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Potential of adopting emerging technologies in public procurement

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Arenevate tehnoloogiate võimalik rakendamine riigihangetes

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Author’s declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

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Abstract

This research investigates the potential adoption of emerging technologies in public procurement, focusing on their benefits, challenges and enablers. By analyzing the preparedness for adopting new technologies in the Estonian public procurement sector, the study aims to provide insights into enhancing technology adoption in public procurement processes. Through semi-structured interviews with experts and high-level procurement specialists, the study identifies motivations, barriers and enablers for adopting emerging technologies.

The study reveals a range of emerging technologies, which hold promise for significantly improving procurement procedures and outcomes. Procurement experts perceive these technologies as beneficial for enhancing the quality, productivity and efficiency of procurement processes. However, concerns are expressed regarding the potential loss of control of the work done by technologies, legislative requirements, data risks, justification for investments, legacy systems' compatibility and time constraints for procurement specialists. To address these challenges, the study proposes a set of recommendations based on identified enablers from literature and insights from interviews.

The research contributes to the understanding of potential adoption of emerging technologies in the Estonian context, providing valuable insights for public procurement organizations to remain innovative. Future research directions include exploring the real-life experiences and best practices adopting emerging technologies, which could potentially give in-depth insights of the enabling factors along with gained benefits and lessons learnt.

Keywords. Emerging technologies, Public procurement, Procurement 4.0, Industry 4.0, Artificial Intelligence, Big Data, Internet of Things, Blockchain

This thesis is written in English and is 63 pages long, including 5 chapters, 4 figures and 2 tables.

Annotatsioon

Arenevate tehnoloogiate võimalik rakendamine riigihangetes

Käesolevas uuringus uuritakse uute tehnoloogiate võimalikku kasutuselevõttu riigihangetes, keskendudes nende eelistele, väljakutsetele ja soodustavatele teguritele. Analüüsides valmisolekut uute tehnoloogiate kasutuselevõtuks Eesti riigihangete sektoris, on uuringu eesmärk anda ülevaade tehnoloogia tõhusaks kasutuselevõtuks hankemenetlustes. Poolstruktureeritud intervjuude abil ekspertide ja kõrgetasemeliste hankespetsialistidega tehakse uuringus kindlaks uute tehnoloogiate kasutuselevõtu motiivid, takistused ja soodustavad tegurid.

Uuringust selgub rida uusi tehnoloogiaid, mis lubavad hankemenetlusi ja -tulemusi märkimisväärselt parandada. Hankespetsialistid peavad neid tehnoloogiaid kasulikuks hankemenetluste kvaliteedi, tootlikkuse ja tõhususe suurendamisel. Samas väljendatakse muret seoses tehnoloogiate abil tehtava töö võimaliku kontrolli kaotamise, õiguslike nõuete, andmeriskide, investeeringute põhjendatuse, vanade süsteemide ühilduvuse ja hankespetsialistide ajaliste piirangute pärast. Nende väljakutsega tegelemiseks pakutakse uuringus välja rida soovitusi, mis põhinevad kirjandusest leitud soodustavatel teguritel ja intervjuudest saadud kogemustel.

Uurimus aitab kaasa arusaamisele uute tehnoloogiate võimalikust kasutuselevõtust Eesti kontekstis, andes väärtuslikke teadmisi riigihankeorganisatsioonidele, et jääda uuenduslikuks. Tulevaste uuringute suundade hulka kuulub uute tehnoloogiate kasutuselevõtu tegelike kogemuste ja parimate tavade uurimine, mis võiks anda põhjaliku ülevaate soodustavatest teguritest koos saadud kasu ja õppetundidega.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 63 leheküljel, 5 peatükki, 4 joonist, 2 tabelit.

List of abbreviations and terms

AI	Artificial Intelligence
BD	Big Data
CPB	Centralized Purchasing Bodies
DLT	Distributed Ledger Technology
EC	European Commission
EU	European Union
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
ICT	Information and Communications Technologies
INT	Interview
IoT	Internet of Things
ML	Machine Learning
NLP	Natural language processing techniques
OECD	Organization for Economic Co-operation and Development
PEOU	Perceived Ease of Use
PU	Perceived Usefulness
PwC	PricewaterhouseCoopers International Limited
QA	Questions and Answers
RPA	Robotic Process Automation
SME	Small and Medium sized Enterprise
TAM	Technology Acceptance Model
WHO	World Health Organization

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1 Introduction

Organization for Economic Co-operation and Development (OECD) has defined public procurement as “the purchase by governments and state-owned enterprises of goods, services and works. As public procurement accounts for a substantial portion of the taxpayers’ money, governments are expected to carry it out efficiently and with high standards of conduct in order to ensure high quality of service delivery and safeguard the public interest.” (OECD, n.d.). Accordingly, governments are increasingly acknowledging the significant potential of public procurement to address numerous key policy challenges like combating corruption, facilitating market access for small and medium-sized enterprises (SMEs), fostering citizens' trust in public buyers, promoting innovation and supporting environmentally and socially sustainable growth (Rodríguez Bolívar & Prados Prados, 2022).

Each year, more than 250 000 public entities in the European Union (EU) allocate approximately 14% of GDP to procure goods, services and works. Across various sectors like energy, transportation, healthcare and education, public entities serve as the primary buyers (European Commission, n.d.). Procurement is one of the areas in government most prone to corruption. Even in EU nations with robust procurement systems, estimated losses from expenditure can range from 10 -20% (Mavidis & Folinas, 2022). Enhancing public procurement through modernization, effective management and efficiency is crucial for maintaining high-quality public services. The potential for substantial savings is significant as even a 1% improvement in efficiency could result in annual savings of 20 billion euros (European Commission, n.d.).

Considering the vast scale and impact of public procurement, it is imperative that this spending is effectively managed. Emerging technologies such as Robotic Process Automation (RPA), Internet of Things (IoT), Big Data (BD), Artificial Intelligence (AI), Machine Learning (ML) and Blockchain play a pivotal role in achieving this. In 2020, a study published by European Commission (EC), gave an overview on uptake of such emerging technologies in public procurement. It contained a long-list of 96 initiatives

worldwide and gave a comprehensive description of lessons learnt. However, out of this global list of initiatives, only 35 cases were fully deployed and incorporated into the procurement process. As a result, one of the conclusions of the study was that "future work could investigate further some of the key enabling steps required in order to implement these technologies" (European Commission, 2020). Despite the proven benefits, there is reluctance among public administrations to embrace new technologies. (Boechat et al., 2023). According to research carried out by van Noordt & Misuraca, among the sample of 250 AI cases in public sector examined, 30% (76 cases) was identified as being utilized by public administrations for internal management purposes and out of that only 5% (4 cases) for improving public procurement processes (van Noordt & Misuraca, 2022). Similarly, academic literature review by Boechat et al. identified a gap in the research to address the reasons behind the non-adoption of the technology in public procurement processes (Boechat et al., 2023). There is a need for research aimed at better understanding of both the advantages and obstacles presented by emerging technologies so public procurement decisions can be smarter (Rodríguez Bolívar & Prados Prados, 2022).

The problem of the thesis is the limited adoption of emerging technologies in public procurement and as a result possible missed opportunities to enhance efficiency and effectiveness in procurement processes, gain better purchasing outcomes and cost-efficiency in spending public resources. The goal is to identify what is motivation and key barriers and enablers to adopt these new technologies and provide recommendations for next steps for public procurers to enhance adoption of emerging technologies.

The questions of the research are:
RQ How to enhance adoption of emerging technologies in public procurement?
SQ1. Why emerging technologies are considered in public procurement?
SQ2. What are the main barriers and enablers of introducing emerging technologies in public procurement?

To get an overview of what is state of play, preparedness for adopting new emerging technologies in Estonian public procurement sector, the author has done research by conducting semi-structured interviews with experts and high-level procurement specialists from most influential government institutions, agencies and state owned

enterprises. This provided invaluable insights into the participants' experiences and perspectives regarding the adoption of new technologies. To provide recommendations for enhancing adoption of new technologies, theoretical framework is combined from research papers, articles and documents from OECD, EC, PwC and Deloitte.

In the second chapter of the thesis, it gives a theoretical framework for the following research. The third chapter focuses on the methodology of the study and the fourth chapter provides analysis and results of the qualitative research: it focuses on identifying the technology acceptance level in Estonian influential public procurers and provides recommendations for enhancing the adoption of emerging technologies in public procurement. In the final chapter, discussion, limitations and future research is presented.

2 Theoretical framework

This study's theoretical framework gives an overview of the technological development and different eras in public procurement. It also presents list of emerging technologies and reviews main benefits, challenges and enablers in adoption of new technologies in public procurement.

2.1 Technological development in public procurement

Public procurement is a complicated process that is always aiming to be efficient, objective and transparent. Using technology is one way to make it better (Boechat et al., 2023). Procurement practises have been around for ages, with records dating back thousands of years, like those from ancient Egypt. Over the past century, these methods have modernized, moving from paper-based systems to using technology and electronic methods for procurement (Mackey & Cuomo, 2020) Over the past three decades, digitalization trends have provided growing opportunities for the public sector. Commencing with the advent of mainframe computing in the late 1950s, progressing through the introduction of personal computers in the late 1970s, and culminating in the rise of the internet and open networks in the 1990s, governments and public sector entities boast a significant legacy of embracing technological advancements. They use these technologies to enhance internal and external collaboration, streamline resource planning and procurement operations, empower data-driven decision-making and overhaul service delivery to align with the evolving needs of citizens and businesses (Ubaldi et al., 2019)

The industrial sector has experienced numerous advancements, ranging from minor adjustments to significant transformations. Certain pivotal shifts are often referred to as industrial revolutions, driven by technology and needing fundamental economic and societal transformations. The steam engine symbolized the shift from manual to mechanical labour, marking the key technology of the first industrial revolution. Subsequently, two more industrial revolutions unfolded: mass production facilitated by electric power and automation advancements driven by information technology (Schiele

et al., 2021). Consequently, the latest significant shift in procurement systems occurred with the advent of Internet and communication technology, leading to the development of e-procurement systems (Tripathi & Gupta, 2020). In the era of Industry 3.0, e-procurement systems started to connect with information beyond their own databases (Mavidis & Folinas, 2022).

2.1.1 Procurement 3.0

The Internet's evolution into a global marketplace, aided by web-based applications, high-speed data transfer and mobile connectivity, led to the development of e-procurement systems. These systems are more comprehensive, versatile, adaptable and capable of interfacing with other technologies (Mackey & Cuomo, 2020). It represents a significant shift in procurement structure, leveraging cutting-edge technologies for procurement objectives (Althabatah et al., 2023).

E-procurement enhances process efficiency and effectiveness through simplification and automation, utilizing various Information and Communications Technologies (ICTs) to transform traditional procurement and supply processes into e-processes. E-tendering, for instance, utilizes ICTs for disseminating procurement information, expressing interest, accessing tender documents, submitting bids and finalizing selections, aiming to streamline tender management, reduce bureaucracy and accelerate communication. Its remote accessibility empowers users to engage with tender management platforms globally, overcoming location constraints and facilitating seamless participation from anywhere (Siciliani et al., 2023). Democratic accountability is a key feature of public e-procurement systems, governed by regulations and various control mechanisms. Enhanced competition among public vendors can significantly streamline procurement processes, reduce costs and yield improved outcomes (Mavidis & Folinas, 2022).

E-procurement systems offer a fundamental advantage by digitizing information for various procurement phases, enabling to store, read, write and search for it. While these systems enhance transparency, facilitate automation and integrate other technologies, their most significant function lies in generating savings. Savings can be achieved through process improvements, as demonstrated by a 2010 study of a pilot e-procurement system in Greek, Spanish and Belgian hospitals. This system reduced the time needed to create a

list of goods by half and decreased tender preparation time from 1 hour to just 15 minutes, highlighting the primary objective of savings (Mackey & Cuomo, 2020). Electronic procurement tools aim to standardize procedures and improve access to information and transparency in management. However, moving forward, it's essential to define the shift to modern tools of the fourth industrial revolution (Mavidis & Folinas, 2022).

2.1.2 Procurement 4.0

The rise of Industry 4.0 has led to a significant change in procurement, resulting in the emergence of Procurement 4.0. Moving beyond a cost-centric focus, procurement started to emphasize profit, reshaping both what and how is procured (Althabatah et al., 2023). The integration of various emerging technologies under Industry 4.0 such as IoT, BD, AI and Blockchain, is driving radical change in procurement. While e-procurement uses technology to assist with manual tasks, Industry 4.0 focuses on intelligent systems that automate the entire procurement process, from routine tasks to strategic decision-making (Tripathi & Gupta, 2020). In Industry 4.0, there is a focus on machine-to-machine communication and integrating physical and digital using advanced technologies. Unlike in Industry 3.0, where the emphasis was on human-machine interaction, now the innovation lies in robots being able to interact with each other without human involvement (Mavidis & Folinas, 2022).

The fundamental three components of Industry 4.0 are automation, connectivity and advanced analytics. There are some key examples from various industries to highlight the transformative impact of Industry 4.0 technologies on procurement processes. In the public sector, the World Health Organization (WHO) emphasizes the vital role of Industry 4.0 technologies in global healthcare management. WHO actively addresses disease outbreaks, optimizes medical supply chains and enhances resource allocation by exploiting data-driven insights and predictive analytics. In the private domain, Walmart displays adept integration of Industry 4.0 technologies, ushering in a new era of advanced procurement. Utilizing the potential of IoT and real-time analytics, Walmart efficiently manages inventory levels, improves demand forecasting accuracy and reduces stockouts, thus boosting customer satisfaction and operational efficiency (Althabatah et al., 2023).

It is important to understand these developments and different eras in the public procurement as they come with their own set of benefits, challenges whereas Industry 4.0 is an advancement of Industry 3.0 and needs to be considered in order to be implemented successfully. Emerging technologies would work alongside, rather than independently from e-procurement systems. This means they would integrate with or enhance existing e-procurement approaches (Mackey & Cuomo, 2020). For example a cognitive procurement, which uses self-learning technologies to process data and involves various technologies, including automation, BD, ML, AI, NLP, master data management, advanced analytics and algorithms (Saw & Khuan, 2019).

A short overview of the main characteristics and challenges of Industry 3.0 and Industry 4.0 is given in Table 1.

Table 1 Characteristics and challenges of Industry 3.0 and Industry 4.0.

	Industry 3.0	**Industry 4.0**
Characteristics	Automation, digitization Supply side optimization Supplier collaboration Contextual data recording Increased efficiency Cost reduction Increased procurement transparency Cloud based tools	Streamlined processes Improved supply chain visibility Collaboration of different stakeholders Data-driven decision-making Pro-active decision-making Savings Transparency of transactions Emerging technologies
Challenges	Organizational readiness User acceptance Supplier integration Data security Compulsory regulatory framework	Organizational change Resistance to digital transformation Interoperability Data security Regulatory compliance

Source: Author based on Althabatah et al. tables (2023)

2.2 List of emerging technologies

The strategic importance of supply chain and procurement functions for organizations remains pivotal, contributing significantly to management decisions. Digital changes in procurement aim to streamline operations. Technologies like data analytics, AI and robotics play a big role in managing suppliers strategically, improving predictability in demand planning and giving buyers better negotiating power. The digital shift in procurement is anticipated to primarily enhance predictability in demand planning, streamline the entire procurement process for quicker and more efficient workflow among stakeholders and boost proactive supplier management. This supports decision-making, forecasting, risk management and future planning for procurement professionals, while also driving overall cost-effectiveness, efficiency and organizational growth. (Uluç, 2022). Lots of digital procurement tools aim to give access to data that wasn't available before or organize large, messy data sets (Deloitte, n.d.). In Procurement 4.0, technologies are classified into four main areas based on their functions:

1) "Connectivity and communication, encompassing IoT, cloud and cybersecurity;
2) Data, intelligence and analytics, including BD, data analytics and AI;
3) Human-to-machine (H2M) and machine-to-machine (M2M) interaction, involving manufacturing technologies, virtual/augmented reality (VR/AR);
4) Logistics, covering autonomous transportation and advanced robotics."

When comparing e-procurement against Procurement 4.0 —manual effort required and buyer-supplier collaboration— a distinct contrast emerges. Procurement 4.0 enables full process automation and seamless integration, whereas e-procurement is confined to ICT-supported operational tasks (Tripathi & Gupta, 2020).

List of emerging technologies and possible benefits is summarized in Table 2.

Table 2 Emerging technologies and possible benefits

Emerging technologies	**Benefits**
Artificial Intelligence (AI)	• Enables predictive analytics, process automation and optimization by using algorithms and softwares able to learn specific tasks • Enhances strategic sourcing and supplier evaluations • Improves risk management, contract management and compliance • Reduces manual intervention • Increases data processing and boosts productivity • Improves reporting
Deep Data Analytics Data Mining Big Data (BD)	• Detects hidden patterns and insights from large and complex datasets • Enables to examine and analyze big data • Helps to identify cost-saving opportunities, forecast demand and optimize supplier portfolios • Improves procurement strategies, risk management, efficiency and accuracy in strategic planning and decision-making • Enhances contract analysis, streamlines the contract creation process
Internet of Things (IoT)	• Enables to connect virtual and physical domains • Tracks assets and orders real-time through the use of special sensors • Tailors processes and workflows by using performance data • Optimizes inventory management • Improves logistics and supply chain visibility
Blockchain technology	• Uses trusted peer-to-peer network and cryptologic data structure to generate digital transaction ledgers to validate and verify transactions • Enhances transparency and security • Improves integrity and traceability • Reduces the risk of fraud or corruption • Simplifies procurement processes • Triggers automated payments

Machine Learning (ML)	• Enables to analyze historical procurement data by using algorithms able to recognize patterns from past behavior • Identifies patterns, trends and correlations • Helps to predict demand and estimate prices • Optimizes procurement processes
Natural language processing techniques (NLP)	• Enables processing and understanding unstructured data (emails, user information requests etc) by using algorithms able to read, understand and analyze human language • Improves communication between procurement specialists and system users
Robotic Process Automation (RPA)	• Recognizes and learns patterns to streamline and optimize large, repetitive and time-consuming tasks • Decreases risks and errors in processing information • Enables to approve orders and process invoices • Helps to monitor Key Performance Indicators (KPIs)
Chatbot	• Provides government specialists with a friendly interface to interact with when ordering goods and services • Improves user experience • Leverages historical spending data, contract data and other sources of information • Simplifies internal ordering process while reducing the risk of fraud and invoice discrepancies
Computer Vision	• Enables analyzing images and videos in procurement processes • Helps to control the quality and authenticity of products • Enhances automation of inspection of goods against specifications
Deep Learning	• Enables complex tasks such as speech and image recognition • Analyzes and extracts information from unstructured data sources like images of product catalogs or voice recordings of supplier negotiations
Predictive Analytics	• Combines ML, AI, modeling, statistics with third-party data sources for forecasting future procurement outcomes • Helps in predicting demand, assessing supplier performance and identifying potential risks or bottlenecks in the procurement process

Recommender Systems	• Recommends relevant suppliers, products or procurement strategies based on historical data • Helps in making informed decisions • Detects new products or suppliers
Cognitive Computing	• Leverages pattern recognition software and iterative machine learning algorithms to categorize unstructured data • Enables complex decision support systems • Enhances analyzing large volumes of data˘ • Gives recommendations to procurement specialists
Visualization	• Converts data into easy-to-understand visual formats • Offers new insights and recommendations • Streamlines decision-making
Virtual reality and spatial analytics	• Utilizes video, location data or pattern analysis to identify events or changes in status to facilitate virtual supplier visits or audits • Enables procurement professionals to achieve more with fewer resources

Source: Author

There is an emphasis on utilizing multiple technologies to enable interconnected applications. It has been emphasized by procurement practitioners that a combination of IoT, BD, AI and cloud is pivotal in transforming information systems (Tripathi & Gupta, 2020). Blockchain technology, whether used alone or in conjunction with other technologies, is a newcomer with the potential to disrupt the current ecosystem of public administration technologies (Benítez-Martínez et al., 2023). As these technologies are frequently mentioned in the literature to become one of the most influential emerging technologies in the context of public procurement, in order to understand AI, BD, IoT and Blockchain more in depth, a short description of each technology is provided.

2.2.1 Artificial Intelligence (AI)

While AI finds widespread application in various domains, its integration into procurement processes is still in the early stages, despite its considerable potential (Guida et al., 2023). The emergence of AI enables to enhance public procurement processes,

streamline operations, accelerate data-driven decision-making and increase transparency, accountability and cost efficiency. While AI may not possess the intuition and creativity of humans, it excels at executing repetitive tasks and analyzing vast amounts of data to uncover inefficiencies and opportunities with unmatched speed and precision (Bansal & Jain, 2023).

AI serves users either actively or passively. Active service involves using predictive analytics to offer push notifications or choices to users. Passive service entails executing transactions based on user commands. Current AI trends focus on automating specific job tasks rather than replacing purchasing professionals entirely. AI performs tasks such as forecasting purchase prices, creating supplier contract templates and conducting initial supplier evaluations (Saw & Khuan, 2019).

AI is also utilized through robotics and cognitive automation, to perform various tasks such as answering questions, querying databases, processing documents, completing forms, translating texts and accurately directing requests. These process automation technologies present a significant opportunity for public sector to enhance productivity, reduce paperwork, lower costs and overcome resource constraints. It allows optimizing the workforce and reallocating civil servants to more complex, value-adding tasks. Notably, ML has become the primary approach in AI technology. It involves teaching machines to make decisions by providing them with numerous examples of correct decisions or defining a set of rules for them to learn through trial and error. Other key areas of AI include NLP, robotics and computer vision (Ubaldi et al., 2019).

2.2.2 Big Data (BD)

The digitization of procurement has led to the accumulation of vast amounts of data, known as BD, which has spurred the application of AI in supply management (Uluç, 2022). Data mining, coupled with comprehensive data analytics, is utilized to scrutinize and analyze all incoming and outgoing "big data" from government departments. This process aims to identify patterns, uncover insights and enhance efficiency and accuracy in strategic planning and decision-making (Bansal & Jain, 2023).
The application of BD brings various benefits, including increased visibility, improved bargaining power in negotiations, enhanced risk management and better decision-making.

It enables lower procurement costs by providing insights into supply processes at different stages. BD aids in spending control through data analysis and mitigates risks by identifying potential supply chain disruptions. Moreover, predictive analytics techniques can be utilized for market analyses and negotiations, thereby significantly enhancing the procurement process (Althabatah et al., 2023). Visualization techniques could prove to be an important tool to use on BD to facilitate easier access and retrieval of information (Siciliani et al., 2023).

2.2.3 Blockchain technology and smart contracts

Blockchain technology, alongside smart contracts, offers valuable benefits due to its technical features like transparency, immutable records, permanence, and inability to alter data once recorded. These advantages make it highly applicable in various sectors, including public procurement (Čeke et al., 2022). While blockchain comes in various iterations, its core concept revolves around serving as a decentralized ledger for transactions. This ledger is collectively managed and updated by a network of participants, whether they trust each other or not, without the oversight of a single central authority (Ubaldi et al., 2019). Distributed Ledger Technology (DLT) solutions can boost e-government reforms by improving trust-building, speeding up public information management and enabling secure public service delivery. This has sparked greater interest in using Blockchain to address scalability and trust concerns (Rodríguez Bolívar & Prados Prados, 2022).

Blockchain can help save resources by reducing the need for middlemen and their associated costs. When appropriately constructed, blockchain holds the potential to provide greater resilience against cyberattacks and IT system fraud compared to centralized systems. This is attributed to its decentralized structure, which eliminates the single point of failure often present in centralized databases. Numerous ongoing experiments are based on permissioned chains, which appear particularly suitable for the public sector. These chains enable control over who can input new transactions, thereby enhancing accountability through identity management and transparent transactions (Ubaldi et al., 2019). The adoption of blockchain technology is expected to enhance security, mitigate manipulation and corruption, and improve the efficiency and

transparency of information processing in public administration (Benítez-Martínez et al., 2023).

A practical application of blockchain in public procurement is through smart contracts, which have autonomous and automated self-execution capabilities. Smart contracts operate without intermediaries or reliance on authorities or third parties, relying instead on the consensus of network users. Among other functions, they can automate bid evaluations, facilitate contract negotiations and handle associated payments (Mircea et al., 2022). The implementation of smart contracts directly contributes to anticorruption solutions in e-procurement by facilitating secure and agile contracting through digital signatures and automated execution systems. Contracts are executed automatically when conditions are met and verified, enhancing efficiency and reducing the risk of corruption. However, there is a challenge is how to use blockchain while preserving the confidentiality of the contractual process documents (Benítez-Martínez et al., 2023)

2.2.4 Internet of Things (IoT)

Another emerging segment of digital tools is associated with IoT, where sensors and wearables can enhance procurement processes (Uluç, 2022). They can track assets and orders using specially designed sensors that monitor temperature, location and other variables, leveraging performance data to customize procurement practices and workflows (Bansal & Jain, 2023). IoT facilitates the establishment of a web of smart devices, enabling collecting and sharing data, inventory level monitoring, virtual mock-ups of real-world products and the creation of virtual markets (Mircea et al., 2022). Accessing the shipment location of goods enables procurement professionals to obtain accurate real-time information and reports, significantly contributing to the overall efficiency of the procurement process (Uluç, 2022). In public procurement, using hybrid technological solutions, like combining Blockchain and IoT (BIoT), can create new operational and commercial opportunities. BIoT solution utilizes IoT devices to send data to private blockchain networks, creating tamper-proof transaction records. These networks are owned by contracting authorities or economic operators. Blockchain components facilitate data sharing without central control, ensuring verifiable transactions and building trust among authorized network members involved in the procurement process (Mircea et al., 2022).

2.3 Main benefits of applying emerging technologies in public procurement

Common complaints often heard in government agencies include “We lack sufficient manpower to keep pace”, “Navigating extensive case law is overwhelming”, “The excessive paperwork is hindering our productivity” or "We lack visibility into events and incidents due to inadequate tracking." Emerging technologies offer solutions to these types of challenges (Eggers et al., 2017). The advent of Industry 4.0 in the procurement sector marks a notable paradigm shift. Organizations now have unparalleled chances to revolutionize their procurement procedures and attain strategic goals. By embracing cutting-edge technologies, harnessing data analytics and promoting collaboration, procurement experts can elevate their decision-making capabilities, streamline supply chain operations and foster sustainable growth (Althabatah et al., 2023). In general, main benefits of the emerging technologies in public procurement can be divided into 7 categories: 1) information 2) productivity 3) savings 4) quality 5) cost 6) safety and 7) transparency and accountability.

2.3.1 Information

Collaboration is a notable aspect enabled by Industry 4.0 in procurement. Through interconnected systems and platforms, smooth communication, sharing of information and productive collaboration occur among stakeholders throughout the supply chain. This results in better coordination, increased visibility and accelerated decision-making processes (Althabatah et al., 2023).

Digital procurement solutions aim to unlock previously inaccessible data and organize vast, unstructured datasets. For instance, contracts stored in hard copy or PDF formats may hinder quick access to detailed specifications, negotiated terms, penalties and pricing. ML-powered intelligent content extraction can convert static documents into actionable data points. Connected sensors digitize raw material status and transactions, capturing demand, delivery and consumption changes in real-time (Deloitte, n.d.).
Emerging technologies facilitate the analysis of extensive and complex BD, delivering timely insights to support and enhance decision-making for government procurement teams. Predictive analytics, driven by AI, enables forecasting based on historical data

(Bansal & Jain, 2023). Processing BD through ML not only offers deeper insights into suppliers and market trends but also provides visibility in evaluating the best value and prices for organizations. Unstructured data comprises both internal and external sources, including company emails, reports and various other information channels. Cognitive analytics handles this complex qualitative data through ML processes, aiding not only in gathering information but also in elucidating underlying ideas and concepts (Uluç, 2022).

2.3.2 Productivity

AI can decrease the average duration of the public procurement process by 25-60%, as it operates around the clock. It can notably cut down on time-consuming tasks like bid selection, has the capability to automate numerous repetitive tasks, including data entry, invoice processing and document verification. This streamlines the procurement workflow, minimizes manual errors and saves time for procurement personnel (Bansal & Jain, 2023). AI also performs purchase price forecasting, generates supplier contract templates and conducts preliminary supplier evaluations. Data analytics is valuable for predicting supplier quality and managing risks and aids in supplier negotiation (Saw & Khuan, 2019).

AI can aid in contract management by automatically overseeing contract compliance, tracking key performance indicators and issuing renewal notifications. This diminishes administrative burden and ensures contracts are efficiently managed throughout their lifecycle. Integrating AI with ML enhances productivity across the procurement and delivery process, enabling government procurement teams to concentrate on tasks that add more value (Bansal & Jain, 2023).

RPA stands out as a modern digitalization tool in procurement, focusing on rule-based tasks that influence efficiency in contract, supplier, category and third-party risk management (Uluç, 2022). RPA employs software, known as "bots," to automate tasks typically performed manually. These bots mimic human actions, such as completing forms, purchase orders or transferring data between spreadsheets and databases, quickly and accurately. With RPA, significant productivity gains can be achieved without the need for extensive process redesign (Deloitte, 2017).

Additionally, IoT offers real-time visibility into purchased quantities consumption and their utilization, aiding procurement in enhancing catalogue content and spend control. This enhances efficiency and productivity of procurement processes (Saw & Khuan, 2019). Emerging digital technologies like sensors and spatial analytics are advanced tools that empower proactive management in procurement by supporting predictive demand planning and supplier management (Uluç, 2022).

2.3.3 Savings

Automating and digitizing procurement processes streamlines operations, minimizes manual errors and leads to savings in time and resources (Althabatah et al., 2023). AI can streamline the procurement workflow by automating repetitive tasks such as verifying documents, processing invoices and making data entries. This not only reduces manual errors but also saves time for procurement personnel. Additionally administrative overhead is reduced by AI-powered systems that can strengthen contract management by automatically monitoring contract conformity, tracing key performance indicators and providing notifications for renewal and renegotiation (Bansal & Jain, 2023).

The impacts of these initiatives are typically quantified by measuring efficiency gains related to time saved for employees. This is particularly prevalent in AI, BD, RPA, ML and data analytics projects. Among these, RPA case studies generally reported the highest measured employee time saved. For BD and data analytics projects, significant time savings were believed to exist, with certain tasks becoming much more efficient, such as reducing price research time from 6 weeks to 6 minutes (European Commission, 2020).

There is data highlighting significant variations in cost savings between different types of public procurement processes. It suggests the necessity of distinguishing between two types of competition environments within public procurement processes: external and internal competition. The number of bidding companies involved in a public tender influences external competition. Internal competition arises from the procurement process itself and how its various aspects promote cost-saving competition. Technology has been identified as one of the primary factors driving this internal competition for more efficient public procurement processes. In addition, the immutability feature and increased transparency of emerging technologies like blockchain could stimulate competition in the

procurement process. Companies may offer lower prices in public tenders due to the perceived heightened competitive environment. In short, the effectiveness of technology utilized in procurement processes can lead to increased competition and savings (Rodríguez Bolívar & Prados Prados, 2022).

2.3.4 Quality

AI ensures consistent quality by minimizing manual work and automating and enhancing time-consuming tasks, thereby reducing the risk of errors. AI algorithms are capable of assessing supplier performance across a range of criteria, including price, quality, delivery and compliance. By analyzing supplier data and feedback, AI can pinpoint the most suitable suppliers for specific sourcing requirements, mitigating the risk of choosing underperforming or non-compliant suppliers (Bansal & Jain, 2023). Advanced control systems enable procurers to streamline operations and facilitate purchasing decisions. Integrated systems empower purchasing managers to efficiently handle tasks on a lean data platform, eliminating the need to navigate multiple inconsistent programs or software (Uluç, 2022). Beyond its administrative function, procurement acts as an intermediary with suppliers, ensuring bid conformity with initial specifications, negotiating contracts and overseeing implementation. From the examples of RPA adoption, technology enhances stakeholder satisfaction and the quality of buyer-supplier relationships as RPA accelerates processing data like invoice management and eludes human error, so the operational quality of the process refines (Viale & Zouari, 2020).

2.3.5 Costs

AI has the capability to analyze extensive sets of procurement data, pinpointing patterns, trends, and anomalies. This kind of analysis empowers procurement professionals to make informed decisions, identify priority areas for optimization and uncover potential cost reductions. AI can suggest alternative procurement options based on parameters such as availability, cost and quality. Predictive analytics helps to optimize inventory, forecast demand and procurement requirements. By analyzing historical data, external factors and trends in the market, analytics deliver precise forecasts, facilitating proactive planning and cost-effectiveness in procurement. Overall, this supports the application of efficient strategic action plans (Bansal & Jain, 2023).

Hybrid technological solutions, like combining Blockchain and IoT, can boost efficiency and profitability in various economic activities. For instance, IoT can label goods and connect relevant information to a cloud system, facilitating faster decision-making for stock management. This approach reduces unit costs, manufacturer retail prices and pending order quantities. Shortages are quickly communicated to suppliers via cloud data, enabling automatic renewal calculations. IoT can also identify changes in materials, prices and quality, selecting suitable suppliers for future cooperation. Additionally, it prioritizes and addresses issues efficiently within the smart system, facilitating adaptive solutions across the network (Mircea et al., 2022).

2.3.6 Safety

AI has the capability to identify irregularities, anomalies or suspicious activities in procurement processes, aiding in the prevention of fraud and corruption. ML algorithms can scrutinize historical procurement data and highlight transactions that diverge from established patterns. This early detection enables the identification of potential risks and fraudulent attempts. AI mitigates the risk of fraud by assisting government departments in selecting the most suitable supplier (Bansal & Jain, 2023).

Blockchain reduces corruption through decentralization and transparency of information flow. Decentralized smart contracts mitigate corruption and fraud by eliminating centralized control, particularly in stages vulnerable to forged records or unjustified information disclosure. Blockchain ensures security and integrity of transaction data by eliminating the need for third-party involvement. Immutable data in blockchain prevents fraud by disallowing intervention, while transparency and verifiability of events deter corruption in contract management. Transactions are permanently recorded in blockchain and the unchangeable audit trail in blockchain enables participants to track actions, reducing the risk of data loss when interacting with third-party systems (Mircea et al., 2022).

2.3.7 Transparency and accountability

AI enhances the transparency of government procurement processes by offering auditable tracking of actions and decisions. It aids in ensuring accountability, mitigating the risk of corruption and bolstering trust in public procurement systems. Through the deployment

of AI algorithms, organizations can mitigate bias and establish an equitable environment for all suppliers. These systems objectively assess offers based on predetermined criteria, eliminating human subjectivity from the evaluation process (Bansal & Jain, 2023). Digital transformation in procurement significantly enhances control and compliance, facilitated by advanced monitoring features that align with procurement processes. With the ability to track and manage all processes from a single screen or software, workflow integrity is ensured. This standardized approach fosters transparency in process operations and enables real-time tracking under purchasing rules (Uluç, 2022). In addition, smart contracts offer benefits like immutability, decentralization, transparency, self-execution and verifiability of agreements, simplifying audits and facilitating timely alerts (Mircea et al., 2022).

2.4 Main enablers of applying emerging technologies in public procurement

It is crucial to discuss the adoption of emerging technologies in public procurement rather than just their implementation, as the entire stakeholder ecosystem needs to embrace these new solutions, integrate them into their processes and ultimately become more productive. Particularly in public procurement, it is essential to establish oversight and enforcement mechanisms that are transparent to the public. This legitimacy certification will foster adoption through awareness training and ongoing rational reforms, shaping the relationship between technologies, organizational structures and people (Mavidis & Folinas, 2022).

The adoption of emerging technologies require more than just funding, it also needs actions like legislative changes, upskilling or reskilling human resources, reengineering processes, re-evaluating culture and information architecture in organizations. Like any other change process, success depends on a coordinated effort to achieve clearly defined objectives to develop a smart public procurement system (Mircea et al., 2022) Integration of Industry 4.0 technologies in procurement needs a holistic approach that encompasses organizational change management, technological investments and ongoing learning (Althabatah et al., 2023).

2.4.1 Data management

A study published by European Commission concluded that a critical factor enabling various emerging technologies is data management. Effective data management practices are essential for providing high-quality training data for AI and ML projects, ensuring the integrity of data sources for BD and data analytics initiatives and delivering standardized data that RPA tools can effectively process. Furthermore, blockchain technology has been identified as a potential facilitator of data management, offering the technological infrastructure for establishing a trusted single source of data (European Commission, 2020).

Data is also an important factor that organizations must carefully address in terms of data security, privacy, regulatory conformity and interoperability when adopting new technologies. The potential risks associated with heightened reliance on digital systems, including cyber threats and data breaches, must be carefully managed. Robust risk management strategies and investments in cybersecurity measures are essential to mitigate these risks effectively (Althabatah et al., 2023).

It is crucial to consider how and where data is gathered and processed. Emphasize is on the importance to enable cross-functional use and avoid data silos (Spreitzenbarth et al., 2024). A comprehensive 360° data vision should be adopted to ensure effective data utilization. This involves not only creating a data strategy but also establishing fundamental principles to foster a common view on data collection, management, governance and use (Ubaldi et al., 2019).

Aside from effective data management, according to research by OECD, four key sets of factors were identified that facilitate the adoption of emerging technologies in the public sector. These are described in more detail in following sub-paragraphs 2.4.2-2.4.5.

2.4.2 Public sector commitment

Public sector commitment particularly concerns political support, alongside cultural dedication to innovation and reforms, creativity among civil servants and a robust legal framework. Implementing emerging technologies in the public sector requires a shift in mindset, skills and leadership to ensure commitment to sustainable and inclusive digital

transformation. Crucial requirement is the need to gain support from internal stakeholders and users. This need becomes particularly evident in larger-scale projects, where securing funding, obtaining approval from IT security personnel and fostering widespread adoption of the solution across the organization are essential (Ubaldi et al., 2019).

To foster innovation in the public sector, it is important to incentivize change and embrace uncertainty. This involves revising incentive systems to value learning through trial-and-error and integrating experimentation into performance evaluations. It should be encouraged to conduct structured experiments that balance risk-taking with stability and value-for-money. These efforts will nurture a culture of continuous improvement and innovative thinking in public sector. Pragmatic risk-taking also helps to gain political support as differentiating less risk-averse areas from others allows for value-for-money decisions. Moreover, granting more autonomy for experimentation at the local level before scaling up nationally enables learning from successful outcomes (Ubaldi et al., 2019).

In addition, regulatory adaptations are needed to address modern technological challenges, including safeguarding personal data, enhancing cybersecurity and mitigating the risks of corruption and discrimination. One of the recommendations is to establish certification protocols to ensure end users hold ultimate responsibility for controlling and operating electronic procurement tools (Mavidis & Folinas, 2022). It is crucial to prioritize regulating process and outcomes rather than dictating specific systems. Regulations that are overly reliant on technology may become stagnant and struggle to adapt to the rapid pace of technological advancements (Ubaldi et al., 2019).

2.4.3 Partners engagement

Partner's engagement involves both the private sector as technology providers or co-developers and various other stakeholders in the ecosystem (Ubaldi et al., 2019). The expertise and knowledge of procurement managers play a vital role in the adaptation process. They are tasked with not only expanding their own knowledge but also educating and aligning internal and external stakeholders with the new digital platforms, tools and practices (Uluç, 2022).

Another important factor is supplier integration, achievable through the implementation of shared resources and platforms for managing and distributing data. By leveraging the expertise of various suppliers, AI can encourage collaboration and knowledge sharing (Uluç, 2022). Collaborating with technology vendors, industry partners and research entities can facilitate not only knowledge exchange, but expedite the adoption and implementation process of emerging technologies (Althabatah et al., 2023).

Smart collaborations can enhance technological expertise and knowledge to improve efficiency and reduce costs. The intense competition among global clusters may secure the best partners for implementing digital technologies and enhancing profitability. However, building such collaborations and alliances is challenging, as companies require suitable infrastructure and technologies for effective communication and alignment with AI-driven requirements. Another promising avenue for improving efficiency in supply chain and procurement is through crowdsourcing which enables discover new supply markets, exchange ideas with experts and monitor supply chain trends (Uluç, 2022).

2.4.4 Technological maturity

Technological maturity is characterized by a vibrant academic environment fostering creativity, the presence of innovation hubs and advanced research institutions (Ubaldi et al., 2019). Authorities should restructure management frameworks, fostering collaboration among departments and stakeholders without silos or exclusions. Public administrations and suppliers should cultivate a culture of cooperation and knowledge exchange to foster innovation adoption (Mavidis & Folinas, 2022).

An agile approach, focusing on short, iterative sprints, proves effective for digital project delivery. Organizations can start modestly, selecting one or two solutions and prioritizing projects based on impact, cost and implementation speed. Subsequently, they can swiftly validate selections through quick results, promote successes to build momentum and foster a culture of procurement innovation and ongoing enhancement (Deloitte, n.d.).

Legacy of existing systems and platforms is a different challenge and it is a critical decision when the management decides to invest and integrate with new systems and different platforms. To transform and fully digitalize the procurement process, there

needs to be a structured plan and investment decision (Uluç, 2022). The integration of various technologies might present compatibility challenges and require adjustments in organizational structures and procedures. To maximize the potential of emerging technologies in procurement, organizations should develop a comprehensive strategy that aligns their strategic goals with technology adoption. This strategy should take into account factors such as organizational culture, stakeholder involvement and change management (Althabatah et al., 2023).

To overcome some of the challenges during the transition to new technologies, one of the enabling factors is to strategically integrate legacy applications with emerging technologies, ensuring seamless data input and output. Also to design user-friendly applications, allowing users to understand how algorithms work in these decision-making processes (Mavidis & Folinas, 2022). Procurement leaders often grapple with devising a digital strategy amid existing legacy investments. However, both maturing and emerging solutions can cater to an organization's current maturity level. For those with minimal investments, a leapfrog approach allows value to be found in solutions that bypass certain core technology investments. Moderate investment levels can be supplemented with targeted investments to fill gaps and enhance value from existing infrastructure. Even organizations heavily invested in legacy technologies can leverage emerging solutions to boost procurement team performance (Deloitte, n.d.).

2.4.5 Education and societal readiness

The population's digital literacy, expertise and acceptance of emerging technologies among public servants and the level of digitization gauge education and societal readiness across different societal sectors (Ubaldi et al., 2019). Transitioning from traditional tools and platforms to new digital technologies necessitates not just structural adjustments but also a significant level of adaptation among all relevant stakeholders. Digital technological awareness is still evolving and greater dissemination within organizations is essential to promote the adoption of these technologies that enhance procurement efficiency (Uluç, 2022).

Public sector staff and management are pivotal for driving innovation, yet efforts to develop, motivate and deploy internal talents are often insufficient. Digital capabilities

and awareness of technology's impact are generally lower in the public sector, exacerbated by an aging Baby Boomer workforce. Some countries face acute personnel challenges while others grapple with overburdened staff handling mundane tasks (Ubaldi et al., 2019). While Industry 4.0 technologies offer automation and efficiency improvements, they should be viewed as tools to enhance human capabilities rather than entirely replace human involvement. Prioritizing the development of digital skills, along with providing training and support, is crucial to ensure the successful adoption and utilization of these technologies. The integration of digital technologies can profoundly influence the procurement profession, leading to shifts in job roles, skill demands and supplier dynamics. Procurement professionals must be ready to adapt and embrace ongoing learning to stay relevant in the era of Industry 4.0 (Althabatah et al., 2023).

Public managers should inspire and motivate staff by articulating a clear vision and documenting the rationale behind technological choices, while also investing in staff training and development (Mavidis & Folinas, 2022). Resistance to change in the public sector stems from various factors, including fear of failure or job displacement due to automation and disintermediation technologies. Technologies like blockchain, with their radical transparency, can expose errors and incompetence, further fuelling resistance. Addressing the fear of being replaced by technologies and implementing proper strategies to handle potential employment implications of automation is crucial, as they reshape work dynamics (Ubaldi et al., 2019).

In addition, technologies come with their own set of individual prerequisites that needs to be taken into consideration. For example, it has been identified that an organization is suitable for automation with RPA if it meets certain criteria (Viale & Zouari, 2020):

1) “Clear rules as robots require rigid instructions to function effectively;
2) Limited exception handling as processes with many exceptions may not be suitable for automation and are better handled by humans;
3) High and predictable volumes. Although stability is not necessary, predictability helps control average volume and performance;
4) Operating in a stable environment. If the environment is unstable, robots may need frequent reconfiguration;
5) Access to multiple systems. IT systems facilitate faster navigation between systems compared to humans, reducing labor costs and processing time;

6) Known costs by considering the standard unit of time or average handling time for human execution."

2.5 Main barriers of applying emerging technologies in public procurement processes

The adoption of Industry 4.0 technologies in procurement is accompanied by challenges that organizations must handle. Issues such as data privacy and security, the necessity for upskilling and reskilling the workforce and the synthesis of legacy systems with new technologies pose significant hurdles. To realize the full potential of applying new technologies in public procurement processes, organizations must develop robust strategies to address these challenges effectively (Althabatah et al., 2023).

According to research by OECD, three main types of barriers were identified that hinder the adoption of emerging technologies in public sector organizations (Ubaldi et al., 2019). These are described in more detail in following sub-paragraphs 2.5.1-2.5.3.

2.5.1 Technical and practical challenges

Technical and practical challenges are about the availability of quality data, the interoperability of different IT systems, the absence of common standards and inadequate infrastructure (Ubaldi et al., 2019). Important prerequisite revolves around access to high-quality data, especially in AI, ML, BD, RPA and data analytics. Furthermore, AI and ML projects demand structured training data as a fundamental requirement (European Commission, 2020).

Assessing the readiness of infrastructure for digital technology implementation is another challenge. Adopting certain technologies may necessitate a complete overhaul of infrastructure to ensure compatibility among various data platforms across different functions. Despite the anticipated enhancement of procurement workflow alignment with other organizational divisions, it is hindered due to the concern about the unknown initial investment and operating costs (Uluç, 2022).

The development and upkeep of AI systems require the involvement of various stakeholders throughout the process. With multiple actors making decisions at different stages of the AI lifecycle, identifying a specific decision responsible for any adverse outcome can be challenging. This complexity extends beyond the responsibilities within public entities, making it difficult to pinpoint a single cause for potential harm arising from AI systems. These systems are employed to analyze extensive datasets for tasks such as predictions, recommendations, classifications and decisions. However, the complexity of these datasets and advanced AI techniques can render the systems incomprehensible or non-functional, leaving developers and users uncertain about specific outcomes. Furthermore, certain technologies enable AI models to continually learn from new data and user interactions, leading to evolving situations and potential adversarial attacks on the system, even if the original model is well understood. (Bansal & Jain, 2023).

Occasionally lock-ins are mentioned as potential risk and hindering factor when organization has developed solution relies on different types of proprietary technology. In addition, in some cases there is hesitation and resistance about granting bots access to their IT environments, fearing unforeseen actions (European Commission, 2020).

2.5.2 Resource and capacity constraints

Resource and capacity constraints include the low digital literacy in society, the lack of specific skills within public administration, insufficient training and insubstantial investment and funding (Ubaldi et al., 2019). One of the major barriers occurs when procurement department lacks recognition as a strategic entity and support from top management in terms of work force and financial resources to implement emerging technologies. Instead management prioritizes short-term cost reductions, failing to perceive the immediate or long-term benefits of adopting emerging technologies (Saw & Khuan, 2019).

While the adoption of new technologies is anticipated to improve the overall workflow of procurement, many organizations remain cautious due to the uncertain initial investment and operating costs. Implementing certain technologies in procurement may necessitate a complete overhaul of infrastructure to ensure compatibility among different data platforms across various functions. This could entail the supply of digital tools and

significant investment (Uluç, 2022). Even if the costs are known, it could still prove to be challenging as it is either too expensive to implement or there are no tangible immediate benefits (Saw & Khuan, 2019).

Another risk highlighted is the limited expertise and knowledge available due to the "emerging" nature of the technology being used. This lack of understanding contributes to uncertainties regarding expected outcomes (Deloitte, 2020). Significant challenge also revolves around digital literacy, particularly concerning the operational integration of these technologies to enhance procurement processes. Many stakeholders and employees have not fully recognized the processes, objectives and overall value of these new technologies (Uluç, 2022). Both training data scientists in procurement processes and educating procurement professionals in data science could pose challenges. Research has shown that data scientists may not have interest in specializing in procurement, while procurement professionals may find data science and emerging technologies daunting. Moreover, the high turnover rate among procurement professionals poses another obstacle to talent development. This is exacerbated by the need for training and the learning curve associated with custom procurement software (Saw & Khuan, 2019).

2.5.3 Institutional, legal and cultural barriers

Inappropriate legal and regulatory framework, defiance to change, intolerance for failure, lack of political commitment and stakeholder involvement constitute institutional, legal and cultural barriers (Ubaldi et al., 2019). Adopting new paradigms in procurement presents challenges in organizational engagement and cultural transformation. Engagement of stakeholders across functions is imperative and suppliers and manufacturers must also embrace the technology (Rejeb et al., 2018).

Public administrations frequently resist embracing innovations due to their aversion to errors and risks, which can hinder the adoption of technologies. This reluctance aligns with the concept that the integration of new technologies in public administration tends to occur gradually rather than through abrupt or radical changes (Boechat et al., 2023).

From the regulatory perspective, privacy and security risks are frequently identified as hindering factors in implementing new technologies (European Commission, 2020).

Privacy and confidentiality pose challenges blockchain applications, requiring a delicate balance between decentralization and privacy settings. While permissionless chains offer transparency and independence from central authorities, they also pose risks of personal data exploitation. One common solution involves storing identity information off-chain to safeguard confidentiality, but this compromises transparency and independent auditability, thereby undercutting blockchain's distributed trust advantages. Additionally, this approach may introduce a single point of failure and diminish the benefits of a distributed network, including system availability and reliability (Ubaldi et al., 2019).

A significant concern in data protection is the apparent conflict between blockchain technology and the General Data Protection Regulation (GDPR). This discrepancy primarily revolves around two key issues. Firstly, the absence of a designated data controller responsible for safeguarding individual rights as mandated by EU data protection legislation. Secondly, the inability to modify or erase recorded data, a fundamental feature of blockchain technology, directly contradicts the principles outlined in the GDPR. Another challenge arises from the inherent immutability of smart contracts, which may pose inconsistencies with the legal framework governing procurement procedures. Moreover, the lack of uniformity in evidentiary regulations and the varying interpretations by different judicial systems further complicate matters (Mircea et al., 2022). The absence of regulatory frameworks and governance standards hampers the advancement of innovative blockchain services beyond initial trial stages. Additionally, smart contract breaches may stem from either party or inherent flaws within the contract, such as coding or design errors. Current legal systems face challenges in assigning responsibility for damages caused by technology to end users, particularly in cases of contract flaw (Ubaldi et al., 2019).

A critical aspect of digital transition in the context of Industry 4.0 involves linking the digital, physical and human elements through networks, processes and data, which are then converted into knowledge and action. Recently, emerging technologies have shifted their focus from purely technical aspects such as linking devices and collecting data to connecting devices, data, organization goals, people and processes (Mavidis & Folinas, 2022). Figure 1 outlines the potential challenges and issues related to public procurement and gives an overview of the three main barriers clusters: technological, organizational and environmental context.

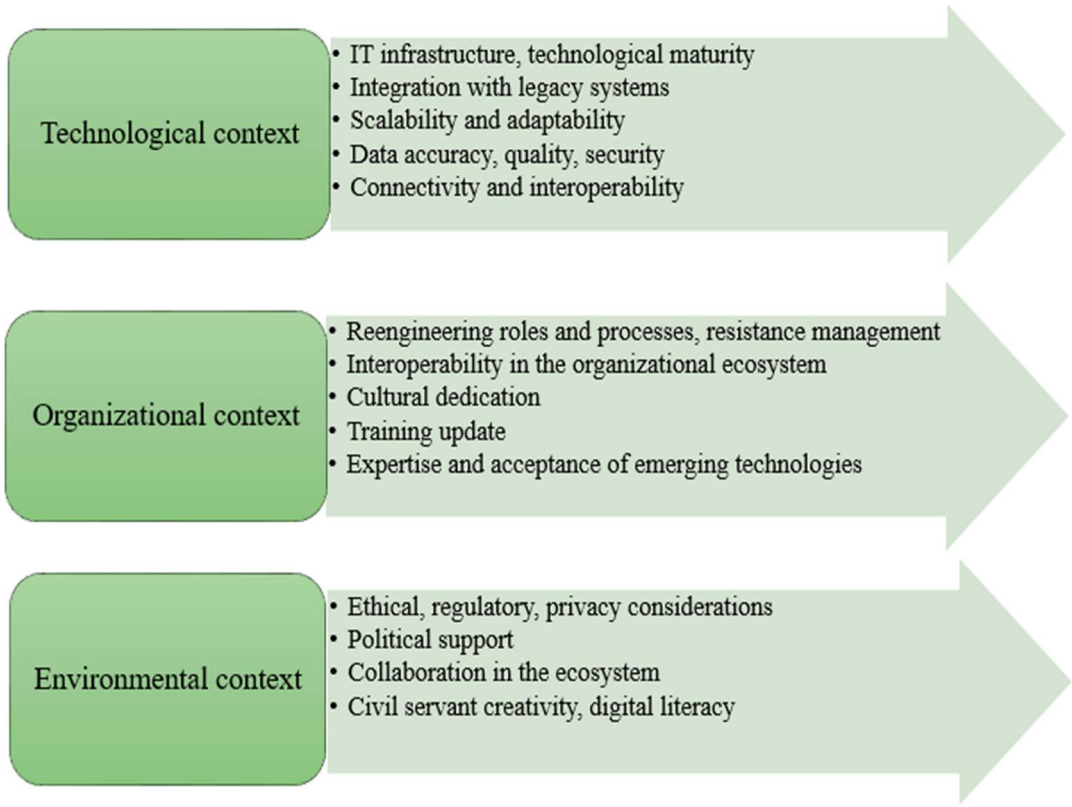

Figure 1 Challenges in technological, organizational and environmental context. Source: Author

The theoretical framework presents list of benefits, barriers and enablers in adoption of emerging technologies in public procurement. Despite these insights, there is a research gap in understanding the potential adoption of new technologies in Estonian context and whether perceived usefulness, ease of use and possible hindering factors match the list of benefits and challenges described in literature.

3 Research design and methodology

3.1 Research method and data analysis

Study aims to identify key barriers and motivation to adopt emerging technologies in Estonian public procurement and provide recommendations for next steps to enhance adoption of emerging technologies. A qualitative research method has been chosen to understand and explain social phenomena in their natural context as it explores the nature and meaning of experiences (Õunapuu L., 2014, 53). To understand challenges, benefits and enablers of adopting emerging technologies in Estonian context, the author opted for thematic data analysis. This involved establishing a set of codes derived from the theoretical background to identify common patterns and themes.

Technology Acceptance Model (TAM) model was chosen to draw up an interview guide for data collection. Introduction of new technologies in procurement triggers new dynamics among professionals, which can be best understood through TAM. This model, proven in prior research on information systems, suggests that individuals' intention to use new procurement solutions depends on perceived usefulness and ease of use. According to this theory, perceived usefulness and ease of use moderate the impact of external factors, like development process and training, on intention to use. Thus, TAM offers a clear framework to grasp the challenges of new technologies implementation in procurement, encompassing cultural, perceptual and technical barriers, as well as training needs (Guida et al., 2023). Original version of TAM (Davis et al., 1989) is presented in Figure 1.

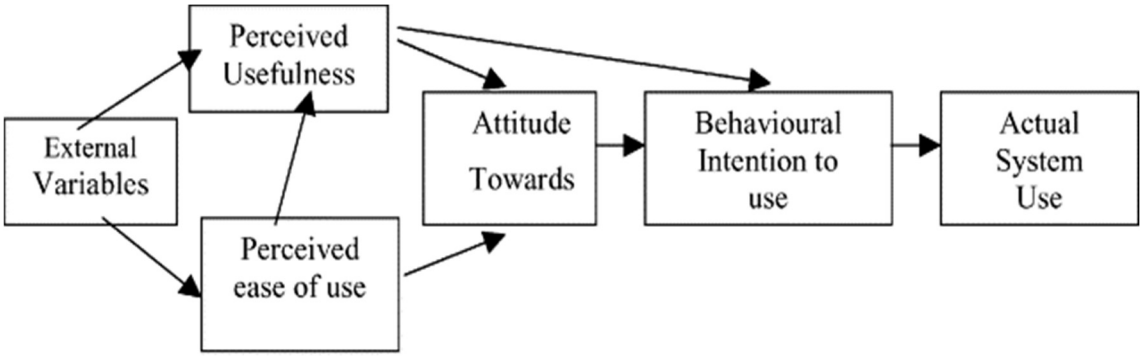

Figure 2 TAM model. Source: Davis et al., 1989

The study's design follows a thorough review of existing research literature to identify important theories, benefits, challenges and enablers on adopting emerging technologies in public procurement. The research then delves into the experiences of 9 high-ranking public procurement experts, from Estonian influential public procurement organizations. Data was collected through semi-structured interviews, allowing for in-depth exploration of participants' viewpoints and experiences with emerging technologies and their motivation and willingness in adopting and advocating emerging technologies within their respective organizations.

3.2 Sampling procedure and sample size

To conduct interviews, author selected most influential public procurement representatives based on the size and impact in the public procurement sector in Estonia. The sample has been selected using the following criteria:

1) Public procurer from top 4 largest sectors based on the number of procurement procedures and public procurement contract value in 2023 as shown in Figure 3:
    - Central government organization
    - Public entity
    - Network sector entity
    - Local government
2) Central Purchasing Body (CPB) in Estonia or represents centralized procurement (to some extent) in specific sector;
3) Experts have at least 3 years of experience in public procurement in total, including from different public procurement organizations and roles (legal, procurement, management).

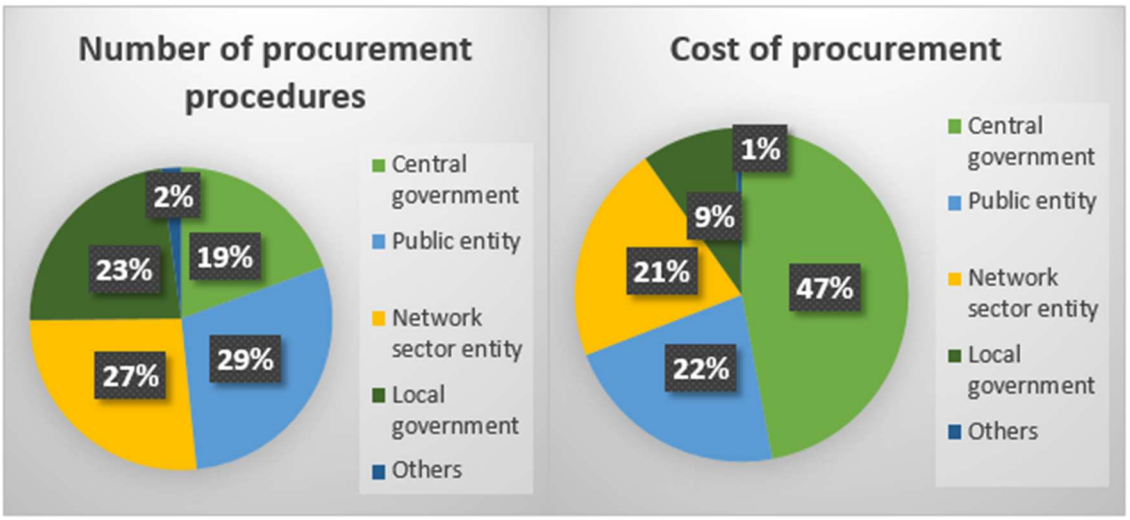

Figure 3 Number of procurement procedures and cost of procurement by type of procurement entity in 2023, Estonia. Source: Ministry of Finance in Estonia statistics infographics

The sample consists of 9 Estonian public procurers, including 4 central government organizations, 3 public entities, 1 network entity and 1 local government. The full list of the participating organizations and procurement experts can be found in Appendix 2.

4 Research results and data analysis

This chapter presents results from the 9 semi-structured interviews conducted with experts, specialists and managers representing number of Estonian most influential public procurers. All interviews were conducted as virtual meetings in Teams. An interview guide was drawn up based on TAM model. Results are presented in coded format: INT1, INT2, INT3 etc. Analysis focuses on identifying the Estonian perspective of potential adoption of emerging technologies in public procurement and developing recommendations based on the insights gained.

Next section is divided into 4 paragraphs where paragraph 4.1 opens the public procurement main principles together with description of centralized purchasing system in Estonian context. Paragraphs 4.2-4.4 focus on benefits, challenges and acceptance of emerging technologies from the perspective of Estonian public procurers.

4.1 Public procurement in Estonia

The field of public procurement in Estonia is governed by the Public Procurement Act and various regulations issued by the Government of Estonia. The Ministry of Finance oversees public procurement policy, including drafting legislation, providing consultation and supervision (Ministry of Finance of Republic of Estonia, n.d.). Public procurement refers to purchases conducted by the state or public sector buyers, following legal regulations. These purchases encompass goods, services or construction works Riigiportaal Eesti.ee, n.d.).

Estonia is one of the leading countries in conducting electronic public procurement. Information about procurement intentions and procedures is centralized in the Public Procurement Register, providing easy access for all stakeholders and serves as an innovative e-procurement platform for tender submissions and contract awards (Ministry of Finance of Republic of Estonia, n.d.). Details about concluded contracts and disputes are also available in the platform. The specific documentation requirements for each public procurement are outlined in the procurement documents (Riigiportaal Eesti.ee n.d.). Procurers define the specifications of the works, products or services, along with

the terms of reference and oversee the procedure of awarding public contracts (Ojandu et al., 2017). Main phases in the process of public procurement are presented in the Figure 4.

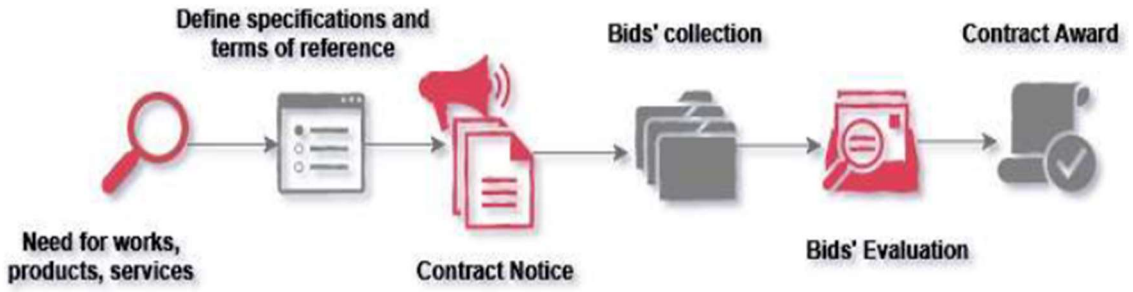

Figure 4 Main phases of public procurement. Source: Ojandu, et al., 2017

List of main activities in public procurement in Estonia based on Public Procurement Act (Riigihangete seadus. 2024):

1) Inserting procurement to procurement plan (over threshold procurements), publishing procurement plan (usually on organization's website)
2) Preparation of the procurement- conducting market research, needs assessment, drafting technical specification, setting qualification criteria and terms of reference, compiling and harmonizing procurement documents
3) Inserting procurement conditions and documents to the Public Procurement Registry (over threshold procurements)
4) Publication of the call for bids (contract notice) in the Public Procurement Registry
5) Questions and answers (QA-s) during the deadline for submission of tenders in the Public Procurement Registry
6) Submission of bids in the Public Procurement Registry
7) Opening of bids in the Public Procurement Registry
8) Verification of the absence of exclusion grounds and qualifications of bidders in the Public Procurement Registry
9) Verification of conformity of bids in the Public Procurement Registry
10) Asking clarifications from bidders (if necessary)
11) Negotiations (in case of negotiated procedure)
12) Evaluation and award of bids in the Public Procurement Registry

13) Award and signing of the contract
14) Contract award reporting in the Public Procurement Registry
15) Contract management
16) Contract performance reporting in the Public Procurement Registry

Most of the activities are carried out in the Public Procurement Registry, which has enabled digitization of procurement procedures and aggregation of procurement information in one platform in Estonia. According to conducted interviews, the Public Procurement Registry has been the most recent innovation in the public procurement sphere and emerging technologies are not in the scope of Estonian public procurers. Many procurers use Excel-tables and e-mails as their main tools to plan and collaborate with stakeholders. In some cases, there is software used which help to plan procurements, manage internal processes and disseminate information. However, based on the feedback from the interviews, the level of automation and interoperability between different systems and databases is rather low.

Aside from the implementation of Public Procurement Registry, legislation also gives another option for increased efficiency in public procurement – collaborating in joint procurement or establishing Centralized Purchasing Bodies (CPBs). Joint procurement means that buyers agree to collaborate, with one buyer conducting the procurement on behalf of others based on a mandate. CPBs are either purchasing supplies or services for buyers or award contracts for them (Ministry of Finance of Republic of Estonia, n.d.). Based on the feedback from the interviews, in Estonia, majority of procurement departments of CPBs finalize procedures by awarding contracts and contract management is handed over to buyers or field specialists in other departments. This means buyers order goods or services directly from the suppliers based on the contracts provided to them by CPBs.

CPBs bring along economies of scale and effective procurement management. Instead of tens or hundreds of procedures every year by different buyers, needs are collected into one procedure by CPB. This saves time and resources. Centralized procurement is especially beneficial for smaller buyers who may gain much better prices and discounts due to the large quantities involved. For example, the products offered by the CPBs are

up to 30% below the average market price. In Estonia, there are 7 CPBs which are appointed by the Estonian government. Local authorities may establish a central purchasing body based on the Local Government Organization Act (Ministry of Finance of Republic of Estonia, n.d.).

4.2 Potential benefits from the perspective of Estonian public procurers

In exploring the potential benefits of emerging technologies in Estonian public procurement, study delves into the insights of various procurement experts, revealing promising opportunities for efficiency, productivity, quality enhancement and savings. Based on the findings in theoretical framework, main benefits of the emerging technologies in public procurement are analyzed and presented in following sub-paragraphs based on seven categories: information, productivity, quality, savings, costs, safety, transparency, and accountability.

4.2.1 Information

According to conducted interviews, one of the most influential potential benefits of adopting new technologies is considered improved information management, which can lead to more efficient time management and procurement procedures. Most noted were solutions that would allow utilizing past experiences, linking expertise, lessons learnt, procurement outcomes from previous procurements in Estonia as well as in EU and overall gather information from different databases (INT1, INT3, INT4, INT5, INT6, INT8, INT9). This helps to strategically plan new tender procedures and use this knowledge in various actions throughout entire process, like writing justifications to protocols when asking clarifications from bidders (INT4) or finding needed information from previous QA-s between Ministry of Finance and other buyers (INT6).

INT1 noted that efficient information searching tools could be beneficial for bidders as well, for example avoiding unnecessary QA-s, as necessary information tends to be already in the procurement documentation. INT9 emphasized the ability to run through different databases and analyze vast volumes of datasets could be invaluable source for market intelligence. This potential benefit could be underrated, as most interviewed

organizations are CPBs, which often do not conduct market research themselves, but rather it is carried out by buyers they represent or by field specialist from other departments. It was also highlighted that in order to save time and resources, procurement data should be based on once-only principle via interconnected systems, programs and platforms (INT3, INT5, INT9).

4.2.2 Productivity

From the perspective of enhanced productivity in public procurement, several key themes emerged regarding the potential for efficiency gains through the adoption of emerging technologies and streamlined processes. Participants highlighted various automation possibilities for different resource-intensive repetitive tasks, like drafting technical specifications (INT6), verifying bidders' reference and exclusion grounds (INT2, INT4), bid analysis (INT1, INT3, INT6, INT7), managing and inserting data to Public Procurement Registry (INT4, INT6), answering QA-s and audit questions (INT1, INT2, INT3) or automate all repetitive tasks that are possible to automate (INT8). In order to streamline information dissemination, raise quality in stakeholder management and save time, new technologies could offer solutions for sending automatic updates to buyers they represent (INT3, INT5).

Interviewees offered automated document composition as potentially beneficial solution to save time for specialists. Technologies could draft templates together with guiding tips for less experienced specialists (INT1) and procurement documents together with contract drafts based on best practices and other sources of information (INT3, INT7). Even if public procurer has some experience with available tools that gather information for document drafting, there is room for improvement to enable searches and quality feedback in Estonian (INT7). Although automated document composition could be useful in general for all public buyers, there are number of organizations that already use standardized conditions, guidelines, templates and automated document drafting (INT1, INT4, INT5, INT8) and possibly therefore not in the focus of main benefits.

Most centralized procurement departments end its procurement cycle by signing contracts and handing it over to buyers they represent. However, in some cases where procurement department needs to monitor contracts and receive status updates in an ongoing basis,

tools for enhanced contract management are anticipated by buyers (INT5, INT7, INT9). In addition, INT9 highlighted potential automatic invoice verification and overview of deliveries to cut down manual work for stock management. To sum up, all of the interviewed experts marked one or several options that could potentially increase productivity in procurement procedures and as result lead to quality raise and savings.

4.2.3 Quality

Interviews revealed two underlying themes for highlighting the potential for improved outcomes and reduced risks through enhanced processes and automation. Firstly, there are possible mistakes and errors in the documentation that could be avoided or decreased to minimum. This could be done by reducing resource-intensive repetitive tasks (INT1, INT2, INT3, INT4, INT5, INT6, INT7), by drafting templates and pinpointing legal contradictions in procurement conditions (INT1), by providing automatic verification of documents and suggestions to pay attention to certain parts (INT3) and automating data insertion to contracts (INT7). In addition, opportunity for bidders to verify bids for missing data or errors before final submission could significantly raise quality of bids; avoid unnecessary clarifications and QA-s (INT7).

Secondly, interviews emphasized expectations that AI or other technologies could be most useful in terms of offering new ideas and guidance in procurement processes and help to plan procurements more strategically. This could be done by proposing better or new procurement conditions (INT3, INT8), standardized options to draw conclusions in the bid verification process (INT4), best practices and examples of evaluation criteria (INT7) and comprehensive market analysis together with the list of potential bidders (INT9). In addition, by drawing up all knowledge to one single source and analyzing the needs of the buyers in an ongoing basis, potentially could provide automatic suggestions by AI to when and how to plan new tender procedures (INT5, INT6). All interviewees note that these interventions could potentially save a lot of time for procurement specialists and raise the quality of procurement procedures.

4.2.4 Savings

Savings are generated by streamlining operations, automating repetitive tasks, minimizing errors, verifying documents, monitoring contracts and providing proposals for improvements. As described in previous sub-paragraphs 4.2.1-4.2.3, this is achieved through improved information management and raising quality and productivity in the procurement processes. It is important to understand that although interviewees are frequently emphasizing time savings, this also automatically correlates to cost savings as usually experienced procurement specialist has high hourly rate (INT1).

Examples that are more concrete include significantly speeding up decision-making process and announcing successful bidder, which could free up bidders' reference resources and they can compete more actively in the market. This will increase competition and potentially give better prices (INT2). In addition, competition could be boosted and savings gained by simplifying and enhancing entire procurement procedure, which allow bidders to make much more informed and quicker decision to enter competition. This has been already proven when introducing standardized documentation for same type of procurements and receiving higher number of bidders and lower prices (INT7). In cases where the bidders list changes frequently, it could drive competition and help to achieve better prices if possible bidders are automatically tracked and notified about possibilities to participate in the tender procedure (INT9).

4.2.5 Costs

Cost optimization includes pinpointing patterns and trends, identifying priority areas for optimization, forecasting demand, composing efficient strategic action plans and uncovering potential cost reduction. Majority of interviewed organizations' procurement departments receive need assessments and input for technical specifications from field specialists or from the buyers they represent. This also applies to stock management, execution of the contract and cost control. Therefore, it can be assumed that these potential cost-optimizing benefits are not in a high priority list for centralized public procurement and therefore not explicitly mentioned during the interviews. Only exception is INT9 organization that also owns and manages warehouse for stocks and has emphasized the benefits of having constant in-depth and updated knowledge from the market, stock situation and trends to discover cost reduction opportunities.

4.2.6 Safety, transparency and accountability

As safety, transparency and accountability were not explicitly mentioned in the interviews and due to their interconnected nature, they are grouped in one sub-paragraph. There could be number of reasons why these topics were not in the focus, including the overall constructions of interviews that focused on the current pain points and as a result most important potential benefits. In addition, this could derive from the possibility that interviewed organizations already have robust auditing systems and corruption measures in place and consequently problems occurring very rarely. Partly it is probably due to Public Procurement Platform that has brought high level of transparency and accountability to Estonian procurement procedures. However, from the perspective of having streamlined and transparent information flow, the importance to have consolidated platform to connect different systems was emphasized (INT3, INT5, INT9).

To conclude, interviews have confirmed the significant potential advantages of innovative tools and streamlined processes in various aspects of procurement. From effectiveness in information management to the gains in productivity, efficient tender procedures and substantial time savings. While interviews highlight potential immediate advantages of technological integration, there remain untapped potentials for hidden areas. Areas such as safety, transparency, and accountability, though not explicitly addressed in our interviews, represent areas that need further research.

4.3 Potential challenges from the perspective of Estonian public procurers

In exploring challenges facing Estonian public procurers in potential adoption of emerging technologies, study confronts the novelty of the topic and lack of experience presenting a barrier to envisioning concrete challenges. Based on theoretical framework, aim is to shed light on the technical, resource-related, institutional, legal, and cultural barriers that may impede the seamless integration of innovative solutions.

4.3.1 Technical and practical challenges

Technical and practical challenges revolve around quality, security and accuracy of the data, interoperability of different systems, legacy infrastructure and absence of common

standards. As databases and IT infrastructure usually concerns other departments and stakeholders aside procurement units, this can explain why interviewees mentioned listed challenges only in few occasions. INT5 and INT8 mentioned legacy systems and compatibility of existing systems as a possible hindering factor in adoption new technologies. Instead, interviewees concentrated on problems concerning capabilities of the new technologies. For example, INT6 pointed out language ontology issues and the need to teach AI to use Estonian language properly. It was considered difficult in the implementation phase. INT5 and INT2 expressed hesitation about data accuracy provided by AI. They discussed possibilities about AI providing misleading, incorrect information or its limited ability to recognize slight changes in the context of which inquiries are made. INT9 added that there are risks for AI manipulations and ways of teaching AI to produce content that distorts competition.

4.3.2 Resource and capacity constraints

According to conducted interviews, main challenges around resources are about having sufficient investments, budget and experts time to adopt emerging technologies. Interviewees have expressed concerns about having enough budget for implementation and maintenance of technologies or enough reasoning for substantial investments (INT5, INT8). INT8 has added that there has to be clear understanding of investment payback period and the amount of cost savings these interventions could bring.

All interviewees are positive about organizations and workforce willingness to adopt new technologies, including organizations' readiness to provide necessary trainings and knowledge during entire adoption period. Main concern is procurement specialists' time resources that tend to be critical (INT4, INT7). In addition, INT3 have highlighted issue that potentially could hinder adoption process in long-term as after some time specialists could become too reliant and trusting of the technologies and losing control over the accuracy of provided content over time. INT4 added a risk of losing procurement competencies over time resulting in inability to handle situations when technologies are not working properly.

4.3.3 Institutional, legal and cultural barriers

Public procurement is not simply purchasing process but activity regulated with very specific set of rules and requirements for buyers. Consequently, legal concerns need to be addressed if there are changes in processes. INT6 have noted that procurement experts need to foresee possible needs for legislative changes or other related issues before considering implementation of new technologies. Especially as legislative processes can be lengthy. In case of considering if and how much AI or any other technology can be implemented in the Public Procurement Registry, INT8 expressed the need to analyze it from the legal point of view.

Data protection and security issues are mentioned in cases where bids contain personal data and General Data Protection Regulation GDPR regulations apply. For example, if bids present list of references (INT2). INT9 added that technology most probably should not have access to all systems in organization. For example, from the perspective of data security and protection, restricted access to procurement specialist's e-mails.

Another concern that was highlighted by several interviewees was specialists' hesitation for adopting technologies from the perspective of accountability of specialists for the work done by technologies. This stemmed from the notion that full automation is not safe and that there has to be "human eye" checking all transactions (INT7), including automated answers in QA-s (INT3) or drafted procurement documents (INT1). Possible workforce resistance can occur if technologies are too difficult to adopt or out of fear of losing a job (INT3). INT7 added that the change cannot be abrupt and too fast and adoption have to be gradual. INT5 emphasized that any new technological solution has to be simple, logical, user-friendly and with clear benefits in order to be adopted. If introduced solution is more complicated than sending an e-mail, people will keep sending e-mails.

Harnessing the potential of emerging technologies in Estonian public procurement is fraught with diverse challenges. From technical hurdles surrounding data quality and security to resource constraints and institutional complexities, study has highlighted a spectrum of obstacles that demand careful consideration and strategic mitigation strategies. However, willingness and readiness of organizations to embrace change,

coupled with a commitment to providing necessary training and support, offer a promising foundation for progress.

4.4 Acceptance of emerging technologies from the perspective of Estonian public procurers

The primary aim of TAM is to track how external factors influence internal beliefs, attitudes and intentions. It proposes that perceived ease of use (PEOU) and perceived usefulness (PU) are the two critical factors in explaining technology use (Legris et al., 2003).

PU is summarized in paragraph 4.2 as potentially most influential benefits that Estonian public procurers envision based on current "painpoints" and assumptions that emerging technologies can bring change. PEOU was measured during the interviews by receiving feedback on ease of integration and potential training and support provided. All interviewees confirmed that their respective organization are rather or very prone to innovation and new solutions that bring efficiency and savings to work procedures. In some cases, interviewees described already existing solutions, like Planpro, Jira or in-house developed systems as overarching planning tools (INT5, INT7, INT8). Others gave examples of current developments for searching new innovative ways to eliminate duplicative tasks (INT1), to automate work procedures (INT2), to use AI to streamline processes (INT3), to connect the Public Procurement Registry and internal databases (INT4) or simply constantly looking for solutions to ease the workload and make procedures more efficient (INT6, INT9). In addition, INT3 and INT7 noted high interest in technologies and trying different AI- based solutions out of personal interest.

In addition, all interviewees validated their organizations readiness to provide trainings and support if new technologies or systems are implemented. This is solved in many different ways, including providing regular information days, seminars, trainings, guidelines or simply dedicated contact persons that provide guidance and help if problems occur. Based on described experiences, interviewees assumed that similar positive trend could apply to new emerging technologies and organizations are ready to integrate any solution that brings extra value. Once the decision has made and risks mitigated,

specialists are accustomed to embrace change and generally not afraid of new technological developments.

However, interviewees outlined the importance of regular practice and usage in order to be implemented successfully. Specialists handling 1-2 procurements a year are probably less motivated to learn new technologies to avoid making mistakes (INT1, INT6). Overall, majority of interviewees see themselves advocating new technologies in their organizations. However, in some cases, it was stressed that the first step is to carefully consider all impacts and put in place risk mitigation methods (INT5, INT8). In addition, it was added that based on experience, it would be more successful to start small, either step-by-step approach or pilot projects (INT3, INT7).

5 Conclusions and recommendations

5.1 Recommendations

Interviewed public procurers in Estonia have noted list of benefits as well as hindering factors for potential adoption of emerging technologies in public procurement procedures. To tackle these challenges, there are list of enabling factors identified from literature together with insights from the interviews that serve as a foundation for following recommendations to enhance acceptance and adoption of new technologies in public procurement organizations:

- Developing strategy

Developing a comprehensive strategy that aligns organizations strategic goals with technology adoption. Starting by selecting suitable technologies and evaluating their adoption taking into account following list of recommendations. There should be short-term plan for implementation phase together with long-term vision, which considers fast developments of new technologies.

- Mapping legal aspects

Mapping possible needs for legislative changes or other related issues before considering implementation of new technologies. Implementing measures to safeguard personal data, applying necessary restrictions for technology access to different systems and enhancing cybersecurity. Regulating process and outcomes rather than specific systems.

- Incentivizing change

Establishing incentive systems that value learning by conducting structured experiments that balance risk-taking with stability and value-for-money. Using either step-by-step approach or pilot projects before scaling up enables learning from successful outcomes and promote next interventions.

- Integrating legacy applications

Strategically integrating legacy applications with emerging technologies, ensuring seamless data input and output. Designing user-friendly, simple and logical applications. Considering language ontology issues.

- Budgeting

Reasoning the investment by considering various factors when budgeting for adoption of new technologies: implementation and maintenance costs, payback period and potential savings.

- Collaborating and motivating

Procurement managers expanding their own knowledge, aligning internal and external stakeholders, motivating staff by articulating a clear vision and the rationale behind technological choices, while ensuring investment into staff training and development. Training continuing after adopting technologies to maintain competencies over time with ability to handle situations when technologies are not working properly.

- Managing resistance

Implementing proper strategies to address fear of failure or replacement by technologies. Promoting vision of emerging technologies viewed as tools to enhance human capabilities rather than entirely replace human involvement. Clearly defining control measures and accountability of specialists for the work done by technologies. Critically evaluating procurement specialists time resources and availability to participate actively in planning and implementation of new technologies.

- Managing data

Adopting data strategy with a comprehensive 360° data vision to ensure effective data utilization and cross-functional use. Carefully evaluating the level of automation to ensure control over quality of content provided by technologies. Ensuring robust risk management strategies and investments, including mitigation of risks associated with heightened reliance on digital systems and losing control over time of provided content accuracy.

5.2 Discussion

This chapter provides a brief overview of the study analysis, which were presented in chapter 4. The choice of research method was guided by the objectives of the study, which shaped the design of the interview guide and the selection of interviewees. The interviewees' responses are summarised and main findings are presented.

To understand the underlying motivation and barriers to adopt new technologies in Estonian public procurement context, 9 semi-structured interviews were conducted with experts, specialists and managers representing number of Estonian most influential public procurers. Research found that although covering a number of biggest public buyers in Estonia, none of the experts had experience with emerging technologies in the context of public procurement. As a result, all feedback is based on perceived usefulness and challenges of technologies and actual experience with different technologies is missing. However, majority of interviewees expressed high interest towards new technologies and possibilities to enhance public procurement management. In some cases, experts have been exploring AI-based solutions out of personal interest, other cases organizations have introduced software like Planpro and Jira, which help to plan and organize procurement procedures. Overall, interviewees find their respective organizations rather tech-savvy, pro innovation and willing to adopt new technologies, including readiness to provide necessary trainings and knowledge during entire adoption period. This allows concluding that Estonian public procurement organizations' have innovative culture and mindset and has a good starting point for adoption of new technologies.

Research also showed that Estonian public procurers estimate raise in the quality of conducting procurement procedures, in productivity and in efficiency of information management as three most influential benefits in adopting emerging technologies. There is high interest to quickly and effectively find information, expertise and experiences of the past similar tender procedures and use this for better planning of new procurements. Also, to automate as much as possible, both in terms of repetitive manual tasks as well as composing documentation. Procurers expect AI and other technologies to help conducting procurement procedures by offering ongoing guidance, by helping notice mistakes and proposing new ideas. All of these enhancements are considered as key

sources for considerable time savings. Compared to findings from the literature, there is less emphasis on stakeholder and contract management as well as on safety, transparency and accountability. This can be explained, as CPBs in Estonia usually are not contract managers themselves but hand over the contracts to buyers for execution. In addition, most probably there are already robust measures in place against corruption, data breaches and other security issues and therefore not the most influential from current point of view.

In terms of potential challenges, research has found that the most hesitation is about giving the technology too much independence by fully automating as much as possible, like answering bidders' questions or composing procurement decisions. Interviewees emphasize the need to double-check everything with "human eye" and consider the value of technologies rather from the perspective of drafting and proposing solutions. Author finds this a contradictory finding, as the aim of emerging technologies is on machine-to-machine communication and automating as much as possible. In addition, there are concerns about potential required legislative changes, personal data risks, sufficient justification for investments, legacy systems compatibility and constrains for procurement specialists' time capacities. Procurers have also highlighted some of the aspects that are not found in the literature, like ontology issues or AI manipulations with the aim to produce content that distorts competition. In addition, some worrying long-term impacts, like specialists becoming too reliant and trusting of the technologies and losing procurement competencies over time.

To conclude, specialists have found potential benefits attractive and with substantial influence both in terms of enhancing efficiency and gaining better procurement outcomes. Challenges make an input for organizations to analyze potential impacts from different perspectives and develop strategy for risks mitigation. Experts have highlighted that it would be more successful to start small, either step-by-step approach or pilot projects.

5.3 Limitations and future work

Conducting the research, author has identified number of limitations. First, there is a sample size. Although majority of CPB-s, biggest public buyers in Estonia, were covered in interviews, it still represents limited portion of different positions and stakeholders in the system. For example, buyers that are represented by the CPB-s or managers of the organizations that are decision-makers for adopting new technologies. The second limitation is the scope of the research, which only considers Estonian situation. It could be very valuable to compare similar experiences and approaches in other countries. The third limitation is that the research did not find any actual experience of new technologies in public procurement in Estonian context, which means the actual impact of adopting emerging technologies is not studied.

Considering limitations, it can be concluded that future research needs to explore real-life experiences and best practices adopting emerging technologies, which could potentially give in-depth insights of the enabling factors along with gained benefits and lessons learnt. To increase the generalizability, future research must increase the number and scope of the interviews, both in terms of different stakeholders in public procurement life cycle as well as including experiences from other countries. Lastly, it could be beneficial to develop a roadmap for organizations with the desire to adopt emerging technologies in public procurement procedures.

5.4 Conclusion

This study explored the potential adoption of emerging technologies in public procurement by identifying key benefits, challenges and enablers. To have an overview of state of play, study analysed preparedness for adopting new emerging technologies in Estonian public procurement context.

The questions of the research were:

1) How to enhance adoption of emerging technologies in public procurement?
2) Why emerging technologies are considered in public procurement?
3) What are the main barriers and enablers of introducing emerging technologies in public procurement?

Study showed that there is list of emerging technologies, like AI, BD, IoT, blockchain, which can potentially significantly enhance the procurement procedures and gain better procurement outcomes. Results show that procurement experts perceive adoption of emerging technologies beneficial as they raise the quality of conducting procurement procedures, productivity and efficiency of information management. From gaining access to large amount data and information outside their own organizations to automating all repetitive tasks, AI is expected to enhance procurement management by speeding up decision-making processes, planning and executing procurement procedures. In terms of potential challenges, research has found that the most hesitation is about giving the technology too much independence by fully automating different tasks and losing control over the content. In addition, there are concerns about legislative requirements, personal data risks, sufficient justification for investments, legacy systems compatibility and constrains for procurement specialists' time capacities.

To address these challenges, author has compiled a list of recommendations based on list of enablers identified from literature together with insights from the interviews. Author proposes to develop a comprehensive strategy that aligns organizations strategic goals with technology adoption and maps all needed legislative changes. To efficiently plan adoption, author emphasises the need for strategic investment decisions, comprehensive budgeting, integration of legacy applications and strategy for data management. To

enhance the usage of new technologies, it is important to have tools to manage resistance, incentivize change and collaborate with different internal and external stakeholders.

The research contributes to the understanding of potential adoption of emerging technologies in the Estonian context, providing valuable insights for public procurement organizations to remain innovative. To make the change, in the era of digitization, technologies play a vital role. Study highlights potential benefits to advocate change and sheds light on potential barriers to be considered by decisions-makers when planning adoption of new technologies in public procurement. As there is still limited experience in the field of public procurement with emerging technologies, this framework can be also adapted outside Estonia.

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Appendix 2 – Interview guide

Subject	Explanation
Small talk	Welcome and thank you for the opportunity to conduct an interview.
Approval	The information from the interview is used only for this research and the recording will be deleted afterwards. Your name will not be used in the survey (anonymous reference to Interviewee 1, 2, 3 etc). Do you approve recording the interview? Agree: start recording.
Introduction (if needed)	Eveli Bauer, almost 20 years of working experience in the field of public procurement in the health sector, Master student in E-governance Technologies and Services (Taltech)
Research goal	The goal of the research is to give public organisations (procurers) insight about the potential to adopt emerging technologies into public procurement practises.
Estimated time	The interview takes about 1 hour. There are list of prepared questions but no limitations to how much time to discuss certain topic.
Questions	Are there any questions before starting the interview, if not, the recording starts.

Topic	Question	Aspects
Introduction	Could you introduce yourself?	Name Function Organisation Years of experience in public procurement Previous public procurement experience (before current organization)
Knowledge Experience	Could you briefly describe your knowledge/ experience with emerging technologies in the context of purchasing processes?	Emerging technologies: Robotic Process Automation (RPA) Internet of Things (IoT) Big Data (BD) Artificial Intelligence (AI) Machine Learning (ML) Blockchain/smart contracts

Interview guide 1 (expert has to some extent previous knowledge/ experience about emerging technologies)		
Perceived Usefulness (PU):	Improvement in efficiency: How do you believe the emerging technologies would impact the efficiency of public procurement processes? Impact on cost savings: How do you believe emerging technologies would impact the outcomes through public procurement? Do you perceive the technology as a means to achieve cost savings in public procurement? Enhancement of transparency: How do you think emerging technologies would impact transparency and accountability in public procurement procedures?	Planning Tendering Contract management Higher competition Better prices Quality/price ratio Streamlining operations Reducing administrative overhead Data in supply chain Contract management
Perceived Ease of Use (PEOU):	Ease of integration: How easy/ difficult do you think it would be to integrate the emerging technologies with existing procurement systems or workflows? How easy/ difficult do you think it would be to learn how to use emerging technologies for carrying out procurement tasks? User-friendly: How do you believe emerging technologies would impact daily procurement procedures for procurers? Would it simplify or make it more difficult, how? Training and support: Do you feel that the necessary training and support would be provided to facilitate the adoption and usage of the technologies within public procurement organizations?	Compatibility issues Data security concerns Interoperability with other organizational tools and platforms
Behavioural Intention (BI):	Willingness to adopt: *Would you be willing to use emerging technologies in your day-to-day procurement activities?* Intent to advocate: How likely are you to recommend the use of emerging technologies to your colleagues in public procurement?	

	Do you foresee yourself actively advocating for the adoption of emerging technologies within your organization? Commitment to implementation: How committed you foresee yourself to ensuring the successful implementation of the technology within your procurement department or organization?	
Actual Use (AU):	Current usage: Have you already used the technology in any procurement-related tasks, and if so, how frequently? Motivation to Adoption: What was the main motivation (enablers) to start using the technology? Barriers to Adoption: What challenges, if any, have you encountered before starting to use and in using the technology, and how have these influenced your actual usage? Perceived Impact: What benefits or drawbacks have you observed from using the technology in your procurement activities?	

Interview guide 2 (expert has no previous knowledge/ experience about emerging technologies)		
Brief description of emerging technologies in the context of public procurement		
Description	Could you describe typical routine tasks and workflows within the context of public procurement process?	Planning Execution Contract management
Pain points	What are the main challenges or pain points you encounter in your procurement tasks?	Repetitive manual tasks Time-consuming processes Areas where errors commonly occur

Perceived Usefulness (PU):	Improvement in efficiency: How do you think emerging technologies, such as advanced data analytics or automated procurement systems, could help to automate or streamline these routine tasks? Impact on cost savings: What benefits do you envision emerging technologies bringing to public procurement, such as improved efficiency or cost savings?	Time savings Cost reduction Improved accuracy
Perceived Ease of Use (PEOU):	Ease of integration: How likely do you think it is that emerging technologies could be integrated with existing procurement systems and workflows? Is your organization open for innovation? How easy or difficult do you think it would be for you and your colleagues to learn how to use these emerging technologies for procurement tasks? User-friendly: How do you believe emerging technologies would impact daily procurement procedures for procurers? Would it simplify or make it more difficult, how? Training and support: Do you anticipate that the necessary training and support will be provided to help you and your colleagues adopt and use these technologies effectively?	Compatibility issues Data security concerns Interoperability with other organizational tools and platforms
Behavioural Intention (BI):	Willingness to adopt: Would you be open to using emerging technologies in your day-to-day procurement activities? What concerns or obstacles do you foresee in adopting these technologies within your organization? Intent to advocate: Do you see yourself actively advocating for the adoption of emerging technologies within your organization? How likely are you to recommend the use of emerging technologies to your colleagues in public procurement?	

Subject	Explanation
Ending	The end of the interview is declared.
Check	Check if there are any comments, additions or questions as result of the interview.
Thank	Thank interviewee for cooperating.
Conclusion	Stop recording.

Appendix 3 – Table of interviews

Code	Type of public procurer	Position	Interview method	Interview date
INT1	Public entity	Procurement expert	Video call	18.04.2024
INT2	Central government	Procurement lawyer	Video call	29.04.2024
INT3	Central government	Procurement specialist	Video call	29.04.2024
INT4	Public entity	Head of procurement department	Video call	30.04.2024
INT5	Local government	Head of procurement center	Video call	03.05.2024
INT6	Central government	Procurement expert/ Head of procurement	Video call	02.05.2024
INT7	Central government	Head of legal team/ procurement specialist	Video call	02.05.2024
INT8	Network sector entity	Head of procurement department	Video call	30.04.2024
INT9	Public entity	Procurement specialist	Video call	07.05.2024

Appendix 4 – Links to semi-structured interviews

Link to the coding file:

https://docs.google.com/spreadsheets/d/1erODiZkFcFEL4vQUVTkklJm2lmiYMcpW/edit?usp=drive_link&ouid=112987495610605158533&rtpof=true&sd=true

Link to interview recordings:

https://drive.google.com/drive/folders/1izzEhJIvs5uZ5VXCjtxEHCxK4fCYduLw?usp=drive_link

Link to the transcribed interviews:

https://drive.google.com/drive/folders/1cLIDbj6iVTvwnWTxexPBolBnDmHnvwL7?usp=drive_link