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MSc in Supply Chain Management

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*Emerging Technologies in Procurement and Supply Chain
Management*

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*This dissertation is dedicated to my husband John, for all the support he has given me over
all these years.*

*In addition, I would like to express my gratitude to my supervisor for the guidance to make
this project come true.*

1. Abstract

Industry 4.0 technologies can enhance Procurement efficiency and effectiveness when applied to its operations. In addition, by transaction, transportation and cost elimination, Procurement can be considered more sustainable in its application. Technological tools can also create a better understanding of companies' emissions, making possible a more sustainable supplier evaluation and selection. Moreover, Procurement 4.0 era assists Procurement and Supply chain professionals to make more informed decisions, shifting transactional positions to more strategically roles. That might involve specific professions reduction and the enhancement of new more strategic ones. In any case the abilities of humans and computers will remain complementary, making it unlikely at this point machines to replace humans.

Within this research 88 research papers and other resources were identified and reviewed, for the period of 2018 until 2024. From the analysis three sections were created for the purposes of this dissertation. The first one concerned the use of technology within Procurement, the second one involved sustainability within Procurement with the use of technologies, and the third one investigated data that present the complementary abilities of humans and machines. The first section was subdivided into the technologies identified within the available literature, Artificial Intelligence (AI), e-Procurement, Big data analytics, Blockchain, Internet of Things (IoT), Cloud Computing, Robotic Process Automation (RPA), Additive Manufacturing (3D Printing), Radio Frequency Identification (RFID), Cybersecurity, Virtual, Reality (VR), and Unmanned Aerial Vehicles (UAV). The second section of Sustainability was subdivided into Green Procurement and Circular Procurement. After analyzing the papers using a Systematic Literature Review, a comparison was given between the technologies that concerned the Academic community from the year 2018 until 2022 and for the most recent years after 2022 until 2024.

The research gap that this research intends to cover is to collect and present the limited bibliography on Procurement oriented emerging technologies application topic. Although there is an extended literature on emerging technologies and their applications on the wider supply chain management, there are limited publications that concern solely procurement functions. In addition, limited and emerging are the publications on how technology can enhance

sustainability within the Procurement field. Moreover, it was intended to create an updated roadmap for researchers and procurement professionals, on the available technology application within the field, given rapid changes in this topic.

Keywords: AI, , Blockchain, e-Procurement, Big Data Analytics, , Procurement 4.0, Sustainability

2. Περίληψη

Οι νέες τεχνολογίες αιχμής που φέρνει η βιομηχανική επανάσταση 4,0, μπορούν να ενισχύσουν την αποδοτικότητα και αποτελεσματικότητα των Προμηθειών, όταν εφαρμόζονται σε αυτό το πεδίο. Επιπλέον, η μείωση των καθημερινών, επαναλαμβανόμενων διεργασιών, των μεταφορών, καθώς και του συνολικού κόστους λειτουργίας των προμηθειών, οδηγεί στην δημιουργία πιο sustainable εφαρμογών στον τομέα αυτό. Τα διαθέσιμα τεχνολογικά εργαλεία, οδηγούν στην πιο ενημερωμένη λήψη αποφάσεων, τόσο σε σχέση με το sustainability των προμηθευτών, όσο και στην ευρύτερη λειτουργία μιας επιχείρησης. Επιπλέον, η εποχή του Procurement4.0 ενισχύει τις θέσεις των επαγγελματιών προμηθειών και εφοδιαστικής αλυσίδας, μετακινώντας την ανάγκη για νέους πιο στρατηγικούς ρόλους και καταργώντας τους πιο διεκπεραιωτικούς. Σε κάθε περίπτωση οι ικανότητες των επαγγελματιών και των τεχνολογιών παραμένουν συμπληρωματικές και αλληλένδετες, καθιστώντας απίθανη στην παρούσα περίοδο την αντικατάσταση του ανθρώπου από την τεχνολογία.

Στην παρούσα έρευνα, 88 ερευνητικά δοκίμια εντοπίστηκαν και εξετάστηκαν, καθώς και άλλες πηγές, για την περίοδο μεταξύ του 2018 και 2024. Από την ανάλυση προέκυψαν τρεις κατηγορίες, που αφορούσαν τα εξής θέματα: (1) την εφαρμογή της τεχνολογίας στον τομέα των προμηθειών, (2) Το Sustainability στις προμήθειες με την βοήθεια της τεχνολογίας και (3) τις συμπληρωματικές δεξιότητες μεταξύ των ανθρώπων και των μηχανών. Στην συνέχεια η πρώτη κατηγορία υποδιαιρέθηκε, στις τεχνολογίες που εντοπίστηκαν στην βιβλιογραφία, όπως την Τεχνητή Νοημοσύνη (AI), το e-Procurement, τα Big Data Analytics, το Blockchain, το Internet of Things (IoT), το Cloud Computing, το Robotic Process Automation (RPA), το Additive Manufacturing (3D Printing), το RFID, το Cybersecurity, το Virtual, Reality (VR) και τα Unmanned Aerial Vehicles (UAV). Η δεύτερη κατηγορία του Sustainability υποδιαιρέθηκε στις Πράσινες Προμήθειες και τις Κυκλικές Προμήθειες. Αφού αναλύθηκε η σχετική βιβλιογραφία με την χρήση της συστηματικής βιβλιογραφικής ανασκόπησης, συγκρίθηκαν οι τεχνολογίες που απασχόλησαν την ακαδημαϊκή κοινότητα μεταξύ των ετών 2018 και 2022 και της πιο πρόσφατης περιόδου μεταξύ των ετών 2022 και 2024.

Το ερευνητικό κενό το οποίο έχει σκοπό να καλύψει η συγκεκριμένη έρευνα, είναι να συγκεντρώσει και να παρουσιάσει την περιορισμένη βιβλιογραφία των εφαρμογών νέων τεχνολογιών στις προμήθειες. Παρόλο που υπάρχει μια εκτενής βιβλιογραφία για τις εν λόγω

εφαρμογές στην ευρύτερη διαχείριση της εφοδιαστικής αλυσίδας, οι δημοσιεύσεις που αφορούν αποκλειστικά τις προμήθειες είναι περιορισμένες. Επιπλέον, περιορισμένες είναι οι δημοσιεύσεις στο πώς μπορούν οι νέες τεχνολογίες να εμπλουτίσουν το sustainability των προμηθειών. Επίσης, η συγκεκριμένη έρευνα επιδιώκει τη δημιουργία ενός αναθεωρημένου χάρτη των ερευνητικών έργων που έγιναν μεταξύ της περιόδου 2018 και 2024, με σκοπό την χρήση του από άλλους ερευνητές και επαγγελματίες προμηθειών, σχετικά με τις διαθέσιμες νέες τεχνολογικές εφαρμογές στον τομέα αυτό, δεδομένης της ραγδαίας εξέλιξης τους.

Λέξεις – Κλειδιά

Τεχνητή Νοημοσύνη (AI), Blockchain, e-Procurement, Big Data Analytics, Procurement 4.0, Sustainability

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6. List of Abbreviations & Acronyms

Acronym	Full Name
AI	Artificial Intelligence
B2B	Business-to-Business
BDA	Big Data Analytics
BI	Business Intelligence
BC	Blockchain
BIoT	Blockchain-IoT
CSR	Corporate Social Responsibility
CC	Cloud Computing
CS	Cybersecurity
DAI	Distributed Artificial Intelligence
DPP	Digital Passport Product
e-P	e-Procurement
EBDF	Enterprise Blockchain Design Frameworks
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
ESG	Environmental Social, and Governance
GAI	Generative AI
HCAI	Human-Centered AI
I4.0	Industry 4.0
ICT	Information and Communication technology
IoT	Internet of Things
ML	Machine Learning
MRO	Maintenance, Repair, and Operations
OEM	Original Equipment Manufacturer
P4.0	Procurement 4.0
RFID	Radio Frequency Identification
ROI	Return on Investment
RPA	Robotic Process Automation
SCM	Supply Chain Management
SDGs	Sustainable Development Goals
SLAs	Service Level Agreements
SSC	Sustainable Supply Chains
SSCM	Sustainable Supply Chain Management
TBL	Triple Bottom Line
UAV	Unmanned Aerial Vehicles
UGVs	Unmanned Ground Vehicles
VR	Virtual Reality

7. Introduction

Nowadays, procurement acquires a critical role within the supply chain management context, and it is a critical factor to examine when someone intends to increase efficiency in this field.

The emerging technologies of Artificial Intelligence (AI), Internet of Things (IoT), Radio Frequency Identification (RFID), Blockchain, Big Data Analytics, Cloud Computing, Robotic Process Automation (RPA), Additive Manufacturing (3D Printing), Cybersecurity, Virtual Reality (VR), and Unmanned Aerial Vehicles (UAV), have great value to offer when applied to procurement function and consequently improve the entire supply chain.

It is only recently that researchers started to investigate the impact and the potential value that could be derived from the emerging technologies application in Procurement, mentioned above. This value will navigate beyond the cost cutting standard operation of procurement departments, to include efficiency in transportation, sustainability, effective negotiation, improved supplier's relationships and selection, more comprehensive supply contracts, increased transparency of transactions, time efficiency, and performance evaluation.

Furthermore, technology should be considered as a tool to support human functions and to be used in conjunction with it and not as a substitute for it. Human factors will be more efficient with technology and technology shall improve through interaction with humans.

The research questions that this study intends to investigate are first, how technology can improve efficiency in Procurement and consequently in the entire supply chain. How can emerging technologies improve sustainability within the procurement frame. Finally, it intends to determine whether technology is considered in the available literature as a substitute for the human factor, or it will be used as a tool of efficiency.

The methodology that will be used to answer the research questions under consideration is a systematic literature review of the existing papers since 2018, such as to provide an up-to-date framework on the most recent trends in the field, considering the rapid changes in technology. Overall, this study will provide a roadmap for other researchers on the topic, the procurement and supply chain professionals for strategic decision making, as well as for procurement transformation.

8. Research Methodology

8.1. Research questions

The research questions that this study intends to answer are the following:

1. How could technology improve efficiency in Procurement and consequently overall Supply Chain Management?
2. How could technology improve sustainability within the Procurement framework?
3. How are emerging technologies considered regarding human factors? Is there a risk of being a substitute for specific positions in the future?

8.2. Research Method

The research method that will be followed is a Systematic Literature Review. The data were gathered for Scopus database, Research Gate, Emerald Insight, Science Direct and Google Scholar. The focus was on Journals – Articles from 2018 up to 2024, on a view to identify the trend on the type and frequency of the technologies applied then and nowadays. In addition, a few Master/PHD Thesis and books were taken into consideration.

Furthermore, the search was made by title, abstract, and the key words: Supply Chain Management (SCM), Procurement and Emerging Technologies, Blockchain, Artificial Intelligence (AI), Industry 4.0 Sustainability and Procurement 4.0. Moreover, the focus was, on open access articles, in English language publications. Initially, 572 papers were identified, and they were categorized by topic, such as to include only those which focus on the emerging technologies that are applied to the Procurement field. Zotero was used to delete duplicate articles, 185 papers remained after the first screening, and they were further categorized to those that are referred to in emerging technologies applied on the wider Supply Chain Management and those that are focused, specifically on Procurement. The first ones were 97 papers, and the second ones were in total 88.

The technological tools employed for the analysis of the papers were MAXQDA and Zotero. The first one for the coding of the categories and analysis of the papers and the second one for the citation presentation and inclusion. Overall, existing Literature is referred to specific

technologies or to sub-technologies of them, hence further screening and subcategorization was necessary, such as to include all the relevant papers under the same category of technology.

8.3. Study Outline

The research is structured in the following way. The first section includes the introductory framework, motivation, and the research questions that the study intends to answer. In the second section the research methodology that was followed was presented and the criteria that the literature was collected, screened, and analyzed. In the third section the main topics were identified as centric in the current literature. In the fourth section the key findings are given and summarized. In the fifth section a discussion on the findings is developed. In the sixth section the key findings are concluded, future directions are proposed, the importance of the study is explained, and potential limitations of the research are highlighted.

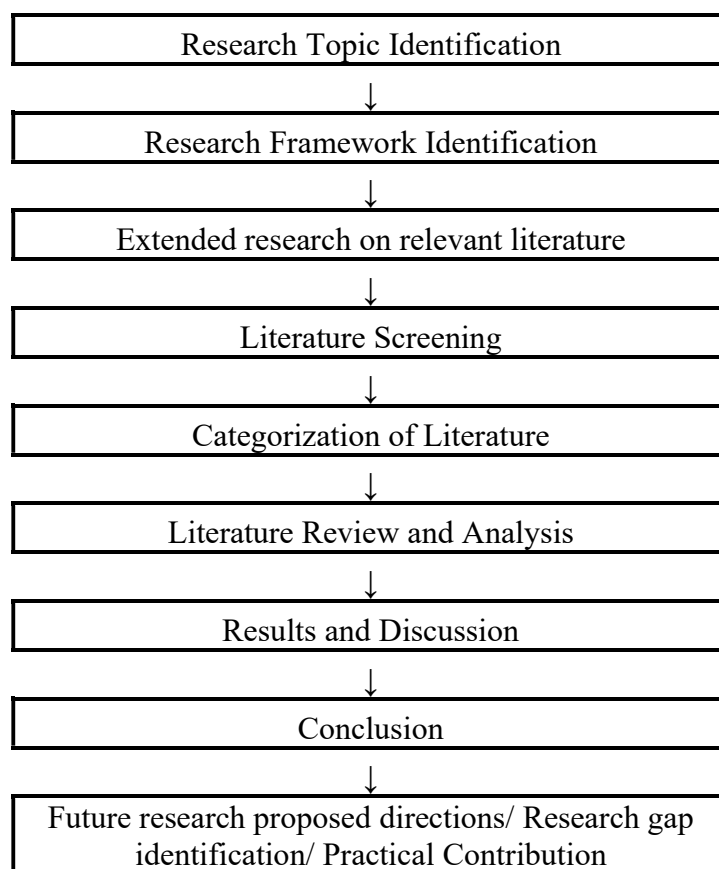


Figure 1: Study Outline

9. Literature Review

9.1. Supply Chain Management Definition

Traditionally Supply Chain Management (SCM) contains processes that are part of the transformation of raw materials to end products for consumers. According to Ibrahim et al. (2023), SCM contains functions such as material procurement, order tracking, and collaborative planning, on a view to ensure product availability, performance optimization, managing supply chain networks effectively, incorporating activities like delivery, storage, and distribution, and coordination among involved parties. The main purpose of SCM is to meet consumer demand by on-time delivery of products and at the best possible cost. (Ibrahim et al., 2023).

Furthermore, as Munir et al. (2023) identified, Sustainable Supply Chain Management (SSCM), integrates environmental, social, and economic factors. The SSCM main goal is to maximize cost efficiency, while maintaining a sustainability profile and in parallel by minimizing environmental impact and maximizing social benefits. The Triple Bottom Line (TBL), persuades organizations to establish goals beyond cost optimization, such as assessing their impact on the society and on the environment. (Munir et al., 2023). This approach requires collaboration across all stages of the supply chain, from raw material sourcing to final delivery, ensuring resilience and adaptability.

9.2. Importance of Procurement in Supply Chain Management

Procurement has evolved from tactical to a more strategic function within the supply chain and it emphasizes aligning procurement functions with the overall organization objectives. Such goals could be risk management and sustainability, as highlighted by Handfield et al. (2019), cited in Cooper, (2024b). In Sweden, green procurement systems have optimized costs by 15% while reducing environmental impact through lifecycle costing (Acheampong, 2024). Similarly, Thailand's adoption of strategic procurement has improved efficiency, supplier management, and economic development (Srisukhumbowornchai & Sedgwick, 2019, cited by

Acheampong, 2024). South Africa has focused on capacity building and policy reforms, achieving cost savings and improved supplier performance (Mafini & Sussman, 2018, cited by Acheampong, 2024).

Procurement plays a significant role in building resilient supply chains. As Cooper (2024b) explains, procurement strategies reevaluation is necessary to deal with supply chain vulnerabilities. This is critical to deal with global disruptions, such as the COVID-19 pandemic or other potential geopolitical crises. Suppliers’ diversification and technological developments are some of the key strategies to follow for procurement effectiveness, to ensure continuity, and sustainable success.

Strategic procurement is linked with organizational success and financial performance. Corboş et al. (2023) mentions that one of the key roles of procurement is cost optimization, secure products quality standards, and enhance market positioning. Procurement 4.0 has transformed procurement into a profitable function that assists in the economic growth of the company and created employment opportunities.

Sustainability is increasingly prioritized in procurement strategies. Integrating corporate social responsibility (CSR) into procurement decisions promotes ethical sourcing and environmental stewardship (Cooper, 2024d). For example, circular economy principles and sustainable procurement practices are gaining traction in Europe, enhancing resource efficiency and quality of life (Corboş et al., 2023).

Nowadays, strategic Procurement involves continues innovation and agility. Technics that are currently employed to meet the new market standards involve collaborative supplier relationship management and category management strategies, which highlight the importance of the function. (Althabatah et al., 2023). Additionally, Procurement offers opportunities to enhance novel business models, products, and services within the supply chain framework. (Vaka, 2024).

9.3. Procurement Definition

Procurement incorporates the acquisition of goods and services, after identifying requirements, potential suppliers, managing transactions and enhancing suppliers' relationships. Althabatah et al. (2023) emphasize that procurement, purchasing, and sourcing, while often used interchangeably, are distinct processes. Procurement is a broader function, encompassing the entire process from identifying needs to payments. It includes functions such as purchasing, transportation, quality control, and auditing. Purchasing focuses on the transactional aspects, such as acquiring goods and services, it identifies users' requirements, researching suppliers, composing agreements, ensuring on time payment, and evaluation of effectiveness. Concerning sourcing, it includes the evaluation and selection of potential new suppliers. (Althabatah et al., 2023). Cooper (2024), highlights the importance of strategic sourcing strategies that enable organizations to negotiate profitable deals, consolidate spending and achieve economies of scale that will improve costs and therefore the organization's profitability and competitiveness compared to its competitors.

Procurement has evolved significantly, transitioning from a tactical function focused on cost reduction, operational efficiency (Procurement 1.0) to more strategic approaches emphasizing value creation, supplier relationship management, category management, cross-functional style, information sharing control, (Procurement 2.0) and later to data-driven optimization with digital tools like e-procurement systems that manage the complete purchasing cycle with multi company capabilities, (Procurement 3.0) (Bagn et al, 2020); (Althabatah et al., 2023). The most recent stage is Procurement 4.0, which aligns with Industry 4.0 principles, incorporates digital technologies such as IoT, big data analytics, artificial intelligence (AI), and blockchain to enhance supply chain integration and decision-making (Munir et al, 2023). This framework emphasizes automation and adaptive systems to optimize the procurement cycle and achieve sustainability goals (Glas & Kleemann, 2016, cited by Munir et al, 2023). For example, smart factories utilize real-time data-sharing platforms to enhance transparency and efficiency, enabling fully automated order generation and processing without human intervention (Henke & Schulte, 201, cited by Bernardo, 2020).

Procurement is divided in two categories the Direct and Indirect Procurement. The first one is used for the procurement of the raw materials, components and parts that are part of finished

products, and it occurs only in a manufacturing process. The second one concerns the buying of all goods and services that are not directly part of a finished product. Although direct procurement is managed centrally for cost efficiency and standardization reasons, the indirect procurement tends to be decentralized, following approval processes and allow for end-users to streamline processes and consequently reduce administrative overhead. It might range from basic back-office supplies to components for maintenance, repair, and operations (MRO), like lubricants and spare parts, as well as complicated construction -associated materials and various services. This type of purchases is usually made on an irregular bases and their demand is hard to predict.(Gebauer & Segev, 2000)

Direct vs Indirect Procurement Items	
Direct, production-related materials	Indirect, non-production related items and services
Scheduled	Not scheduled
Production items	Miscellaneous items
Usually no shelf items	Usually self items
Inventory accounts	Expense and asset accounts
Buyers' destops only	Everybody's desktops
No approvals	Approvals required
Bill of materials	Aggregated catalogs

Source: Adapted from Gebauer & Segev, 2000, p. 2

Table 1: Direct vs Indirect Procurement Items

Furthermore, AI and e-Procurement platforms are increasingly used to monitor the performance of suppliers, with a view to managing them more effectively and as a result gaining cost reductions, better Service Level Agreements (SLAs) and long-term partnerships. Additionally, procurement plays a pivotal role in maintaining competitive advantage by ensuring timely, cost-effective acquisition of goods not produced in-house, aligned with business needs. (Klündera et al., 2019).

Regarding sustainable procurement, it is intended to acquire goods and services in an environmental, social, and economic friendly way within the life cycle. This is core for supply chain management, to enable corporations to decrease their environmental footprint, undertake social accountability and achieve long term financial sustainability. (Smith, 2024).

9.4. Use of Technology in Procurement

Since the early 1990s, business process experts have advocated for a shift in the purchasing function from being initially clerical and transactional to developing to more strategic. However, it is only recently that supporting technologies have emerged, making this transition feasible and economically viable on a wider scale. (Gebauer & Segev, 2024) Digital procurement capabilities were initially identified as the internet-based technologies that concerned all major components of the purchasing processes and was called e-Procurement (developed in 90s, (Herold et al., 2023)), which revealed the maturity level of organizations in utilizing digital technologies concerned purchasing functions. (Hallikas et al., 2021) That was expected to obtain several competitive strengths and benefits for involved organizations, through the automation of business processes, which consequently would improve functionality and ensured consistency. (Hallikas et al., 2021).

Applications tend to be more user-friendly, designed to assist individuals who are not procurement experts, offering significant benefits to purchasing organizations. These include simplifying purchasing processes, increasing contract compliance, enhancing corporate buying power, and providing better spending information and control. (Gebauer & Segev, 2024) Digital platforms, as part of e-Procurement, enable the seamless access, sharing, and processing of information among all supply chain partners, establishing a new real-time operating model with extensive communication capabilities. These platforms allow for the rapid creation of networks that encompass entire production processes and integrate Information and Communication Technology (ICT) systems at various stages of business planning. These stages include inbound procurement, outbound procurement, production, marketing, and interactions between different organizations, forming value networks. Especially in the industrial buying process, which is consisted of a series of complex, interdependent actions, such as recognizing a need, developing a technical specification, evaluating suppliers, and making the final purchase decision. (Rejeb et al., 2018).

Later, new emerging technologies other than e-Procurement have played a significant role in the Procurement field and added efficiency and effectiveness to it. Specifically, technologies such as Artificial Intelligence (AI), Blockchain, Internet of Things (IoT), and Big Data Analytics, have advanced further Procurement processes, increased transparency, and fostered

better decision making. (Acheampong, 2024) The use of those advanced technologies in procurement was called digitalization in academic literature. (Herold et al., 2023) Overall, the combination of them have improved considerably demand forecasting precision, inventory management, decrease supply chain disruptions, hence, fostering operational resilience and efficiency. In addition, with the use of Block Chain there is increased transactions transparency, traceability, and enhanced trust across the supply chain, supporting ethical sourcing standards and decreasing cases of counterfeit goods. (Cooper, M., 2024b). Moreover, Enterprise Resource Planning (ERP) systems often lack user-friendly interfaces that facilitate ongoing master data integrity. As a result, extra third-party vendors may be necessary to perform data cleansing services. New emerging technologies deploy algorithms that identify an item or vendor code and align it with a consistent referential coding system. (Handfield et al., 2019)

Furthermore, Additive Manufacturing (3D printing), digital twins, cyber physical systems, Cloud Computing, and Machine Learning (ML) are considered to have a significant impact not only on business but on society and people, as well. (Delke et al., 2023). They have automated recurring and time-consuming tasks; they have reduced manual errors and shorten procurement cycles. (Acheampong, 2024) Another example is the implementation of digital technologies in the ordering procedure, which could transform upstream operations within the supply chain, convincing procurement professionals to innovate and develop new technological solutions. (ElAmmari et al., 2024). Moreover, digital tools have enabled companies to be agile in fast-changing markets and consequently apply effective procurement strategies, such as strategic sourcing and collaborative partnerships with suppliers, in a more informed decision-making way, within complex supply chains. (Cooper, M., 2024b)

Other advancements that have been identified with the use of technology are operational efficiency, competitive advantage, and customer/market alignment. Furthermore, the use of a combination of technologies will assist in identifying possible risks and act proactively to prevent supply chain disruptions or to recognize potential suppliers' risks, by enabling data-driven findings. (Cooper, M., 2024b) In addition, they improve supplier management practices, automation, centralization and strategic sourcing, on a view business to reduce costs and ensure on time delivery of raw materials, goods and services. (Munir et al., 2023) Hence, managers are encouraged to adopt procurement digitalization in order to manage risks and increase resilience in the supply chain. (Harju et al., 2023)

Neural networks can be utilized to predict supplier tender quotations and assess the chances of successful deals using machine learning techniques. The Chinese IT giant Alibaba has launched an automated request for quotation service with integrated chatbot features to streamline communication. In Utah, USA, artificial intelligence has been employed to aid in the selection of construction suppliers, reducing subjectivity favoritism in decision-making. The Singaporean government uses investigation and control methods to prevent procurement fraud. Meanwhile, Great Britain has issued guidelines for regulating AI and Machine Learning (ML) technologies in public procurement, emphasizing their benefits while also recognizing the necessity for control. (Spreitzenbarth et al., 2024) Transparency, accountability visibility and speed between suppliers' buyers will be increased, which will lead to enhanced trust and coordination. With supplier integration, system can indicate early alerts and reproduce trouble shooting developments for potential disruptions, creating initiative-taking reactions instead of reactive. Moreover, the system can identify alternative suppliers, routes or components that could be used as alternatives to keep production running. Finally, the redesigned procurement processes can be completely automated for straight rebuys. (Tripathi & Gupta, 2020)

In addition, new technologies lead to cost reduction regarding supplier selection cost, direct procurement costs, supplier failure recovery cost, and ordering cost. Suppliers' selection costs include expenses related to information collection, negotiation, and contracting, which are affected by the number of purchases and suppliers considered. By automating supplier pre-qualification and information search, the costs involved with them are expected to decrease. Furthermore, negotiations are expected to be fact-based and supplier failures often happen due to lack of available information and uncertainty. Hence, since information and real time visibility will be available, that implies that suppliers' failure will be at the lowest level. Overall, all costs in procurement processes are expected to be decreased, there will be time savings, as transactions automation will lead to delays reduction, redundant movements decrease, operational activities and communication delays reduction, will cause shorter procurement cycles and resources optimization. (Tripathi & Gupta, 2020)

Companies are advised to integrate procurement practices with broader corporate strategies with a view to fostering a culture of innovation and collaboration and achieve competitive advantage, and sustainable growth, by using technological advancements. (Cooper, M., 2024b). All procurement activities where technology can be used, such as operational

procedures with suppliers, requirement rules, and information systems, can be improved such as to considerable decrease costs and increase quality of inputs, as well as to enhance the relationship between a company and their suppliers. (Corboş et al., 2023) Furthermore, with the use of technologies companies can achieve sustainability goals and regulatory compliance (Fabian Mattaba & Fatahi Valilai, 2024) Besides the advancement of procurement processes, technologies have enhanced contract management, influence procurement power and improved spending information and control. (Gebauer & Segev, n.d.).

Emerging Digital Technologies for the Digital Transformation in Procurement		
Function	Maturing	Emerging
Suppliers Networks	Data Analytics	Blockchain Technologies, Smart Contracts, e-Signatures, e-Payments
Supplier Risk Management	Artificial Intelligence	Internet of Things, Sensors, Wearables
E-Sourcing and E-Tender	Cognitive Computing	Cybertracking
E-Procurement	Predictive Analytics	Virtual Reality/ spatial analytics
E-Catalogues, E-Invoicing	Analytics	
Contract Management	Collaboration Networks, Crowdsourcing, 3D Printing, Robotics	

Table 2: Digital Solutions Applicable to Procurement.

Source: Uluç, N. Ç. (2022). Digital Conflicts in Procurement. p. 92

9.5. E-Procurement

E-procurement is applied in both private and public sectors, and it contains the combination of digital tools in procurement activities aiming to increase efficiency, transparency, and cost-effectiveness. With the use of e-Procurement, manual errors are minimized and corruption risks are controlled. (Acheampong, 2024).

E-procurement is a component of business-to-business (B2B) trade that takes place online, enabling buyers to make direct purchases from vendors through their websites, applying software packages, or via e-marketplaces, e-hubs, and trading exchanges. Companies with e-Procurement applications minimize transaction costs, decrease costs of goods bought and labor expenses, place orders more quickly and achieve shorter delivery times. Furthermore, mobile-based e-procurement can be applied to facilitate supplier selection during tender bidding process, which frequently lacks of sufficient vendor information. This new e-procurement system features an outline directly incorporated with a vendor management system that contains a vendor scoring system, with a view to mitigating the problems of the previous procurement system. (Angrian, 2019).

Frequently e-Procurement and e-Commerce are considered similar, however, there are significant differences, such as the fact that e-commerce serves individual consumers and e-procurement contains transactions with companies. Through e-Procurement application companies can save up to 8%-12% of total purchases costs. (Angrian, 2019).

e-Procurement consists of electronic data interchange (EDI), e-CRM, e-Commerce, SAP, Platforms, which contain portals, internet based electronic marketplaces, internet-based online stores, suppliers' portal, e-Sourcing, digital payment, online catalog services, e-Reverse Auctioning, e-Tendering, e-Auctions, Many to Many, Social Media Platforms, and Android Platforms. Furthermore, it involves e-Collaboration, e-Informing, e-Notices, e-Signature, e-Models, e-Payment, Procure to Pay, e-Invoicing, e-Ordering, e-Transactions, e-Design, e-catalogs, and ERPs.

E-procurement systems have significantly improved supply chain efficiency, reduced procurement lead times, and minimized transaction costs. Countries in West Africa, like Ghana have implemented for example mandatory e-procurement systems, as a mean to decrease procurement cycle times, increase accountability and control corruption. (Acheampong, 2024; Addy et al., 2023). Studies by Vaidya and Campbell (2016) and Ibem et al. (2016), cited in Addy et al, 2023 also highlight the broader advantages of e-Procurement, including faster order processing, cost savings, and better contract management. Governments and private organizations worldwide have recognized these benefits, driving the adoption of e-procurement technologies to optimize procurement outcomes (Adjei-Bamfo et al., 2019; Hasan, 2016, cited in Addy et al., 2023).

The integration of advanced technologies, like AI and ML has further enhanced e-Procurement processes. E-Procurement offers more basic level functionalities, while emerging technologies facilitate decision making and predictive analytics. As a result, supplier relationship management is optimized leading to inventory minimization and cost savings, resulting in operational efficiency (Fabian Mattaba & Fatahi Valilai, 2024). In addition, cloud-based systems assist organizations to manage procurement activities, optimize costs, and adopt sustainable practices (Angrian, 2019; Althabatah et al., 2023). Generally, Industry 4.0 technologies promote a more interconnected and efficient procurement ecosystem.

In addition, e-Procurement promotes sustainability through e-sourcing and e-invoicing tools which are considered ethical and environmentally friendly practices. (Fabian Mattaba & Fatahi Valilai, 2024). Hence, e-Procurement platforms contribute to joint consumption, supply efficiency, and compliance with social and environmental responsibility, fostering a circular economy.

e-Procurement systems have increased transparency, eliminated unauthorized buying, and supported information reporting, enhancing in this way supply chain performance (Hallikas et al., 2021). Digital procurement capabilities, such as e-tendering and enterprise resource planning (ERP) integration, streamline supplier management and reduce cycle times, leading to better overall performance (Hallikas et al., 2021).

9.6. Procurement 4.0

The integration of Industry 4.0 technologies to procurement has led to Procurement 4.0 (P4.0), concept creation, which intends to increase efficiency and performance (Corboş et al., 2023). Procurement 4.0 allows for interconnection among supply chain partners through networks to create a dynamic cooperation and coordination, which goes beyond organization’s boundaries (Althabatah et al., 2023). P4.0 enables real-time data sharing and improved decision-making, making it a foundation of modern procurement strategies.

Procurement 4.0 plays a vital role in advancing circular economy practices through competitive strategies for recycling and remanufacturing, supplier management, and collaboration. It fosters the integration of complex data and employee upskill to achieve sustainability goals (Bueno et al., 2024). Procurement practices such as planning, implementation, and

performance reviews, achieve benefit maximization within the circular economy (Corboş et al., 2023). Procurement functions that are positively affected the most are supplier management, supply chain transparency, and resource allocation (Bueno et al., 2024). Robotic Process Automation applications can enhance further agility and reduce waste. (Jain et al., 2024).

P4.0 technologies improve visibility and optimize processes, thereby reducing uncertainties and benefit circular economy (Bagn et al., 2020). From a technological standpoint, tools like enterprise resource planning (ERP), e-Auctions, and Electronic Data Interchange (EDI), as part of e-Procurement, facilitate tasks traditionally requiring significant manual input, such as connecting suppliers with buyers. E-Procurement can be considered as one of the enable pillars of Industry 4.0 (Ibusuki et al., 2023). Moreover, the technologies of Industry 4.0, like artificial intelligence (AI) and machine learning enhance data analysis capabilities, enabling predictive insights and real-time decision-making (Joseph et al., 2022).

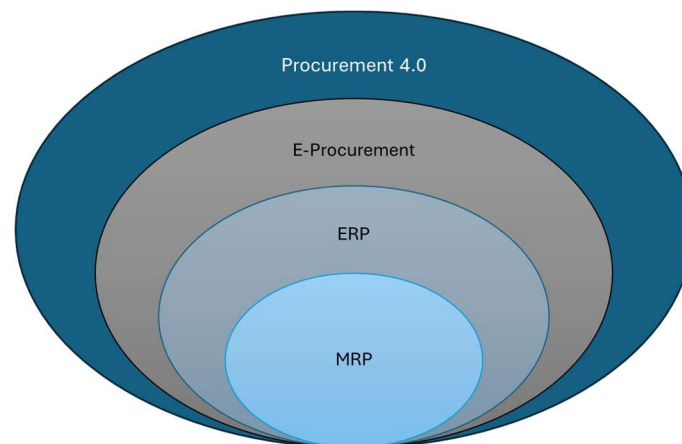


Figure 2: The Evolution of Procurement IT Systems towards Procurement 4.0.

(Adjusted from Glass and Kleemann (2016) cited in Ibusuki et al., (2023), p. 66)

In the pharmaceutical industry, for instance, P4.0 aids in ensuring uninterrupted supply chains by optimizing procurement processes and maintaining ambitious standards of product traceability (Joseph et al., 2022). Similar advancements are noted in industries focused on large-scale engineering projects, where P4.0 solutions ensure competitive advantages through seamless integration of procurement tools (Ibusuki et al., 2023).

Procurement 4.0 integrates traditional computing with advanced automation, supporting enhanced flexibility, improved process speed, and better resource management (Boston Consulting Group, as cited in Bernardo, 2020). Technologies such as robotic process automation (RPA) and advanced manufacturing solutions improve operational efficiency and reduce waste, contributing to sustainable practices (Marković & Mihić, 2022). Furthermore, data-driven performance reviews help businesses identify areas for improvement, optimize procurement cycles, and align supplier selection with environmental sustainability objectives (Althabatah et al., 2023); (Munir et al., 2023).

Strategically, P4.0 enables organizations to align procurement strategies with broader corporate objectives, ensuring a strong strategic fit and fostering collaboration with suppliers (Corboş et al., 2023). Long-term decision-making and regular evaluations of procurement performance are critical components of this approach, facilitating continuous improvement (Corboş et al., 2023).

9.6.1. Artificial Intelligence (AI) in Procurement

The adoption of AI-driven analytics in the USA has eliminated the procurement cycle by 20% procurement cycle and by 15% procurement costs. (Acheampong, 2024). AI-powered systems enable predictive analytics, automated supplier selection, and contract negotiation (Liu & Cao, 2020, cited in Acheampong, 2024) and have been found to improve procurement forecasting accuracy by up to 25%, as shown in Chen and Wang’s (2018), cited in Acheampong, 2024, case study analysis.

AI consists of Biometrics, Natural Language, Negotiation Support, Automated Negotiations, Negotiation bots, Autonomous Negotiation, Cognitive Procurement, Cognitive Analytics, Clustering, e-Negotiation, e-Evaluation, Augmentation, Digital Passport Product (DPP). It is pivotal in transforming procurement by enabling intelligent automation, predictive analytics, and cognitive decision support.

Applications include compliance management, supply chain optimization, supplier selection, and risk assessment. AI-powered systems such as those proposed by Wang et al. (2023), cited in Cooper, 2024, improve compliance auditing with enhanced accuracy and efficiency.

Intelligent algorithms are suggested by Jemmali et al., 2023, cited in Althabatah et al, 2023, for supplier selection, as they will exaggerate decision-making speed and accuracy. Moreover, AI-driven federated learning frameworks support smart contracts and decentralized operations, enhancing resilience during disruptions like the COVID-19 pandemic (Althabatah et al., 2023; Aslam, 2024). Encompassing predictive analytics for supplier assessment, risk analysis, and performance forecasting. For instance, AI facilitates automating supplier evaluation, categorizing requisitions and invoices, eliminate suppliers' duplicates or correcting misspellings, consolidating expenditures across individual group companies in the holding structure and enhances sustainability. (Lutz, 2024).

Generative AI (GAI), a subset of artificial intelligence, is revolutionizing supply chain management by creating new content and generating innovative solutions from real-world data patterns. It can produce several types of material, such as text, images, videos, audio, and even digital simulation. Chatbots were the first applications of GAI (Anantrasirichai & Bull, 2022, cited in Aishwarya, 2023). The application of GAI in procurement allows businesses to analyze a range of parameters, such as cost, quality, and sustainability (Richey Jr et al., 2023) Generative AI also promotes inclusivity by recommending strategies to include minority-owned or women-owned suppliers. (Aishwarya, 2023). Generative AI increase supply chain agility by proposing alternative logistics networks, detecting alternative suppliers' databases, and by building a portfolio of diverse procurement tactics. It creates simulations of supplier bankruptcy, force major or economic crises to facilitate risk assessment. (Mentzer et al., 2021, cited in Aishwarya, 2023).

In addition, digital transformation in procurement optimizes tasks like price forecasting, cost-effectiveness, streamline processes, and manage knowledge-intensive tasks, bridging talent gaps and enhancing decision automation (Lee et al., 2022). It automates complicated tasks and enables data-driven strategies. AI-powered solutions offer capabilities such as real-time data analysis, predictive modeling, and adaptive learning to optimize procurement processes. (Aslam, 2024; Acheampong, 2024).

Adoption of AI in supply chain management has led to significant performance improvements. (Exxact, 2023, cited in Aishwarya, 2023) highlights a 35% reduction in inventory levels, a 15% drop in logistical costs, and improved service levels for businesses utilizing AI-powered solutions. AI algorithms enable better procurement forecasting accuracy by 25% and

consequently leading to substantial inventory cost reduction and minimized stock-outs (Acheampong, 2024; Aslam 2024; Cooper, 2024). Inventory levels, distribution roots and production schedules can be adopted based on real-time demand due to data analytics, making in this way organizations flexible and agile. (Belhadi et al., 2021). AI's predictive capabilities are transforming inventory management by providing accurate demand forecasts and developing adaptive strategies for inventory control. These innovations include just-in-time inventory practices, storage costs reduction, and profit maximization. (Meriton et al., 2021). The symbiotic relationship between Sustainable Supply Chains (SSC) and Artificial Intelligence (AI) is overly complicated. AI technologies assist to enhance sustainability within supply chains by improving operations, upgrading decision-making processes, and detecting ways to optimize resources. AI-powered monitoring systems can track suppliers' environmental and social performance, to ensure that they comply with sustainability standards and promote transparency within the supply chain. (Spreitzenbarth, 2024).

AI-powered platforms facilitate real-time data sharing and visibility, fostering innovation and continuous improvement across the supply chain (Aslam, 2024). AI systems that incorporate hybrid models, such as Bayesian fuzzy games and distributed AI, have been employed to address multi-issue negotiations and uncertainty in supplier selection (Spreitzenbarth et al., 2024). These systems leverage knowledge representation and reasoning to enhance decision-making, particularly in complex scenarios. Furthermore, autonomous agents can provide unbiased negotiations and decisions, which cannot be affected by unethical practices, such as expensive gifts and entertainment, which could affect supplier selection (Spreitzenbarth et al., 2024).

Incorporating resilience into supply chains, AI enables risk prediction, enhances visibility, and supports collaborative relationships with suppliers. The concept of “gresilience,” (Mahmoudi et al., 2021, cited in Shivajee, 2022), which integrates green and resilient supply chain practices, highlights the role of AI in achieving sustainability along with disruptions (Shivajee, 2022). AI and predictive analytics facilitate innovative resource management, these tools help organizations meet participants requests for increased sustainability and corporate social responsibility (CSR). (Cooper, 2024c). The conjunction of AI and Sustainable Supply Chain Management (SSCM) offers significant opportunities to address environmental, social, and economic challenges. AI-driven analytics optimize inventory management, reduce waste, and

monitor supplier sustainability performance. These innovations align procurement practices with Sustainable Development Goals (SDGs), emphasizing transparency and stakeholder collaboration (Spreitzenbarth et al., 2024).

In public procurement, AI and ML enhance transparency, reduce administrative costs, and mitigate risks of corruption. Compliance audits can be automated and contract terms can be automatically analyzed, improving in this way efficiency and ensure governance (Mallesham, 2024). Furthermore, the use of AI aligns procurement functions with business goals, generates supplier innovation and competitive advantage. AI applications guide users to follow ethical standards and adopt governance. In this way trust is built on how public money is spent and value-based decision making is enabled. (Mallesham, 2024).

In the construction industry AI-driven tools facilitate material quantification, optimize logistics, and promote low-carbon practices (Kumar & Zhang, 2024). Furthermore, early stakeholder involvement and cooperative approaches, such as integrated project delivery (IPD), have been successful in enhancing sustainability in procurement (Kumar & Zhang, 2024).

The use of AI into supply chain processes is significant for companies that are pursuing a competitive advantage. Aishwarya (2023) highlights that the sooner participants adopt AI systems, the more prepared they are to manage modern supply chains disruptions. Technology enables professionals to handle large datasets, extracts informed insights, assists decision-making, fosters innovation and enables businesses to succeed in a rapidly changing global landscape.

9.6.1.1. Machine Learning (ML)

Information Processing, Fuzzy Algorithms, Neural Networks, Autonomous technologies supported by AI and machine learning are established to modernize procurement. These systems can autonomously manage repetitive tasks, negotiate using game theory principles, and enhance decision-making through data insights (Herold et al., 2023). For instance, AI applications can analyze supplier behavior and predict market conditions, assisting in strategic procurement planning (Jahani et al., 2021).

AI and ML are increasingly recognized as transformative forces in public procurement. Mallesham (2024) highlights that public procurement represents 16.9% of GDP in Europe and

plays a vital role in the European Single Market. The use of AI systems aligns procurement with broader business objectives and fosters innovation. (Mallesham, 2024).

AI systems, which involve machine learning technology, can address complex procurement processes, such as supplier evaluation, risk prediction, and demand forecasting. For example, neural networks and distributed artificial intelligence (DAI) have been used to direct uncertainties in supplier selection (Lutz, 2024). These tools enable organizations to optimize procurement decisions, creating a competitive advantage.

AI and ML are not only tools for operational improvement but also critical enablers of data-driven decision-making. Mallesham (2024) illustrates how AI helps understand buying behavior, predict supplier risks, and lead synchronized responses to procurement challenges. AI and ML integration into both tactical and strategic functions could transform procurement to a central function as a source of creativity and innovation within the organization.

Examples from case studies highlight the benefits of AI in procurement, like a telecommunications company, which automated its documents processing and validation, which reduced project cycle time. Similarly, a supplier of optical networking hardware improved demand forecasting accuracy with the use of time-series neural networks. These implementations demonstrate the potential of AI/ML in streamlining procurement processes, improving accuracy, and enhancing supplier evaluations (Mallesham, 2024).

9.6.2. Blockchain in Procurement

Blockchain technology enables data sharing in a transparent and certified way, improving collaboration among stakeholders. Blockchain was initially used within financial sector with the use of Bitcoin platform, however, later its application was expanded to other sectors such as the supply chain. The latter application is still on the rise, and it has the potential to improve a lot of the business and corporate processes. There are three categories of Blockchain systems public, private, and consortium, depending on the level of access and privacy required. Smart contracts, a critical component of blockchain technology, automate processes and implement transactions based on predefined conditions, enhancing operational efficiency.

Blockchain technology is a well-organized set of blocks, which contain recorded transactions through agreed mechanisms, it is tamper-proof: any information recorded in the distributed records is permanent and cannot be changed. Blockchain-based smart contracts have transformed procurement by industrializing and decentralizing contract management processes. (Cammarano et al., 2023). Althabatah et al. (2023) highlights its role in justifying inefficiencies in traditional procurement systems by improving contract transparency, security, and trust among involved parties. Some of its applications are highlighted from Pinheiro et al. (2023), cited in Althabatah et al. (2023), such as a method that integrates blockchain, symmetric encryption, and computational trust to enhance file integrity in cloud storage systems. In addition, Guo et al. (2023), cited in Althabatah (2023), proposed a blockchain-enabled contract management system to address security weaknesses in integrated e-contract systems.

Blockchain's integration into specific industries has revealed substantial benefits. For example, Omar et al. (2023), cited in Althabatah et al. (2023) explored its application in healthcare supply chains, emphasizing its role in automating procurement contracts and improving communication among stakeholders. Kim et al. (2023), cited in Althabatah et al. (2023), highlights the benefits of blockchain application in the construction industry, where it reduces transaction costs and improves procurement evaluation processes. As a result, blockchain enhances efficiency and increases security in several procurement circumstances.

Blockchain technology has also transformed supply chain management by enabling transparency, traceability, and accountability. Bottoni et al. (2020) refers that smart contracts enhance relationship among supply chain parties through processes automation, such as profits sharing and payment allocation. They proposed an "Intelligent Smart Contract" framework, which incorporates planning and optimization capabilities, to maximize profitability and trust in supply chain ecosystems. Cammarano et al. (2023) further highlighted blockchain's ability to mitigate the bullwhip effect by increasing visibility across the supply chain, reducing delivery times, and achieving customer satisfaction.

Technology has been particularly effective in addressing challenges in humanitarian supply chains. Rodríguez et al. (2023), cited in Althabatah et al. (2023) analyzed case studies where blockchain, artificial intelligence, and 3D printing reduced congestion, improved stakeholder collaboration, and enhanced material traceability during crises, such as the Tabasco floods of 2007 in Mexico.

Blockchain's integration with other Industry 4.0 technologies, such as IoT and big data, has expanded its potential in procurement. Rane and Narvel (2023), cited in Althabatah et al. (2023) and in Govindan et al. (2024), proposed a Blockchain-IoT framework for project resource management, which offers real-time data acquisition, decentralized coordination, and enhanced security. This integration enables organizations to make informed decisions, optimize resources usage, and increase organizations responsiveness to the fast-changing market conditions. (Govindan et al., 2024).

Further developments involve the progress of Enterprise Blockchain Design Frameworks (EBDF), which address the challenges of blockchain implementation by creating systems applicable across industries (Nodehi et al., 2023, cited in Althabatah et al., 2023). These frameworks emphasize the importance of stakeholder motivation and proper utilization of blockchain capabilities to ensure extensive adoption and effectiveness.

9.6.3. Big data analytics

Business Intelligence (BI), Descriptive Analytics, Prescriptive Analytics, External Data Analytics, Internal Data Analytics, Advanced Analytics, Predictive Analytics, Data Governance.

Big data analytics (BDA) play a transformative role in modern procurement by enhancing decision-making processes through data-driven insights. Acheampong (2024), highlights that the application of big data analytics for supplier performance management can improve quality by 30% and decrease lead times. The integration of big data with procurement systems can effectively analyze suppliers' performance measures and optimize procurement results.

BDA also increases visibility in supply chain processes, achieves better risk management, enables more informed decision-making, and enhances strategic supplier relationships. For instance, Gholizadeh et al. (2020) proposed an eco-sustainability model with the use of big data analytics to optimize transportation efficiency, as well as minimize carbon emissions and information fraud. In addition, Hallikas et al. (2021), cited in Althabatah et al. (2023), highlight

the improved performance of supply chain management and increased procurement capabilities, with the use of internal and external data analytics, respectively.

Sustainability has become a central goal in procurement, with digital technologies playing a critical role in the achievement of environmental and social objectives. Segun-Ajao (2024) mentions that big data and AI technologies raise sustainability by utilizing resources and reducing waste. Moreover, Nasser Tuwali et al. (2024) highlighted that big data analytics increase transparency and accountability in procurement, enabling ethical practices and reducing corruption risks.

The concept of Circular Procurement 4.0, as outlined by Bueno et al. (2024), integrates Industry 4.0 technologies with circular economy principles to enhance environmental performance. This approach highlights technologies like big data analytics and blockchain, by presenting their role in achieving sustainability goals.

9.6.4. Cloud Computing Adoption in Procurement

Further to previously mentioned technologies, a centric role plays cloud computing by improving efficiency and modernizing operations. For instance, Jones and Smith (2019), cited by Achempong (2024), found that cloud-based procurement systems reduce administrative costs by 20% and enhance efficiency by 15%, among leading companies. In addition, Wang, and Li (2019), cited by Acheampong (2024), highlighted that cloud technologies improve collaboration among procurement stakeholders by 60%, significantly reducing document processing times.

The role of cloud computing in procurement is pivotal, as it facilitates real-time data sharing, improves supply chain resilience, and enables green procurement practices. Cloud-based platforms, such as a Service (PaaS), include a full operating system, servers, relational database, without the applications. The service providers own the equipment and are responsible for its operation, upgrade, and maintenance. These platforms allow for seamless integration of resources across procurement lifecycles, offering cost savings, increased flexibility, and enhanced security (Bernando, 2020). These systems also decrease capital

expenses by reducing the need for physical infrastructure and licensing fees, while ensuring 24/7 availability (Florian & Abubaker, 2018). Cloud computing includes Digital Storage, Information Sharing, Data Sharing, Mobile Computing, Edge Computing and Cloud Procurement.

The literature also highlights the benefits of these technologies in fostering collaborative supply chain ecosystems. Delke et al. (2023) is referred to the evolution of "smart supply chain management," which leverages blockchain and cloud technologies for more agile organizations, with the use of integrated networks.

9.6.5. Internet of Things (IoT) in Procurement

IoT devices, such as sensors and RFID tags, provide real-time visibility into inventory levels, delivery tracking, and warehouse conditions. Acheampong (2024) refers to IoT technology that improves logistics efficiency and operational decision-making. Furthermore, Li and Zhang (2017), cited in Acheampong (2024), found that IoT-enabled inventory management reduced stockouts by 40% while optimizing inventory levels.

Beyond inventory, IoT facilitates green procurement through recycling and refurbishing of end-of-life products. Fang et al. (2023), cited in Althabatah et al. (2023), proposed an IoT-based model to collect and track recycled goods using wireless sensor networks, enhancing circular economy practices. In addition, smart algorithms embedded in IoT devices enable data-driven supplier selection and replacement strategies, leading to cost-efficient procurement. (Jemmali et al., 2023, cited in Althabatah, 2023).

IoT technology increases transparency and traceability, improves buyer-supplier relationships, and fosters trust and responsibility among the parties involved. Florian and Abubaker (2018) highlighted that IoT-driven transparency leads to improved long-term partnerships by ensuring information consistency and visibility across supply chains.

Blockchain complements IoT by offering secure, decentralized data management. It enhances transparency, trust, and accountability in procurement systems, particularly through the integration of Blockchain-IoT (BIIoT) technologies (Rane & Thakker, 2023, cite in Althabatah,

2023). This integration supports green procurement by enabling real-time tracking and sustainable resource utilization.

Rane and Narvel (2023), cited in Althabatah (2023), refers to the use of a BIoT-driven model for project resource management, as a means to enhance transparency, decentralization, and agility within engineering and construction industries. Moreover, Bueno et al, 2024, introduced the concept of Circular Procurement 4., which is the combination of Procurement 4.0 and the circular economy, for sustainability goals.

Overall, literature shows that blockchain and IoT integration address challenges such as fraud detection and compliance in public sector procurement systems (Modrušan et al., 2021).

9.6.6. RFID in Procurement

RFID technology plays a critical role in creating intelligent and transparent procurement systems. During the last ten years, RFID has developed to include smart tags with processing capabilities, allowing real-time tracking of goods and materials (ElAmmari et al., 2024). RFID systems improve inventory management by automating data collection and monitoring, reducing manual errors, and increasing operational efficiency (Harsanto et al., 2024).

Innovative applications of RFID include its integration with drones and unmanned ground vehicles (UGVs) for automated inventory tasks. Fernández-Caramés et al. (2019) highlighted the use of UAVs equipped with RFID readers to automate inventory tracking in warehouses, achieving high accuracy and time efficiency.

9.6.7. Robotic Process Automation (RPA) in Procurement

Robotic Process Automation (RPA) has emerged as a transformative tool within the domain of procurement, enabling automation of repetitive and rule-based tasks. By automating functions such as purchase order processing, invoice handling, and contract management, RPA allows procurement professionals to focus on strategic activities, such as supplier relationship management and value-driven decision-making (Acheampong, 2024; Cooper, 2024). Literature indicates that RPA technology enhances efficiency, improves accuracy, and reduces

errors, places it as core one for the digital transformation in procurement processes (Acheampong, 2024).

Furthermore, Jones and Brown (2016) mention that RPA implementation reduces procurement cycle times and minimizes errors in tactical procurement operations. In addition, Van Hoek et al. (2022) is referred to Maersk’s successful RPA implementation, which led to a substantial improvement in buyer managing times, reducing average response rate from 13.1 days to 3.6 days. This case study also demonstrated how RPA not only improves operational performance but also strengthens staff capacity by allowing employees to concentrate on higher-value tasks, such as strategic planning.

The potential of RPA to support strategic progress in procurement is further emphasized by its integration with other advanced technologies. RPA combined with Artificial Intelligence (AI) and Machine Learning (ML), gain predictive capabilities for demand forecasting and initiative-taking supplier management (Mалlesham, 2024). Moreover, it constitutes a tool for effective responsiveness to force major supply chain issues.

Flechsigg et al. (2021) refer that digital readiness and maturity of each organization, shall affect the successful implementation of RPA. Their research contains both best practices and drawbacks in RPA applications, with a focus on process standardization and cost reduction in both private and public sectors.

According to Lorentz et al. (2021), RPA processes automation can reduce errors, improve contract management, and upgrade supplier authentication. Furthermore, automation improves processes, decreases cycle times, and rationalizes resources allocation. Moreover, Rejeb et al. (2018) justifies that RPA make transactional processes quicker, augments accuracy, and enable procurement managers to shift their focus to strategic tasks.

Van Hoek et al. (2022) Maersk case study, offers insights into RPA evolution, emphasizing the importance of starting with small-scale implementations and expanding scope in parallel with the organizational commitment growth. They also highlight the "human-in-the-loop" model, where RPA undertakes routine tasks, but human intervention remains critical for handling exceptions and decision-making. This balance ensures that automation supplements rather than replacing human expertise, aligning technology deployment with broader organizational goals.

9.6.8. Additive Manufacturing (3D Printing) in Procurement

Additive manufacturing (AM), commonly referred to as 3D printing, constructs physical objects by successively adding layers of material, with the use of data driven computer-aided design process. (Althabatah et al., 2023). It can create complex shapes, reduce waste, and produce customized objects, offering a competitive advantage to the companies they use it, across various sectors.

3D printing applications in procurement and supply chain management enables decentralized manufacturing and adjusts logistic systems. For instance, AM facilitates the on-demand production of spare parts, reducing dependency on original equipment manufacturers (OEMs) and enabling just-in-time (JIT) inventory strategies (Sekhar et al., 2023). This is particularly beneficial in various industries, where supply chain disruptions during the COVID-19 created shortages. (Althabatah et al., 2023).

With the use of 3D printing, physical stock is replaced by digital inventories of 3D model files decreasing warehouse costs. In addition, transportation costs are eliminated with the on-demand printing of objects near to end user premises and by carbon emission elimination there is a positive impact on the environment and creating more agile supply chains. (Bernardo, 2020).

There are several benefits from AM implementation in the procurement field, as follows:

1. AM enables customized designs based on specific industrial needs. It fosters innovation in product design and produces lighter, stronger parts, with complex shapes. (Althabatah et al., 2023).
2. The fact that parts can be produced near to or at the end user premises, allows for transportation cost minimization, delivery times optimization, and inventory minimization through minimum order quantity (MOQ) removal and manufacturing hubs centralization. (Sekhar et al., 2023). These efficiencies make AM a viable alternative for small-batch or specialized production requirements.
3. AM enhances supply chain agility by minimizing reliance on OEMs and reducing the risks associated with global supply chain disruptions (Althabatah et al., 2023; Sekhar et al., 2023).

4. AM fosters environmental sustainability through material waste elimination, energy consumption, and transportation emissions reduction. The shift to digital inventories and localized production further aligns with green logistics principles, (Bernardo, 2020).

9.6.9. Unmanned Aerial Vehicles (UAVs) in Procurement

Unmanned Aerial Vehicles (UAVs) automate repetitive and time-consuming tasks, such as inventory management and item traceability. It has evolved to include advanced control units, sensors, and UAV frames, and as time goes by it continuously becomes more cost-efficient. UAVs are considered critical tools for increased operational efficiency and secures data accuracy and trustworthiness in industrial places. (Fernández-Caramés et al., 2019).

UAVs are widely utilized for inventory tasks, leveraging technologies such as Radio Frequency Identification (RFID) tags, QR code readers, and 3D Light Detection and Ranging (LIDAR). UAVs provide real-time tracking of stock and increases traceability. There are QR code-based UAVs which are as accurate as 98.08%, on the condition that they have uninterrupted line-of-sight for optimal performance. When they are combined with blockchain technology and decentralized storage systems they provide data security and automation. (Fernández-Caramés et al., 2019).

The integration of UAVs with other systems, such as Unmanned Ground Vehicles (UGVs), expands their capabilities. In such arrangements, UGVs serve as ground references for UAVs during indoor flights. This combination permits UAVs to identify specific inventory locations and transmit data in real time to a centralized system. Such systems enhance inventory operations optimization and decrease manual tasks. (Fernández-Caramés et al., 2019).

UAVs implementation in industrial environments provide organizations with multiple benefits, including improved speed and accuracy in data collection, reduced manual tasks, and enhanced security through decentralized systems. However, challenges remain, such as the limitations of certain technologies (e.g., line-of-sight requirements) and the complexity of integrating UAVs into existing industrial ecosystems. Despite these drawbacks, UAVs have proved to enhance inventory and traceability tasks effectiveness. (Fernández-Caramés et al., 2019).

9.6.10. Virtual Reality (VR) in Procurement

There is a developing category of technologies, which includes Virtual reality (VR), cyberattacking, blockchain, sensors, wearables, and spatial analytics, which are very promising in enhancing further procurement efficiency and decision-making. Deloit (2017) report, cited in Uluc (2022), discusses procurement evolvement in the future with the use of these technologies. (The Future of Procurement in the Edge of Supply Networks, 2017). According to the same report there is an evolving application of virtual Reality in combination with spatial analytics, called as “Procurement’s Path to Digitalization,” which is expected to adapt supplier visits or audits through location data or pattern investigation using event recognition or deviations of status using video. In this way, VR provides an innovative approach to optimizing procurement operations (Uluç, 2022). The combination of all the technologies included in the third category will contribute to a competitive edge for organizations by improving transparency, enhancing security, and enabling automation in key procurement tasks.

9.6.11. Cybersecurity in Procurement

One of the nine technology pillars of Industry 4.0, is Cybersecurity, which when it is combined with the rest of the eight emerging technologies, such as Big Data and AI analytics, Vertical and horizontal integration, Cloud computing, Augmented reality, Industrial Internet of Things, Additive manufacturing (3D printing), Autonomous robots, Simulation or digital twins, can reach its full potential in procurement, by creating intelligent and autonomous systems. (Vaka, 2024)

Arland (2024), refers due to the dynamic nature of cybersecurity, it is important to emphasize the criticality to be continuously aligned with emerging cyber threats. Collective resilience can be achieved through enhanced communication and knowledge sharing and in parallel the security of data and systems. Risk management emphasizes the need to assess risk regularly, response immediately to incidents and continues improving cyber threat management across the Supply Chain.

In addition, it is critical for the participants to be aware of enhancing cyber resilience, on a view not just to prevent breaches but also create a resilient infrastructure. Considering suppliers perspective, there is an increased need to enhance cybersecurity requirements and procurement

security measures. Hence, higher cybersecurity standards are necessary and frequent audits within the procurement processes, ensuring that all involved suppliers meet the minimum requirements to maintain integrity and security within the supply chain. (Arland, 2024),

Bienhaus and Haddud (2018) is referred to cybersecurity as a cross-functional system which should be adopted by all the supply chain stakeholders to secure interconnected supply chains from cyber-attacks and ensure operational continuity. Bernardo (2020) highlights how a lot of companies sign contracts with partners that offer products like IoT devices without considering that they give permission to third parties to process their data for commercial purposes. Organizations which collect data from billions of devices should be well prepared to face potential data leakages and manage the risks associated with IoT. The first malicious campaign, based on IoT systems, indicated that more than 750,000 phishing and spam emails launched from 100,000 visible everyday items.

Finally, Segun-Ajao (2024) proposes future research developing robust cybersecurity measures, such as exploring advanced encryption protocols, and multi-factor authentication methods, and implementing stricter access controls to protect sensitive data. Cybersecurity awareness should be enhanced from the procurement teams, such as to be equipped with the knowledge to identify and mitigate potential cyber threats.

9.7. Sustainability in procurement and the industry 4.0

According to Bernardo, (2020) There are strong connections between procurement 4.0 and sustainability. A critical component of sustainability in procurement is green procurement. Green procurement is the process by which an organization acquires supplies in a way that does not damage the environment. There is a big push for green procurement in the public sector for its social and community implications. Green procurement term has arisen to include sourcing materials and products that are environmentally friendly, socially responsible, and economically sustainable. Furthermore, it involves the handling of renewable resources, the reduction of energy spending, the minimization of waste and in parallel the decrease of greenhouse gas emissions (Nagle et al., 2022; van Capelleveen et al., 2021, cited in Bus, 2023). In addition, remanufacturing is usually related to green procurement. (Galeazzo et al., 2021;

Sundin & Bras, 2005, cited in Bus, 2023). It involves processes such as recovering, disassembly, reestablishing, and disinfecting components for reuse under the design of “future products” or the refurbishing of “existing products” without compromising on the functionality, quality, and consumer requirements (Abedsoltan et al., 2022; Govindan, 2022, cited in Bus, 2023). The goal is to achieve sustainable consumption of resources. (Meehan & Bryde, 2011, cited in Bus, 2023), increase product life cycle (Hazen et al., 2017), generate new income flows (Massaro et al., 2021, cited in Bus, 2023), and increase competitiveness (Patyal et al., 2022, cited in Bus, 2023).

Overall circular economy contains principles such as reduction, recycle and reuse with a view to maximizing resource utilization and waste minimization to achieve strategic objectives of the organization. (Bag, Dhamija, et al., 2021; Kamble and Gunasekaran, 2021; Kumar et al., 2019, cited in Bus, 2023).

Casandra et al., 2023 mentions the critical role of technological tools to evaluate the environmental impact of supply chains. It refers carbon footprint calculators, environmental management systems, life cycle assessment techniques, traceability technologies, and other digital solutions that enable data-driven decision-making, risk mitigation, and process optimization. With the use of emerging technologies tools, transparency, accountability, and innovation are enhanced. Carbon footprint calculators are important tools for the estimation of greenhouse gas emissions at the various stages of a products lifecycle, including raw material mining, manufacturing, transportation, use and end of life disposal. Furthermore, sustainability platforms exist to present, evaluate, and forecast environmental concerns. They enable the parties involved to visualize material flows, transportation directions and potential areas for optimization. To enhance sustainability results with the use of technology, suppliers should be involved in the entire process at an early stage of technological change. Furthermore, these tools enable organizations to identify and mitigate risks related to regulatory compliance, resource shortage and reputation damage. (Casandra, 2023).

Cloud-based e-Procurement system that increases efficiency and decreases data protection costs. The cloud-green e-procurement model fosters sustainability within the procurement field. (Althabatah et al, 2023). In addition, Big Data Analytics, mobility, IoT and AI. Technologies can support sustainable procurement by making it more environmentally

friendly, and in parallel improve implementation of procurement 4.0. These solutions can help to effect so-called reverse logistics. (Bernardo, 2020).

Bagn et al, (2020), specify that procurement acquires a centric role in Circular Economy based functions, such as supplier selection, strategic supplier partnerships, green certifications and green process adopted by suppliers, which assist companies to achieve their sustainability goals. Procurement 4.0 provides capabilities that assist companies to adapt quickly through resource flexibility. Its corresponding strategies must be aligned with the sustainability goals of each company to maximize benefits. Digitalization of the procurement process can significantly reduce waste in the supply chain through the elimination of overstocking/understocking inventory in the warehouse. The optimization of resources not only saves money and improves profit margins but also saves the consumption of limited natural resources. Supply chain transparency limits transportation roots and reduces vehicles fuel and maintenance costs. Procurement 4.0 secures visibility and flexibility in the process, which creates closed-loop supply chain operations. Overall, procurement digitalization can achieve great savings of resources and carbon footprint limitation. Nevertheless, it is important for government bodies to create a framework, which will enhance awareness about I4.0 tools and correct directions about circular economy operations, supporting in this way companies to achieve sustainability objectives. Procurement 4.0 strategies can guide firms to use clean energy and have a wider impact on their community through better work environments and by reducing negative implications on the environment. CE performance evaluation and reporting improvement can help firms to reflect a higher level of greenness, which will strengthen their brand image and confidence among involved parties and society. Procurement 4.0 supports CE operations promoting companies to achieve their sustainability goals.

Toyota, in the automotive sector, achieved improved production efficiency and waste reduction through lean and just-in-time procurement practices. Sourcing from suppliers that adopt sustainable practices, applying Environmental, Social, and Governance (ESG) criteria into supplier evaluations, and developing sustainable sourcing strategies, assisting companies to align with sustainability goals and enhance their resilience to a wider range of risks and contribute to long-term supply chain sustainability. The role of digital transformation in procurement extends further to sustainability and corporate social responsibility (CSR). Organizations are using digital technologies to ensure ethical sourcing, decrease carbon

footprints, and foster transparency in the supply chain. For instance, digital tools enable organizations to track and verify the sustainability credentials of their suppliers, ensuring compliance with environmental and social standards. This capability is progressively significant as stakeholders require higher transparency and responsibility from organizations. (Cooper, 2024b) AI and Predictive Analytics enable initiative-taking resource management, while Blockchain ensures ethical sourcing and transparency. (Cooper, 2024c).

By leveraging emerging technologies, such as AI and Blockchain, organizations achieve competitive advantage through continuous innovation, operational excellence and efficiency, and cost reductions. Additionally, advanced market responsiveness and agility enable organizations to adapt immediately to market dynamics and customer needs. Cooper, (2024f).

The emerging concept of industry 5.0 is focused on sustainability, human-centricity, and resilience. Humans' communication, critical thinking, and understanding are important when facing challenges of new technologies applications. (Vallhagen and Rudqvistb, 2024).

Organizations with the aid of technologically advanced solutions can take a holistic look at their compliance protocol in which the issue of the flow of information is being looked after systematically, transparently, and efficiently. In addition, the adoption of technology features in the realization of strong audit systems throughout the supply chain and, consequently, contributes to how the suppliers are inspected if they comply with legal and ethical standards. In this respect, integration is also proven to help diagnose the risk signs with accuracy in no time, and hence, the potential compliance breaches are avoided. The use of current technologies such as AI, e-procurement systems, and blockchain in the procurement process help in supporting the practice of sustainable procurement through improved environmental performance, promotion of social responsibility, offering great economic benefits. (Mattaba, & Valilai, 2024).

According to Singh and Chan, (2022), higher-levels of sustainability are reached, after the implementation of e-procurement technologies in procurement operations and supply chain management. In this approach, concentrating on e-procurement and sustainable supply chains is a crucial step towards greater adoption, usage, and implementation of sustainability practices, because, in an organization, procurement and supply chain analysis concerns the entire product life cycle, straddling raw material processing through to distribution to the end user.

Procurement 5.0 also targets sustainability. The intelligent systems are capable of guiding in advance for demand, resource, and supplier management, and as a result the need or the demand and costs of purchasing are better evaluated and predicted to decrease costs with a return of increase in efficiency and productivity of firms. The term “Procurement Supply Chain Managers 5.0” is also quite new, and these professionals are expected to comply with the digital workflow and continuously expanding digital transformation in procurement practices while they should equally be role model leaders developing their teams. (Uluç, 2022). Drivers not frequently identified but might gain attention in the future are promoting paperless environment and promoting sustainable goals by firms. Sustainability and customer satisfaction are influencing the adoption of e-procurement. (Yevu & Yu, 2019).

9.8. Complementary abilities of humans and computers with emerging technologies application in Procurement.

Nagitta et al., (2022) cites in Althabatah et al, (2023), is referred to a human-centered AI (HCAI) dialogue in procurement systems. It highlighted the importance of a personalized AI-powered procurement system in the public sector, with a human-centric manual process to identify potential challenges of AI technologies among humans. This approach to AI is crucial in the world and many companies are adopting such a strategy to keep dignity and respect for humankind. It is critical to consider ethical effects, data quality, and the need for human-AI cooperation.

Furthermore, technology supports the work of professionals, such as data analytics are easing the decision-making process for strategic purchasing. Moreover, process automation will substitute work in operational procurement activities, such as ordering and managing payment processes. Autor et al. (2003), cited in Delke et al., (2023), highlights that automation substitutes work for cognitive and manual tasks and supplement work for non-routine problem-solving and communications tasks. Hence, humans will continue to provide their input in non-routine cognitive tasks. (Autor et al., 2003, cited in Delke et al. 2023). Industry 4.0 technologies will also change more complex tasks, such as negotiations, reducing workload and improving negotiation results. (Schulze-Horn et al., 2020, cited in Delke et al., 2023). Thus, technology will substitute jobs only in operational and routine activities. (Delke, et al., 2023).

According to Handfield (2019), the issue of how cognitive systems will interact with, and possibly replace procurement professionals, is of great concern to many people. However, the specific skills and capabilities that will remain in human decision making will need to be specified. Furthermore, Herold et al., (2023), refer that the work of procurement employees will be improved by digital technologies, which will provide additional information and support. The procurement employees will continue to be in the lead (“human acts”), while the digital technology will support them to be more effective or efficient (“machine supports”). Augmentation requires significant human involvement, and it can be linked to complex, strategic procurement tasks. The improvement or augmentation of the procurement employees involves using technology as a support mechanism, rather than automating or fully replacing a previously analogue task. For instance, augmentation in procurement could be AI applications that aim to exchange on-line data among involved parties. Supply market intelligence, predictive pricing, and costing tools are additional examples. (Colombo et al., 2021, cited by Herold et al., 2023).

Automated systems or technologies can process pre-defined workflows without the need of human incorporation. Only in cases where a deviation from the “standard process” occurs is human involvement needed to clarify what must be done because the system (or technology) is unable to proceed. Thus, emerging technologies take over human tasks (“machine acts–human supports”), but some human involvement is still necessary for cases when the system is not trained to undertake or adjusting and improving a selected system. Today’s robotics process automation (RPA) technologies are intended to automate manual processes using business policies and predefined activity commands to complete various tasks. Hence, “procurement employees will be able to delegate orders. (Herold et al., 2023).

Autonomization contains autonomous technologies (or systems), which can process several tasks in each field of expertise independently. The system does not rely on humans (machine acts independently), and the considered actions are easy and recurring; hence, less human participation is necessary comparing to augmentation and automation (Medium, 2019, cited in Herild, 2023).

Human creativity and ideas cannot be replaced by machines. If the third industrial revolution was to use information technology, electronics, and bioengineering to automate equipment to assist production, the fourth industrial revolution, which is now making machines smarter, is

meant to allow these devices to handle production processes on their own, as AI analyzes the data collected through Internet of Things connections to calculate reasonable data to perform work to create production capacity. Moving toward digitalization or even digital optimization is an inevitable trend, but how to implement and achieve a balanced human-machine collaboration is something that needs to be considered before moving into Industry 4.0 or even Industry 5.0. Industry 5.0 will be more human oriented, as well as more sustainable, concerning manufacturing flexibility. (Lo, 2023).

In addition, with the use of emerging technologies it is possible to review many contracts quickly and consistently provide negotiation support to the buyers. Autonomous negotiation can support the buyers in the supplier selection with computing power, decision speed and precision. Buyers and suppliers may choose to deploy artificial intelligence agents to manage small requisitions and utilize human-AI teams to maximize performance. However, this may leave many smaller suppliers behind, as the digital share increases. (Lutz, 2024).

Although AI procurement systems can make decisions, such as awarding purchases, they cannot assume political accountability opposed to citizens. The citizens will ask for responsibilities of the executive workforce of the public sector, who choose systems or train the AI machines. Therefore, the public executives should involve citizens, to maintain the democratic feeling. They should discover the decision-making patterns of the procurement cycle by humans and machines and allow citizens to express their opinion and make alterations. (Mavidis and Folinas, 2022).

Furthermore, Procurement 4.0 applications can reduce the number of employees in procurement by over 37%. Benefits can be achieved between back office categories, middle office, and front office, with the most significant impacts in the back office, in terms of savings which are estimated as 89%. This category is characterized by recurring and regular tasks that suit procurement 4.0 solutions, such as RPA. The tasks in the front office need greater creativity and relational capabilities. They allow savings of just 7% on employees costs. Finally, the middle office is expected to bring a saving of 75%. The benefits in terms of processes can be divided into strategic, tactical, and transactional activities. Transactional level applications are significant enough to generate savings up to 90% of the current job content. This category includes all routine and repetitive tasks and there is room for 36% reduction of total workforce. Finally, the strategic level is estimated to bring a saving of 24% of the total, thus showing a

less effective result. Tasks with the highest focus on relationships or that involve more intellectual contribution, typically of a strategic type and concentrated in the front office, are expected to see fewer benefits with the introduction of procurement 4.0 solutions. In this case, it is more difficult to replace human labor with the solutions technology can offer. (Bernardo, 2020).

Big Data analytics provide the foundation for informed decision-making. Human expertise remains crucial for difficult negotiations and suppliers' relationship management, but technology acts as a powerful enabler for a more holistic and strategic approach. Concerning AI, it automates tasks and provides valuable insights, human judgment, and expertise remain irreplaceable in areas like complex negotiations, supplier relationship management, and navigating unforeseen circumstances. Optimizing the human-machine collaboration will lead to increased effectiveness of procurement strategies. (Segun-Ajao, 2024).

It is agreed within literature that humans and computers acquire complementary abilities that can develop each other. If applied correctly, the use of artificial intelligence and machine learning technologies could enhance considerable capabilities in the future, for all the involved parties within procurement and supply chain management (Nitsche et al., 2021a; Spreitzenbarth et al., 2022, cited in Spreitzenbarth et al., 2024). Machines are autonomous to make a lot of negotiations rounds, nevertheless, the human expertise is still necessary to identify and appropriately measure the real preferences of procurement function, which are linked with the business goals. (Spreitzenbarth et al., 2024). The role of humans in procurement will shift from operative activities towards more strategic activities and negotiation jobs. (Tripathi & Gupta, 2020).

Moreover, there are evidence from Maersk case study, that RPA augments work rather than replace staff. Procurement professionals' time is freed up by automation enabling them to focus on more strategic tasks. Case of exception can be managed by humans, who will take over from robots, nuance the finding around being able to focus more on strategic activities. Maersk refers to this approach as “human in the loop”—where the robotic process is temporarily given back to humans, who will manage the exception and then resume the process to automation.

Overall, robots can be trained, growing their effectiveness over time. The intention of emerging technologies application is not only on workforce reduction, but it could happen due to the time

saved by automation. Nevertheless, the need for human intervention where necessary remains until all human capabilities and capacities are automated. Emerging technologies for procurement will enhance strategic progress and advance the concept of triple values (enterprise, customer, and employee) within a supply chain framework. (Hoek et al., 2022).

9.9. Challenges for Procurement Transformation

Nevertheless, the adoption of Procurement 4.0 implies an extreme restructuring of business organizations and procurement departments, and it is significant the reorganization of relations with the overall Supply Chain Management. (Althabatah et al., 2023) While these technologies offer immense benefits, the proficiency of procurement professionals in employing them remains in its nascent stages. (Khuan, 2019) Hence, this creates resistance to change for procurement transformation. There is skepticism from the managers' point of view about the capabilities that Industry 4.0 can offer to procurement functions. (Bruzzi S, 2019) With the adoption of the right strategies organizations can successfully navigate procurement digital transformation and release its full potential for agile procurement in a fast-changing marketplace. (Cooper, 2024a) There are models, such as technology acceptance model (TAM) originated by Davis in 1989, which focuses on how users come to accept the use of new technologies according to perceived usefulness and user-friendly applications, this model can help procurement professionals to understand the factors that influencing their willingness to adopt those technologies. (Acheampong, 2024) In addition, the assessment of any system is not made by individuals solely, but they are influenced by the opinion of others, which guided their attitude. Hence, the more the benefits from the past, the higher the expectations concerning the future benefits, which consequently will increase the interest in the system's application. (Kumar & Ganguly, 2020) Moreover, talent management is a challenge, as procurement professionals do not have the knowledge to interpret data and data scientists do not have interest in specializing in procurement function. There is also a high turnover of procurement professionals, creating additional problems in talent training. (Khuan, 2019).

Additional factors that negatively affect emerging technologies application are the initial high investment, the cost of maintenance united with inadequate infrastructure, the limited scalability coupled with difficulty in its usage that promotes extra behavioral resistance to

digital transformation, the limited management support in financial terms, the immature legal and regulatory support, and the associated social and environmental concerns. (Govindan et al., 2024) There are also data security concerns for the cloud file storage and smart contract security, which to overcome them, organizations must ensure they have robust cybersecurity measures to protect their data and maintain the trust of their stakeholders. Hence, the effective implementation of Industry 4.0 in procurement forces an integrated strategy that incorporates technological investments, change management within the organization, and continues learning. (Althabatah et al., 2023).

Additional barriers for procurement transformation can be considered, the lack of leadership management within an organization, which cultivates an environment that can foster creativity and innovation. Furthermore, the existing current job functions, roles, and descriptions, which should be adapted to the new role of procurement, and the existing infrastructure capability to support the digital transformation. (Bienhaus & Haddud, 2018).

Another challenge is that many organizations have legacy systems that are incompatible with new digital tools, leading to inefficiencies and data silos. To overcome this difficulty, businesses need to invest in modern, accessible platforms that can effortlessly integrate with their current infrastructure. This often involves significant initial costs, which can be a barrier for some organizations, particularly small and medium-sized enterprises (SMEs). (Cooper, 2024b) Moreover, it is highlighted that the compatibility of AI and blockchain platforms with different ERP systems and procurement management tools create technical difficulties that required specialized expertise and resources. It is important thorough change management strategy, active stakeholder engagement, and cross-functional collaboration to effectively address these integration complexities. (Cooper, 2024c).

Furthermore, the success of digital transformation in procurement depends on the availability and quality of data. Data-driven decision-making requires accurate, real-time information, but many organizations struggle with data management issues, such as inconsistent data formats, lack of data standardization, and poor data quality, which causes limited usage of advanced analytics (Cooper, 2024c).

Additional obstacles could be considered the ethical issues of technology (Spreitzenbarth et al., 2024), designs protected as intellectual properties, customized requirements, and material

compatibility (Bhattacharyya et al., 2023) Moreover there are significant concerns regarding accountability for autonomous decisions made by the system and the legal ownership of digital assets. Besides, the procurement of complex technology for transformation is itself a substantial challenge in the redesign process, but this can be overcome with the assistance of consultancy experts. (Tripathi & Gupta, 2020).

Additionally, government and regulatory bodies play a critical role in creating and enabling the appropriate framework for the widespread adoption of emerging technologies in procurement. Policy makers should consider incentives to motivate the involved parties to adopt new technologies and innovation, such incentives could be tax credits, grants, and subsidies. (Acheampong, 2024) Other significant challenges are regulatory complexities, geopolitical uncertainties, supply chain disruptions due to force majeure, which necessitate adaptive approaches from procurement managers. (Cooper, 2024c) ,

Challenges in Adopting Emerging Technologies	
Themes	Key Challenges
Data Security	Concerns over data breaches and cybersecurity threats.
Integration Complexity	Challenges in integrating new technologies with existing systems.
Skills Shortages	Lack of expertise in managing AI and Blockchain technologies.
Regulatory Compliance	Ensuring adherence to data protection and privacy regulations.

Source: Adopted from Cooper. 2024f, p. 6

Table 3: Challenges in Adopting Emerging Technologies

Other factors that need to be addressed for successful procurement digitalization are how ready smaller suppliers are to offer real-time links between their systems. This is not always necessary given the fact that supplier contracts in many cases accept 48-72-hour deliveries. However, real-time integration between systems could create a performance problem on the overall system if there is not the appropriate IT architecture available, especially when end users go beyond pilot period. In addition, there are not already available in the market solutions for smaller companies, both buyers and suppliers, such as advanced tools to support negotiation and bidding processes. (Gebauer & Segev, 2000) Moreover, the lack of knowledge from

smaller companies, which operate only on a national level, is an issue. (Govindan et al., 2024). All challenges can be even greater for SMEs, which have lower resources in terms of both financial and human factor. (Jahedul Alam Bhuiyan et al., 2024).

There may be also environmental barriers specific to an organization's local country's legal and regulatory requirements, diverse standpoints of various stakeholders, which affect their response to procurement digitalization, data handling, continue technological updates, lack of fairness and transparency of data and algorithm create concerns to the involved parties, on top of new technological specifications and architecture development needs. Scalability needs and overestimating potential gains from technology implementation increase skepticism to many organizations, especially those with limited availability of resources. (Jain et al., 2024) Other obstacles are the management of nondigital vendors, a lot of protocol and control management for errors prevention, the need for structured and systematic data governance strategies implementation. (Jain & Gupta, 2024).

Interdepartmental communication is also critical for digitalization success, it is necessary the existence of a strong chain of communication and sharing of data and information among all the departments involved. Organizations tend to suffer by “silo effect” which causes limited information sharing and communication among departments. Moreover, the effectiveness of the implementation of new technologies will always be affected by the culture and behavioral change to support it. Another issue is the fact that Industry 4.0 techniques face potential leakages of information that could negatively affect suppliers' relationship management. As a result, many suppliers might be unwilling or incapable to implement Procurement 4.0, which prevents the release of full potential of new technologies application. Moreover, the vague return on investment (ROI) from technology application, might make top management reluctant to support such projects, the lack of understanding of requirements and benefits, the inertia in some organizations, the extreme external changes like pandemic might cause reluctance to internal changes. (Joseph Jerome et al., 2022).

Another drawback could be the challenge to select and incorporate different types of emerging technologies and lack of electronic data switch to achieve full potential of e-Procurement. Moreover, in many cases there is not the expertise and skill to identify the right tools to cooperate with suppliers, which further delays emerging technologies' adoption. (Khuan, 2019) The mutual dependency of buyers' digital procurement readiness and supplier's digital

readiness indicating a passage of co-evolution, this harmonization between buyer – supplier digital willingness is expected to facilitate the implementation of digital technologies. (Kosmola et al., 2019).

The challenges of implementing e-procurement in the government sector extend beyond just software integration, data management, and rollout strategy. Legal and administrative procedures, IT infrastructure, outsourcing contracts, and IT skills were some of the difficulties faced. (Addy et al., 2023). Similar barriers were highlight by Mavidis and Folinas in 2022 for the public sector, such as environmental factors, including political choices about offering resources, infrastructures, administrative law adjustment, as well as extra organizational issues, such as the bureaucratic culture.(Mavidis & Folinas, 2022) Furthermore, it is difficult when public procurement is concerned, to invest heavily in e-Procurement, especially when digitalization benefits cannot be translated to financial figures. (Guarnieri & Gomes, 2019).



Source: Adopted from Uluç, N. Ç. 2022, p. 99

Figure 3: Conflicts in Digitalization Process of Procurement

Overall, it is necessary a holistic approach that will include factors mentioned from Florian and Haddud in 2018, such as leadership management that supports “Creative Freedom”, suppliers involved in the digitalization process, lean and flexible communication structure, confidence on digitalization decision, risk management tools in place to handle digital transformation,

clear digital strategy vision, resources availability and capacities for digital transformation, appropriate capabilities of employees for digital transformation. (Bienhaus & Haddud, 2018) Consequently, technological investment is necessary with sound governance frameworks, talent development programs and strategic alignment with business goals. (Cooper, 2024f).

10. Results and Discussion

This chapter contains the results and analysis of the literature reviewed. The analysis was categorized into three sections, one was the Use of Technology in Procurement, the second one was Sustainability, and the third one was the complementary abilities of humans and computers. Then subcategories per section were created, where necessary and in particular as follows: (1) The Use of Technology in Procurement, was split to 12 subcategories of Artificial Intelligence (AI), e-Procurement, Big data analytics, Blockchain, IoT, Cloud Computing, Robotic Process Automation (RPA), Additive Manufacturing (3D Printing), RFID, Cybersecurity, Virtual, Reality (VR), and Unmanned Aerial Vehicles (UAV). (2) Sustainability was split into Green Procurement and Circular Procurement.

A summary table of the papers that are analyzing each technology was created and presented in Tables 4, and Figure 4 is offering the papers issued per technology from 2018 year to 2024, which presents the issuance trend per year. As it is observed there is an increased trend of papers referring to AI technology over the years, with a pick of publications in 2024. The same holds for e-Procurement publications, as well, which have been less than AI based publications, after 2022. This indicated the increased interest in AI technology, which has the highest number of publications in 2024, as emerging technology, which can extend the levels of efficiency in procurement. E-Procurement works as the basis to build on with AI. E-Procurement, which contains all the applications that are referring to electronic data interchange (EDI), e-CRM, e-Commerce, SAP, Platforms that are further subdivided to portals, internet based electronic marketplaces, internet-based online stores, suppliers portal, e-Sourcing, digital payment, online catalog services, e-Reverse Auctioning, e-Tendering, e-Auctions, Many to Many, Social Media Platforms, and Android Platforms. Furthermore, it involves e-Collaboration, e-Informing, e-Notices, e-Signature, e-Models, e-Payment, Procure to Pay, e-Invoicing, e-Ordering, e-Transactions, e-Design, e-Catalogs, and ERPs, and it is considered to have been established already in most of the organizations and it is at a maturity level. The rest of the emerging technologies are still under development and evaluation, with most publications exploring their potential in Procurement and Supply Chain Management applications.

Document Title	AI	e-Procurement	BDA	BCH	IoT	CC	RPA	3D Printing	RFID	CS	VR	UAV
Aarland, M. (2024). Cybersecurity in digital supply chains in the procurement process: Introducing the digital supply chain management framework.										x		
Acheampong - 2024 - Role of Emerging Technologies in Improving Procurement Efficiency and Effectiveness in Ghana.	x	x	x	x	x	x	x					
Andrade, G. P., Abreu, J. C. A. D., & Santos, R. C. D. (2024). The impact of blockchain on Brazilian public procurement processes from the perspective of transaction costs: Scenarios as perceived by experts				x								
Bueno R.E. et al, (2024), The Procurement 4.- Contributions to Circular Economy.	x		x	x	x							
Cooper, M. (2024a). Agile Procurement in a Changing Marketplace: Examining Adaptability and Responsiveness in Supply Chain Management.	x	x	x	x								
Cooper, M. (2024b). Building Resilient Supply Chains: Perspectives on Procurement Risk Management.	x		x	x								
Cooper, M. (2024c). Exploring the Role of Digital Transformation in Procurement: Voices from Industry Leaders.	x	x	x	x			x					
Cooper, M. (2024d). Navigating Complexity: Insights into Strategic Procurement Practices in Global Supply Chains.	x		x	x								
Cooper, M. (2024f). Procurement Innovation: An Inquiry into the Adoption of Emerging Technologies in Supply Chain Management.	x	x	x	x								
Douaioui et al. (2024) - Optimizing Procurement Strategies for Diverse Product Segments: A Case Study in Pharmaceutical Supply Chain Management.	x	x										
ElAmrani A., Arif J., JA W A B F, (2024) - Procurement Improvement Process Based on Industry 4.0 & Lean Manufacturing: A Case Study.					x				x			
Eriksson K VALLHAGEN J and RUDQVIST B A, (2024) - Virtual Commissioning During the Manufacturing Equipment Procurement Process: From an Industrial Expert Point of View.											x	
Fabian Mattaba, C., & Fatahi Valilai, O. (2024) - Enabling Sustainability and Compliance for Technological Transformation.	x	x		x	x		x			x		
Govindan K et al (2024), Blockchain technology as a strategic weapon to bring procurement 4.- truly alive: Literature review and a future research agenda.	x	x	x	x	x			x				
Jahedul Alam Bhuiyan et al., (2024) -). Digital procurement practices in SMES: Comparative cases of advanced and emerging economies.												
Jain P, Priyadarshini J and Gupta AK (2024) - Frameworks, Linkages, Benefits, Challenges, and Future Scope in Procurement 4.0: A Systematic Literature Review From 2014 to 2023.	x	x	x	x	x	x	x	x				
Jain, P., & Gupta, A. K. (2024). Digital procurement towards new performance frontiers: A systematic literature review and future research fronts	x	x		x		x						
Kumar, D., & Zhang, C. (2024). Carbon emission reduction in construction industry: Qualitative insights on procurement, on procurement, policies and artificial intelligence.	x		x			x						
Lee et al. - (2024) - Investigating the factors affecting e-procurement adoption in supply chain performance: An empirical study on Malaysia manufacturing industry.		x				x						
Lutz (2024) - Value of artificial intelligence in purchasing and supply management Business School.	x	x	x			x	x					
Mallesham, (2024) - Modernizing Procurement in Supply Chain with AI and Machine Learning Techniques.	x	x		x		x	x					
Nasser Tuwali et al, (2024) - Role of big data analytics and information processing capabilities in enhancing transparency and accountability in e-procurement applications.	x	x	x									
Segun-Ajao, E. (2024). Revolutionizing Procurement: Harnessing Emerging Technologies for Agility and Sustainability in the US Supply Chain.	x		x	x						x		
Smith (2024) - Sustainable Procurement and Supplier Selection in Green Supply Chain.	x		x									
Spreitzenbarth et al., (2024) - Artificial intelligence and machine learning in purchasing and supply management: A mixed-methods review of the state-of-the-art in literature and practice.	x		x			x						
Zejjari and Benhayoun, (2024). The use of artificial intelligence to advance sustainable supply chain: retrospective and future.	x			x								
T P Babarinde and A O Oyeibisi, (2024) - Examining the Strategic Impact of Procurement on Improving Supply Chain Resilience and Performance: A Case Study of Coca-Cola.	x			x	x							
Vaka, D. K. (2024). Procurement 4.-: Leveraging Technology for Transformative Processes.	x	x	x	x	x	x	x	x		x		
Wang, L., Song, H., Yang, Y., & Han, M. (2024). A systematic literature review and bibliometric analysis of green procurement.			x	x	x							
Addy, M. N., Addo, E. T., Kwofie, T. E., & Yartey, J. E. (2023). Predicting the adoption of e-procurement in construction projects		x										
Althabatah et al. - (2023) - Transformative Procurement Trends Integrating Industry 4.0 Technologies for Enhanced Procurement Processes.	x	x	x	x	x		x	x				
Bus Strat Env - (2023) - Sahoo - Industry 4 - deployment for circular economy performance Understanding the role of green procurement and remanufacturing activities.	x	x	x	x	x	x	x					
Cammarano et al. - (2023) - Blockchain as enabling factor for implementing RFID and IoT technologies in VMI: a simulation on the Parmigiano Reggiano supply chain.				x	x				x			
Cassandra Okogwu et al. (2023) - Exploring the integration of sustainable materials in supply chain management for environmental impact.	x			x	x				x			
Corboş et al. (2023) - The Effects of Strategic Procurement 4.0 Performance on Organizational Competitiveness in the Circular Economy.												

Table 4: Summary Table of Literature by Technology Part-1

Document Title	AI	e-Procurement	BDA	BCH	IoT	CC	RPA	3D Printing	RFID	CS	VR	UAV
Delke V et al (2023) - Implementing Industry 4.- technologies: Future roles in purchasing and supply management.	x	x	x	x		x	x	x				
Harju, A., Hallikas, J., Immonen, M., & Lintukangas, K. (2023). The impact of procurement digitalization on supply chain resilience: Empirical evidence from Finland.		x	x			x						
Herold, S., Heller, J., Rozemeijer, F., & Mahr, D. (2023). Dynamic capabilities for digital procurement transformation: A systematic literature review.	x		x	x			x					
Ibrahim et al., (2023) - The effect of supply chain innovation and e-procurement implementation on supply chain performance of manufacturing organization.		x										
Ibusuki U. et al (2023) - Application of e-auction based on Procurement 4.- strategies in a global company of the power systems sector in Brazil.		x	x	x								
Lo H W (2023) - A data-driven decision support system for sustainable supplier evaluation in the Industry 5.- era: A case study for medical equipment manufacturing.						x						
Maagi, (2023) - Applicability of blockchain technology in improving efficiency in supply chain operations in public procurement in Tanzania.				x								
Makudza et al., (2023) - Enhancing supply chain agility through e-procurement in a volatile frontier market.	x	x										
Munir et al. (2023) - Procurement 4.- and Sustainable Supply Chain Performance: The Mediating Role of Procurement Process Optimization (PPO).		x										
Sekhar S et al (2023) - Study of emerging avenues in supplychain resilience; the case of integration of additive manufacturing with spare parts procurement.								x				
Wang et al. (2023) - A Literature Review on the Application of Digital Technology in Achieving Green Supply Chain Management.	x		x	x	x	x						
Alabdali M. A. and Salam M A (2022) - The Impact of Digital Transformation on Supply Chain Procurement for Creating Competitive Advantage: An Empirical Study.												
Delke V. et al (2022) - Differentiating-between-direct-and-indirect-procurement-roles-skills-and-Industry-4	x	x	x				x					
Ferreira and Silva, (2022) - Supplier selection and procurement in SMEs insights from the literature on key criteria and purchasing strategies.	x		x	x	x		x					
Joseph Jerome, J. J., Saxena, D., Sonwaney, V., & Foropon, C. (2022). Procurement 4.- to the rescue: Catalysing its adoption by modelling the challenges.	x		x		x	x		x				
Lee C. et al (2022) - Data science and reinforcement learning for price forecasting and raw material procurement in petrochemical industry.	x		x									
Mavdis A and Folinas D (2022) - From Public E-Procurement 3.- to E-Procurement 4.-: A Critical Literature Review.	x	x	x	x	x		x	x				
Saeed et al.(2022) - A systematic review of digital technology and innovation and its potential to address anti-corruption, transparency, and accountability in the pharmaceutical supply chain.		x		x					x			
Shahin et al. (2022) - The Role of E-procurement in Supply Chains. In N. Kryvinska & M. Greguš.		x										
Shivajee (2022) Procurement system for resilient supply chain amid the COVID-19 pandemic.	x		x	x	x		x	x	x			
Siddiqui et al. (2022) - Effects of E-Procurement on Supply Chain Management in the modern era.		x										
Singh and Chan (2022) - The Impact of Electronic Procurement Adoption on Green Procurement towards Sustainable Supply Chain Performance-Evidence from Malaysian ISO Organizations.		x										
Uluç, N. Ç. (2022). Digital Conflicts in Procurement.	x	x	x	x	x		x	x	x		x	
Van Hoek, R., Gorm Larsen, J., & Lacity, M. (2022). Robotic process automation in Maersk procurement–applicability of action principles and research opportunities.							x					

Table 5: Summary Table of Literature by Technology Part-2

Document Title	AI	e-Procurement	BDA	BCH	IoT	CC	RPA	3D Printing	RFID	CS	VR	UAV
Bruzzi S. et al (2021) - Toward the strengthening of enabling technologies in Italy: results of the second survey on procurement 4.0.	x		x	x		x		x		x		
Hallikas, J., Immonen, M., & Brax, S. (2021). Digitalizing procurement: The impact of data analytics on supply chain performance.		x	x									
Jahani et al., (2021) - Application of Industry 4.- in the Procurement Processes of Supply Chains: A Systematic Literature Review.	x	x		x								
Lorentz, H., Aminoff, A., Kaipia, R., & Srai, J. S. (2021). Structuring the phenomenon of procurement digitalisation: Contexts.	x	x	x			x	x					
Modrušan, N., Rabuzin, K., & Mršić, L. (2021). Review of Public Procurement Fraud Detection Techniques Powered by Emerging Technologies.	x	x	x	x	x	x						
Bagn S et al (2020) - Procurement 4.- and its implications on business process performance in a circular economy.	x	x	x		x	x	x		x			x
Bottoni et al. (2020) - Intelligent Smart Contracts for Innovative Supply.				x								
Gholizadeh H, Fazlollahabadi H and Khalilzadeh M (2020). A robust fuzzy stochastic programming for sustainable procurement and logistics under hybrid uncertainty using big data.			x									
Nandankar (2020) Electronic procurement adoption, usage, and performance: a literature review.		x										
Bernardo, (2020) - Procurement 4.0 and the Fourth Industrial Revolution. The Opportunities and Challenges of a Digital world.	x	x	x	x	x	x	x	x		x		x
Seyedghorban, Z., Samson, D., & Tahemnejad, H. (2020). Digitalization opportunities for the procurement function: pathways to maturity.												
Shatta et al. (2020) -Legal Framework Influence Towards E-Procurement Adoption Model in Developing Countries: Buyers' - Suppliers' Perception in Tanzania.		x										
Surajit et al (2020) Procurement 4.- and its implications on business process performance in a circular economy.	x	x	x	x			x					
Tripathi, S., & Gupta, M. (2020). A framework for procurement process re-engineering in Industry 4.-	x	x	x	x	x	x	x	x			x	
Angrian, (2019) - Development of vendor management and e-Procurement systems using android platform.		x										
Bruzzi S. (2019) - The new frontiers of procurement in the digital age. Results of an empirical survey on procurement 4.0 in Italy.						x						
Guarnieri, P., & Gomes, R. C. (2019). Can public procurement be strategic? A future agenda proposition.		x										
Handfield, R., Jeong, S., & Choi, T. (2019). Emerging procurement technology: Data analytics and cognitive analytics.	x	x	x	x	x							
Khuan, L. S. (2019a) - The challenges of emerging technologies the experience of procurement professionals.	x	x	x	x	x							
Klindera T et al (2019) Procurement 4.-: How the digital disruption supports cost-reduction in Procurement.												
Kosmola T, Reimann F and Kaufmann L(2019) - You'll never walk alone: Why we need a supply chain practice view on digital procurement.		x	x		x	x		x				
Kumar (2020) Non-financial e-procurement performance measures. Their interdependence and impact on production cost.		x										
Yevu, S. K., & Yu, A. T. W. (2019). The ecosystem of drivers for electronic procurement adoption for construction project procurement		x										
A systematic review and future research directions.												
Bienhaus F and Haddud A (2018). Procurement 4.-: factors influencing the digitisation of procurement and supply chains.	x	x	x		x	x			x	x		
Florian and Abubaker (2018) Procurement 4.-: factors influencing the digitisation of procurement and supply chains.	x	x	x		x	x			x	x		
Osmontbekov, T., & Johnston, W. J. (2018). Adoption of the Internet of Things technologies in business procurement: Impact on organizational buying behavior.					x							
Rejeb, A., Süle, E., & Keogh, J. G. (2018). Exploring new technologies in procurement.	x		x	x	x		x					x

Table 6: Summary Table of Literature by Technology Part-3

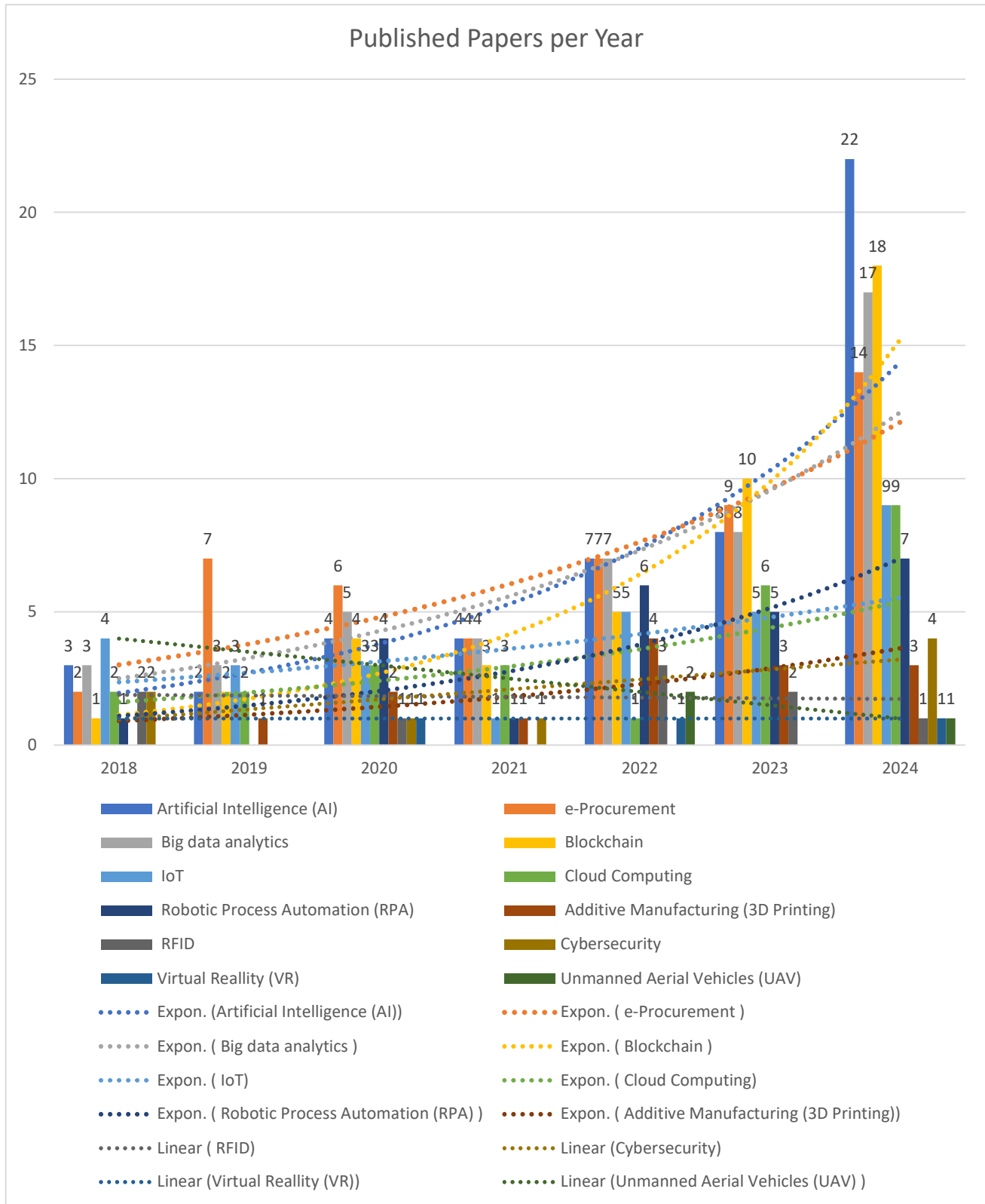


Figure 4: Trends of Published papers on the topic of emerging technologies in Procurement

The focus of the papers starting from the most popular in 2024 to the less one is as follows: Artificial Intelligence (AI), e-Procurement, Big data analytics, Blockchain, IoT, Cloud Computing, Robotic Process Automation (RPA), Additive Manufacturing (3D Printing), RFID, Cybersecurity, Virtual Reality (VR) and Unmanned Aerial Vehicles (UAV). There has been an increased trend of interest particularly for AI and Blockchain in recent years, followed by Big Data Analytics and e-Procurement. In addition, as is presented from the trend lines after 2022, interest in the first two technologies surpasses the one for e-procurement and big data analytics, which are at similar levels to the number of publications. RPA, IoT and Cloud computing technologies are at similar levels of publication as well, which follow an upwards trendline as time goes on. The same holds for 3D Printing and Cybersecurity technologies, which although have a slight upward trend of publications, the interest on those is quite low. The lowest interest in publications is given to the latest three technologies, RFID, UAV and VR. RFID and UAV interest decreased during the years and VR remained stable.

The above results might occur for several reasons. For instance, AI and Blockchain technologies are the most popular ones, as they open new horizons for procurement departments and the companies that apply them. When they are combined, they can offer increased efficiency to involved parties, extremely reduce, or even eliminate the handling time of transactional, repetitive tasks, which can be supported by RPA technology. They increase transparency, hence, trust among the parties involved, especially with the use of blockchain, where unchangeable records remain through transactions within the supply chain. E-Procurement and Big data analytics are topics discussed within the literature frequently in earlier years, and although they are still referred to in publications, it has been slowed down. That could happen because they are at a maturity level, most of the companies have already applied to them, and there are clear benefits from their application. They are still very centric in the current bibliography, as they work as the basis for the rest of the emerging technologies to be applied on top of them.

Regarding RPA, IoT, and Cloud computing, a referred much less in the literature, probably because they can offer benefits, mainly if they are combined with other technologies. For example, RPA if it is combined with AI can increase efficiency, IoT if it is combined with RFID, can enhance efficiency in warehouse management and inventory management. And cloud computing is usually combined with Big Data Sharing, for increased and accurate data

sharing. In addition, RPA and cloud computing are in a maturity level and IoT could be considered in developing to established level, varying per industry.

Furthermore, although there is an increased interest in 3D Printing and Cybersecurity technologies, they remain at low levels. That might occur for several reasons, although 3D printing can offer great flexibility to companies on the quick production or customized parts or the immediate replacement of defective spare parts, which can be produced and delivered to the end users from nearby warehouses, reducing transportation costs, avoiding MOQs and achieving sustainability goals, it is in its maturity level. When compared to OEM parts, their lifecycles might be much less, hence, their durability could be questioned, something that might reduce any potential cost savings from transportation costs, as companies might rebuy them more frequently. In addition, 3D printing is usually used in customized applications, that might not be widely available, or it does not attract the interest of academic society, as the latter tends to focus on more widely used topics.

Concerning cybersecurity, it might still be at low levels of publications as it is in a developing to established stage, depending on the industry. Besides, procurement-cybersecurity coordination needs expertise in both fields, creating a niche field, hence limiting the relevant publications. Furthermore, cybersecurity applications in procurement might contain sensitive data that might not be publicly available for security reasons. As the results of this research indicate, papers tend to focus on broader topics, such as cloud computing rather than on niche applications.

RFID and UVA technologies publications, which concern applications on procurement, are even declining, during the years and since 2018 they have been too little. That might occur for several reasons such as that the focus is given in wider topics like IoT, or because both technologies concern the supply chain management with a focus on logistics and inventory management rather than procurement. The papers involved in this research were focused on procurement applications of emerging technologies.

Virtual Reality publications remain at low level as it is in emerging level and concern mostly Industry 5.0 applications in procurement to be adopted in the future.

Further to the above research on publications on this topic through time, table 5 offers a summary with the applications of emerging technologies in procurement, as identified within

the reviewed papers. The top five most frequently referred applications within the literature are smart contracts with the use of blockchain, which offers transparency, traceability and enhance trust between buyers and suppliers. The second one is suppliers' relationship management with the use of e-Procurement, this could be mainly because e-Procurement enables real time data sharing, hence, improves transparency and enhances collaboration. The third one is Suppliers prequalification and evaluation with the use of AI. This application enables procurement professionals to make more informed decisions, in a more efficient way, reducing most of the administrative tasks of prequalification and focusing on the strategic tasks of the process. The fourth one is Innovation application with the use of AI, IoT, Blockchain and RPA. Companies can combine these technologies to innovate and achieve their objectives. The fifth most popular application in literature was e-Sourcing with the use of e-Procurement. It is critical application which is enhanced with transparency that e-procurement provides. It assists with the potential supplier's identification, evaluation, and selection, which are linked with cost reductions, increased efficiency, and supplier's performance. All the above information answers the Research Question (RQ) 1.

“Kalogeropoulou Kleopatra,” “Emerging Technologies in Procurement and Supply Chain Management”

No	Technology Applications in Procurement	Type of Technology	Total
1	Smart Contract	Blockchain	33
2	Suppliers' Relationship Management	e-Procurement	22
3	Supplier pre-qualification/ Evaluation	AI/ Industry 5.0	12
4	Innovation	AI/ Blockchain, IoT, Digital Passport Products, Robotics	11
5	e-sourcing	e-Procurement	9
6	Augmentation	AI	9
7	Supplier Performance Management	Advanced Analytics and Performance Dashboards/ Blockchain/ Smart Contracts	7
8	Information Sharing	Cloud Computing Adoption	6
9	Mobile Computing	Cloud Computing Adoption	6
10	Automation and Standardisation	Robotic Process Automation (RPA)	6
11	Inventory Management	IoT/ RFID	6
12			
13	Risks Assessment	Digitalization/ Information Sharing/ Data Analytics	6
14	Data Governance	Big data analytics	5
15	e-Tendering	e-Procurement (Platforms)	4
16	e-Auctions	e-Procurement (Platforms)	4
17	Regulatory Compliance	Digitization, data analytics and information sharing	3
18	Supply Chain Resilience	AI	3
19	Internet-Based Online Stores	e-Procurement (Platforms)	3
20	Information Processing	AI/ML	3
21	Sustainability > Sustainable Procurement	Information Sharing/ Big Data Sharing	3
22	Sustainability > Green e-Procurement	Cloud-Based e-procurement	3
23	Operational Efficiency	Robotic Process Automation (RPA)/ Big Data Analytics/ AI/ Blockchain	3
24	Cost Reduction	AI	3
25	Smart Supply Chain	AI	2
26	Increased Quality	Digital data-driven technology /AI	2
27	Electronic Data Interchange (EDI)	e-Procurement	2
28	Spend Analysis	e-sourcing, e-procurement(e-invoicing, e-catalogs, Platforms) Contract Management, Spend Analytics.	2
29	Internet Based Electronic Market Places	e-Procurement (Platforms)	2
30	Smart Working	Cloud services/ Blockchain technology/ Big Data Analytics/ AI (ML)/ IoT/Augmented Reality/ Traceability/ e-Procurement	2
31	Online Catalog Services	e-Procurement (Platforms)	2
32	e-Reverse Auctioning	e-Procurement (Platforms)	2
33	e-Payment	e-Procurement	3
35	e-Invoicing	e-Procurement	2
36	e-Design	e-Procurement	2
37	e-catalogs	e-Procurement	2
38	Negotiation bots	AI	2
39	Cognitive Analytics	AI	2
40	Data Sharing	Cloud Computing Adoption	2
41	Supplier pre-qualification/ Evaluation	AI-assisted sourcing decision-making/ Industry 5.0 technologies	2
42	Vendor Managed Inventory (VMI)	IoT/ RFID	3
43	Traceability and inventory management/ Automatic Cargo Transport applications	Unmanned Aerial Vehicles (UAVs) /Big Data analytics/ RFID/ Cybersecurity/ Information Sharing/ Blockchain/ Smart Contract	2
44	e-Contracting	Blockchain	1
45	Competitiveness	e-Sourcing, e-Procurement (e-Invoicing, e-catalogs)/ Contract Management/ Spend analytics	1
46	Procurement Risks	e-Sourcing, e-Procurement (e-Invoicing, e-catalogs)/ Contract Management/ Spend analytics	1
47	Emotional Intelligence	AI	1
48	Web of Relationships	e-Procurement	1
49			
50	e-CRM	e-Procurement	1
51	e-Commerce	e-Procurement	1
52	Project Procurement Management	IoT, mobility, business intelligence, blockchain, and robotic process automation (RPA), e-Procurement	1
53	Reduce Uncertainty	AI	1
55	Suppliers Portal	e-Procurement	1
56	Dynamic Capabilities (DC)	e-Procurement/ Spend Analytics/ Contract Management	1
57			
58	Flexibility	e-Procurement/ Spend Analytics/ Contract Management	1
59	Corruption in Public Procurement	data mining and business intelligence techniques/ e-Procurement/ Contract Management/ Spend Analytics	1
60	Category Management - Bundling Purchasing	AI/ e-procurement (e-invoicing, e-catalogs)/ Contract Management/ Spend Analytics	1
61	Formalization	e-procurement (e-invoicing, e-catalogs)/ Contract Management/ Spend Analytics	1
62	Supply Chain Agility	AI	1
63	e-Informing	e-Procurement	1
64	e-Notices	e-Procurement	1
65	e-Collaboration	e-Procurement	1
66	e-Signature	e-Procurement	1
67	e-Models	e-Procurement	1
68	Fraud detection	Big data, Cloud Computing Platforms, AI (ML), biometrics (ID4D), FinTech digital money, distributed ledger technology or Blockchain, IoT	1
69	e-Ordering	e-Procurement	1
70	e-Transactions	e-Procurement	1
71	Automated Negotiations	AI	1
72	Negotiation Support	AI	1
73	Autonomous Negotiation	AI	1
74	Cognitive Procurement	AI	1
75	Clustering	AI	1
76	e-Negotiation	AI	1
77	e-Evaluation	AI	1
78	Augmentation > Digital Passport Product (DPP)	AI	1
79	Digital Storage	Cloud Computing Adoption	1
80	Edge Computing	Cloud Computing Adoption	1
81	Public Procurement > E-GP	AI (ML)/ E-Public Procurement	1
82	Autonomization	Blockchain/ AI/ Augmentation/ Optimal Character Recognition (OCR) and learning algorithms	1
83	Sustainability > Circular Procurement 4.0	Big Data Analytics, AI, Blockchain and IoT	1
85	Sustainability > Green Public Procurement	AI/ e-Procurement	1
87	Sustainable Supplier Evaluation (SSE)	Digital Transformation, Real-Time Information Sharing/ Organizational Culture Transformation	1
88	Supplier Diversity and Inclusion	Optimal Character Recognition (OCR) and learning algorithms/ e-Procurement	1
89	External Partnerships	Optimal Character Recognition (OCR) and learning algorithms/ e-Procurement	1
90	Facility Management	Blockchain/ Optimal Character Recognition (OCR) and learning algorithm	1

Table 7: Summary of Emerging Technologies Application in Procurement.

Concerning the RQ 2, Sustainability in Procurement, 16 out of 88 reviewed are referred to this topic and there are various terms used to describe this trend.

Paper	Year	Green Procurement	Green e-Procurement	Sustainable Procurement	Green Public Procurement	Circular Procurement 4.0
Alabdali M. A. and Salam M A (2022) - The Impact of Digital Transformation on Supply Chain Procurement for Creating Competitive	2022			x		
Althabatah et al., (2023) - Transformative Procurement Trends Integrating Ind	2023	x	x			
Bagn S et al (2020) - Procurement 4.0 and its implications on business process performance in a circular economy	2020		x	x		
Bueno R.E. et al, (2024), The Procurement 4.0 Contributions to Circular Economy	2024	x				x
Bus Strat Env., (2023) - Sahoo - Industry 4 0 deployment for circular economy performance Understanding the role of green	2023	x				
Casandra Okogwu et al. (2023) - EXPLORING THE INTEGRATION OF SUSTAINABLE MATERIALS	2023	x				
Corboş et al. (2023) - The Effects of Strategic Procurement 4.0 Performan	2023					
Delke et al.(2023) - Implementing Industry 4.0 technologies Future rol	2023	x				
Gholizadeh H, Fazlollahabbar H and Khalilzadeh M (2020), A robust fuzzy stochastic programming for sustainable procurement and	2020			x		
Lo H W (2023) - A data-driven decision support system for sustainable supplier evaluation in the Industry 5.0 era: A case study	2023				x	
Bernardo, (2020) - Procurement 4.0 and the Fourth Industrial Revolution	2020	x	x		x	
Shivajee (2022) Procurement system for resilient supply chain amid the COVID-19 pandemic	2022	x				
Singh and Chan - 2022 - The Impact of Electronic Procurement Adoption on G	2022	x	x			
Smith (2024) - Sustainable Procurement and Supplier Selection in	2024			x		x
Wang et al. (2023) - A Literature Review on the Application of Digital	2023	x				
Wang, L., Song, H., Yang, Y., & Han, M. (2024). A systematic literature review and bibliometric analysis of green procurement	2024	x				

Table 8: Summary of Literature on Sustainability in Procurement

As was indicated within the literature reviewed, most papers referred to Green Procurement, followed by green e-Procurement, Sustainable Procurement, Green Public Procurement and Circular Procurement 4.0. Green Procurement referred to in the literature includes an environmentally friendly, social responsibility, and economically sustainable sourcing. Part of Green Procurement is the renewable resources utilization, energy efficiency, waste reduction

and the reduced greenhouse gas emission. The technological tools that are employed for sustainability purposes during Procurement 4.0 era are AI, IoT, Blockchain and e-Procurement, which enhance sustainability and operational efficiency. Especially, e-Procurement and AI enhances applications such as demand forecasting, resource management and compliance, it facilitates ethical sourcing and supply chain transparency. Overall, digital tools can calculate the carbon footprint of corporations, estimate the lifecycle of a product, increase traceability, offer sustainability reporting platforms, and enable data-driven decisions and processes optimization. Industry 5.0 in the future is intended to be more sustainability oriented, focused on human factors and resilience. Technologies of Procurement 5.0 will involve communication, critical thinking and understanding.

Regarding the RQ 3, complementary abilities of humans and computers topic, 15 papers out of the 88 reviewed, were referred to it, as in the following table:

Paper/ Source	Complementary abilities of humans and computers
Althabatah et al. (2023) - Transformative Procurement Trends: Integrating Industry 4.0 Technologies for Enhanced Procurement Processes.	x
Delke V et al (2023) - Implementing Industry 4.0 technologies: Future roles in purchasing and supply management	x
Handfield, R., Jeong, S., & Choi, T. (2019). Emerging procurement technology: Data analytics and cognitive analytics.	x
Herold, S., Heller, J., Rozemeijer, F., & Mahr, D. (2023). Dynamic capabilities for digital procurement transformation: a systematic literature review.	x
Lo H W (2023) - A data-driven decision support system for sustainable supplier evaluation in the Industry 5.0 era: A case study for medical equipment manufacturing.	x
Lutz (2024) - Value of artificial intelligence in purchasing and supply management, Business School, University of Mannheim.	x
Mavidis A and Folinas D (2022) - From Public E-Procurement 3.0 to E-Procurement 4.0; A Critical Literature Review.	x
Bernardo (2020), Procurement 4.0 and the Fourth Industrial Revolution. The Opportunities and Challenges of a Digital World.	x
Segun-Ajao, E. (2024). Revolutionizing Procurement: Harnessing Emerging Technologies for Agility and Sustainability in the US Supply Chain	x
Singh and Chan - (2022) - The Impact of Electronic Procurement Adoption on Green Procurement towards Sustainable Supply Chain Performance- Evidence from Malaysian ISO Organizations.	x
Spreitzenbarth et al. - 2024 - Artificial intelligence and machine learning in pu	x
Tripathi, S., & Gupta, M. (2020). A framework for procurement process re-engineering in Industry 4.0.	x
Uluç, N. Ç. (2022). Digital Conflicts in Procurement. In F. Özşungur (Ed.), Conflict Management in Digital Business.	x
Van Hoek, R., Gorm Larsen, J., & Lacity, M. (2022). Robotic process automation in Maersk procurement—applicability of action principles and research opportunities.	x
Yevu, S. K., & Yu, A. T. W. (2019). The ecosystem of drivers for electronic procurement adoption for construction project procurement: A systematic review and future research directions.	x

Table 9: Complementary Abilities of Humans and Computers

According to what was identified from the research there is a tendency for more humancentric AI, which will create new links and balances between human functions and applications that can be eliminated and substituted by computers. There are a lot of ethical considerations though regarding the data quality that can be produced from machines and the need for human – AI collaboration to maximize benefits. Automation will substitute transactional tasks and professionals shall free time to focus on more strategic ones. Industry 4.0 technologies are assisting in improving negotiations, reducing workload, and enhancing procurement results. Human factors will continue to be in the lead and will be supported by machines to improve

efficiency and sustainability. In addition, only humans can manage exceptional cases. AI can support decision-making but now it is impossible to compete with human creativity, judgement, and political accountability. Hence, human expertise remains essential for complex tasks. Collaboration between humans and machines promotes complementary abilities and develops procurement functions.

11. Conclusion

This dissertation concerns the review of 88 papers and other sources on the topic of emerging technologies in Procurement and Supply Chain Management. The research was categorized into three sections. The first one was the use of technology in Procurement, the second one was Sustainability, and the third one was the complementary abilities of Human and computers. The first one was further subdivided into 12 subcategories: Artificial Intelligence (AI), e-Procurement, Big data analytics, Blockchain, IoT, Cloud Computing, Robotic Process Automation (RPA), Additive Manufacturing (3D Printing), RFID, Cybersecurity, Virtual Reality (VR), and Unmanned Aerial Vehicles (UAV). The Sustainability section was subdivided into Green Procurement and Circular Procurement.

The results showed that more papers on e-Procurement, IoT and Big Data Analytics were written from 2018 until 2022 and after that AI and Blockchain have occupied more the Academic community. There are still papers on Big Data Analytics and e-Procurement, but publications have slowed down, and they were overpassed by the other two technologies.

Other technologies such as Robotic Process Automation (RPA), Additive Manufacturing (3D Printing), cloud computing IoT and Cybersecurity, remain at low levels of interest with upwards trends. That might happen since the Academic community is focusing on wider topics, or because information might not be disclosed for security reasons. Cybersecurity is a relatively new application in Procurement; hence an increased interest is expected through Industry 5.0 technologies application in Procurement soon. The same holds for Virtual Reality and Spatial Analytics, which are expected to assist suppliers' audits enabling them to identify events by comparing historical video data. All these technologies that are expected to be enhanced with Industry 5.0 will be more human centric, sustainable and will include higher understanding.

Finally, it was observed that there was a decline of interest in RFID and UAV, which might happen because those technologies are applied mainly in the wider Supply Chain Management, as part of Logistics and Inventory Management. Hence, the selected papers on Procurement applications might not identify them as directly benefiting the procurement operations but indirectly.

Overall, each technology is as important as procurement applications efficiency and effectiveness are concerned, but when they are combined, they can release their full potential. Especially, when e-Procurement is combined with big data analytics, AI, and RPA, enhance data-driven decisions and automated process. The combination of AI and Blockchain increase transparency with the use of smart contract for example. When IoT is combined with 3D printing, products customization based to customers' specifications, and delivery efficiency can be achieved. Through transaction and transportation costs reduction a more sustainable Procurement can be created, paperless and automated and those benefits can be released in both Private and Public Sectors.

Finally, the implications for the workforce were considered, and it was identified that the adoption of Industry 4.0 technologies will lead to transactional repetitive tasks elimination and shifting procurement professionals to be involved in more strategic tasks. That might indicate that positions in transactional operations might be reduced and on the other hand more strategic roles will be enhanced. In any case the results showed that both human and computer abilities are necessary, and that human understanding cannot be replaced by machines. The latter will be built to assist humans, and both will learn and be trained the one from the other. Human centered AI application remains essential in public procurement as well to enhance ethical practices, reduce fraud and address social risks. This trend created a balance between automation and human abilities, making more inclusive and efficient procurement systems.

12. Practical contribution - impact of the research, limitations. Future directions.

This research intends to investigate how emerging technologies such as Blockchain, AI, ML, IoT, Data Analytics and so on, will enable procurement and supply chain professionals to work smarter, such as to release time that will be used in more strategic operations of their departments. How technology could undertake more transactional activities and present data and information already available internally or externally, in a more organized way to enable informed decision making. Working more efficiently is likely to replace some positions with other more sophisticated ones, improving business operations in this way and consequently leading to profit maximization, by adding value at optimum cost of handling and by using more sustainable and transparent methods.

The research gap that this research intends to cover is to collect and present the limited bibliography on Procurement oriented emerging technologies application topic. Although there is an extended literature on emerging technologies and their applications on the wider supply chain management, there are limited publications that concern solely procurement functions. In addition, limited and emerging are the publications on how technology can enhance sustainability within the Procurement field. Furthermore, there are high concerns about the possibility that computers could partially or totally replace humans. Hence, reviewing technological – procurement-oriented papers and identify experts’ opinions has shed light on future expectations in this field.

Concerning the practical contribution of the research, it was intended to create a roadmap on emerging technologies application within Procurement that can be used by researchers on the topic and procurement professionals for procurement transformation. In addition, it was aimed to compare the technological topics discussed in the earlier years starting from 2018 versus the topics that are debated within recent years until 2024. Hence, observed technologies applications evolution within Procurement and identified future directions This provides up to date information and a follow up on the topic, which is significant due to the rapid changes in technology.

Finally, since the research method was a Systematic Literature Review, this could be a limitation, due to the lack of qualitative information. In addition, the focus on more recent studies might have led to the exclusion of technological breakthroughs before 2018, which however could be considered obsolete nowadays. A more qualitative approach could be used in the future, to add primary data in this field of study, by involving professionals’ opinions through their experience with emerging technologies application, after a longer trial period. In addition, a follow-up systematic literature review could be undertaken after a few years, to include the applications of emerging Procurement 5.0 technologies.

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14. Appendix A: Summary table of Literature per Technology

Year	AI	e-Procurement	BDA	Block-chain	IoT	Cloud Computing	RPA	3D Printing	RFID	Cyber-security	VR	Unmanned Aerial Vehicles
2024	22	14	17	18	9	9	7	3	1	4	1	
2023	8	9	8	10	5	6	5	3	2			
2022	7	7	7	5	5	1	6	4	3		1	
2021	4	4	4	3	1	3	1	1		1		
2020	4	6	5	4	3	3	4	2	1	1	1	2
2019	2	7	3	2	3	2		1				
2018	3	2	3	1	4	2	1		2	2		1
Grand Total	50	49	47	43	30	26	24	14	9	8	3	3

Document Title	AI	e-Procurement	BDA	BCH	IoT	CC	RPA	3D Printing	RFID	CS	VR	UAV
Aarland, M. (2024). Cyber-security in digital supply chains in the procurement process: Introducing the digital supply chain management framework.										x		
Acheampong - 2024 - RRole of Emerging Technologies in Improving Procurement Efficiency and Effectiveness in Ghana.	x	x	x	x	x	x	x					
Andrade, G. P., Abreu, J. C. A. D., & Santos, R. C. D. (2024). The impact of block-chain on Brazilian public procurement processes from the perspective of transaction costs: Scenarios as perceived by experts				x								
Bueno R.E. et al, (2024), The Procurement 4.- Contributions to Circular Economy.	x		x	x	x							
Cooper, M. (2024a). Agile Procurement in a Changing Marketplace: Examining Adaptability and Responsiveness in Supply Chain Management.	x	x	x	x								
Cooper, M. (2024b). Building Resilient Supply Chains: Perspectives on Procurement Risk Management.	x		x	x								
Cooper, M. (2024c). Exploring the Role of Digital	x	x	x	x			x					

Transformation in Procurement: Voices from Industry Leaders.												
Cooper, M. (2024d). Navigating Complexity: Insights into Strategic Procurement Practices in Global Supply Chains.	x		x	x								
Cooper, M. (2024f). Procurement Innovation: An Inquiry into the Adoption of Emerging Technologies in Supply Chain Management.	x	x	x	x								
Douaioui et al. (2024) - Optimizing Procurement Strategies for Diverse Product Segments: A Case Study in Pharmaceutical Supply Chain Management.	x	x										
ElAmmari A, Arif J, JAWAB F, (2024) - Procurement Improvement Process Based on Industry 4.0 & Lean Manufacturing: A Case Study.					x				x			
Eriksson K VALLHAGEN J and RUDQVISTb A, (2024) - Virtual Commissioning During the Manufacturing Equipment Procurement Process: From an Industrial Expert Point of View.											x	
Fabian Mattaba, C., & Fatahi Valilai, O. (2024) - Enabling Sustainability and Compliance for Technological Transformation.	x	x		x	x		x			x		
Govindan K et al (2024), Blockchain technology as a strategic weapon to bring procurement 4.- truly alive: Literature review and a future research agenda.	x	x	x	x	x			x				
Jahedul Alam Bhuiyan et al., (2024) -). Digital procurement practices in SMES: Comparative cases of advanced and emerging economies.												
Jain P,Priyadarshini J and Gupta AK (2024) - Frameworks, Linkages, Benefits, Challenges, and Future Scope in Procurement 4.0: A Systematic Literature Review From 2014 to 2023.	x	x	x	x	x	x	x	x				
Jain, P., & Gupta, A. K. (2024). Digital procurement towards new performance frontiers: A systematic literature review and future research fronts	x	x		x		x						
Kumar, D., & Zhang, C. (2024). Carbon emission reduction in construction industry: Qualitative insights on procurement, on procurement, policies and artificial intelligence.	x		x			x						

Lee et al. - (2024) - Investigating the factors affecting e-procurement adoption in supply chain performance: An empirical study on Malaysia manufacturing industry.		x				x						
Lutz (2024) - Value of artificial intelligence in purchasing and supply management Business School.	x	x	x			x	x					
Malleshham, (2024) - Modernizing Procurement in Supply Chain with AI and Machine Learning Techniques.	x	x		x		x	x					
Nasser Tuwali et all, (2024) - Role of big data analytics and information processing capabilities in enhancing transparency and accountability in e-procurement applications.	x	x	x									
Segun-Ajao, E. (2024). Revolutionizing Procurement: Harnessing Emerging Technologies for Agility and Sustainability in the US Supply Chain.	x		x	x						x		
Smith (2024) - Sustainable Procurement and Supplier Selection in Green Supply Chain.	x		x									
Spreitzenbarth et al., (2024) - Artificial intelligence and machine learning in purchasing and supply management: A mixed-methods review of the state-of-the-art in literature and practice.	x		x			x						
Zejjari and Benhayoun, (2024)- The use of artificial intelligence to advance sustainable supply chain: retrospective and future.	x			x								
T P Babarinde and A O Oyeibisi, (2024) - Examining the Strategic Impact of Procurement on Improving Supply Chain Resilience and Performance: A Case Study of Coca-Cola.	x			x	x							
Vaka, D. K. (2024). Procurement 4.-: Leveraging Technology for Transformative Processes.	x	x	x	x	x	x	x	x		x		
Wang, L., Song, H., Yang, Y., & Han, M. (2024). A systematic literature review and bibliometric analysis of green procurement.			x	x	x							
Addy, M. N., Addo, E. T., Kwofie, T. E., & Yartey, J. E. (2023). Predicting the adoption of e-procurement in construction proje		x										
Althabatah et al. - (2023) - Transformative Procurement Trends Integrating Industry	x	x	x	x	x		x	x				

4.0 Technologies for Enhanced Procurement Processes.												
Bus Strat Env - (2023) - Sahoo - Industry 4 - deployment for circular economy performance Understanding the role of green procurement and remanufacturing activities.	x	x	x	x	x	x	x					
Cammarano et al. - (2023) - Blockchain as enabling factor for implementing RFID and IoT technologies in VMI: a simulation on the Parmigiano Reggiano supply chain.				x	x				x			
Casandra Okogwu et al. (2023) - Exploring the integration of sustainable materials in supply chain management for environmental impact.	x			x	x				x			
Corboş et al. (2023) - The Effects of Strategic Procurement 4.0 Performance on Organizational Competitiveness in the Circular Economy.												
Delke V et al (2023) - Implementing Industry 4.- technologies: Future roles in purchasing and supply management.	x	x	x	x		x	x	x				
Harju, A., Hallikas, J., Immonen, M., & Lintukangas, K. (2023). The impact of procurement digitalization on supply chain resilience: Empirical evidence from Finland.		x	x			x						
Herold, S., Heller, J., Rozemeijer, F., & Mahr, D. (2023). Dynamic capabilities for digital procurement transformation: A systematic literature review.	x		x	x			x					
Ibrahim et al., (2023) - The effect of supply chain innovation and e-procurement implementation on supply chain performance of manufacturing organization.		x										
Ibusuki U. et al (2023) - Application of e-auction based on Procurement 4.- strategies in a global company of the power systems sector in Brazil.		x	x	x								
Lo H W (2023) - A data-driven decision support system for sustainable supplier evaluation in the Industry 5.- era: A case study for medical equipment manufacturing.						x						
Maagi, (2023) - Applicability of blockchain technology in improving efficiency in supply chain operations in				x								

public procurement in Tanzania.												
Makudza et al., (2023) - Enhancing supply chain agility through e-procurement in a volatile frontier market.	x	x										
Munir et al. (2023) - Procurement 4.- and Sustainable Supply Chain Performance: The Mediating Role of Procurement Process Optimization (PPO).		x										
Sekhar S et al (2023) - Study of emerging avenues in supplychain resilience; the case of integration of additive manufacturing with spare parts procurement.								x				
Wang et al. (2023) - A Literature Review on the Application of Digital Technology in Achieving Green Supply Chain Management.	x		x	x	x	x						
Alabdali M. A. and Salam M A (2022) - The Impact of Digital Transformation on Supply Chain Procurement for Creating Competitive Advantage: An Empirical Study.												
Delke V. et al (2022) - Differentiating-between-direct-and-indirect-procurement-roles-skills-and-Industry-4	x	x	x				x					
Ferreira and Silva, (2022) - Supplier selection and procurement in SMEs insights from the literature on key criteria and purchasing strategies.	x		x	x	x		x					
Joseph Jerome, J. J., Saxena, D., Sonwaney, V., & Foropon, C. (2022). Procurement 4.- to the rescue: Catalysing its adoption by modelling the challenges.	x		x		x	x		x				
Lee C. et al (2022) - Data science and reinforcement learning for price forecasting and raw material procurement in petrochemical industry.	x		x									
Mavidis A and Folinas D (2022) - From Public E-Procurement 3.- to E-Procurement 4.-; A Critical Literature Review.	x	x	x	x	x		x	x				
Saeed et al.(2022) - A systematic review of digital technology and innovation and its potential to address anti-corruption, transparency, and accountability in the pharmaceutical supply chain.		x		x					x			
Shahin et al. (2022) - The Role of E-procurement in Supply Chains. In N. Kryvinska & M. Greguš.		x										

Shivajee (2022) Procurement system for resilient supply chain amid the COVID-19 pandemic.	x		x	x	x		x	x	x			
Siddiqui et al. (2022) - Effects of E-Procurement on Supply Chain Management in the modern era.		x										
Singh and Chan (2022) - The Impact of Electronic Procurement Adoption on Green Procurement towards Sustainable Supply Chain Performance-Evidence from Malaysian ISO Organizations.		x										
Uluç, N. Ç. (2022). Digital Conflicts in Procurement.	x	x	x	x	x		x	x	x		x	
Van Hoek, R., Gorm Larsen, J., & Lacity, M. (2022). Robotic process automation in Maersk procurement—applicability of action principles and research opportunities.							x					
Bruzzi S. et al (2021) - Toward the strengthening of enabling technologies in Italy: results of the second survey on procurement 4.0.	x		x	x		x		x		x		
Hallikas, J., Immonen, M., & Brax, S. (2021). Digitalizing procurement: The impact of data analytics on supply chain performance.		x	x									
Jahani et al., (2021) - Application of Industry 4.- in the Procurement Processes of Supply Chains: A Systematic Literature Review.	x	x		x								
Lorentz, H., Aminoff, A., Kaipia, R., & Srai, J. S. (2021). Structuring the phenomenon of procurement digitalisation: Contexts,	x	x	x			x	x					
Modrušan, N., Rabuzin, K., & Mršić, L. (2021). Review of Public Procurement Fraud Detection Techniques Powered by Emerging Technologies.	x	x	x	x	x	x						
Bagn S et al (2020) - Procurement 4.- and its implications on business process performance in a circular economy.	x	x	x		x	x	x		x			x
Bottoni et al. (2020) - Intelligent Smart Contracts for Innovative Supply.				x								
Gholizadeh H, Fazlollahtabar H and Khalilzadeh M (2020), A robust fuzzy stochastic programming for sustainable procurement and logistics under hybrid uncertainty using big data.			x									

Nandankar (2020) Electronic procurement adoption, usage, and performance: a literature review.		x										
Bernardo, (2020) - Procurement 4.0 and the Fourth Industrial Revolution. The Opportunities and Challenges of a Digital world.	x	x	x	x	x	x	x	x		x		x
Seyedghorban, Z., Samson, D., & Tahernejad, H. (2020). Digitalization opportunities for the procurement function: pathways to maturity.												
Shatta et al. (2020) -Legal Framework Influence Towards E-Procurement Adoption Model in Developing Countries: Buyers' - Suppliers' Perception in Tanzania.		x										
Surajit et al (2020) Procurement 4.- and its implications on business process performance in a circular economy.	x	x	x	x			x					
Tripathi, S., & Gupta, M. (2020). A framework for procurement process re-engineering in Industry 4.-	x	x	x	x	x	x	x	x			x	
Angrian, (2019) - Development of vendor management and e-Procurement systems using android platform.		x										
Bruzzi S. (2019) - The new frontiers of procurement in the digital age. Results of an empirical survey on procurement 4.0 in Italy.						x						
Guarnieri, P., & Gomes, R. C. (2019). Can public procurement be strategic? A future agenda proposition.		x										
Handfield, R., Jeong, S., & Choi, T. (2019). Emerging procurement technology: Data analytics and cognitive analytics.	x	x	x	x	x							
Khuan, L. S. (2019a) - The challenges of emerging technologies the experience of procurement professionals.	x	x	x	x	x							
Klündera T et al (2019) Procurement 4.-: How the digital disruption supports cost-reduction in Procurement.												
Kosmola T, Reimann F and Kaufmann L(2019) - You'll never walk alone: Why we need a supply chain practice view on digital procurement.		x	x		x	x		x				
Kumar (2020) Non-financial e-procurement performance measures. Their interdependence and impact on production cost.		x										
Yevu, S. K., & Yu, A. T. W. (2019). The ecosystem of		x										

drivers for electronic procurement adoption for construction project procurement A systematic review and future research directions.												
Bienhaus F and Haddud A (2018), Procurement 4.-: factors influencing the digitisation of procurement and supply chains.	x	x	x		x	x			x	x		
Florian and Abubaker (2018) Procurement 4.-: factors influencing the digitisation of procurement and supply chains.	x	x	x		x	x			x	x		
Osmonbekov, T., & Johnston, W. J. (2018). Adoption of the Internet of Things technologies in business procurement: Impact on organizational buying behavior.					x							
Rejeb, A., Süle, E., & Keogh, J. G. (2018). Exploring new technologies in procurement.	x		x	x	x		x					x

15. Appendix B: “Summary Table of Applications”

No	Technology Applications in Procurement	Type of Technology	Total
1	Smart Contract	Blockchain	33
2	Suppliers' Relationship Management	e-Procurement	22
3	Supplier pre-qualification/ Evaluation	AI/ Industry 5.0	12
4	Innovation	AI/ Blockchain, IoT, Digital Passport Products, Robotics	11
5	e-sourcing	e-Procurement	9
6	Augmentation	AI	9
7	Supplier Performance Management	Advanced Analytics and Performance Dashboards/ Blockchain/ Smart Contracts	7
8	Information Sharing	Cloud Computing Adoption	6
9	Mobile Computing	Cloud Computing Adoption	6
10	Automation and Standardisation	Robotic Process Automation (RPA)	6
11	Inventory Management	IoT/ RFID	6
12			
13	Risks Assessment	Digitalization/ Information Sharing/ Data Analytics	6
14	Data Governance	Big data analytics	5
15	e-Tendering	e-Procurement (Platforms)	4

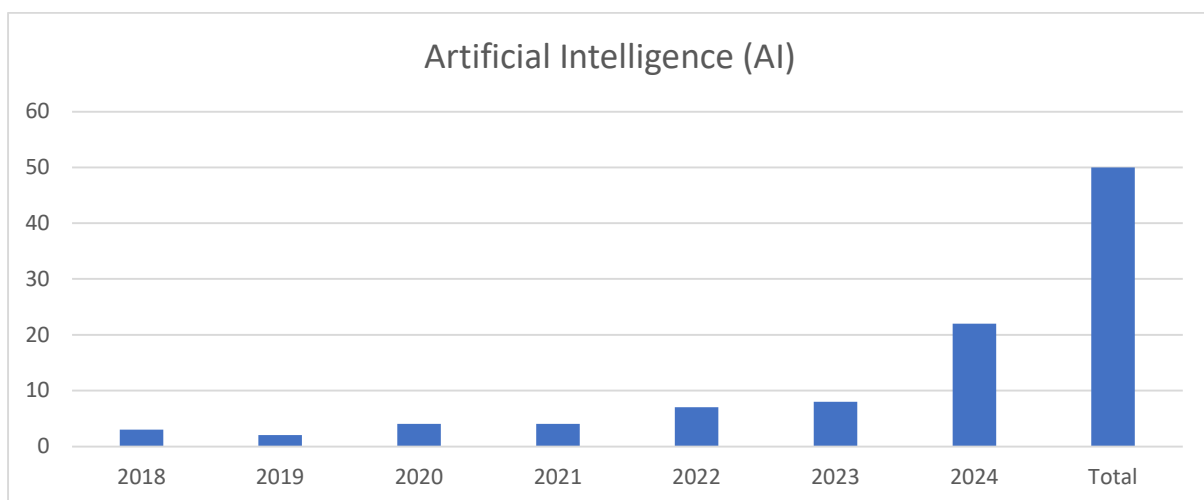
16	e-Auctions	e-Procurement (Platforms)	4
17	Regulatory Compliance	Digitization, data analytics and information sharing	3
18	Supply Chain Resilience	AI	3
19	Internet-Based Online Stores	e-Procurement (Platforms)	3
20	Information Processing	AI/ML	3
21	Sustainability > Sustainable Procurement	Information Sharing/ Big Data Sharing	3
22	Sustainability > Green e-Procurement	Cloud-Based e-procurement	3
23	Operational Efficiency	Robotic Process Automation (RPA)/ Big Data Analytics/ AI/ Blockchain	3
24	Cost Reduction	AI	3
25	Smart Supply Chain	AI	2
26	Increased Quality	Digital data-driven technology /AI	2
27	Electronic Data Interchange (EDI)	e-Procurement	2
28	Spend Analysis	e-sourcing, e-procurement (e-invoicing, e-catalogs, Platforms) Contract Management, Spend Analytics.	2
29	Internet Based Electronic Market Places	e-Procurement (Platforms)	2
30	Smart Working	Cloud services/ Blockchain technology/ Big Data Analytics/ AI (ML)/ IoT/Augmented Reality/ Traceability/ e-Procurement	2
31	Online Catalog Services	e-Procurement (Platforms)	2
32	e-Reverse Auctioning	e-Procurement (Platforms)	2
33	e-Payment	e-Procurement	3
35	e-Invoicing	e-Procurement	2
36	e-Design	e-Procurement	2
37	e-catalogs	e-Procurement	2

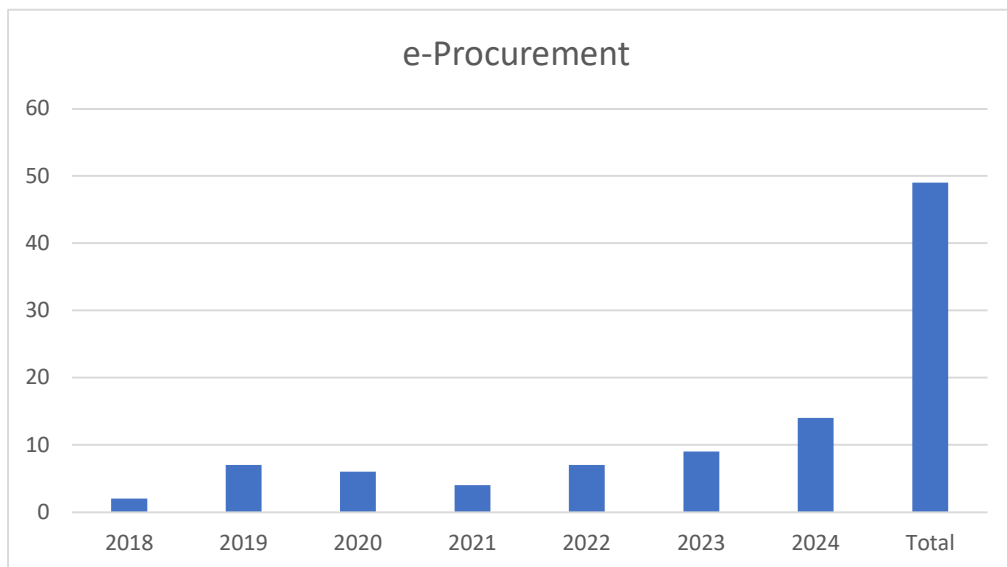
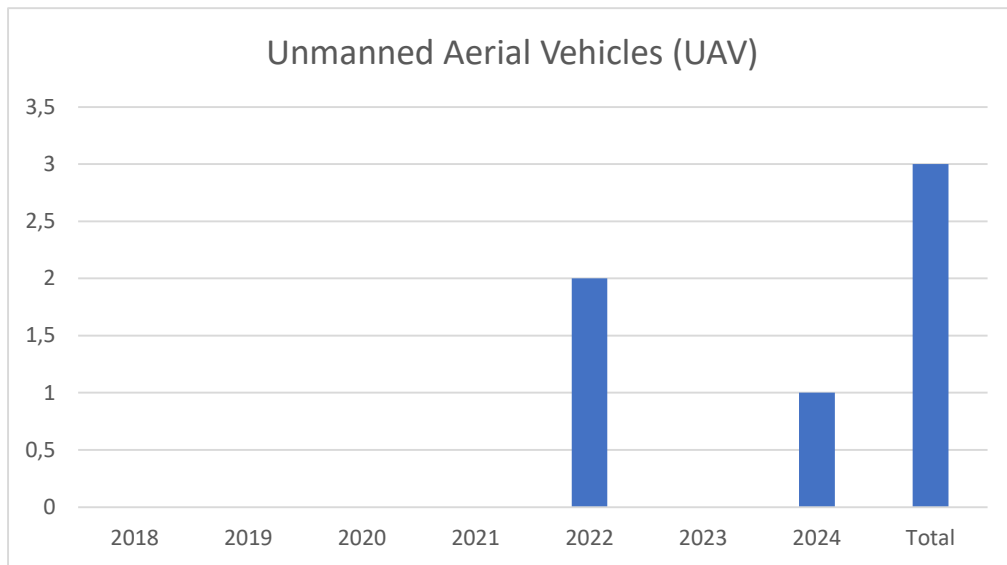
38	Negotiation bots	AI	2
39	Cognitive Analytics	AI	2
40	Data Sharing	Cloud Computing Adoption	2
41	Supplier pre-qualification/ Evaluation	AI-assisted sourcing decision-making/ Industry 5.0 technologies	2
42	Vendor Managed Inventory (VMI)	IoT/ RFID	3
43	Traceability and inventory management/ Automatic Cargo Transport applications	Unmanned Aerial Vehicles (UAVs) /Big Data analytics/ RFID/ Cybersecurity/ Information Sharing/ Blockchain/ Smart Contract	2
44	e-Contracting	Blockchain	1
45	Competitiveness	e-Sourcing, e-Procurement (e-Invoicing, e-catalogs)/ Contract Management/ Spend analytics	1
46	Procurement Risks	e-Sourcing, e-Procurement (e-Invoicing, e-catalogs)/ Contract Management/ Spend analytics	1
47	Emotional Intelligence	AI	1
48	Web of Relationships	e-Procurement	1
49			
50	e-CRM	e-Procurement	1
51	e-Commerce	e-Procurement	1
52	Project Procurement Management	IoT, mobility, business intelligence, blockchain, and robotic process automation (RPA), e-Procurement	1
53	Reduce Uncertainty	AI	1
55	Suppliers Portal	e-Procurement	1
56	Dynamic Capabilities (DC)	e-Procurement/ Spend Analytics/ Contract Management	1
57			
58	Flexibility	e-Procurement/ Spend Analytics/ Contract Management	1

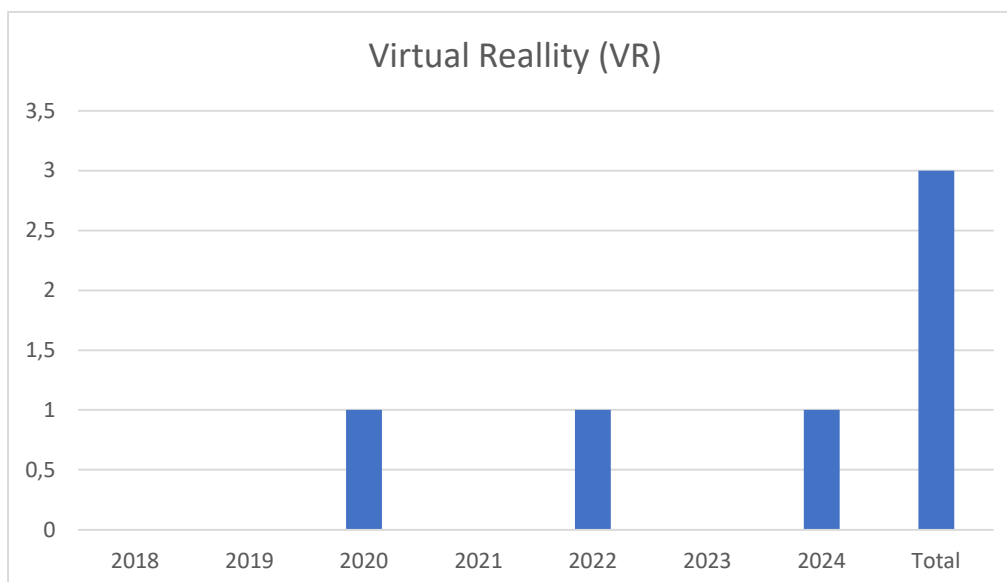
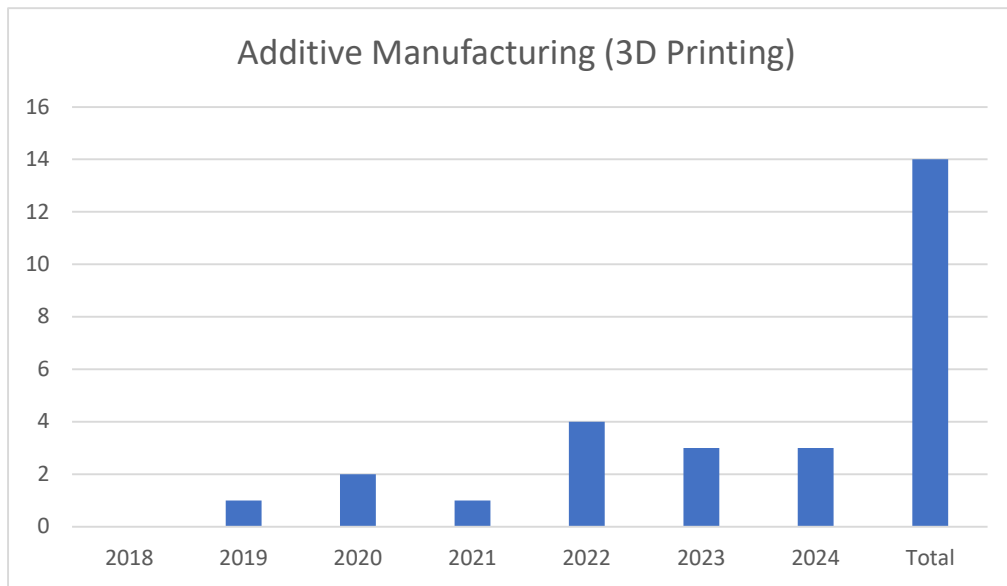
59	Corruption in Public Procurement	data mining and business intelligence techniques/ e-Procurement/ Contrat Management/ Spend Analytics	1
60	Category Management - Bundling Purchasing	AI/ e-procurement (e-invoicing, e-catalogs)/ Contract Management/ Spend Analytics	1
61	Formalization	e-procurement (e-invoicing, e-catalogs)/ Contract Management/ Spend Analytics	1
62	Supply Chain Agility	AI	1
63	e-Informing	e-Procurement	1
64	e-Notices	e-Procurement	1
65	e-Collaboration	e-Procurement	1
66	e-Signature	e-Procurement	1
67	e-Models	e-Procurement	1
68	Fraud detection	Big data, Cloud Computing Platforms, AI (ML), biometrics (ID4D), FinTech digital money, distributed ledger technology or Blockchain, IoT	1
69	e-Ordering	e-Procurement	1
70	e-Transactions	e-Procurement	1
71	Automated Negotiations	AI	1
72	Negotiation Support	AI	1
73	Autonomous Negotiation	AI	1
74	Cognitive Procurement	AI	1
75	Clustering	AI	1
76	e-Negotiation	AI	1
77	e-Evaluation	AI	1
78	Augmentation > Digital Passport Product (DPP)	AI	1
79	Digital Storage	Cloud Computing Adoption	1
80	Edge Computing	Cloud Computing Adoption	1
81	Public Procurement > E-GP	AI (ML)/ E-Public Procurement	1

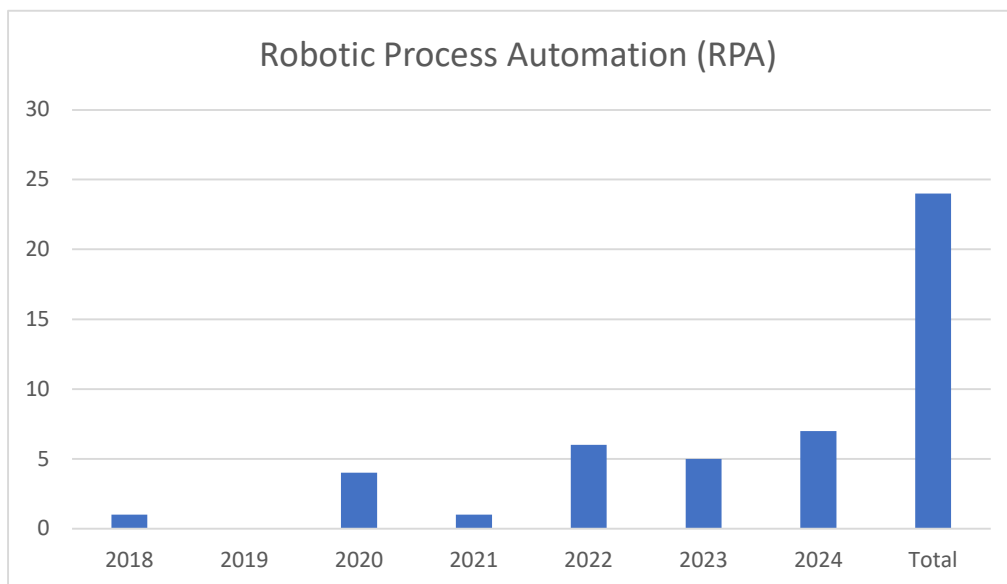
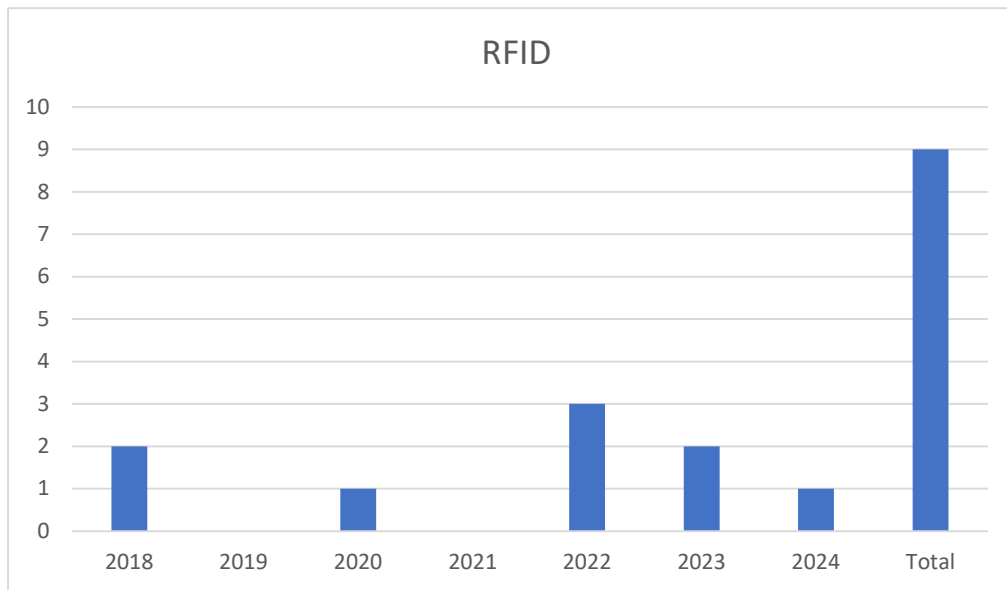
82	Autonomization	Blockchain/ AI/ Augmentation/ Optimal Character Recognition (OCR) and learning algorithms	1
83	Sustainability > Circular Procurement 4.0	Big Data Analytics, AI, Blockchain and IoT	1
85	Sustainability > Green Public Procurement	AI/ e-Procurement	1
87	Sustainable Supplier Evaluation (SSE)	Digital Transformation, Real-Time Information Sharing/ Organizational Culture Transformation	1
88	Supplier Diversity and Inclusion	Optimal Character Recognition (OCR) and learning algorithms/ e-Procurement	1
89	External Partnerships	Optimal Character Recognition (OCR) and learning algorithms/ e-Procurement	1
90	Facility Management	Block Cain/ Optimal Character Recognition (OCR) and learning algorithm	1

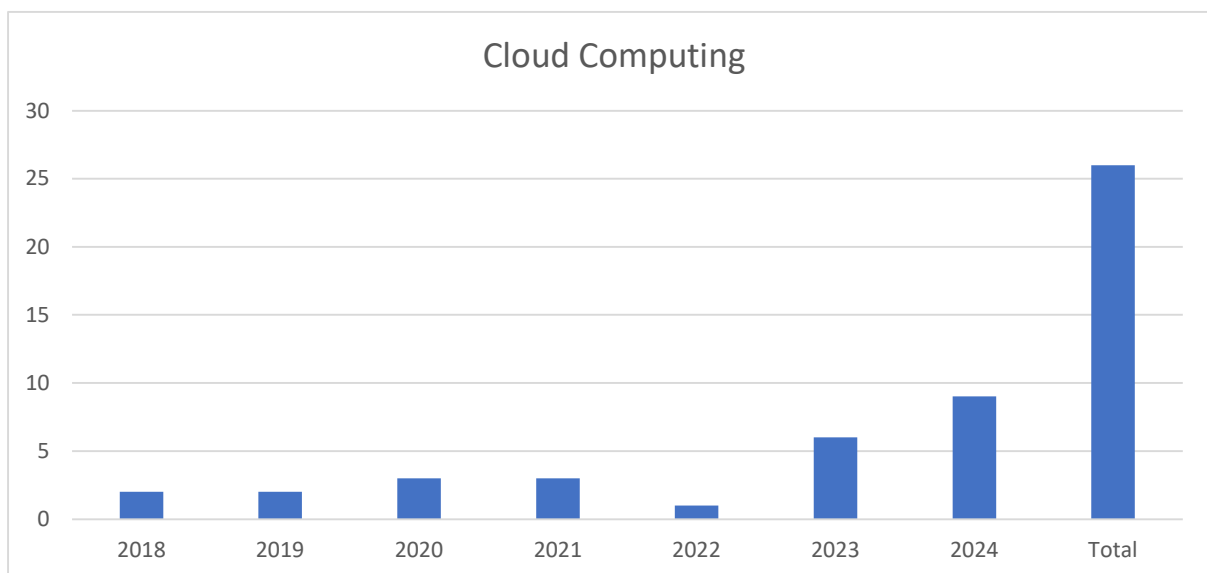
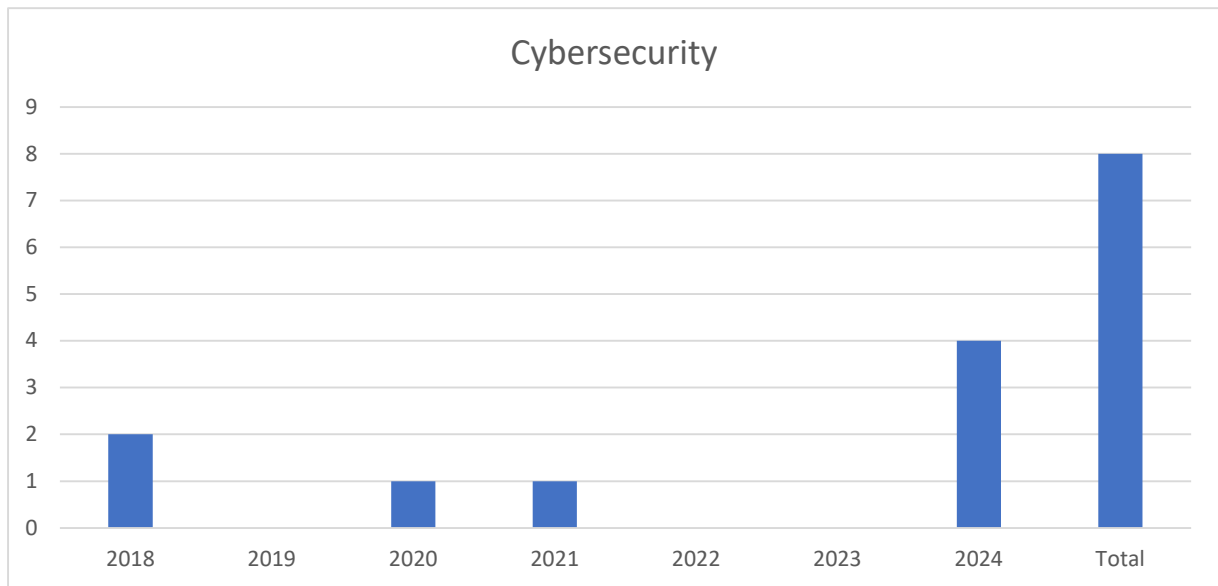
16. Appendix C: Charts of publications per Technology

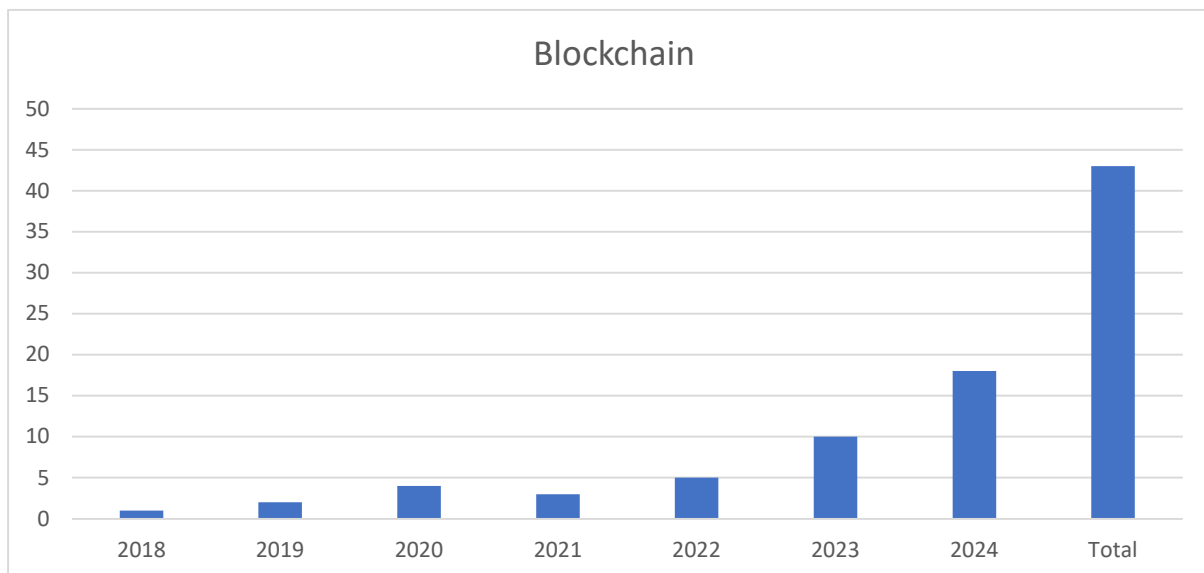
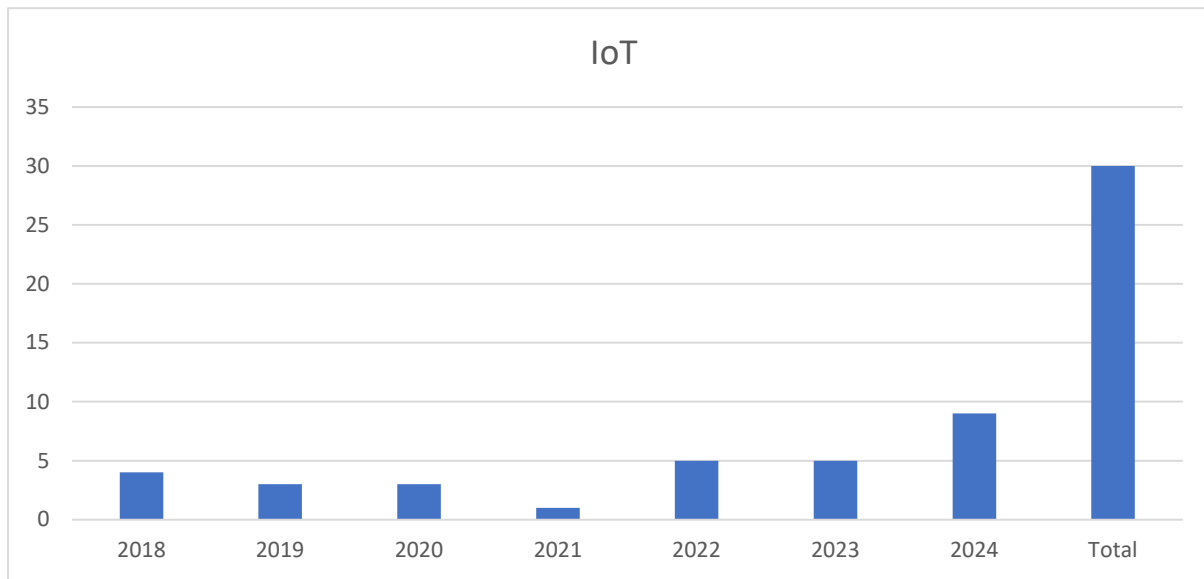


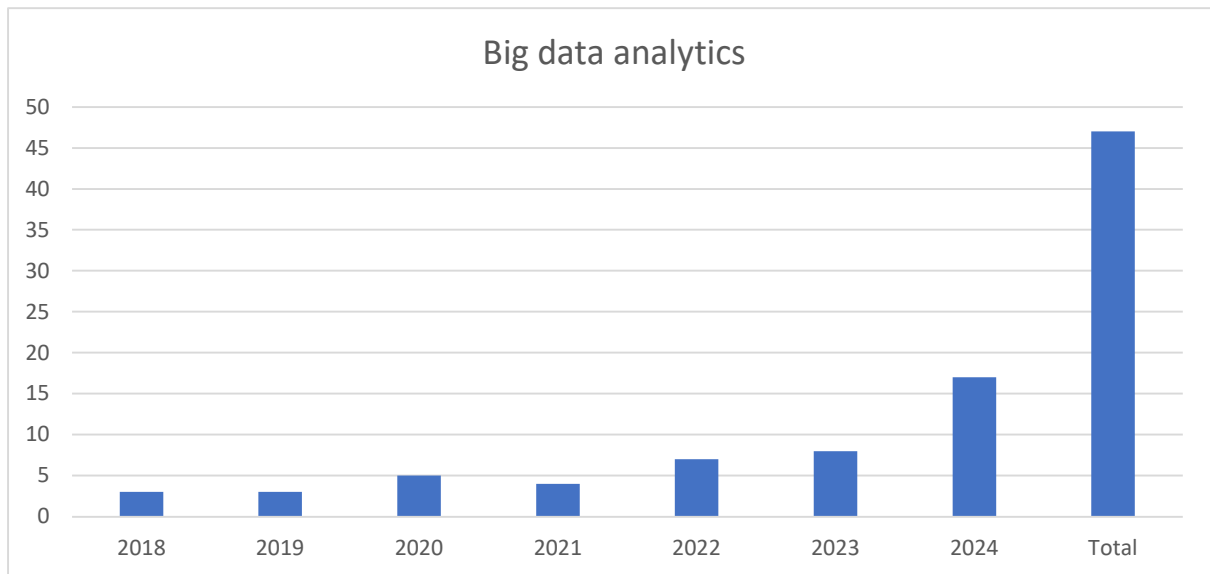












Author’s Statement:

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