0 process automation.

This multi-method investigation revealed that, although the academic literature frequently addresses advanced and even visionary applications, their practical implementation remains limited, despite practitioners acknowledging clear benefits. Accordingly, the findings highlight a gap between academic debate, practical implementation and perceived potential, referred to herein as the Theory–Practice–Potential gap. To elaborate on the Theory–Practice–Potential gap, the key findings are synthesised below by answering the research questions.

The first two research questions were examined through an SLR.

RQ 1: What are the Procurement 4.0 applications described in the current literature?

RQ 2: What procurement processes can be supported by technologies or technology bundles, forming an application?

Both research questions were addressed by systematically developing a conceptual framework that maps 275 Procurement 4.0 applications identified in the literature to an extended procurement process model visualised by the Procurement 4.0 application heatmap (Figure 8). This heatmap provides a comprehensive and structured overview of potential use cases, serving as a foundation for both strategic planning and operational deployment.

Of the 100 identified technologies and technology-related concepts, 18 account for 70% of all mentions across applications. In terms of frequency, three clusters are evident in the heatmap among these 18 technologies and related concepts, with Blockchain, IoT, AI, and Big Data forming the most frequently discussed cluster.

The subsequent two research questions were examined through an exploratory qualitative multiple case study approach in the private manufacturing industry.
RQ3: What are the defining characteristics of Procurement 4.0 applications currently implemented in practice?
RQ4: What effects do these applications have, particularly regarding process automation?

This study identified a total of 169 factors along the conceptual research framework, based on the five cases examined. Of these, 93 relate to the two overarching categories: success factors and pain points. The research revealed patterns of overlap and divergence across applications, highlighting key factors influencing technology adoption, as synthesised in Table 30

The final two research questions were addressed through an expert survey conducted in the first round of a Delphi study.
RQ5: How do experts perceive the current level of adoption of specific Procurement 4.0 automation applications in practice?
RQ6: How is this adoption expected to develop over the next ten years?

On the one hand, the findings presented in Figure 17 and Figure 18, long with the tables in Chapter 5.3, indicate that experts do not regard the surveyed Procurement 4.0 applications as common practice in procurement as of 2025. On the other hand, these applications are already perceived as having considerable potential from today's perspective, highlighting a clear gap between current practice and current potential.
Looking ahead, all surveyed applications are expected to see increased adoption over the next ten years. This suggests that, while companies in the manufacturing sector are currently trailing in the implementation of Procurement 4.0, they have acknowledged its advantages and intend to catch up.

The Theory–Practice–Potential gap in the field of Procurement 4.0 within the manufacturing industry, identified through the multi-method exploration conducted in this PhD thesis, is summarised in Figure 19. The figure presents the key findings from the methodological phases, which are discussed in Chapter 6.1.

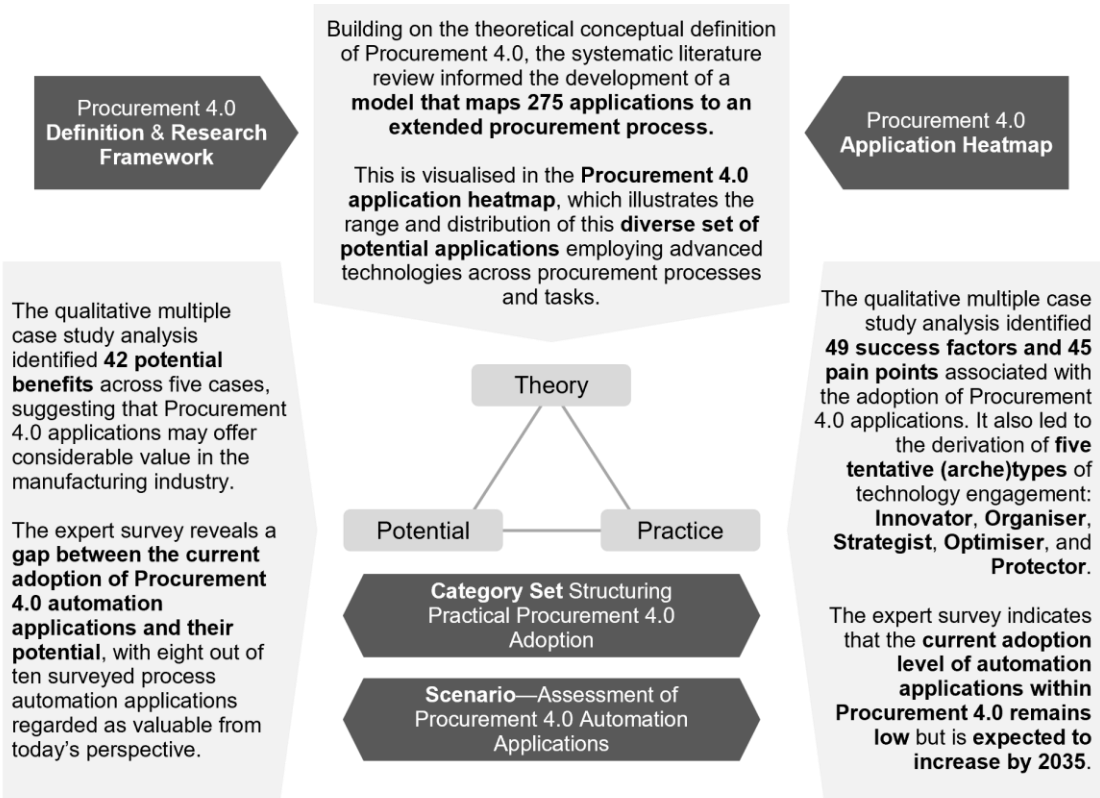


Figure 19: Key findings of this study in relation to the Theory–Practice–Potential gap

The figure illustrates how the results contribute to the formation of the Theory–Practice–Potential gap. The definition of Procurement 4.0 and the findings from the systematic literature review inform the theory dimension. The qualitative multiple case study analysis and the expert survey contribute to both the practice and potential dimensions. Taken together, these findings reveal an area of tension surrounding the adoption of Procurement 4.0 automation applications in the manufacturing industry. The concluding insights are discussed in the following section.

6.1. Discussion

The SLR underscores a theory–practice gap by highlighting a disconnect between academic debate and practical implementation, exemplified by the case of blockchain. Although blockchain is extensively analysed in procurement research and emerges as the most referenced technology in the heatmap, its practical adoption remains limited. While one-third of the top 50 *Forbes* companies have implemented blockchain in supply chain applications (Keresztes et al., 2022, p. 16) its adoption rate among German companies remains low, with only 7% reporting current or planned implementation (Bunde and Wolf, 2024, p. 37). In the expert survey, the blockchain application was ranked eighth out of ten in terms of current adoption in 2025, and experts also expressed scepticism regarding its future adoption by 2035. Barriers mentioned by respondents include high costs, high energy consumption, limited computing power, and industry-specific constraints. Two possible interpretations may be drawn from these findings: either current research is focusing on a technology that does not align with practical procurement needs, or the potential of blockchain applications has not yet been realised in practice.

The P2P process also serves to illustrate both a theory–practice gap and a practice–potential gap. As outlined in the introduction, another contemporary trend influencing the Procurement 4.0 transformation is the shift in labour market dynamics, including workforce shortages and evolving generational expectations. However, while academic discussions on Procurement 4.0 primarily emphasise strategic and tactical applications, the heatmap analysis reveals that comparatively less attention is directed toward the operational P2P process. This discrepancy may partly be explained by Gartner's Hype Cycle for Procurement, which suggests that S2P suites are approaching the 'plateau of productivity' in the near future (Gartner, 2024; Zip, 2024). Nevertheless, the application of full P2P automation with human exception handling (P04) is one of the two projections showing the largest discrepancy between current adoption (median = 2), perceived benefit (median = 5), and expected adoption by 2035 (median = 5). This contrast is particularly striking given that, in 2021, the management consultancy Kearney claimed that 'full automation is very nearly here' in procurement (Pearce et al., 2021). Such discrepancies—between the scientific literature outlining a broad range of possibilities, optimistic forecasts from consulting firms, the multitude of solutions offered by technology providers, and the actual state of practice—reinforce the notion of a persistent theory–practice gap that organisations are expected to address.

Moreover, across all examined Procurement 4.0 automation applications employing advanced technologies, the expert survey reveals a gap between the current state of adoption, the expected development over the next ten years, and the value already attributed to these applications from today's perspective by the panel. In addition, a comparison between perceived benefit and current adoption—conducted using the Wilcoxon signed-rank test—indicates a statistically significant difference. This finding further supports the existence of a practice–potential gap, alongside the already observed theory–practice gap.

With regard to the academic debate on procurement autonomisation as part of the Procurement 4.0 transformation, early use cases involving AI (Herold et al., 2022, p. 11), Blockchain and Smart Contracts (Hofbauer and Sangl, 2019, p. 32; Jahani et al., 2021, p. 17), and IPA (Flechsig, 2021b, p. 14) indicate a gradual shift towards autonomization. However, the SLR reveals that most procurement applications—particularly those associated with the dominant technology cluster of Blockchain, IoT, AI, and Big Data—exhibit only moderate levels of automation. This suggests that research continues to position technology primarily as an enabler of human decision-making (i.e. augmentation), while full automation remains limited to supervised tasks.

Similarly, no clear tendencies toward autonomisation were identified in the qualitative multiple case study analysis. Instead, the findings suggest a focus on augmentation and automation. Only one interviewee mentioned a potential use case involving AI to enable autonomous C-parts procurement.

This is further supported by the expert survey, which indicates that the examined autonomisation use cases—particularly those involving strategic decision-making or negotiation—are currently perceived as less widely adopted. Apart from *AI-Driven Supplier Prequalification* and *Autonomous Detection of Automation Potential in Daily Tasks*, which are anticipated to experience broader implementation, the other autonomous applications are expected to see only limited uptake. To conclude, expert ratings indicate a greater perceived relevance of augmentation and automation applications over full autonomisation, suggesting that fully autonomous procurement may remain an aspirational goal rather than an operational reality—even beyond 2035. This highlights a further theory–practice gap in the domain of autonomous procurement.

Assisting technologies and augmentation-focused applications are currently perceived by experts as more widely adopted. According to the panel, this trend is expected to continue through to 2035, with the notable exception of *Full P2P Automation with Human Exception Handling*. In this context, it is worth noting that Frey and Osborne (2013, pp. 44, 72; 2017), in their widely cited ‘Oxford Study’, ranked ‘Procurement Clerks’ 680th out of 702 occupations, assigning a computerisation probability of 0.98. ‘Order Clerks’ were ranked even lower, at 687th, also with a probability of 0.98. Their forecast spanned a time horizon of one to two decades. Now that one of these decades has passed—and considering the societal concern prompted by this and similar studies on the future of work in the context of advancing automation[47]—it is striking that, as of 2025, automation in procurement still appears relatively underdeveloped. However, in accordance with Amara’s Law, it remains to be seen what the future will ultimately bring. Furthermore, the interview discussions on AI and the future of procurement suggest that the full extent of the technological impact cannot yet be reliably assessed. As noted in three interviews, the rapid development and diffusion of OpenAI’s ChatGPT illustrates how the adoption of technologies can accelerate rapidly once momentum is achieved.

Despite the challenges outlined, there are actions that practitioners can take. This is supported by the multiple case study analysis, in which the organisational context is most consistently emphasised—particularly among success factors. Success factors are concentrated around *Leadership* (4), *Project Management* (4), *Process Management* (3), and *Education and Training* (3). In contrast, the potential pain points are more often associated with technological and environmental factors, indicating underlying complexity. These are more dispersed, with only the *Solution* itself (4) and *Process Management* (3) recurring in more than two cases. This

[47] For further discussion on this topic, see, for instance, Precht (2022).

fragmentation underscores the diverse challenges associated with the implementation and operation of Procurement 4.0 applications. It further suggests that successful adoption may require more holistic and integrated approaches—considering process requirements (process–solution), resulting effects (solution–process), and organisational implementation (project and leadership–solution/process)—to effectively manage the pressures of transformation. In this context, developing Procurement 4.0-specific procedural models could support managers and promote wider uptake of advanced technologies in procurement.

The various aspects presented under the deductive category *Actionable practical recommendations* may serve as potential building blocks for company-specific Procurement 4.0 roadmaps. In this regard, Trautmann (2021, p. 102) discusses the agile dimension of digitalisation, noting a preference for shorter sprints over long-term roadmaps, and proposes integrating this aspect into dynamic roadmaps. This is supported by one of the studied cases, where the respondent noted that—as with other topics—it is difficult to predict where an organisation will stand at a specific point in the future with regard to sustainability, and that progress is instead made step by step.

The five tentatively derived (arche)types of technology engagement—*Innovator*, *Organiser*, *Strategist*, *Optimiser*, and *Protector*— may offer additional practical orientation for organisations facing similar challenges in the context of Procurement 4.0 transformation. These profiles may serve as a basis for strategic prioritisation, depending on a company's starting point, objectives, and expected benefits.

They include cases that, while limited in scope and comparatively straightforward to implement, yield targeted effects (e.g. *Innovator*), as well as more far-reaching applications (*Organiser* and *Optimiser*) with broader strategic implications. The latter, however, require several years of comprehensive implementation to realise their full potential. In terms of process automation, all five cases demonstrated tangible gains in productivity, aligning with the notion of 'achieving more with the same'. In particular, the cases presented illustrate opportunities to professionalise and automate traditional administrative processes previously supported by MS Office programmes.

6.2. Limitations and outlook

This research contributes novel insights through an explorative multi-method approach and a focus on concrete, practitioner-informed applications within the context of Procurement 4.0 automation in the manufacturing industry. To the author's knowledge, it represents the only recent Delphi-based expert survey explicitly examining automation applications and the future of procurement in a Procurement 4.0 setting. The findings aim to support practitioners and advance academic understanding of the dynamics of technology adoption in procurement.

Despite the methodological rigour applied, the study is subject to certain limitations, particularly due to its qualitative and exploratory nature. The multiple case study draws on a limited sample from the Austrian manufacturing industry. As such, broader and quantitative validation is required to assess the extent to which these findings are generalisable.

Moreover, the results of the expert survey are based solely on the first round of a Delphi study. While they provide initial insights into current tendencies and practitioner perspectives on Procurement 4.0 automation, they offer only limited grounds for projecting future scenarios. A second Delphi round, scheduled for Q4 2025, is expected to yield further clarity regarding the future of procurement in the context of Industry 4.0.

The study also provides a starting point for further investigations in additional expert settings. Future research could involve consultants or solution providers to compare their perspectives with those of practitioners. The propositions and exploratory theses identified in this study could be further examined, tested, and quantified in future research. Furthermore, the Procurement 4.0 definition developed in this study could serve as a foundation for future research aimed at developing dynamic roadmaps to support the broader dissemination and adoption of automation applications.

Given the rapid pace of technological advancement, new Procurement 4.0 applications are continually emerging. The ProcureTech100, developed in association with Kearney, reflects this dynamic by highlighting 100 *'pioneering digital procurement solutions'*, selected from an *'analysis of more than 5,000 technology, data, and analytical digital procurement solutions'* (ProcureTech, 2024). In light of this, future research must remain dynamic and evolve in tandem with these developments.

Even though the current level of Procurement 4.0 adoption appears underdeveloped, expert forecasts suggest that significant transformation may occur by 2035, approximately 17 years after the first indexed academic publication on the topic appeared in Scopus.

Against this backdrop, the academic debate may be beginning to lay the groundwork for the next stage of development, potentially referred to as 'Procurement 5.0'. This concept could align with the European Commission's Industry 5.0 vision, which supports the transition to a sustainable, human-centric and resilient European industry (European Commission, 2022). Yet a Scopus search conducted on 14 June 2025 for 'Procurement 5.0' in titles, abstracts and keywords returned no results. In this context, the study identifies several areas in which human capabilities are likely to remain indispensable, indicating that people will continue to play a vital role in the future of procurement. Accordingly, this human-centric perspective represents another avenue for future research.

In conclusion, the promise of automation emerges as a recurring theme throughout this research, reflecting a central motivation behind the study: to explore how automation can relieve procurement professionals of routine, burdensome tasks and enable them to focus on more strategic, value-adding activities. The findings presented here are intended to offer constructive points of connection for both practice and future academic work in this field.

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Appendix

A) 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., 2024	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., 2022	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., 2022	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
46	Sahoo & Jakhar, 2024	Industry 4.0 deployment for circular economy performance—Understanding the role of green procurement and remanufacturing activities	Journal	2

#	Source	Title	Source Type	Number of Applications
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	Sjodin et al., 2021	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

Table 53: Sources considered in the SLR

B) Procurement 4.0 Applications – Analysis Table

#	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., 2024	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

#	Source	Technologies and Concepts							Procurement Processes and Tasks					DoA	DoI	Application description (paraphrased)
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., 2022	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., 2022	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., 2022	artificial intelligence							Negotiation	Contracting & Onboarding				2	2	Use of AI in the design and execution of negotiations
37	Delke et al., 2022	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

#	Source	Technologies and Concepts							Procurement Processes and Tasks					DoA	DoI	Application description (paraphrased)
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 & Prequalification	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)

#	Source	Technologies and Concepts							Procurement Processes and Tasks					DoA	DoI	Application description (paraphrased)
64	Flechsig, 2021	intelligent process automation	market intelligence						Supplier Identification & Prequalification	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 & Prequalification					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 manufacturing						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

#	Source	Technologies and Concepts							Procurement Processes and Tasks					DoA	DoI	Application description (paraphrased)
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

#	Source	Technologies and Concepts							Procurement Processes and Tasks					DoA	DoI	Application description (paraphrased)
106	Herold et al., 2022	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

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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

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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)

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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 & Prequalification	Supplier Relationship Management & Partnering	Controlling & Reporting	Organizational 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 cognitive 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

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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 & Prequalification	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

#	Source	Technologies and Concepts							Procurement Processes and Tasks					DoA	DoI	Application description (paraphrased)
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	Sjodin et al., 2021	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 efficiences
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

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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

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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

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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

Legend: *DoA–Degree of Automation | IC–Information Content*

Table 54: Procurement 4.0 applications – analysis table