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**Procurement 4.0: Investigating AI adoption for
Intelligent and Resilient Supply Chains**

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ABSTRACT:

The thesis investigates the adoption of AI technologies in procurement of large project-based companies to evaluate their effectiveness in minimizing project disruptions and enhancing supply chain resilience. The study is motivated by the critical impact that supply chain disruptions can have on the supply chain procedures, which in turn affects economic stability, environmental sustainability, and social well-being. This research explores established AI solutions and assesses the internal and external business environmental factors which hinder the adoption of these solutions. The central research problem addresses the shortcoming in technology adoption that can improve the resilience of complex supply chains. The theoretical basis of the study draws on concepts from supply chain resilience, artificial intelligence, procurement and business environment factors. A qualitative research methodology is employed, utilizing open-ended questionnaire for interviews with supply chain managers, project managers, and technology experts. Focus group interviews, complemented by an analysis of industry trends and academic literature, serve as the main approach for data collection. The findings highlight how AI can improve procurement processes and operational responsiveness, which are crucial for minimizing disruptions and optimizing supply chain performance. The study identifies challenges in AI adoption and strategies to integrate AI technologies into the supply chains and procurement processes of project-based companies. In addition to these findings, the study reveals that the successful integration of AI technologies hinges on strategic planning and adaptation to sector-specific challenges. It is demonstrated that existing technologies, when effectively implemented, can significantly mitigate risks associated with supply chain disruptions. The thesis underscores the potential of AI technologies studying in detail two applications i.e. IoT and Blockchain in monitoring procurement processes and mitigating cyber risks. Furthermore, Procurement Maturity Model is evaluated to study the current procurement status following its readiness and strategic alignment for AI adoption. Thus, the results highlight the ability of AI-driven systems to enhance real-time monitoring of supply chain operations, enabling organizations to respond swiftly to potential inefficiencies or risks. In conclusion, the research establishes that leveraging existing AI solutions, is essential for developing resilient supply chains in project-based companies with complex supply chain networks. This research thus provides a valuable foundation for future studies aiming to refine and expand the integration of AI in complex, high-stakes environments, along with shaping the future of SCM in global organizations.

KEYWORDS: Business Environment Factors (BEF), Artificial Intelligence (AI), Procurement Maturity Model (PMM), Supply Chain Resilience (SCR), Internet of Things (IoT), Blockchain

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List of Abbreviations

AI	Artificial Intelligence
AR	Augmented Reality
BEF	Business Environment Factors
CG	Capital Goods
DOI	Diffusion of Innovation
E2E	End-to-end
ERP	Enterprise Resource Planning
EPC	Engineering, Procurement and Construction
ETO	Engineer to Order
Gen AI	Generative Artificial Intelligence
GPS	Global Positioning System
GSM	Global System for Mobile Communications
ICS	International Chamber of Shipping
IoT	Internet of Things

IMO	International Maritime Organization
JIT	Just-In-Time
ML	Machine Learning
NFC	Near Field Communication
NLP	Natural Language Processing
O&G	Oil and Gas
P2P	Procure to Pay
PMM	Procurement Maturity Model
RBV	Resource-Based View
RFID	Radio-Frequency Identification
R&D	Research and Development
ROI	Return on Investment
SC	Supply Chain
SCA	Supply Chain Agility
SCFS	Supply Chain Financial Security
SCI	Supply Chain Integration
SCM	Supply Chain Management
SCR	Supply Chain Resilience
TAM	Technology Acceptance Model
TOE	Technology Organization Environment
UNCTAD	United Nations Conference on Trade and Development

1 Introduction

In the rapidly evolving landscape of global supply chains, unique challenges arise in capital projects due to complex logistics and high stakes in project delivery timelines and costs. Disruptions, often caused by inefficiencies in supply chain processes or unforeseen external factors, can lead to significant economic losses and impact societal and environmental aspects. The advent of digital technologies offers a promising avenue to enhance the resilience of supply chains, making them more capable of withstanding and recovering from such disruptions. The thesis studies the adoption of AI technologies in procurement to enhance resilience in supply chains and optimize procurement processes. Through empirical analysis and case studies, this study provides insights into the role of AI in strengthening procurement strategies in capital goods delivery projects.

1.1 Background, Purpose & Structure

Supply chain resilience has become a critical focus in modern industries as organizations seek to mitigate risks and ensure continuity in the face of disruptions. Capital projects or ETO projects are known for complex and large-scale procurement processes, long lead times, and fluctuating demand patterns, requiring effective strategies to address unique challenges. In recent years, Artificial Intelligence (AI) has emerged as a transformative force in supply chain management, offering tools to enhance operational efficiency, supplier management and predict disruptions (Ponomarov & Holcomb, 2009; Negri et al., 2021). Technologies such as machine learning algorithms, predictive analytics, and automated decision-making systems have reduced long lead times and helped in predicting fluctuating demand patterns. For instance, in manufacturing, AI-powered collaborative robots, or "cobots," work alongside human operators to handle repetitive and physically demanding tasks, thereby streamlining operations and reducing costs (AI's Impact on Major Industries, 2024).

The purpose of this study is to examine the role of AI and advanced procurement technologies in enhancing supply chain resilience. The study will explore how modern AI technologies can be implemented to improve the efficiency and robustness of supply chains at the procurement stage for on-time delivery of capital goods. The study will address the existing research gap by evaluating the implementation and effectiveness of these technologies, focusing on two categories: cybersecurity and monitoring systems. The thesis will also study the latest technological trends in procurement, which have the potential to prevent project disruptions, ensuring greater reliability and efficiency in complex supply chains.

Table 1. AI industry applications (derived from AI's Impact on Major Industries, 2024).

Industry	Application	Benefits	Tools
Manufacturing	AI-powered cobots, quality control	Reduces downtime, improves efficiency,	IBM Watson IoT
Healthcare	AI diagnostics, robotic surgery	Improve accuracy, enhance patient care	Google DeepMind
Finance	Fraud detection, algorithmic trading, risk assessment	Minimize fraud, increase profitability	Falcon
Retail	Virtual shopping, dynamic pricing	Personalize shopping, optimal inventory	Amazon Forecast
Supply chain Logistics	route optimization, warehouse automation	Reduce cost, enhance resilience	Blue Yonder
Automotive	Self-driving technology, AI design	Accelerate innovation, enhance safety	Tesla FSD
Energy	Smart grids, renewable energy optimization	Reduce waste, improve sustainability	AutoGrid
Telecommunication	AI chatbots, network maintenance	Service quality, network efficiency	Nokia Bell Labs AI
EPC	Autonomous machinery, safety monitoring	Reduce delay, mitigate project disruptions	OpenSpace AI
Education	Adaptive learning, AI tutor	Personalize education, enhance learning	Coursera

While AI has the potential to transform industries, integrating it into existing systems remains a major challenge. Successful adoption requires a holistic approach that includes technological upgrades, enhanced data management, and organizational change management. These challenges are especially pronounced in manufacturing, where legacy systems and data silos obstruct seamless AI implementation. The complexity of existing processes and the need for a robust data infrastructure further complicate integration. Many companies also struggle with data collection, storage, and analysis due to outdated systems or the absence of a cohesive data strategy (Karim, 2024). Despite the growing body of research on AI in supply chains, there is limited focus on its practical implementation at the procurement stage for complex projects. This study aims to bridge this gap by examining how AI-driven procurement solutions can enhance supply chain resilience, offering actionable insights for industry stakeholders.

This study is organized into seven chapters. The first chapter provides the introduction, outlining the background, research objectives and questions, and the justification for the study. The second chapter presents the empirical study of the case study to explore the latest trends and regulations in current industrial practices. The third chapter, which is the literature review, covers the main themes of the study which are: supply chain resilience, procurement, which further discusses procurement maturity model, artificial intelligence which extends to two applications IoT and Blockchain and business environment factors discussing the internal and external factors that support or affect AI adoption. The fourth chapter explains the research methodology, detailing the data collection and analysis techniques. The fifth chapter presents the results and analysis of the data collected. Chapter six discusses the findings in depth and connects them to existing literature. Finally, the seventh chapter concludes the study, summarizing key insights and suggesting avenues for future research in AI adoption for procurement.

1.2 Research Objectives and Questions

The research aims to investigate the integration and application of AI technologies in the procurement stage and evaluate their effectiveness for enhancing supply chain resilience and procurement optimization. The study follows the following research objectives:

1. Explore the challenges faced in procurement processes.
2. Study the Procurement Maturity Model to assess the current state of procurement.
3. Investigate AI's potential (focusing on IoT and Blockchain) in supply chain processes.
4. Assess the readiness of organizations by studying the Business Environment Factors.

Based on the research objectives, the paper's research question is:

“How can AI technologies be adopted to enhance resilience in the procurement processes of capital goods delivery projects?”

To study AI use in procurement, the following secondary research questions will help explore the current challenges at the procurement stage, models and frameworks, and make recommendations for the implementation of AI tools in complex supply chains.

1. What are the current challenges in managing project disruptions at the procurement stage and what strategies are employed to address these challenges?
2. What is the current maturity level of Procurement processes?
3. How can AI (including IoT and blockchain) enhance resilience and intelligence in procurement?
4. What are the key business environment factors that affect the adoption and integration of AI in procurement and supply chain management systems?

1.3 Research Gaps

The following research gaps are identified through the study of existing literature on applications of AI in procurement for enhancing supply chain resilience.

1. **Limited Evaluation of AI in Procurement:**

While the role of AI in supply chain management is well-documented, there remains a lack of empirical research that investigates its impacts and integration in procurement practices specifically aimed at enhancing resilience in the capital goods delivery industry. This gap presents an opportunity to evaluate AI's practical potential in mitigating disruptions and improving procurement efficiency in complex projects.

2. **Sector-Specific Challenges Unexplored:**

Existing studies highlighted general procurement challenges in retail industry supply chains and have limited research in the capital goods industry. This study examines AI-driven solutions specifically designed to address the unique challenges in this sector.

3. **Lack of Integration Frameworks for AI in Procurement:**

Despite advancements in AI technologies, there is a lack of strategies for effectively adopting these technologies across various areas of expertise. This research aims to provide recommendations for integrating AI, based on the suggestions of participants. This can provide a roadmap for capital goods businesses to optimize their procurement processes.

4. **Inadequate Attention to Real-World Applications:**

Current research mainly focuses on theoretical models and general industry insights, lacking practical exploration of AI in procurement, especially in complex projects. By showcasing real-world AI applications through interviews with industry stakeholders,

this study will highlight how these technologies address specific procurement challenges, bridging the gap between theory and practice for industry relevance.

By addressing these gaps, the thesis offers practical insights that can contribute to both academic understanding and real-world application of AI in procurement operations.

1.4 Limitation & Justification

The primary limitation of this study is its specialized focus on the application of artificial intelligence within a specific stage of the end-to-end (E2E) supply chain, particularly the procurement stage. Therefore, it does not examine other stages of the supply chain, such as production or logistics. Moreover, the study will focus on the application of existing artificial intelligence and will not involve the development of new digital solutions. Furthermore, the study's exclusive focus is capital goods industry, which restricts its applicability to SME businesses or retail supply chains. The thesis focus on complex projects with capital goods delivery limits the applicability of results to projects that have different operational dynamics and supply chain characteristics.

This thesis responds to a critical need for specialized knowledge in AI strategies that can prevent disruptions and optimize procurement operations— in the context of capital projects where efficiency and reliability are paramount. With a background in Computer Science and ongoing studies in Strategic Project Management, I aim to explore how established AI technologies are being applied and aiding in mitigating project disruptions. The insights derived from this study will assist in formulating strategic interventions based on existing technologies, ensuring that they are not only theoretically sound but also practically proven, thereby offering substantial value to both academic research and industry applications.

2 Context of Empirical Study

This section delves into the empirical research, focusing on a case study-based analysis. The selected company is a well-renowned leader in the maritime solutions industry with diverse global suppliers and complex supply chain. The section explores the maritime supply chain or capital goods industry, focusing on the disruptions that occur during the procurement stage and their impact on project execution. It examines the challenges faced by the industry that affect the overall supply chain flow.

"Capital goods companies' profitability is now higher than before COVID-19. That is quite an achievement – the ability to hold on to price took many observers by surprise." — Sven Siepen (Gareth, 2024, p. 3). Following Sven's statement, Gareth added:

Winners are winning on two scores: First, they have managed to increase their invested capital by roughly 40 percent compared to 2020. And second, that puts them in a position to continue growing now, while others are struggling. (Gareth, 2024, p. 2)

The article from Roland Berger discusses the strong performance of the capital goods industry in 2023 despite economic challenges. It highlights how companies in this sector managed to achieve growth through strategic resilience and innovation. The following figure from the article illustrates the overall revenue development in the capital goods industry, showing a steady increase from 2017 to 2023. While there was a slight decline in 2020, revenue rebounded in subsequent years, reaching \$3.34 billion in 2023. The year-over-year growth rate also reflects this recovery, with a significant jump of 7.2% in 2021, followed by continued growth of 6.2% in 2022 and 4.9% in 2023. These figures indicate the industry's ability to maintain positive momentum despite past disruptions. In conclusion, the article emphasizes that the capital goods industry outperformed expectations, demonstrating resilience and steady growth in a challenging market (Gareth, 2024).

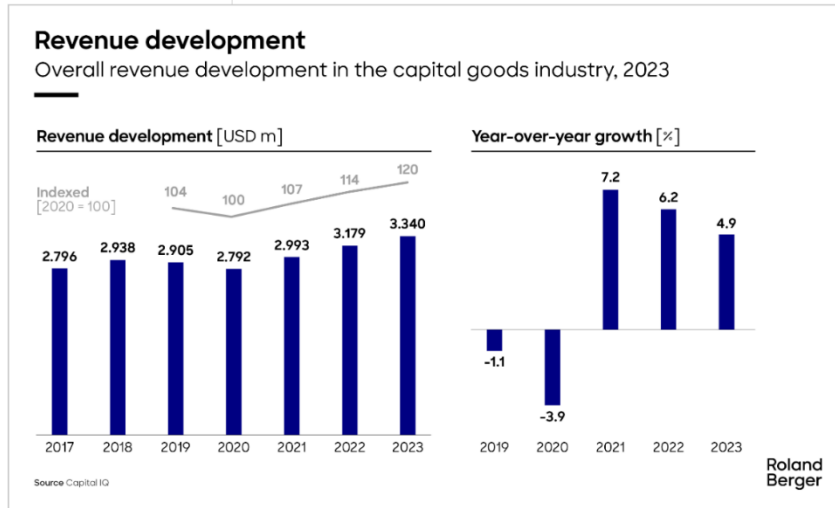


Figure 1. Revenue development in the capital goods industry (Berger, 2023).

The capital goods industry experienced a 4.9% top-line growth in 2023, overcoming challenges such as shrinking backlogs, supply chain bottlenecks, and geopolitical tensions. To sustain and enhance this momentum, companies are advised to prepare for six emerging industry trends over the next several years, focusing on innovation, digital transformation, and strategic investments. The sector is undergoing significant changes driven by several emerging trends, as highlighted by o9 Solutions. Digital transformation is at the forefront, with companies integrating technologies like AI, IoT, and big data analytics to improve operational efficiency and enable predictive maintenance. Sustainability is another key focus, with manufacturers adopting eco-friendly practices to comply with regulations and meet the growing demand for green products. Geopolitical factors are also influencing the industry, prompting firms to restructure supply chains, localize production, and diversify suppliers to mitigate risks. Additionally, economic fluctuations, such as the recent rise in U.S. core capital goods orders, indicate cautious optimism despite market variability. Lastly, increased competition from emerging markets is pushing companies to invest in research and development, fostering innovation and operational improvements (o9solutions, 2024).

2.1 Maritime Supply Chain (focusing on capital goods delivery)

The maritime industry encompasses all activities related to the transportation of goods and passengers by sea, including shipping, port operations, shipbuilding, and maritime services. It plays a pivotal role in global trade, facilitating the movement of approximately 80% of world trade by volume and over 70% by value (Review of Maritime Transport 2021, 2021). Guy Platten, Secretary General of the International Chamber of Shipping (ICS), emphasized this significance by stating, "Shipping is the backbone of the global economy, ensuring the uninterrupted flow of goods and commodities worldwide". As global population growth and trade volumes increase, the maritime industry continues to expand, highlighting its indispensable role in sustaining economic development. For an estimate, 11 billion tonnes of goods, equivalent to 1.5 tons per person annually, are transported by ships (ICS Leadership Insights Live, 2021).

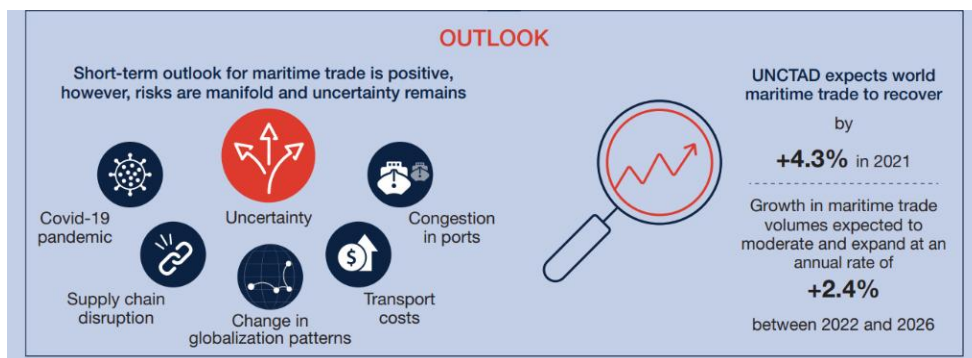


Figure 2. Review of Maritime Transport 2021.

The Review of Maritime Transport 2021 by UNCTAD provides an outlook on global maritime trade, highlighting both recovery prospects and ongoing challenges. The short-term outlook remains positive, but significant risks and uncertainties persist. Key challenges included disruptions caused by the COVID-19 pandemic, port congestion, and overall supply chain instability. Additionally, shifts in globalization patterns and rising transport costs contribute to the uncertainty in the industry. Despite these challenges, UNCTAD projects a 4.3% growth in global maritime trade in 2021, with an expected 2.4%

annual growth rate between 2022 and 2026. This indicates a moderate expansion in trade volumes, although market volatility and logistical constraints may continue to pose risks (Chapter 1, 2021).

Furthermore, the report provides an overview of the global shipping fleet and its evolving infrastructure. As of early 2021, the world fleet consisted of 99,800 ships with a total capacity of 2.13 billion deadweight tons (dwt). The global fleet grew by 3% in the year leading up to January 2021, with ships aged between 5 to 9 years representing the largest share of carrying capacity. However, ship deliveries declined by 12% in 2020, reflecting potential disruptions and industry challenges. Shipping companies are adapting to trade growth while addressing decarbonization targets by scaling up investments to expand fleet size and retrofitting or replacing existing vessels. The green transition is expected to bring structural changes, impacting fleet distribution, ship travel distances, routing patterns, vessel types, and overall maritime logistics costs. These shifts highlight the industry's efforts to balance sustainability goals with operational efficiency (Chapter 2, 2021, p. 2).

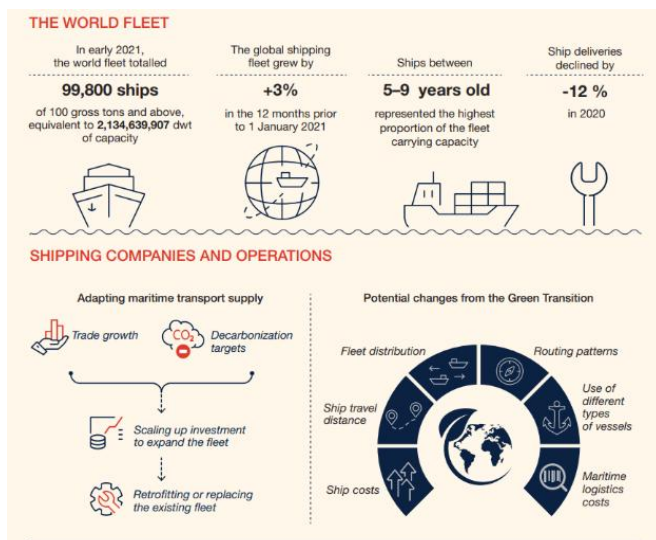


Figure 3. Review of Maritime Transport 2021.

The maritime supply chain is a complex and interconnected system, encompassing various players, infrastructure, processes, and stakeholders involved in the transportation, storage, and distribution of goods via sea routes. It involves sourcing raw materials like steel and aluminum, manufacturing components such as engines and propellers, managing the logistics of transporting these parts to shipyards and overseeing the assembly process (Nguyen et al., 2022). These materials are often outsourced from specialized suppliers, often located in different regions, making the supply chain operations complex and challenging (Heizer et al., 2017). SCM in the maritime industry requires seamless coordination between raw material suppliers, component manufacturers, and shipyards to meet production timelines and quality standards (Stopford, 2009). Given the complexity and importance, any disruption in the maritime supply chain can negatively affect global trade, economic growth, and commodity prices (Nguyen et al., 2022).

The supply chain faces several significant challenges, including the complexity introduced by product customization to meet specific customer requirements, which adds intricacies in sourcing, production, and delivery. The ongoing energy transition further complicates operations, as there is a need to balance traditional products with the integration of green technologies like batteries and hybrid systems. Supplier delays or disruptions can cause project setbacks and increased costs, while coordinating various components requires precise timing to ensure smooth assembly and delivery. Quality assurance remains critical, as all components must meet strict specifications. Additionally, the reliance on a global network of external suppliers adds vulnerability to disruptions caused by events such as pandemics or geopolitical tensions. With no in-house manufacturing, the supply chain depends heavily on supplier relationships, logistics, and quality control across diverse regions. Managing long lead times for essential parts, such as hybrid systems, further adds to the complexity, requiring meticulous planning and oversight. Effective risk management is essential to navigate these challenges and maintain operational resilience. (case company)

2.2 AI Adoption in the European Market & Finland

The adoption of AI across Europe is advancing at an unprecedented rate, with an average of five businesses integrating the technology every minute, as highlighted in AWS's latest annual report, "Unlocking Europe's AI Potential 2025." The report reveals that currently, 42% of European businesses are consistently utilizing AI, with over 90% experiencing increased revenue or enhanced productivity. This rapid expansion translates to nearly three million businesses adopting AI across the continent within the past year. Additionally, the proportion of European firms regularly leveraging AI has surged from approximately 33% in 2023 to 42% in 2024 (Amazon, 2025). Europe faces a high demand for AI and ML software development, driven by a skills shortage, growing awareness of AI's potential, and a push from businesses and governments to leverage these technologies. Companies are increasingly open to AI and ML adoption for seeing automation as a solution. However, Europe lacks enough AI and ML developers, leading firms to seek outsourcing partners. The market is expanding rapidly, with AI software expected to grow nearly 40% annually in Europe (2021–2028), closely following North America's 42% growth. According to an estimate, only 8% of European enterprises were using AI technology in 2021. Industry experts believed that this percentage would at least double by January 2023. In some industries, as many as 75% of European enterprises are now using AI technology. This is mainly due to the launch of ChatGPT in the autumn of 2022 (CBI, 2023).

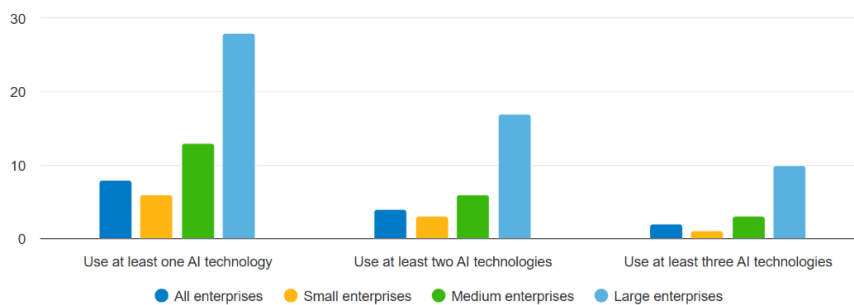


Figure 4. Enterprises using AI technologies in Europe, year 2021 (Sourced from CBI, 2023).

In recent years, Finland has made remarkable strides in integrating AI into business operations. According to a 2022 report by Silo AI, 35% of Finnish companies had adopted AI technologies, reflecting an increase from 31% the previous year. This upward trajectory underscores the growing recognition of AI's potential to enhance efficiency and drive innovation. Additionally, the Finnish government has taken a proactive approach to promoting AI integration. As noted in the European Commission's 2017 report, the Ministry of Economic Affairs and Employment introduced the national AI strategy, "Finland's Age of Artificial Intelligence," in October 2017, aiming to position the country as a leader in AI applications. However, despite these efforts, Finland continues to face challenges in fully adopting and integrating AI technologies into industry practices. A key obstacle is the shortage of skilled AI professionals—despite the country's strong education system, the demand for AI expertise surpasses the available talent pool, limiting companies' ability to develop and implement AI-driven solutions effectively (Aleksi Teivainen, 2021). Additionally, AI systems require high-quality data, but Finnish businesses struggle with data silos and strict privacy regulations, complicating data sharing and AI utilization (OECD, 2023). High implementation costs, including investments in technology, infrastructure, and training, make it difficult for SMEs—key players in Finland's economy—to justify AI adoption due to uncertain returns (Berger, 2023). Organizational resistance is another barrier. Employees fear job displacement, leading to reluctance in adoption (Aleksi Teivainen, 2021). Infrastructure limitations, such as connectivity gaps and inadequate computing resources, also restrict AI deployment in certain regions (OECD, 2023). Additionally, integrating AI into existing systems is challenging, requiring strategic planning and expertise to ensure smooth implementation. To overcome these obstacles, Finland must invest in education, foster collaboration, and develop policies that support AI adoption. By addressing these challenges, the country can strengthen its position as a leader in AI innovation (Khan, 2024).

3 Literature Review

"Supply chain is in the crawling stage of using artificial intelligence. In the next 5 years, AI will revolutionize supply chain in ways most people haven't even thought of yet." — Dave Waters, (Digital Supply Chain - Artificial Intelligence [@DavyWaters], 2025). This statement underscores the profound potential of AI to transform supply chains in today's businesses. As AI continues to evolve, its impacts are reshaping the procurement processes, enabling more efficient, agile, and data-driven decision-making within complex sectors. The literature review explores AI's practical applications, benefits and challenges, and provides insights into its transformative potential for procurement practices to enhance supply chain resilience in the capital goods industry.

The Theoretical Framework has been established by discussing four key areas:

1. SCR framework – SCR, Project disruptions & Challenges in implementing SCR
2. Procurement - Procurement Maturity Model.
3. AI – AI application focusing IoT and Blockchain, AI adoption strategies, opportunities and challenges.
4. Business Environment Factors: Internal and external factors to investigate the factors impacting the adoption and implementation of AI, studying the TOE framework to provide recommendations.

During the literature review process, numerous articles, studies, and research papers were analyzed, with careful consideration given to distinguishing valuable information from less relevant content. The evaluation criteria included quality, relevance, publication date, author credentials, alignment with the research topic, logical coherence, and other key factors. The selected literature was critically assessed to ensure that sources were reliable and high quality.

Table 2. Literature Sources (Created by the author)

Publications	Author	Publication Year
Building the Resilient Supply Chain	Christopher & Peck	2004
Understanding the concept of supply chain resilience	Ponomarov & Holcomb	2009
A Supply Chain View of the Resilient Enterprise	Sheffi & Rice	2005
Integrating sustainability and resilience in the supply chain: A systematic literature review and a research agenda	Negri et al.,	2021
Supply chain disruptions and resilience: a major review and future research agenda	Katsalaiki et.,	2021
Maturity and resilience in supply chains: a systematic review of the literature	Roque Júnior et al.,	2023
The Complete Guide to Understanding the 4 Procurement Maturity Levels	Micheal Pleuger	2024
Towards a definition of the role of enterprise modeling in the context of business and IT alignment	Julia Kaidalove	2015
Organizational Capabilities for AI Implementation—Coping with Inscrutability and Data Dependency in AI	Weber at al.,	2023
Exploring the Readiness of Organisations to Adopt Artificial Intelligence	Flemban at al.,	2024
Enhancing Supply Chain Resilience Through Artificial Intelligence: Developing a Comprehensive Conceptual Framework for AI Implementation and Supply Chain Optimization	Riad et al.,	2024
Generative AI in Supply Chain Management	Shekhar at al.,	2024
IoT-based supply chain management: A systematic literature review	Taj et al.,	2023
The Emerging Cybersecurity Challenges With Artificial Intelligence	Mingo	2024
Blockchain-enabled supply chain management: integrated impact on firm performance and robustness capabilities	Aslam et al.,	2023
Exploratory Analysis of Blockchain Platforms in Supply Chain Management	Keresztes et al.,	2022
Dynamic capabilities as (workable) management systems theory	David J Teece	2018
A Systematic Review of the Literature on Digital Transformation: Insights and Implications for Strategy and Organizational Change	Hanelt et al.,	2020
The Five Competitive Forces That Shape Strategy	Porter	2008
User Acceptance of Information Technology: Toward a Unified View	Venkatesh et al.,	2003

3.1 Supply Chain Framework

The Supply Chain Resilience (SCR) Framework provides a comprehensive approach to understanding how supply chains can prepare for, respond to, and recover from disruptions while maintaining operational continuity. The framework emphasized visibility, flexibility, redundancy, collaboration, and agility to enable resilience. Visibility enables real-time monitoring and communication for better decision-making. Flexibility allows quick adaptation to disruptions, while redundancy, like backup suppliers, ensures continuity. Collaboration and agility foster strong partnerships and rapid responses to unexpected events (Christopher & Peck, 2004). However, Christopher's framework lacked empirical validation and did not consider modern technologies like AI and blockchain. Furthermore, Ponomarov and Holcomb's Supply Chain Resilience Model defined resilience as a supply chain's adaptive capability, highlighting risk and knowledge management as critical enablers (Ponomarov & Holcomb, 2009). However, the study lacked empirical validation and did not fully address digitalization's impact on disruption mitigation. These limitations suggested the need for further empirical research to validate and expand upon the proposed concepts, incorporating contemporary developments in supply chain management.

Complementing this is Sheffi's Resilience Framework, which focuses on strategies to build robust supply chains capable of withstanding disruptions. The framework emphasized developing operational flexibility through modular processes and adaptable infrastructure, creating redundancy through contingency plans and alternative suppliers, and fostering collaboration to address vulnerabilities collectively (Sheffi & Rice, 2005). However, Sheffi primarily focused on the threat of terrorism, overlooking broader disruptions like natural disasters and economic downturns. Additionally, it lacked quantitative models to measure disruption impacts and strategy effectiveness, highlighting the need for updates in response to emerging threats.

3.1.1 Supply Chain Resilience

Supply Chain Resilience (SCR) is typically defined as the ability of a supply chain to anticipate, prepare for, respond to, and recover from disruptions while maintaining continuous operations (Ponomarov & Holcomb, 2009). SCR focuses on minimizing risks, managing uncertainties, and ensuring that the supply chain can quickly adapt to changes in demand, supply, or operational conditions (Pires Ribeiro & Barbosa-Povoa, 2018). Recent advancements in SCR extend beyond operational recovery to encompass sustainability, integrating economic, environmental, and social dimensions into resilience strategies (Negri et al., 2021).

Katsaliaki found that over 56% of companies face annual supply chain disruptions, with more than 80% concerned about resilience. He showed that disruptions can cause a significant drop in profitability and sales growth. According to Katsaliaki, three stages of response are needed to recover from a disruption: detecting the volume of disruption, selecting a predesigned recovery method, and deploying the solution. The authors concluded that achieving supply chain resilience involves a combination of proactive strategies, flexibility, collaboration, investment in technology, and a focus on both prevention and effective recovery (Katsaliaki et al., 2021). However, the research lacked a comprehensive approach to integrate various modeling techniques with digital technologies while considering the human element in SCM and the impacts of major global events such as pandemics.

Disruptions refer to unforeseen events or conditions that interrupt the normal functioning of operations. Biju & Antony stated that disruptions not only hinder the smooth flow of goods but also expose vulnerabilities in supply chain infrastructure and resilience, necessitating robust risk management and adaptive strategies. They examined the impact of disruptions on maritime logistics, highlighting the need for resilient frameworks to sustain global trade (Biju & Antony Thekkanath, 2022).

3.1.2 Challenges in Implementing SCR Frameworks

Despite increasing awareness of the importance of supply chain resilience (SCR), organizations face persistent challenges in its implementation. Cost-efficiency pressures often make it difficult to justify resilience investments, particularly in lean models like just-in-time (JIT), which reduce costs but heighten vulnerability to disruptions. Example: Companies operating in highly competitive markets often struggle to justify additional spending on resilience measures that may not yield immediate returns (Sheffi & Rice, 2005). Additionally, the effective implementation of SCR frameworks relies heavily on advanced technologies, including real-time analytics and predictive forecasting. However, achieving seamless data interoperability remains a critical challenge due to disparities in technological maturity, system incompatibilities, and concerns over data security and privacy (Ivanov et al., 2018).

Collaboration among supply chain partners is another critical requirement for resilience, yet it is often undermined by mistrust, misaligned incentives, and an unwillingness to share sensitive data. Establishing clear communication protocols and standardized data-sharing frameworks may enhance collaborative outcomes (Bakalo & Bogale, 2024). Furthermore, accurately identifying and managing risks remains a complex endeavor, especially in an environment characterized by global uncertainty and rapid technological change. Events, such as pandemics or rapid technological disruptions, challenge organizations' ability to anticipate and respond effectively, resulting in resilience strategies that may be misaligned with actual risk exposure (Ponomarov & Holcomb, 2009).

While these studies provide valuable insights into the financial and technological dimensions of SCR, they overlook the role of cultural, organizational and environmental behavior in resilience-building.

3.2 Procurement

"You must learn that you mustn't make all — or attempt to make all — of the money in any one deal. Let the other fellow make some money. If you try to make all of the money in every deal, you won't make many deals.— J. Paul Getty (Oklahoma, chapter 3).

Getty's statement reflects a key principle in procurement: successful negotiations should create value for all parties involved to foster long-term, sustainable supplier relationships. Instead of focusing solely on maximizing short-term gains, building mutually beneficial relationships ensures long-term success and trust with suppliers. This aligns with modern procurement strategies that emphasize strategic partnerships over purely cost-driven decisions. Procurement refers to the process of acquiring goods, services, or works from an external source, often via a tendering or competitive bidding process. It is a strategic function that involves planning, sourcing, negotiation, and management to ensure that an organization obtains the necessary resources efficiently and cost-effectively (Gianfredi et al., 2021).

Procurement accounts for 50–70% of a company's total spending, making it a critical function for cost control, supply chain efficiency, and overall business success. By carefully managing the stages of procurement and outsourcing, companies ensure the timely acquisition of high-quality materials and components necessary for their product assembly (Iqbal et al., 2020). Effective procurement practices significantly contribute to overall supply chain resilience by enabling strategic sourcing, fostering strong supplier relationships, and ensuring flexibility in responding to disruptions. By integrating digital tools and risk-based procurement strategies, organizations are better positioned to anticipate, absorb, and adapt to external shocks, thereby ensuring continuity and responsiveness across the supply chain (Ivanov et al., 2018). Despite its strategic importance, procurement often faces significant challenges in enhancing supply chain resilience, including limited visibility across tiers, supplier unreliability, and the lack of integrated risk management practices, which hinder timely and coordinated responses to disruption (Tanner et al., 2008).

3.2.1 Challenges in procurement

Procurement processes across various sectors are increasingly complex, influenced by a multitude of technological, strategic, and operational factors. Recent literature highlights several critical challenges that organizations face in optimizing procurement practices.

1. Technological Challenges

A significant challenge is the lack of system integration and standardization, which hampers the full implementation of e-procurement systems (Khuan, 2019). Moreover, the adoption of emerging technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and big data analytics, is often constrained by challenges related to talent acquisition and data security (Khuan, 2019). Additionally, while digital tools like e-invoicing have become increasingly important, they frequently fall short of organizational expectations, indicating a persistent gap between IT capabilities and procurement needs (Tanner et al., 2008).

2. Strategic and Operational Challenges

Strategic and operational dimensions of procurement obstruct the development of balanced business-to-business (B2B) procurement solutions (Tanner et al., 2008). Furthermore, both public and private sector entities often face difficulties in transitioning from transactional to strategic procurement approaches. Glas describes this phenomenon as a “Cycle of Impotence,” wherein organizations struggle to implement long-term procurement strategies (Glas, 2024). In addition to these systemic issues, procurement processes are frequently disrupted by design change challenges. Late-stage or poorly managed modifications to project or product specifications often lead to timeline delays, cost overruns, and coordination failures (Xia & Chan, 2024). These disruptions are especially problematic in sectors requiring tight synchronization between design, production, and delivery.

Another significant operational barrier is supplier incapacity, which occurs when vendors lack the resources or capabilities to meet contractual obligations. This may include insufficient technical expertise, inadequate production facilities, or financial instability. Such limitations compromise procurement performance, increase dependency risks, and necessitate stronger supplier evaluation and development strategies. According to a report by the Chartered Institute of Procurement & Supply (CIPS), many procurement failures stem from over-reliance on underqualified suppliers and a lack of rigorous due diligence during supplier selection (Vendor Risk Assessment | CIPS, 2020).

3. Risk Management

Procurement risk management is increasingly recognized as a critical function in modern supply chains, particularly in an era marked by frequent disruptions, geopolitical tensions, and global supply uncertainties. Despite its growing importance, risk management practices remain underdeveloped in many organizations, often due to limited resources, lack of integrated data systems, and insufficient expertise. Uncertainties related to both supply (e.g., supplier failure, logistics delays) and demand (e.g., forecast inaccuracies, market volatility) pose significant threats to procurement performance. To address these risks, there is a growing need for the adoption of advanced analytical techniques that can support data-driven decision-making under uncertainty. As Tang and Musa note, effective procurement risk management requires a proactive, systemic approach that integrates risk identification, assessment, mitigation, and monitoring across the entire supply chain (Tang & Musa, 2011).

The challenges faced in procurement are multifaceted; therefore, addressing these issues requires a comprehensive approach that emphasizes system integration, supplier collaboration, and risk management. As Hoon and Esperance emphasized, overcoming these challenges involves not only technical and procedural reforms but also cultural and institutional shifts that embed strategic procurement as a driver of value creation and sustainable development (Hoon & Esperance, 2023).

3.2.2 Procurement Maturity Model

Thomas Jonker elaborated that the PMM (Procurement Maturity Model) serves as a strategic tool for organizations to assess and enhance their procurement processes. By evaluating current policies, procedures, and structural elements, organizations can identify areas for improvement and develop strategies to advance their procurement functions. This progression not only optimizes procurement activities but also aligns them more closely with overarching business objectives, leading to increased efficiency and value creation (Jonker, 2020). The procurement maturity model assesses and enhances procurement by evaluating strategy, technology, processes, and organization. Higher maturity levels are associated with better procurement performance, reflecting more advanced and integrated procurement processes (Batenburg & Versendaal, 2008).

The Procurement Maturity Model by Michael Pleuger (2024), highlights the shift from transactional procurement to a strategic business enabler, emphasizing data-driven decision-making, risk management, and AI-driven innovation. This transition enhances value creation through advanced analytics, supplier collaboration, and strategic alignment with business objectives, underscoring the role of technology and cross-functional collaboration in driving efficiency and competitiveness.

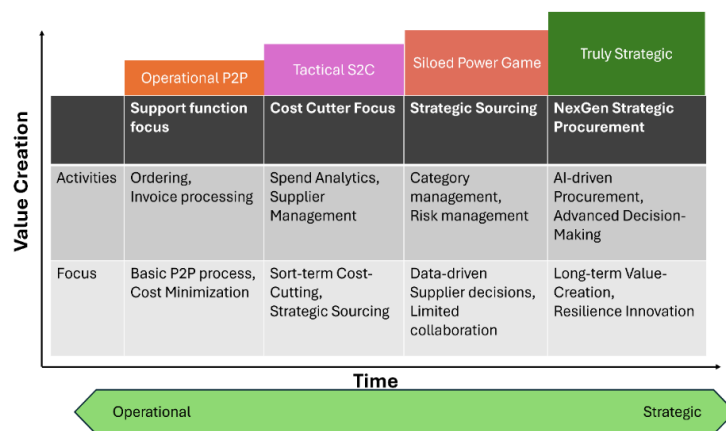


Figure 5. Procurement Maturity Model (Adopted from Pleuger, 2024).

3.2.3 Role of Procurement Maturity Model in Supply Chain Resilience

Joe Canaday, Vice President, Global Procurement Center of Excellence, ADM stated:

Procurement professionals, armed with best-in-breed technology, best-in-class processes and modernized policies and being supported by great leaders, are best positioned to unlock the greatest value for their companies, while simultaneously elevating to trusted advisors within their organizations. (Epstein, 2025; Coupa, n.d.)

The PMM plays a crucial role in enhancing supply chain resilience by aligning procurement strategies with the maturity level of the supply chain. This alignment enables organizations to effectively manage risks and adapt to disruptions, thereby ensuring continuity and stability. The model provides a structured approach to assess and improve procurement processes, which is essential for building resilient supply chains. It also helps organizations identify gaps in their procurement capabilities and implement targeted improvements to enhance overall supply chain performance (Roque Júnior et al., 2023). The following table explains the role of the Procurement Maturity Model in Supply chain resilience.

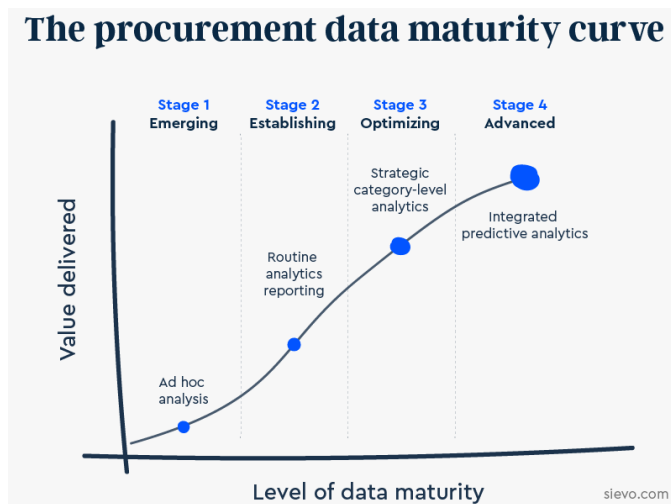


Figure 6. Procurement data maturity curve (Duray, 2023)

The Procurement Data Maturity Curve outlines four stages of analytics evolution in procurement: Emerging, Establishing, Optimizing, and Advanced. At the Emerging stage, organizations rely on ad hoc analysis, often unstructured and reactive (Duray, 2023). As they move to the Establishing stage, they adopt routine analytics reporting, which supports more consistent but still tactical decisions. In the Optimizing stage, procurement leverages strategic category-level analytics to align decisions with broader business goals. The final Advanced stage integrates predictive and prescriptive analytics, often powered by AI and machine learning, enabling proactive, automated decision-making (Rob Handfield, 2007). This maturity curve reflects the growing importance of data-driven insights in enhancing procurement's strategic value and resilience.

Table 3. Role of PMM in SCR (Adapted from Roque Júnior et al., 2023).

<p>1. Risk Management: The maturity model highlights proactive risk management, enabling companies to recognize risk patterns and act swiftly. This ensures resilience against disruptions like natural disasters and supply chain interruptions.</p>	<p>1. Supplier Relationship: Strong supplier relationships, audits, and collaborative risk management enhance stability. Aligning supplier strategies with maturity levels fosters trust and preparedness, strengthening supply chain resilience.</p>
<p>2. IT-Alignment and Digitalization Integrating digital tools improves procurement processes, tracking performance through analytics and data-driven decision-making.</p>	<p>3. Maturity and Resilience Model A theoretical model connects maturity with resilience, guiding organizations in crisis response and supply chain improvements.</p>
<p>4. Procurement Portfolio Management The maturity model encourages organizations to develop a diverse procurement portfolio to avoid over-reliance on a single supplier. Diversifying suppliers reduces reliance on a single source, improving adaptability to disruptions and optimizing sourcing strategies.</p>	<p>5. Strategies for Resilient Procurement Systems Clear leadership, cross-functional teams, and continuous innovation enhance procurement resilience. Self-evaluation tools help assess maturity and benchmark industry standards.</p>

The procurement maturity model supports risk management and supplier strategies to enhance resilience. Roque highlighted that research often reacts to disruptions rather than proactively building resilience, calling for practical tools to assess and strengthen supply chains before issues arise (Roque Júnior et al., 2023).

3.3 Artificial Intelligence in Procurement

Wolfgang Ertel defines Artificial Intelligence (AI) as the ability of machines to perform tasks that would typically require human intelligence. These tasks include reasoning, learning, perception, and problem-solving, often through algorithms that allow systems to make decisions and improve over time (Ertel, 2024). AI technologies are increasingly being integrated into various industries, revolutionizing processes and enabling innovative solutions to complex problems. This transformative potential of AI continues to reshape traditional workflows, driving efficiency and enhancing decision-making across diverse sectors. Dave Waters, a recognized expert in supply chain management and technology, emphasized the transformative role of artificial intelligence technologies such as IoT and blockchain etc in automating the supply chain industry. He stated, "Predicting the future isn't magic, it's artificial intelligence. AI will be rampant in the digital supply chain." — Dave Waters.

Riad, Naimi, and Okar studied how AI enhances supply chain resilience (SCR) by improving predictive capabilities, real-time monitoring, and operational optimization. AI shifts supply chains from reactive to predictive management, enabling companies to anticipate disruptions, simulate scenarios, and implement solutions in real time. For example, AI-driven systems can predict delivery delays and suggest alternative routes or suppliers. Additionally, AI fosters agility and adaptability through continuous learning, keeping supply chains resilient in dynamic environments. However, adoption challenges remain, including data availability, integration costs, and specialized expertise (Riad et al., 2024). Riad and Niami identified the digital divide as a key barrier to AI adoption in less developed regions and highlighted challenges like data privacy and bias in supply chain use, especially in humanitarian contexts. They called for ethical frameworks and further research on integrating AI to improve efficiency across diverse settings.

Paul Lalovich has stated that “Blockchain and AI are converging in ways that will redefine industries, and the organizations that prioritize agility, collaboration, and sustainability will lead the charge.” (Henrik von Scheel and Paul Lalovich, 2025). Artificial Intelligence technologies play a crucial role in enhancing procurement processes by improving efficiency, accuracy, and decision-making. Prabath and Shekhar reviewed AI technologies that improve decision-making and foster resilience. However, their study was limited to a systematic review, lacking an analysis of adoption challenges in specific industries or case studies (Shekhar et al., 2024).

Table 4. AI technologies in procurement (Adapted from Shyla Awasthi, 2024).

<p>1. Predictive Analytics: Demand Forecasting AI algorithms analyze historical sales data, market trends, and consumer behavior to predict future demand accurately. This capability allows businesses to optimize inventory levels and reduce waste, ensuring that procurement aligns with actual market needs.</p>	<p>2. Generative AI: Supplier Assessment Generative AI revolutionizes the sourcing assessment by quickly processing extensive data from potential suppliers. It evaluates various parameters such as cost, quality, and reliability, enabling the creation of an optimal supplier portfolio.</p>
<p>3. Real-Time Monitoring: Risk Mitigation AI technologies provide real-time monitoring of supplier performance, inventory levels, market conditions and production schedules. This proactive approach helps identify potential disruptions early, allowing procurement teams to implement contingency plans and maintain supply chain resilience.</p>	<p>4. Machine Learning: Behavioral Insights Machine learning algorithms analyze supplier performance, market conditions, and contract data to predict risks, performance variations, and supplier reliability. This helps organizations make informed outsourcing decisions, mitigate risks, optimize contracts, and identify the best suppliers aligned with their operational goals and risk tolerance.</p>
<p>5. Automation Tools: Streamlining Processes AI-driven automation tools can handle repetitive tasks such as order processing, invoice management, and compliance checks. This streamlining reduces manual errors and frees up procurement professionals to focus on strategic activities.</p>	<p>6. Blockchain: Enhancing Cybersecurity Blockchain enhances cybersecurity by providing a secure, transparent, and tamper-proof ledger, reducing data breaches and preventing fraud in global supply chains. It ensures only authorized access to sensitive procurement and logistics information, improving trust and resilience.</p>

According to Gartner, the top AI trend in supply chain management is demand forecasting, with an adoption rate of 40%, followed by order management (33%), supply planning (31%), logistics and distribution (27%), and sales and operations planning (24%). The study also highlights a distinction between high and low performers, indicating that AI adoption is influenced by organizational capabilities (Gartner, 2024).

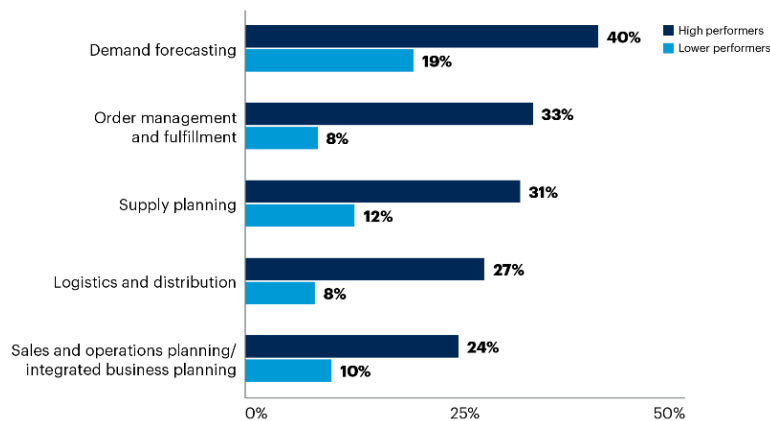


Figure 7. Top AI trends in SCM (Gartner, 2024).

This section of the study explores two practical applications of artificial intelligence (AI) in procurement processes. The primary focus is to understand how AI technologies are being applied or can be applied to enhance procurement efficiency, resilience and optimization. The first application under study is Intelligent Monitoring, a technology-driven approach that leverages AI to track, analyze, and optimize procurement activities in real-time. This includes monitoring supplier performance, contract compliance, and market trends to identify potential risks or inefficiencies. The second AI application analyzed is Blockchain, which provides a decentralized, secure, and transparent system for recording transactions and managing supply chain data. It ensures procurement integrity through immutable ledgers, enhancing cybersecurity and reducing fraud. Combined with IoT, Blockchain improves traceability, enabling real-time tracking of materials throughout the supply chain (Chapman, 2024).

3.3.1 Internet of Things (IoT)

IoT connects physical devices with sensors and software to enable real-time tracking and monitoring in supply chains, improving efficiency and visibility. Integrating IoT with AI creates smart supply chains that self-monitor, analyze, and adapt, optimizing resources and reducing waste. As markets evolve, adopting these technologies is crucial for maintaining competitiveness and operational excellence (Madanchi et al., 2024).

Taj and Imran conducted the first systematic review of IoT-based SCM, analyzing five years of literature. They identified IoT's role in modernizing supply chains and outlined key research areas, including AI and Blockchain applications. The study detailed IoT's three-layer architecture: Perception (sensor data collection), Network (data transmission), and Application (data processing for decision-making). Key IoT-enabling technologies include AI for automation, Blockchain for security, Cloud for real-time data processing, and RFID for inventory tracking. These technologies enhance efficiency, transparency, and automation in supply chain management (Taj et al., 2023).

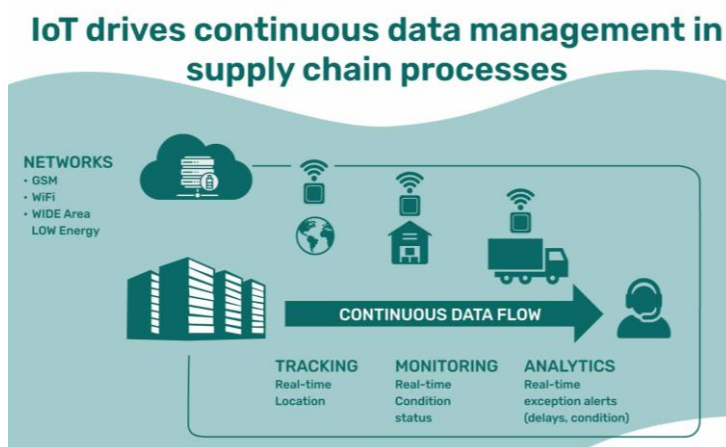


Figure 8. IoT applications in SCM (Nikhil, 2023).

In Figure 9, Nikhil Khandelwal illustrated how IoT (Internet of Things) enables continuous data management to enhance real-time visibility and efficiency in supply chain processes. He highlighted three key components:

1. Networks: Data is transmitted via GSM (Global System for Mobile Communications), WiFi, wide-area, and low-energy networks.
2. Continuous Data Flow: IoT sensors are placed on warehouses, trucks, and shipments, providing real-time data.
3. Functional Areas:
 - Tracking: Provides real-time location updates.
 - Monitoring: Tracks real-time condition status (e.g., temperature, humidity).
 - Analytics: Delivers real-time exception alerts, such as delays or damaged goods (Nikhil, 2023).

Recently, Tayab explained the integration of AI and IoT in supply chain monitoring as it is built on a structured system with six key layers, each playing a crucial role in data collection, processing, and security. By structuring the system into these six layers, companies can efficiently manage supply chain data, improve decision-making, and enhance security while ensuring real-time visibility and optimization (Javed, 2024).

1. Data Ingestion Layer – This is where data is collected from IoT sensors, GPS devices, RFID tags, and ERP systems. Tools like Apache Kafka, AWS Kinesis, and Google Cloud Pub/Sub help manage real-time data flow.
2. IoT Layer – IoT devices, such as sensors and GPS trackers, collect real-time data on location, temperature, and other critical parameters. Edge computing devices process this data locally to reduce delays before sending it to the central system.
3. Data Storage Layer – Once collected, data needs to be stored securely. Time-series databases like InfluxDB and AWS Timestream handle continuously updating data, while centralized storage solutions like Amazon S3 and Google Cloud Storage keep large amounts of structured and unstructured data accessible.

4. **Data Processing Layer** – This layer transforms raw data into useful insights. ETL (Extract, Transform, Load) tools such as Apache Spark and AWS Glue clean and organize the data. AI models built with TensorFlow and PyTorch analyze the data for predictive analytics and anomaly detection.
5. **Data Retrieval and Integration Layer** – Once processed, data must be easily accessible. Query engines like Presto and Amazon Athena help retrieve information quickly, while caching tools such as Redis and Memcached speed up frequently used queries. APIs (RESTful or GraphQL) connect this data to enterprise applications, with middleware like Node.js and Express handling communication between different systems.
6. **Monitoring and Security Layer** – The final layer ensures the system runs smoothly and securely. Monitoring tools like Prometheus and Grafana track performance, while logging solutions such as the ELK Stack and AWS CloudWatch help analyze system events. Security measures include IAM role-based access control, TLS/SSL encryption for data in transit, and AES encryption for stored data (Javed, 2024).

Intelligent Monitoring

Intelligent Monitoring within SCM involves the application of advanced technologies, such as Artificial Intelligence (AI) and machine learning, to analyze data collected from IoT devices and other sources. By integrating AI algorithms, businesses can enhance forecasting accuracy, improve demand planning, and respond swiftly to disruptions, leading to a more resilient and efficient supply chain. Recent studies emphasize that AI-integrated technologies play a crucial role in developing sustainable and responsive supply chains, especially in the post-pandemic era. (Qu & Kim, 2024) Intelligent supply chain management, powered by AI and advanced analytics, can reduce forecasting errors by 20% to 50%, decrease lost sales due to inventory stockouts by up to 65%, and lower warehousing costs by 5% to 10% (McKinsey, 2022).

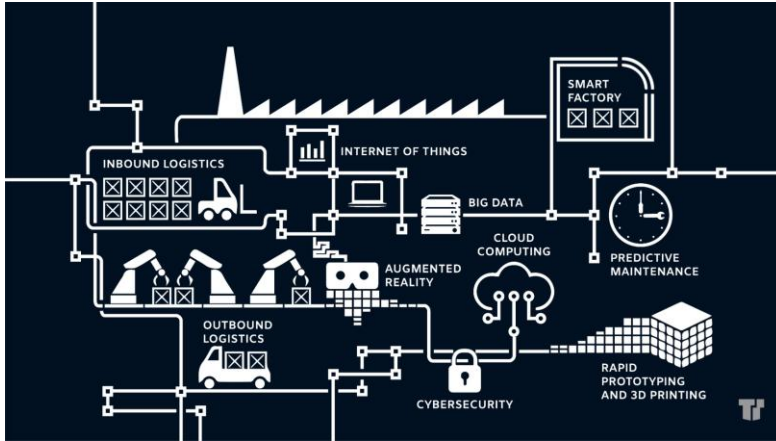


Figure 9. Intelligent Supply Chain (Trusted Tech, 2020).

Figure 9, sourced from Trusted Tech, represents the concept of a smart factory and highlights the various technologies and processes that integrate to enable efficient and advanced manufacturing systems. Here's a breakdown of the key elements:

1. Inbound Logistics: Represents the transportation and storage of raw materials or components that are brought into the factory for production.
2. Outbound Logistics: Refers to the processes involved in distributing finished goods from the factory to customers or retail outlets.
3. Internet of Things (IoT): Connects physical devices, machines, and sensors in the factory to collect and exchange data, enabling real-time monitoring and automation.
4. Big Data: Large volumes of data generated by connected devices and systems are analyzed to gain insights, optimize operations, and improve decision-making.
5. Cloud Computing: Provides a platform for storing, processing, and analyzing data from the factory, enabling remote management and scaling of computing resources.
6. Predictive Maintenance: Using data from sensors and IoT devices to predict when machinery will require maintenance, reducing downtime and avoiding costly repairs.
7. Augmented Reality (AR): Enhances factory workers' ability to perform tasks by overlaying digital information onto the physical world, improving training, troubleshooting, and maintenance.

8. Cybersecurity: Protects the factory's network, data, and systems from potential cyber threats or attacks, ensuring secure and reliable operations.
9. Rapid Prototyping and 3D Printing: Involves quickly producing prototypes or finished products using 3D printing technologies, enabling faster design iterations and customization.

Each of these components is connected and integrated, representing a highly automated and data-driven manufacturing process (Trusted Tech, 2020).

Thus, IoT and Industry 4.0 technologies enhance supply chain digitalization, driving efficiency and competitiveness. IoT generates big data for evidence-based decisions and, when combined with blockchain, improves traceability, visibility, and trust. It fosters innovation, real-time coordination, and service differentiation through RFID and data transparency. While case studies highlight IoT's impact, further research using surveys and interviews is needed to explore its role in business model innovation (Rejeb et al., 2020). However, Rejeb's research was geographically confined to the Australian retail industry, which limited the generalizability of its findings to other regions or sectors.

3.3.2 Blockchain

Gartner describes blockchain as "a digital ledger comprising cryptographically signed, irreversible blocks of records shared among participants in a peer-to-peer network"- (Gartner, n.d.). Blockchain, as a decentralized and tamper-resistant ledger system, allows secure and transparent exchanges between parties without relying on intermediaries. It maintains data integrity through its immutable structure and offers a novel approach to managing transactional data. In procurement, blockchain has been shown to strengthen supply chain performance by boosting integration, responsiveness, and security (Kouhizadeh & Sarkis, 2018). It facilitates real-time information sharing,

end-to-end visibility, and transparency, which are crucial for effective decision-making and operational efficiency. Aslam's study provided a roadmap for adopting blockchain in SCM, highlighting potential problems in existing O&G supply chains and how blockchain can address these issues effectively. It identified three key independent variables: Supply Chain Integration (SCI), which improves coordination and transparency; Supply Chain Agility (SCA), which enables quick responses to demand changes; and Supply Chain Financial Security (SCFS), which secures financial transactions. These variables collectively influence the dependent variable, Firm Performance, while Robustness Capabilities serve as a mediating variable, enhancing a firm's ability to adapt to changes. The framework provided a structured model to understand the positive impact of blockchain on SC performance in the O&G sector (Aslam et al., 2023). Aslam's study focused on the oil and gas sector, overlooking industries like healthcare, manufacturing, and retail. It relied on SCM managers' perceptions rather than practical experience, potentially impacting reliability.

Experts from JAGGAER and EY highlighted that blockchain enables secure, immutable records of transactions, which can reduce fraud and ensure ethical sourcing. By providing a decentralized ledger, blockchain facilitates real-time visibility into supply chain operations, allowing companies to track products from origin to end consumer. The increased visibility can not only improve operational efficiency but also help in meeting regulatory compliance and sustainability goals. Additionally, the integration of blockchain with other technologies, such as IoT and AI, can further streamline procurement processes and foster innovation in supply chain strategies (Chapman, 2024).

Figure 10 by Obaidat presents a privacy-preserving blockchain framework for supply chain management. Sensitive data is identified, sanitized, encrypted, and stored on a blockchain. The supply chain is segmented into sub-chains (plants, distribution centers,

customer locations) to restrict access to authorized parties, ensuring privacy and integrity. Secure blockchain-based data sharing enhances logistics efficiency while protecting sensitive information (Aljabhan & Obaidat, 2023).

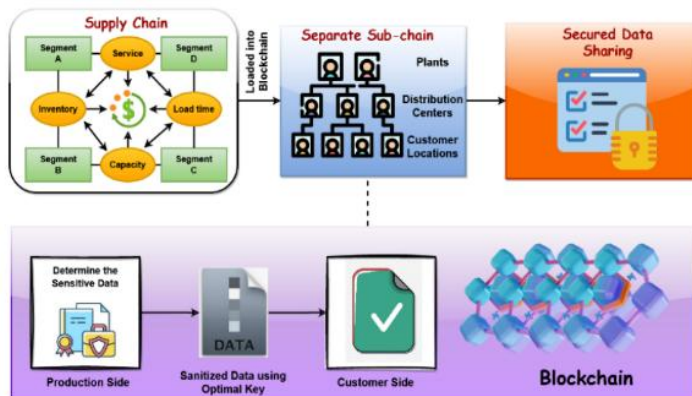


Figure 10. Blockchain framework for SCM (Aljabhan & Obaidat, 2023).

Keresztes and Kovacs classified blockchain applications into security and operational efficiency. Security factors include data accessibility, authorization, smart contracts, and consensus protocols, ensuring transparent transactions. Operational efficiency depends on hash functions, data structures, programming languages, and transaction speed, optimizing performance. Blockchain enhances supply chain management by improving security, efficiency, and transparency across industries like logistics, banking, and manufacturing. Companies like Maersk, Baidu, and BHP use platforms such as Hyperledger and Ethereum for shipment tracking, fraud prevention, and regulatory compliance. While blockchain streamlines procurement and risk management, challenges like high costs, regulatory issues, and interoperability remain barriers to large-scale adoption (Keresztes et al., 2022). Although Keresztes highlighted blockchain's potential in procurement and supply chain management, he did not fully address the challenges of large-scale adoption, such as high implementation costs, regulatory uncertainties, interoperability issues, and resistance to change.

Cybersecurity in procurement

Cybersecurity risks in procurement arise from the integration of digital tools like ERP systems, which store sensitive data such as vendor information and financial records. The adoption of e-procurement and cloud-based platforms increases the vulnerability to data breaches, especially as supply chains grow more complex. Without robust cybersecurity measures, including vendor risk management and data encryption, businesses may face significant risks, including unauthorized access to critical data and financial losses. To mitigate these risks, procurement teams must ensure staff training on cybersecurity best practices and implement strong internal controls, while also ensuring that suppliers uphold robust security measures (riskxchange, 2022).

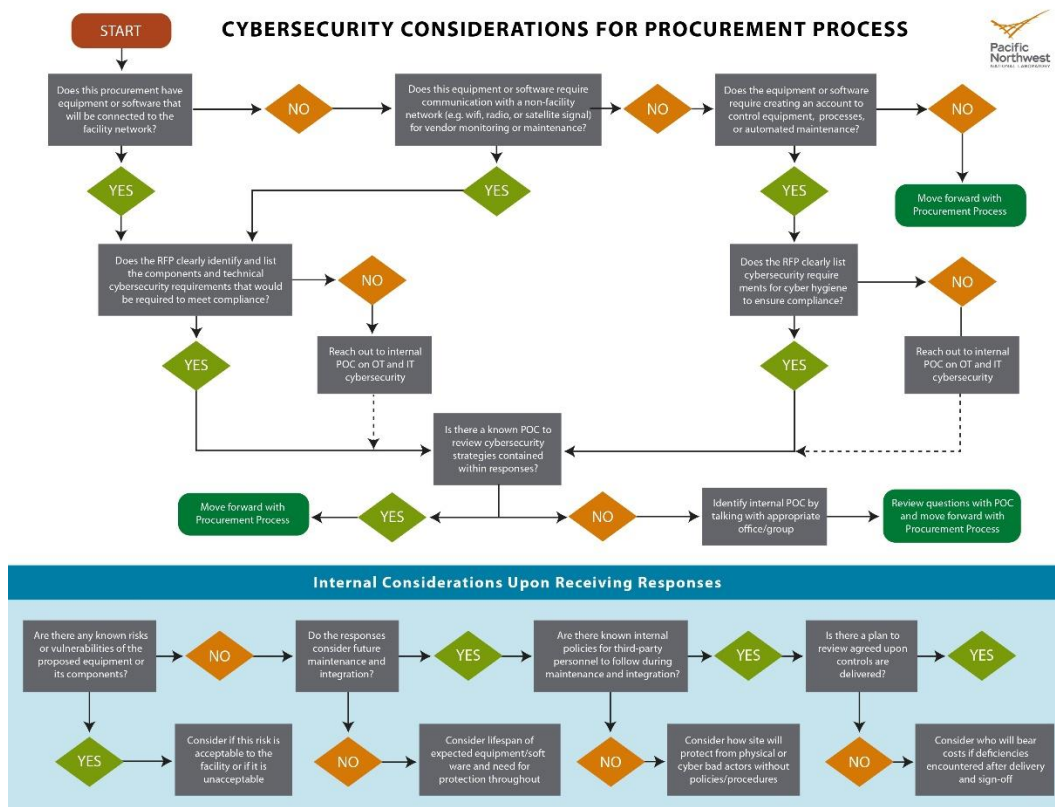


Figure 11. Cybersecurity considerations for procurement decision tree (Sourced from Cybersecurity Considerations for Procurement, n.d.).

The flowchart in Figure 11 outlines cybersecurity integration in procurement. It first determines if equipment or software connects to networks. If so, it checks for cybersecurity requirements in the RFP. Missing requirements prompt internal cybersecurity engagement. Vendor responses are then reviewed for risks, compliance, and costs. If all conditions are met, procurement proceeds with proper cybersecurity measures (Cybersecurity Considerations for Procurement, n.d.). Common venues in procurement prone to cybersecurity attacks include cloud security, where data can be exposed due to misconfigurations, and social media, which can be used for phishing attacks. Other risks involve phishing schemes targeting procurement managers through email, PDF-based malware, and breaches in centralized procurement databases. Additionally, IoT devices in the supply chain can be hacked, and human errors like the accidental sharing of confidential information can also create vulnerabilities (admin, 2023).

Thus, Blockchain technology is transforming supply chain management by providing enhanced transparency, secure data sharing, and real-time traceability, reducing inefficiencies and mitigating risks. Its decentralized nature fosters trust among stakeholders, ensuring greater security and resilience in global procurement networks (The Impact of Blockchain on Supply Chain Management, 2024).

As said by Aušrinė Šilenskytė, a doctoral candidate studying Blockchain adoption at the University of Vaasa (2023), “While blockchain is not a one-size-fits-all solution, it can provide tremendous benefits to industries that require multiple stakeholders and repeated transactions.” (Digital Economy and Beyond, n.d., 2023).

3.3.3 AI Adoption Strategies

Chiragh outlined a 10-step process for optimizing AI and data analytics in supply chain management. This framework emphasizes a systematic AI adoption strategy in supply chain management, ensuring accuracy, integration, and ongoing enhancement for better decision-making and operational efficiency.

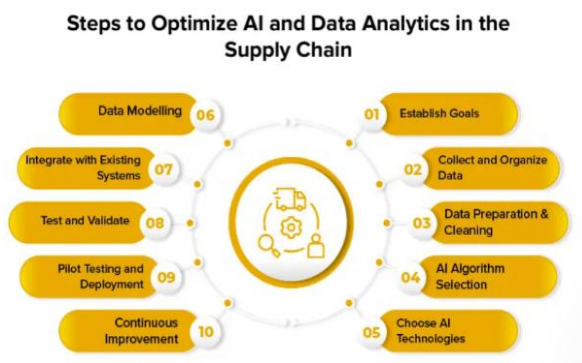


Figure 12. AI optimization in SC (Chiragh, 2024).

1. Establish Goals – Define objectives for AI integration.

2. Collect and Organize Data – Gather relevant supply chain data.

3. Data Preparation & Cleaning – Ensure data quality for accurate analysis.

4. AI Algorithm Selection – Choose suitable AI models for optimization.

5. Choose AI Technologies – Select the right AI tools and platforms.

6. Data Modeling – Develop AI-driven predictive models.

7. Integrate with Existing Systems – Ensure AI solutions work with current supply chain infrastructure.

8. Test & Validate – Verify AI performance before full deployment.

9. Pilot Testing and Deployment – Implement AI on a small scale before a full rollout.

10. Continuous Improvement – Regularly refine AI models for better efficiency (C. Bhardwaj, 2022).

3.3.4 Challenges in the adoption of AI

Organizations encounter various challenges in adopting Artificial Intelligence for real-world applications, particularly in procurement operations and optimizing supply chain performance.

1. Data Quality and Availability: The "Garbage In, Garbage Out" Problem:

Insufficient, inconsistent, or inaccurate data severely limits the effectiveness of AI systems, as machine learning models depend on high-quality data for training and accurate predictions (Kumar, 2024). Large-scale projects often produce vast amounts of data from diverse sources, resulting in inconsistencies, inaccuracies, and missing information (Hanelt et al., 2020). Factors such as differing data formats, manual entry errors, outdated records, and system integration challenges contribute to data heterogeneity. Poor data quality can lead to suboptimal procurement decisions, increased costs, delays, and safety risks. Additionally, cleaning and preparing data for AI use is time-consuming and resource-intensive, creating a significant barrier to adoption (Mingo, 2024).

2. Data Integration and Technical Expertise:

The successful implementation of AI often requires integrating new software with existing databases and applications, which can be challenging due to a lack of interoperability among different systems with varying data formats, protocols, and standards (Duray, 2023). Additionally, implementing and maintaining AI requires specialized skills, especially in large, complex projects. The complexity of AI algorithms, their integration with existing systems, and the need for robust data pipelines can cause delays, cost overruns, and implementation failures. Many organizations lack the internal expertise to manage such implementations, leading to reliance on external consultants or vendors, which increases costs and introduces dependencies (Duray, 2023; Fosso Wamba et al., 2014)

3. Algorithmic Bias: Ensuring Equitable Outcomes:

According to Gollangi, AI systems may inherit biases from their training data, which can result in unequal or discriminatory outcomes, especially in procurement decisions that impact diverse stakeholders. For example, if the training data reflects existing biases in supplier selection, the AI system may perpetuate these biases, potentially disadvantaging certain groups of suppliers. (Gollangi et al., 2024).

4. Resistance to Change: Overcoming Organizational Inertia:

Introducing AI systems can disrupt established workflows and require significant adjustments to organizational processes and culture. This can lead to resistance from employees accustomed to traditional methods and hesitant to adopt new technologies (Asamoah & Frimpong, 2024). Such resistance can hinder the effective implementation and utilization of AI systems. Overcoming this resistance requires a well-planned change management strategy that includes clear communication, training, and support for employees throughout the transition process (Mingo, 2024).

5. Cost-Benefit Analysis:

A thorough assessment of costs and benefits is crucial for making informed decisions. Organizations need to conduct a thorough cost-benefit analysis before implementing AI systems. This analysis should consider not only the initial investment costs but also the ongoing maintenance, training, and potential risks associated with AI adoption (Asamoah & Frimpong, 2024).

While Asamoah & Frimpong studied the role of AI in logistics, the study lacked empirical testing, relying solely on literature. It focused mainly on U.S. industries like e-commerce and automotive, limiting its global relevance and overlooking emerging trends. The study also did not offer recommendations for future research or practical applications.

3.4 Business Environment Factors

Business environment factors refer to external and internal influences that affect an organization's operations, decision-making, and strategic direction. These factors include economic conditions, technological advancements, regulatory policies, competitive pressures, and socio-cultural trends. These factors impact an organization's adoption of the latest trends and determine the feasibility, urgency, and potential benefits of adopting innovations. For example, rapid technological advancements and increasing digitalization push firms to integrate AI, automation, and data-driven decision-making to stay competitive (Teece, 2018). Additionally, regulatory changes and market demands influence the pace at which organizations embrace sustainability and digital transformation (Hanelt et al., 2020). By understanding and addressing these factors, organizations can enhance their ability to leverage AI technologies effectively, ultimately driving innovation and competitive advantage.

3.4.1 Internal Factors

Internal factors are the organization-specific elements that determine AI readiness and successful integration within an organization.

1. Technological Infrastructure & Data Readiness

Technological infrastructure comprises the essential components—hardware, software, networks, and data management systems—that support technology adoption within organizations (C. Bhardwaj, 2022). Data readiness, on the other hand, reflects an organization's ability to utilize data effectively, encompassing data quality, accessibility, governance, and analytical capabilities (Kahn et al., 2002). It plays a critical role in technology adoption, influencing an organization's success in leveraging emerging technologies like IoT and predictive analytics (C. Bhardwaj, 2022). Key aspects of data readiness include data quality (accuracy, completeness, and reliability) and data governance (policies for managing data assets) (Otto et al., 2012). Research indicates

that high data readiness correlates with successful big data analytics implementation (Fosso Wamba et al., 2014). Organizations can strengthen data readiness by improving data governance, ensuring data quality, and fostering a data-driven culture (Kahn et al., 2002).

2. Workforce & Skill Readiness

Workforce readiness is crucial for AI adoption, as AI systems demand new skills and competencies. Organizations must assess skill gaps and enhance digital literacy (Brynjolfsson & McAfee, 2014). A skilled workforce enables effective AI utilization, yet a significant digital skills gap persists. Half of the new jobs in Europe will require AI literacy, but only a quarter of firms report strong AI skills (Amazon, 2025). Investing in training programs focused on data literacy, analytics, and technology use enhances AI readiness (Ghasemaghaei & Calic, 2019). Organizations prioritizing continuous learning cultivate innovation and resilience (McKinsey, n.d.).

3. Organizational Strategy & Financial Commitment

Organizational strategy and financial commitment are key to AI adoption. A clear strategic vision aligned with business goals ensures AI initiatives drive value rather than operate in isolation (M. E. Porter & Heppelmann, 2017). 35% of businesses report that cost is a key barrier to adoption, yet 44% of businesses adopting AI have experienced enhanced automation and efficiency, and over 90% say AI adoption has increased their revenue. Over half (56%) of start-ups identify clear pathways to venture capital and funding as critical to faster growth (Amazon, 2025). Organizations should strategically invest in upgrading their technological infrastructure to support the integration of new technologies. This includes investing in scalable hardware, advanced software solutions, and robust network capabilities (A. Bhardwaj, 2021). However, the financial commitment must be accompanied by a well-defined return on investment (ROI) strategy to justify the expenditures. Organizations that fail to establish clear metrics for measuring the

impact of AI investments may struggle to secure ongoing financial support for their initiatives (Khan, 2024).

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), proposed by Davis (1989), asserts that perceived ease of use and usefulness determine technology acceptance. Widely applied in fields like information systems, healthcare, and e-commerce, TAM's simplicity aids in understanding user behavior. Studies confirm that perceived usefulness shapes attitudes and usage intentions (Venkatesh & Davis, 2000).

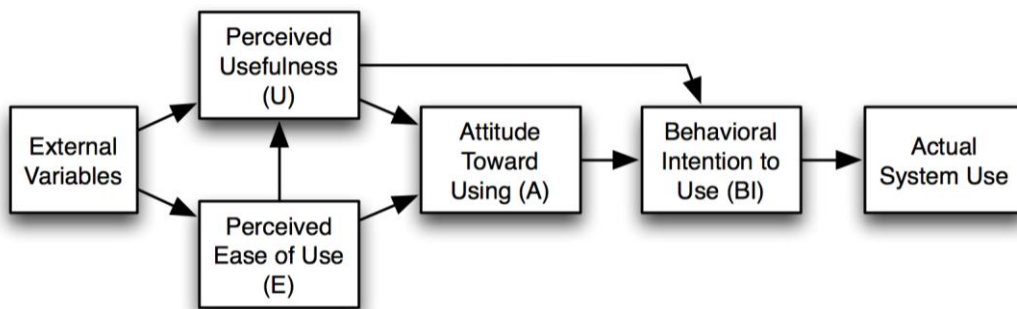


Figure 13. TAM (Sourced from Qingxiong & Liping, 2005).

The TAM model illustrates how external variables influence perceived usefulness (U) and ease of use (E), shaping attitudes (A) and behavioral intention (BI), ultimately leading to system use. Despite its adoption, TAM is criticized for overlooking external factors like organizational culture and user demographics (University of Michigan & Bagozzi, 2007). Additionally, its reliance on self-reported data raises validity concerns, prompting calls for broader contextual considerations in technology acceptance research (Venkatesh et al., 2003).

3.4.2 External Factors

These are macro-level factors that influence AI adoption but are outside the direct control of the organization.

1. Market Conditions & Economic Feasibility

Macroeconomic factors like inflation, interest rates, and GDP growth influence technology investments. Economic downturns lead to budget cuts and cautious decision-making, while growth encourages digital transformation and R&D (Teece, 2018). Stable economies foster AI and automation adoption, boosting productivity and cost efficiency. Economic feasibility assesses a project's financial viability by evaluating costs, revenues, and returns. Sensitivity analysis helps identify risks, while financing options—equity, debt, and grants—affect investment capacity (N. Berger & F. Udell, 1998). Market conditions, including competition and consumer behavior, shape business strategy. Regular market assessments help firms adapt (Kotler & Keller, 1994). During downturns, businesses may cut costs or diversify to sustain market share (Reinartz et al., 2000).

2. Regulatory and Legal Environment

Governments and regulatory bodies shape business operations through laws on data protection (e.g., GDPR, CCPA) and environmental compliance. These regulations influence AI adoption and sustainability efforts, such as AI-powered energy management in the EU (Mikalef & Krogstie, 2020). Regulatory compliance involves adhering to legal requirements, with environmental compliance focusing on sustainability. Non-compliance can lead to fines, reputational damage, and operational risks (Delmas & Toffel, 2004). Many businesses (68%) struggle with EU AI Act requirements, leading to reduced AI investment (Amazon, 2025). However, compliance can offer a competitive edge, enhancing brand loyalty and trust (M. Porter, 2008). As regulations evolve, businesses integrating compliance with market strategies are better positioned for success (Kurucz et al., 2008).

3. Technological Advancements & Industry Trends

Industry competition drives AI and digital adoption as firms seek efficiency and differentiation. In manufacturing, AI-powered predictive maintenance reduces downtime, offering an edge over traditional methods (M. Porter, 2008). Companies also explore new business models, such as digital platforms and subscriptions, leveraging AI, blockchain, cloud computing, and IoT for growth. Failure to adopt these innovations risks market share loss; for instance, AI-driven procurement enhances supply chain efficiency, benefiting early adopters (Hanelt et al., 2020).

Diffusion of Innovation (DOI)

The Diffusion of Innovations theory, developed by Rogers, provides a framework for understanding how, why, and at what rate new ideas and technology spread (Rogers, 1983). At the organizational level, it helps to understand how new technologies, practices, or innovations are adopted within an organization, how different departments or teams may adopt them at varying rates, and the factors influencing adoption.

The DOI theory categorizes adopters into five groups as depicted in Figure 14:

- i. **Innovators** – First to adopt but not always trusted by others.
- ii. **Early Adopters** – Respected within the community and have the resources to adopt innovations.
- iii. **Early Majority** – Open to change but wait to see proven benefits.
- iv. **Late Majority** – Skeptical, adopting only when benefits are clear.
- v. **Laggards** – Resistant to change, sometimes never adopting.

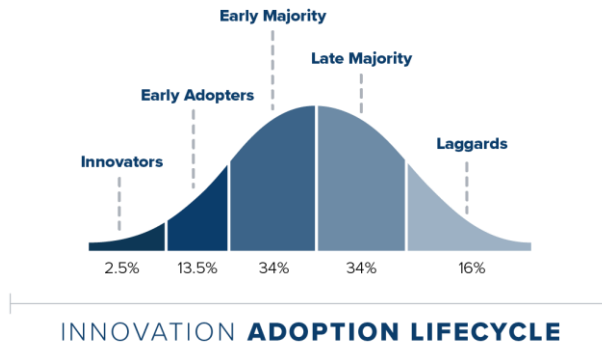


Figure 14. DOI stages (Sourced from Recchia, 2022).

Whereas adoption of the DOI theory depends on factors like:

- i. **Relative Advantage** – Does it offer a clear benefit?
- ii. **Compatibility** – Does it align with cultural values?
- iii. **Complexity** – Is it easy to use?
- iv. **Trialability** – Can it be tested with little risk?
- v. **Observability** – Can others see its effects before adopting?

While the DOI theory has been widely embraced, it is not without its limitations. The emphasis on individual decision-making overlooks the influence of organizational and systemic factors that shape technology adoption, particularly in hierarchical settings (Greenhalgh et al., 2004). Therefore, some researchers integrated DOI with other models like TAM to provide a more nuanced understanding of technology adoption. The integration of TAM and DOI offered a comprehensive framework for understanding technology adoption, as both models highlight different but complementary aspects of the adoption process. While TAM focuses on individual perceptions and attitudes, DOI emphasizes the broader social context and the characteristics of innovations. This integrative approach has been applied in various studies to explore technology adoption in diverse settings.

3.4.3 TOE framework

The Technology-Organization-Environment (TOE) framework is a theoretical model used to understand the factors influencing the adoption of new technologies, such as digital procurement. The TOE framework provides a structured approach to evaluating and implementing digital procurement solutions, ensuring alignment with organizational goals and external environmental factors. Luo and Zhou suggested that the TOE framework offers a comprehensive structure in procurement to analyze critical factors, emphasizing the importance of organizational readiness, technological alignment, and environmental influences, ultimately guiding successful D-procurement adoption (Luo et al., 2023). However, the study conducted by Luo and Zhou focused on a construction company, limiting its applicability to other industries. Sectors like maritime face unique challenges, including global supply chains, regulatory influences, and specialized procurement.

Weber highlighted that effective AI project planning aligns use cases with business goals. Co-developing AI with stakeholders enhances adoption, while strong data management ensures reliable training and decision-making. AI model lifecycle management maintains accuracy and efficiency, driving innovation and long-term success (Weber et al., 2023). Furthermore, Ruikar and Sohail's framework (Figure 17) outlines key factors influencing AI adoption, categorized into technological, organizational, and environmental contexts. Technology readiness depends on compatibility, data availability, and infrastructure. Organizational factors include leadership support, culture, processes, and resources. Environmental influences cover competitive pressure, government support, and external collaboration. These elements collectively shape an organization's AI adoption maturity (Felemban et al., 2024).

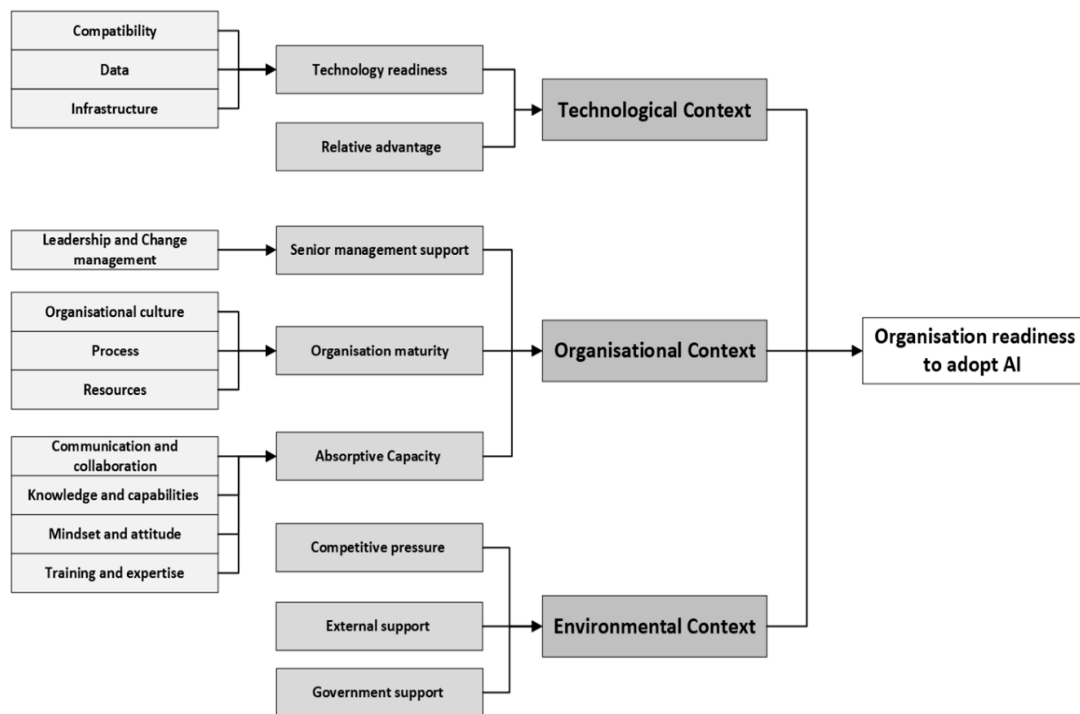


Figure 15. TOE framework for AI adoption (Felemban et al., 2024).

While the traditional TOE framework offers a solid foundation for analyzing AI adoption in procurement scholars argue that AI implementation is not a one-time decision but a continuous process of adaptation, influenced by evolving regulatory landscapes (e.g., EU AI Act), fluctuating supplier ecosystems, and technological convergence with blockchain, IoT, and robotics. Scholars have suggested integrating feedback loops into the TOE model, where organizational learning from pilot AI deployments modifies technological readiness and reconfigures internal processes (Jeff Baker, 2011; L. G. Tornatzky & Jd Eveland, 1990). Additionally, the institutional environment—including public sector mandates, sustainability pressures, and global supply chain standards—plays a more active role than the TOE model traditionally acknowledges. This has led to calls for hybrid models, such as TOE-DOI (Diffusion of Innovation) or TOE-RBV (Resource-Based View), to better account for strategic capability-building and inter-organizational knowledge flows in procurement. Therefore, AI adoption in procurement is not only a matter of internal alignment but also of navigating a co-evolving ecosystem, which demands greater theoretical agility than TOE alone may provide (Sean Xu et al., 2006)

3.5 Conceptual Framework

The section synthesizes key themes central to supply chain resilience (SCR), procurement, and artificial intelligence (AI). The literature review examined the SCR framework, procurement maturity models, AI applications and business environment factors. It explored AI-driven tools such as blockchain and IoT, emphasizing their potential to enhance procurement efficiency. While AI supports resilience by optimizing decision-making and increasing transparency, challenges such as high implementation costs, data quality issues, and expertise gaps remain. Research on AI adoption and integration remains limited in practical terms, highlighting the need for further exploration.

To address this, the study will provide practical AI adoption recommendations based on expert insights. Using a shipbuilding industry case study, it will analyze procurement challenges, technological and regulatory barriers, and best practices for AI implementation. The diagram below illustrates the theoretical framework, showing how AI applications, business environment factors, and organizational readiness contribute to intelligent and resilient supply chains.

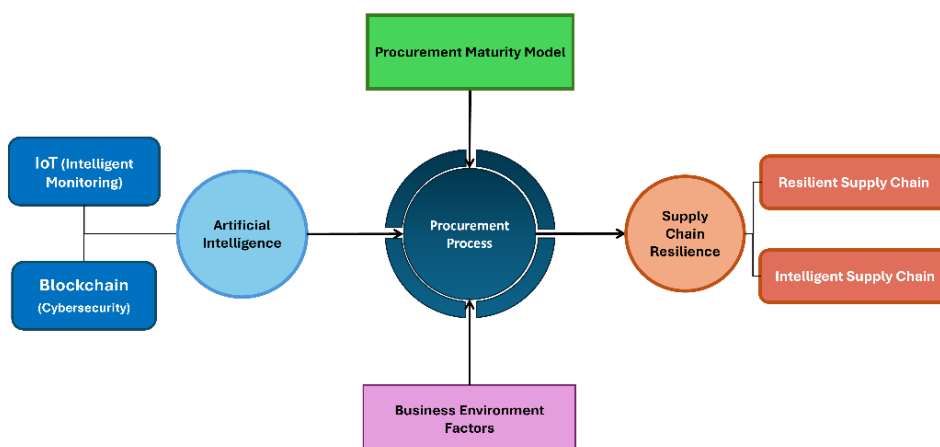


Figure 16. Theoretical Framework (by author using PowerPoint)

4 Methodology

This research used a qualitative case study to explore AI applications in procurement within a marine ETO solution provider company. Through purposive sampling, interviews with supply chain managers, the study aims to provide insights into the adoption and role of artificial intelligence in enhancing supply chain resilience.

4.1 Research Design

The research design employs a qualitative analysis, as it emphasizes understanding human behavior, experiences, and social contexts through non-numerical data, making it well-suited for exploring complex phenomena in depth (Oranga & Matere, 2023). A renowned marine ETO solutions provider was chosen as the case company, offering client-specific products. By examining real-world challenges and successes in managing procurement optimization within the case company, this study seeks to explore how AI impacts supply chain resilience and mitigates risks in large-scale, customized projects.

4.2 Sampling

Purposive sampling is a non-probability sampling technique in which participants are selected based on specific characteristics or qualities that align with the research objectives, ensuring that the sample provides relevant and rich information for the study (Etikan et al., 2016). Supply chain and procurement managers were selected based on their experience in planning, sourcing, purchasing, and supplier management. Participants were familiar with the latest procurement applications and were responsible for key decisions such as supplier evaluation, contract negotiation, and delivery oversight, providing valuable insights into current practices and future possibilities.

4.3 Data Collection

Data collection is a critical phase in the research process, ensuring the acquisition of relevant and reliable information aligned with the study's objectives. The choice of data collection methods depends on the nature of the research questions, the type of data required, and the target population (Creswell & Creswell, 2018). Proper planning, ethical considerations, and the use of clear protocols are essential to ensure the accuracy, consistency, and validity of the collected data (P. Lewis et al., 2023).

- 1. Interviews:** Data was collected through a focus group interview of five participants from the same company via Microsoft Teams in April 2025. The participants were selected based on their relevant experience in supply chain management. This approach is commonly used in qualitative research to gain in-depth insights from individuals with particular knowledge or experience (Alsaawi, 2024).
- 2. Case Study:** In this study, the approach of naturalistic inquiry was employed to explore the phenomenon in its natural context, ensuring that findings were grounded in the real-world experiences of participants, as advocated by Lincoln and Guba (1985). A project-based marine solution provider company was chosen due to its global supplier network and complex supply chain structure involving significant outsourcing.
- 3. Questionnaire Development:** To gather relevant data, an open-ended interview (Appendix 3) guide of 10 questions was developed, aimed at exploring the application of AI in procurement. The questions addressed current challenges and strategies in procurement, technological potential and factors impacting AI adoption in procurement processes. The questionnaire was grounded in a review of existing literature and the latest industry trends.
- 4. Qualitative Analysis:** According to Alsaawi, qualitative research aims to understand phenomena from the participants' perspectives, making it appropriate for studies focused on human experiences (Alsaawi, 2024). Therefore, qualitative analysis using thematic coding was carried out on the interview transcripts to identify recurring patterns and meaningful themes.

5. **Thematic Analysis:** Thematic analysis was conducted using NVivo software, which facilitated systematic coding, organization of themes, and identification of patterns across the interview data (Braun & Clarke, 2006).

4.4 Data analysis

Sutton and Austin describe data analysis as a structured process that aims to generate meaningful insights from collected data, ensuring coherence with the study's theoretical underpinnings (Sutton & Austin, 2015). With the consent of the interviewees, Microsoft Teams' transcription tool was used to transcribe the conversations, ensuring efficiency and accuracy in capturing responses during the interview. The transcript was then reviewed alongside the original audio recording to correct any potential misinterpretations or transcription errors, which were later cross-checked with the participants as well. Following transcription, the next phase of data analysis involved data coding. Coding is a process of organizing data into meaningful groups so that researchers can begin to make sense of and interpret the data (Sutton & Austin, 2015).

The thematic categorization into key themes helped filter out information that was not directly relevant to the study's research objectives. After this process, the refined dataset was further analyzed to identify overarching trends and insights, ultimately shaping the study's empirical findings. NVivo software was employed to facilitate the coding process and ensure a structured and rigorous approach to data analysis. Memos were written throughout the coding process and included summaries of participant responses, interpretive comments, and reflective notes. They were directly linked to relevant nodes in NVivo and were later exported to support the thematic narrative presented in the results and findings section.

4.5 Data Validity and Reliability

To ensure the rigor of this qualitative research, criteria of trustworthiness—including credibility, dependability, confirmability, and transferability—were adopted as recommended by Lincoln and Guba (1985). To enhance validity and reliability, interviews were conducted using a standardized protocol and direct quotes from interviewees were incorporated into the analysis. The quotes included in the results were rechecked and reconfirmed with the interviewees for accuracy and contextual alignment. While the dataset offers valuable insights, it is important to acknowledge that the perspectives gathered from a single organization, albeit from managers with extensive industry experience, represent a limited sample.

4.6 Limitations & Ethical Considerations

Understanding how AI can transform procurement in the maritime industry requires real-world insights, yet capturing a comprehensive picture comes with its challenges. This study, based on the perspectives of 5 managers from the maritime sector, offers valuable firsthand knowledge but is limited by its small sample size. The short research timeframe further restricted the depth of data collection and analysis. Additionally, in 2025, AI-driven procurement technologies were still in their early stages of practical integration, limiting the ability to assess their full potential. Since the study was conducted within the European region, its findings may not be directly applicable to markets with different regulatory, economic, or technological conditions. Moreover, Participants were fully briefed on the objectives of the research, and informed consent was obtained prior to data collection. To uphold ethical standards, confidentiality and anonymity were ensured for both the participants and the organization involved. Additionally, all collected data was handled with strict data security measures, including secure storage and restricted access, to prevent any unauthorized disclosure or misuse.

5 Findings

This chapter presents the findings of the study based on interviews conducted with procurement professionals across various organizational levels. The results are structured around five key themes that emerged during the data analysis: procurement challenges, procurement maturity, applications of AI technologies, business environment factors and the future of AI. These themes align with the study's objective of exploring how organizations, particularly within the capital goods and Engineer-to-Order (ETO) sectors, can respond to technological shifts and operational pressures.

5.1 Theme 1: threats vs impacts

Procurement in complex environments, particularly in Engineer-to-Order (ETO) settings, is increasingly pressured by globalization, supply chain disruptions, and the demand for customization (Paraschiv et al., 2022). Although procurement functions in many firms have matured over time, challenges such as supplier unreliability, late-stage design changes, and insufficient coordination between departments continue to hinder performance (Tanner et al., 2008). These challenges are especially critical in capital goods industries, where long lead times and interdependencies make procurement delays costly.

Participants in this study highlighted several recurring issues. Supplier-related difficulties were frequently mentioned, including overpromising, long delivery times, and limited capacity to adapt to design updates. Design and specification changes occurring late in the procurement process emerged as a major bottleneck. This was particularly problematic in projects involving international teams, where feedback loops between engineering, procurement, and operations were often slow or incomplete. Interviewees

also emphasized communication challenges and siloed workflows, which led to misaligned schedules and reactive, rather than proactive, procurement planning.

The fishbone diagram in Figure 17 visually presents the procurement challenges and their impacts, as derived from the collected data.

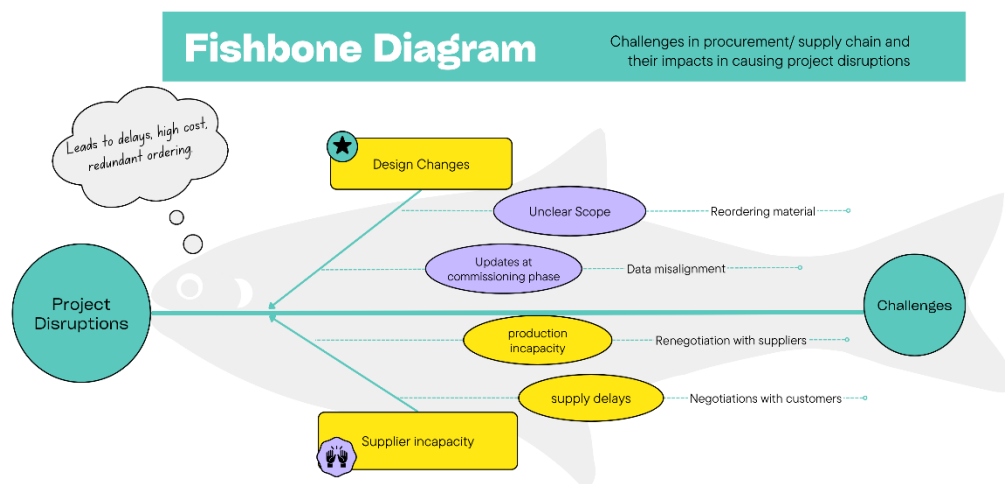


Figure 17. Fishbone diagram of major procurement challenges (Created by the author using Canva)

1. Design-Related Challenges

Interview findings revealed that design changes were a recurring source of project delays and resource strain. Participants frequently cited unclear initial scope, sudden modifications after designs were finalized, and unnecessary changes as key factors. These challenges frequently necessitated the reordering of components, adjustments to supplier contracts, and significant additional workload for procurement and project management teams (Shamsudeen Musa, 2016). Particularly disruptive were design updates introduced during the commissioning phase, which not only jeopardized delivery schedules but also forced teams to implement reactive, last-minute changes

under time pressure. Such late-stage interventions were described as detrimental to workflow stability and overall project predictability (Sudhir D. Shivankar, 2024).

“It causes deviation from the process, and then we need to question a bit also whether this change is even required.” -Participant M.

2. Supplier-Related Challenges

Supplier incapacity emerged as a significant challenge affecting procurement efficiency, particularly in complex and time-sensitive projects. Interviewees reported frequent issues such as suppliers failing to meet agreed delivery schedules, lacking the capacity to scale with project demands, or being unable to accommodate last-minute technical changes. These limitations often resulted in cascading delays, forcing procurement teams to seek emergency alternatives or expedite logistics at higher costs. Such disruptions are consistent with prior research, which highlights supplier underperformance as a critical risk factor in supply chains (Mark Stevenson et al., 2015).

A participant serving as a Delivery Manager stated.

“Supplier incapacity brings headaches from time to time”. -Participant T

Participants also noted that global sourcing adds further complexity, as language barriers, time zone differences, and inadequate visibility into supplier operations limit their ability to proactively manage these issues. As Ivanov argues, disruptions at the supplier level can rapidly propagate across the network, emphasizing the need for improved supplier evaluation, transparency, and capacity assessments. Such disruptions not only slow project momentum but also add pressure on internal teams to manage communication, adjust schedules, and mitigate risks associated with supply chain uncertainty (Ivanov et al., 2018).

5.2 Theme 2: Procurement maturity

This research focuses on the study of the adoption and efficient utilization of existing AI technologies to enhance supply chain resilience in the capital goods delivery sector with Engineer-to-Order (ETO) production. The global and complex nature of supply chains in this industry, where materials and components are often sourced from multiple countries for a customized product, introduces substantial challenges related to lead times, supplier coordination, and risk management (Ivanov et al., 2018). Research indicates that despite the maturity of procurement processes within many organizations, the integration of artificial intelligence (AI) into procurement remains at an early stage (Gunasekaran et al., 2015). While AI holds potential for predictive analytics, supplier risk assessment, and dynamic decision-making (Wamba et al., 2014), its implementation often encounters structural barriers. These include the need for significant investment in digital infrastructure, upskilling of procurement professionals, and robust change management processes to realign workflows and organizational culture (Batenburg & Versendaal, 2008; Duray, 2023).

The interview data concludes that the organization demonstrates a high level of procurement maturity, characterized by strategic engagement with suppliers, internal capability development, and a proactive approach to technological innovation. Operating globally with a wide network of suppliers, the company has established its own digital procurement systems and is actively piloting new technologies, including AI-based solutions and automation tools, to enhance operational efficiency.

“We are a bit advanced in Finland, being the main R&D hub here and the lead branch.”
– Participant M.

The participant added further,

“Procurement is mature, however, still premature in adopting AI.”
– Participant M.

The following figure illustrates the organization's current procurement and data maturity, highlighting its leading and innovation-driven approach as per Pleuger's four-level maturity and Duray's data maturity frameworks.

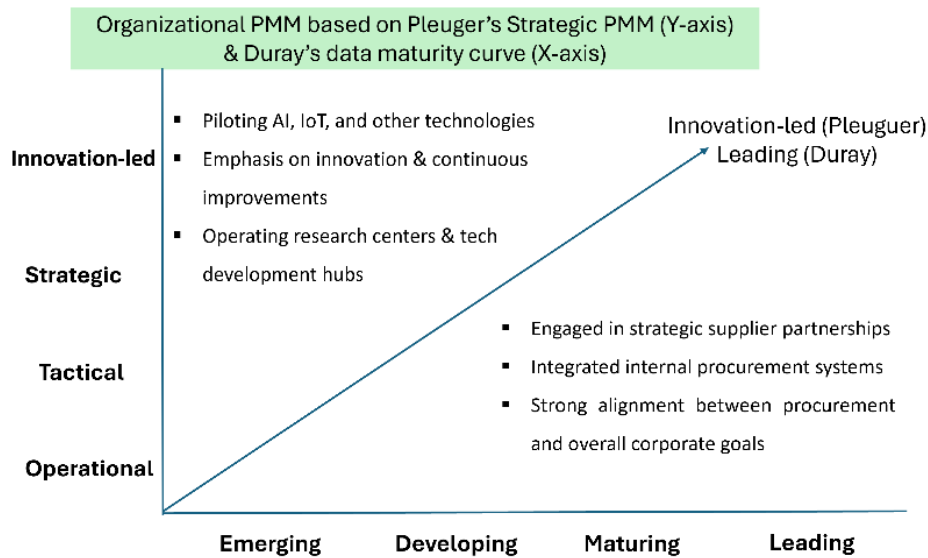


Figure 18. Organization's PMM & data maturity (Created by the author using PowerPoint)

These practices align with the higher stages of procurement maturity described in both Pleuger's strategic procurement maturity model and Duray's (2023) procurement maturity curve. According to Pleuger, mature procurement functions transcend transactional roles and operate as strategic value drivers within the organization—an approach reflected in this company's investment in research centers and continuous improvement initiatives (Pleuger, 2024). Similarly, the organization's willingness to adopt emerging technologies and invest in pilot projects corresponds with the "Leading" stage in Duray's model, where procurement is data-driven, digitally integrated, and innovation-focused (Duray, 2023). Such maturity indicates a shift from reactive procurement to a strategic and analytical function, capable of navigating complex global supply chains while maintaining adaptability and resilience.

5.3 Theme 3: AI applications

AI in procurement is not a new concept, but its practical application remains uneven across industries. According to Dorel, AI technologies, such as machine learning and natural language processing, can significantly improve procurement by enabling real-time data analysis, risk assessment, and process optimization (Dorel Mihai Paraschiv, 2022). Similarly, Wamba argues that AI can support better supplier selection, fraud detection, and contract management (Wamba et al., 2014).

Despite these theoretical advantages, the findings indicate that most organizations are still in the early phases of AI adoption, using it primarily to automate standard tasks. Only a few reported more advanced applications involving predictive analytics and IoT integration. Blockchain, although mentioned frequently, was not yet in active use. This aligns with previous studies that describe AI adoption in procurement as a gradual and evolving process, influenced by factors such as organizational readiness, data maturity, and technological infrastructure (Luo et al., 2023).

The following section presents a thematic summary of the findings related to research on AI Applications in the context of procurement and supply chain management. The adoption and leverage of AI was interviewed and analysed according to the latest industry trends and needs. Four key sub-themes were constructed and analysed using the NVivo qualitative method: Internet of Things (IoT), Blockchain technologies, the most effective areas for AI adoption, and the contexts where AI is perceived to be least effective. This section further presents the results by highlighting the key challenges organizations face in adopting AI in procurement, as well as the strategies they have implemented to overcome these barriers. The findings indicate that while AI is still emerging in many organizations, its current and potential use can reshape procurement practices.

1. AI applications

AI applications can enable automation, predictive analytics, and intelligent decision-making across areas like procurement, supply chain, customer service, and product development (Gollangi et al., 2024). The table below outlines key results from the interview, supported by participant quotes and risks associated.

Table 5. Insights on AI applications in procurement (Created by the author)

Sub-theme	Analysis	Quotes	Risk
Most effective area for AI adoption	Automation of repetitive and redundant data and routine tasks was viewed as the most effective and needed application of AI.	“There's a lot that can be automated. So much information is spread out in different places, only if it were possible to find all this information.” – Participant E	Risk of AI-generated errors (e.g., hallucination) in automated outputs without proper oversight.
Least-effective area for AI adoption	Decision-making was seen as the least suitable area of AI due to the need for human supervision.	“AI can help, but final decisions still need a human touch.” – Participant S	Replacing human roles and the need to learn the use of AI in a sustainable and ethical way.
Internet of Things	IoT can enhance procurement capacity to monitor operations, track equipment and perform predictive analytics at the component level.	“Forecasting can help to indicate where we are heading and what is needed.” – Participant T	Predictive models may not function reliably in project-based or ETO businesses.
Blockchain	The potential of Blockchain in procurement remained unclear as existing methods are sufficient at the moment.	“Traditional systems still meet the needs for now, but Blockchain is something that can be explored as the systems mature and specific use cases become clearer.” – Participant M	High training requirements and implementation costs limit the short-term feasibility of blockchain.

2. AI adoption challenges & Strategies

The results revealed several key challenges organizations face in adopting AI within procurement processes. Participants frequently pointed to licensing complexity and high implementation costs as major barriers (Ofori Issah, 2024), noting that acquiring and maintaining AI systems required a substantial financial commitment. Data security also emerged as a central concern, particularly regarding the handling of sensitive procurement information in cloud-based environments (Mingo, 2024). Another recurring challenge was system compatibility, especially when integrating AI tools with those of suppliers who may lack digital maturity (Iqbal et al., 2020). This often resulted in fragmented processes and limited end-to-end visibility across the supply chain.

In response to these challenges, the organization has introduced a range of internal and external strategies. Two participants emphasized the importance of cybersecurity awareness, stating that their organizations had implemented regular staff training and phishing simulations. One noted,

“We use tools like Hoxhunt (sending fake emails from fake suppliers) to train employees on how to recognize and report suspicious emails.” – Participant N

Another Participant S further stated:

“The company itself is spreading a lot of information and having training sessions. It is now part of our standard onboarding and compliance process.”

Regular internal sessions, workshops, and cross-departmental meetings were also reported as effective methods to enhance AI understanding and readiness. Interdepartmental collaboration—particularly between procurement, IT, and compliance teams—was highlighted as a critical success factor for navigating technical, legal, and operational challenges associated with AI adoption.

5.4 Theme 4: Business Environment Factors

This section explores the internal, external, and TOE factors influencing an organization's readiness to adopt AI. It examines the role of training, cross-department collaboration, and TAM in fostering an eagerness to adopt AI internally. Externally, it highlights the impact of early adopters, research investments, and the advantages of being in Finland and Europe. The TOE framework outlines both favorable conditions and challenges for successful AI integration.

1. Internal Factors (TAM)

The TAM framework is used to explain how employees' perceptions of usefulness and ease of use influence their acceptance of AI technologies (Venkatesh & Davis, 2000). Results indicated that the organization's internal environment is highly supportive of AI adoption, particularly through the emphasis on training, skill-building programs, and cross-departmental collaboration. The Technology Acceptance Model (TAM) aligns with this positive attitude, with employees eager to learn and embrace AI technologies. However, while eagerness to adopt AI is evident, some challenges remain, such as gaps in formal training and inconsistent collaboration across departments, which could hinder the smooth implementation of AI initiatives.

1. **Perceived Usefulness and Ease of Use:** Employees widely recognized AI's ability to enhance operational efficiency, reduce repetitive tasks, and support data-driven decision-making. These perceptions align with Davis's TAM model, which posits that perceived usefulness is a key determinant of technology adoption. As stated by a team leader,

“Internally, employees are eager to learn AI and IoT.” – Participant M

2. **Training and Awareness:** Regular training sessions, workshops, and informal peer learning have fostered a pro-technology culture. Similar to Venkatesh and Davis's extension of TAM, employees' experience with AI systems improved their perceived

ease of use and increased overall acceptance (University of Michigan & Bagozzi, 2007).

3. **Cross-Department Collaboration:** Cross-functional collaboration was cited as a key enabler. Teams in procurement, IT, and analytics often collaborate in pilot projects, reflecting the importance of shared understanding and knowledge transfer as facilitators of TAM constructs (Qingxiong & Liping, 2005).
4. **Leadership Support:** Management actively encourages experimentation with new technologies. Leadership engagement is known to boost trust and reduce resistance to change, reinforcing positive attitudes toward AI (Teece, 2018).

“There is curiosity in organization and management is supportive. We have internal development teams that ensure strong collaboration between departments”.

– Participant E

4. External Factors (DOI)

The results indicated that, externally, the organization is an early adopter with the geographic advantage of being situated in Finland and Europe. The company is actively involved in pilot projects and research initiatives, positioning itself within a growing community of AI adopters. These actions are driving readiness for AI adoption by creating a supportive environment for experimentation and innovation. Additionally, being in Finland and Europe provides the organization with access to funding, grants, and a favorable regulatory framework, which enhances its ability to invest in AI technologies. The early adoption culture and geographical advantages are pivotal in accelerating the organization's journey toward AI integration. In line with the DOI framework, participants acknowledged the role of government support in enabling AI initiatives, but emphasized that the organization's responsiveness is more closely shaped by competitive dynamics and market expectations:

“Government support is helpful, but what really matters is industry standards, location, and the competition.” – Participant M

5. TOE Framework

The TOE framework suggests that while the internal and external conditions are favorable for AI adoption, several challenges persist (Jeff Baker, 2011). Technologically, the organization faces concerns regarding the compatibility of data and systems internally and externally with supplier management systems, implementation costs, scalability and data security challenges. Organizationally, there are hurdles related to readiness at all levels, from management support to workforce training and high cost for technology adoption among employees. Furthermore, environmental factors, such as industry trends and stakeholder compatibility, pose additional challenges to seamless AI adoption (Khan, 2024; Sean Xu, 2006; Tanner et al., 2008). Results indicated that despite these obstacles, the organization is aware of these issues and is actively seeking solutions, indicating a proactive approach to addressing the barriers to successful AI integration. The internal environment is learning-oriented, and externally, the organization is an early adopter and tech-receptive. The following figure illustrates the result insights in the context of the TAM, DOI and TOE framework.

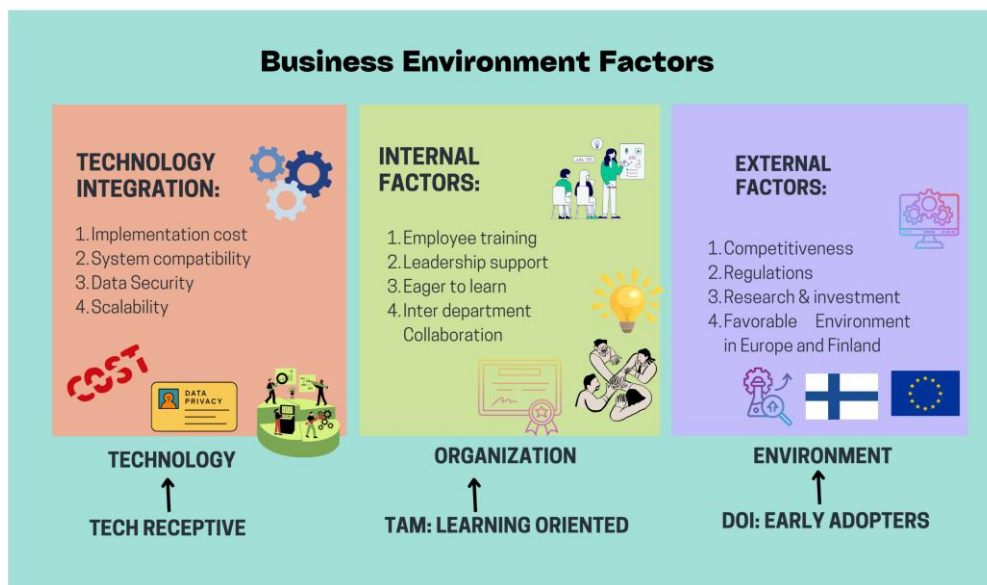


Figure 19. Result Insights for BEF (Created by the author using Canva)

5.5 Theme 5: AI and the Future

Participants expressed varied but generally aligned perspectives on how artificial intelligence (AI) will impact the future of human labor. There was a shared understanding that while AI is progressing rapidly and offers significant efficiencies, it is unlikely to replace humans entirely. Rather, participants highlighted a shift toward collaborative human-AI systems, where machines handle routine tasks and humans provide oversight, emotional intelligence, and critical decision-making. Some participants pointed to specific examples of automation, such as transportation, where AI could drastically reduce the need for human drivers.

As said by Participant M: “In New York, there will be at least half of the taxi drivers replaced by the robot. So maybe, maybe even all”. However, even within highly automatable industries, participant M emphasized the need for human involvement.

“Especially when it comes to project business, we really need human brains because there are so many different adaptations to be made and judgment. So robots cannot make [those decisions].” – Participant M.

Another participant stressed the balance between technological advancement and human contact:

“I’m quite sure it will replace some people. Still needs to be like the human contact spot” – Participant E.

There was also a sense of urgency around keeping up with AI trends to maintain competitiveness:

“It will become a competitive advantage. It's developing so fast... we just need to make sure we're keeping up with the competition” – Participant E.

Geographical context played a role in participant responses. For instance, Finland was seen as being ahead in AI development due to its strong R&D & government support:

“Finland is among the top players in Europe... we are a bit advanced in R&D” – Participant M.

In summary, participants acknowledged that AI will transform the workplace, however, human judgment will always be needed. To conclude, humans will always "supervise the machines" — signaling a shift in job types, not just job loss.

5.6 Discussion of Findings in Relation to the Revised Framework

This section discusses the study's main findings in relation to the existing literature and theoretical framework presented in Chapter 2. The aim is to interpret the results in light of prior research, identify patterns, and highlight confirmations and deviations from previous studies.

Internally, the results supported the Technology Acceptance Model. Employees showed a positive attitude toward AI adoption, driven by its perceived usefulness and supported by training initiatives and collaborative efforts. These elements reflected the importance of organizational readiness in shaping user acceptance. Externally, the organization's use of pilot projects and alignment with EU-level digital initiatives illustrated characteristics of the Diffusion of Innovation theory. Early adopters were instrumental in testing new tools, reinforcing the role of innovation champions in facilitating change.

The TOE framework helps contextualize both enablers and barriers. While the organization demonstrated strong technological and managerial support, challenges

persist in terms of high implementation costs, data and system integration, and inconsistent digital maturity across departments. These findings suggest a need for a more coordinated strategy to fully realize the benefits of AI in procurement.

The results also show that while procurement functions are mature, AI integration is still in early stages, signalling untapped potential. Design changes and supplier constraints emerged as key issues that could be mitigated through greater automation and real-time visibility. Emerging technologies like IoT show practical promise in Engineer-to-Order (ETO) projects, particularly for tracking deliveries and forecasting recurring component needs. However, the potential role of blockchain, while highlighted in the literature, did not clearly emerge from the findings, suggesting that it may be better suited for future exploration.

Results indicated that these technologies, particularly AI and IoT can contribute to the development of intelligent and resilient supply chain systems that are not only adaptive to dynamic demands but also robust in the face of disruptions (Al-Ibrahim & Aksoy, 2024). As Ali concludes, in today's dynamic environment, resilient supply chains are not just about recovery but about adaptability and transformation, enabling organizations to thrive amidst disruptions (Atieh Ali et al., 2024). This insight resonates with the evolution of procurement and supply chain management, where the integration of AI, IoT, and other emerging technologies is not merely about efficiency but about cultivating systems that are both intelligent and resilient (Bobde et al., 2024). Embracing adaptability ensures that supply chains can withstand disruptions and continue to thrive in an ever-changing global landscape.

Overall, the results confirm much of the existing literature on the transformative potential of AI in procurement, particularly in building more adaptive and resilient supply

chains. Figure 20 presents a revised version of the original theoretical framework (Figure 16), now updated to incorporate the key findings of this study.

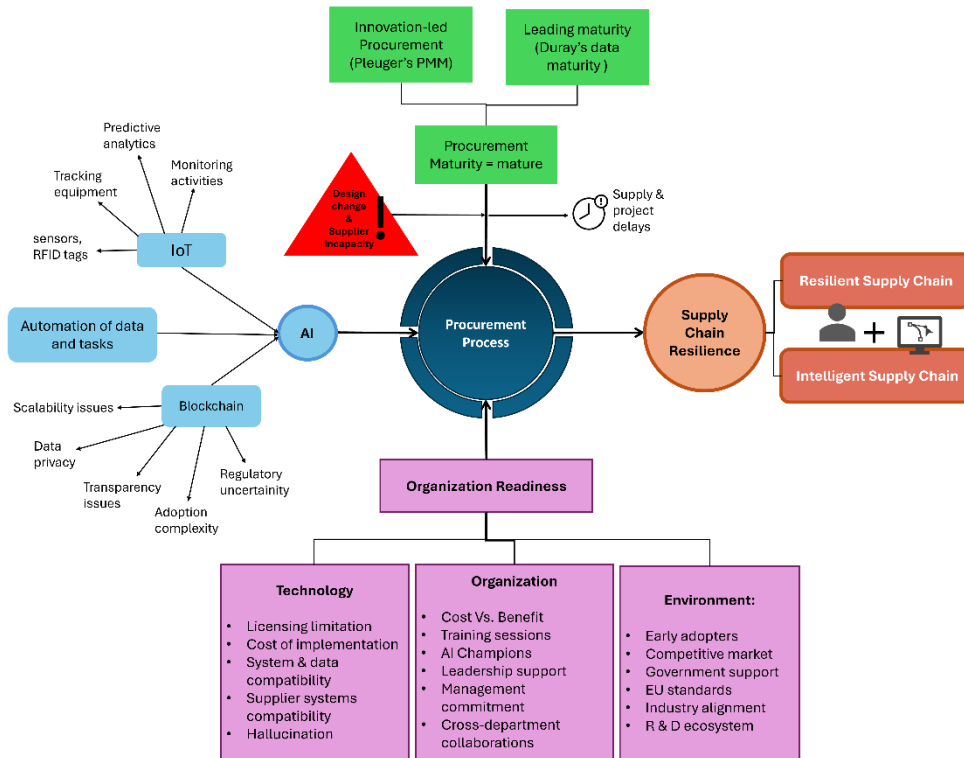


Figure 20. The synthesis of theory and empirical findings (Created by the author using PowerPoint)

6 Discussions

This chapter interprets the key findings of the research, considering the research objectives and theoretical frameworks used. The chapter delves into the key challenges faced by the organization, the maturity of its procurement processes, and the role of AI applications, specifically in IoT and blockchain, while considering the broader business environment factors that influence the adoption of AI across its global operations. Each research question is analysed individually, followed by a synthesis of major themes and implications.

RQ1: What are the current challenges in managing project disruptions at the procurement stage and what strategies are employed to address these challenges?

While the broader literature on procurement highlighted a wide spectrum of challenges, such as regulatory complexity, cost pressures, operational and technological integration (Tanner et al., 2008). This study revealed that organizational actors primarily focus on two core issues: supplier performance and design limitations. These findings suggest a localized narrowing of procurement concerns, possibly shaped by contextual or industry-specific factors. However, this specific case study revealed that procurement challenges within the organization are predominantly centered around two key issues: supplier performance and design limitations. These findings indicate a more focused set of challenges, possibly shaped by the specific industry context or organizational dynamics. The issue of supplier reliability aligns with prior studies emphasizing the strategic risk associated with global sourcing (Foerstl et al., 2015).

In the case of design challenges, the results echo sentiments found in product-service system research, where poor alignment between procurement requirements and design specifications leads to inefficiencies (Sudhir D. Shivankar, 2024). These challenges may

hinder the efficiency of the procurement process and complicate the introduction of advanced technologies, such as AI, that rely on smooth supplier integration and design compatibility. From a TOE framework perspective, the challenges identified highlight that if foundational procurement processes are not optimized, particularly in terms of supplier relationships and design alignment, introducing new technologies like AI may exacerbate existing inefficiencies, rather than resolving them.

The results of this study indicate that traditional procurement approaches remain dominant, which often lack the agility needed to deal with unexpected changes. Therefore, there is a need for greater integration between procurement and design teams, a sentiment also supported by scholars who argue that early collaboration between design and procurement functions can lead to more efficient and successful product development cycles (Reghimi, 2021). If these challenges are not resolved, the introduction of AI could exacerbate existing issues, rather than streamline processes, as noted by (Luo et al., 2023), who emphasize the importance of aligning technological adoption with the organization's existing structure and processes.

RQ2: What is the current maturity level of procurement processes?

Procurement maturity models by Michael Pleuger (2003), offered a structured approach to evaluating the evolution of procurement practices within an organization. The model focused on factors like strategic alignment, process integration, and supplier relationship management, with the aim of advancing procurement from a tactical to a more strategic function. While the results indicate that procurement processes are strategically mature, however organization is still at an early stage of maturity, particularly in terms of its integration of advanced technologies like AI into procurement processes.

The literature suggests that organizations move through several stages of procurement maturity, from basic operational processes to highly strategic, data-driven decision-making models. At a lower maturity level, procurement is often reactive, focusing on cost control and transactional relationships with suppliers. In contrast, at a higher level, procurement integrates advanced technologies, such as AI and machine learning, and establishes collaborative relationships with suppliers that drive innovation and long-term value creation (Pleuger, 2024).

While this study did not explicitly analyze procurement maturity according to Pleuger's model, the results suggest that the company's procurement processes are still evolving. For example, the challenges related to supplier performance and design misalignment point to areas where procurement is still working to optimize its practices, which would be characteristic of an organization at an early maturity stage. Furthermore, while some adoption of AI was mentioned in the results, it appears to be more in the pilot and testing phases rather than fully integrated into the procurement strategy. This aligns with the middle stages of procurement maturity, where the organization is experimenting with new technologies but has not yet fully embraced their potential to drive transformation (Batenburg & Versendaal, 2008). However, the organization demonstrates a behavior of both a tech learner and integrator, aligning with early adopter traits.

RQ3: How can AI (including IoT & blockchain) enhance resilience and intelligence in procurement?

AI is increasingly being recognized as a transformative force within procurement processes, enabling managers to streamline operations, reduce costs, and improve decision-making. The results indicate that AI technologies such as IoT, blockchain, automation, and predictive analytics offer significant opportunities to improve resilience and intelligence in supply chain management and procurement. By enhancing visibility,

security, efficiency, and decision-making, these technologies can transform SCM processes, although their implementation requires careful consideration of the associated challenges (Shyla Awasthi, 2024).

- 1. IoT:** IoT technologies are viewed as highly promising in procurement. Their ability to enable real-time tracking and monitoring can allow for better visibility of material flow and equipment tracking, improved forecasting for frequently purchased items, cost reduction through proactive issue detection and tracking of after-sales defective components. This enhances efficiency and helps procurement teams move from reactive to data-driven, proactive strategies. (Javed, 2024) Participants indicated that IoT could help “clear the blind spots” and support smarter prioritization in dynamic supply environments. The literature supports the view that IoT can drive supply chain efficiency through predictive analytics and automation, but widespread implementation faces barriers, including high costs and security concerns (Taj et al., 2023).
- 2. Blockchain:** In contrast to IoT, results indicate that the application of blockchain in procurement is still unclear and underdeveloped. Many participants expressed uncertainty about its real-world utility. However, the blockchain can offer a compelling vision for its future role when combined with AI: Blockchain provides a secure, tamper-proof ledger ensuring data transparency and integrity. AI can analyze blockchain data to detect anomalies, predict risks, and enforce compliance automatically. This integration could significantly improve procurement security, fraud prevention, supplier verification, and contract transparency. Though underutilized, the AI-blockchain synergy holds great potential to reshape trust and traceability in supply chain ecosystems. (Ramamoorthy & Manivannan, 2025)
- 3.** Furthermore, the application of AI also extends to automation and predictive analytics. Automation streamlines repetitive tasks, such as invoice processing, order tracking, and inventory management, freeing up human resources for higher-value

strategic activities. Predictive analytics uses historical data and machine learning to forecast trends, detect anomalies, and optimize decision-making. These technologies contribute to improved decision quality, cost reduction, and increased operational efficiency, making organizations more adaptive and resilient to supply chain disruptions (University of Michigan & Bagozzi, 2007).

In summary, results indicate that IoT is essential for procurement operations, and its adoption and integration show promising effectiveness, while blockchain remains conceptual but holds potential if paired with AI for security-driven procurement transformation. This highlights the growing need for IoT integration to enhance efficiency, while also paving the way for the future exploration of AI and blockchain synergies in transforming procurement processes.

RQ4: What are the key business environment factors that affect the adoption and integration of AI in procurement and supply chain management systems?

The business environment factors for AI adoption in procurement is shaped by both internal and external readiness, as explained through DOI, TAM, and TOE.

- 1. External factors:** Externally, the **Diffusion of Innovation (DOI) model** is relevant in understanding how AI adoption spreads within the organization's global network. The DOI model suggests that early adopters play a crucial role in promoting new technologies through innovation, research, and pilot projects (Rogers, 1983). The company, based in Finland, benefits from a conducive external environment, with supportive government policies and a growing AI ecosystem in Europe. Finland's leadership in AI research and development provides the company with a strong foundation for innovation adoption. However, the process of spreading AI adoption across different locations may face challenges in regions with different levels of

technological infrastructure, regulatory environments, and cultural readiness. This variability, as outlined in the DOI model, suggests that a tailored approach to AI adoption will be needed to address country-specific challenges and promote a more uniform diffusion of innovation. Results show that the organization is well-positioned to be an early adopter of AI, particularly in regions with strong research ecosystems. However, the adoption of AI still depends on several factors. First, its relative advantage must be clear—AI must demonstrate that it outperforms traditional tools. Additionally, its compatibility with current organizational values and workflows is crucial for successful integration. The complexity of AI solutions also plays a role, as simpler tools are more likely to be adopted. Lastly, trialability and observability are important factors, with stakeholders preferring low-risk trials and wanting to observe tangible benefits before committing to full-scale investment (Greenhalgh et al., 2004).

- 2. Internal factors:** Internal factors driving AI adoption are analyzed through the **Technology Acceptance Model (TAM)**, which posits that perceived ease of use and perceived usefulness are the primary determinants of technology adoption (Venkatesh & Davis, 2000). In the case of this organization, the study revealed a strong internal readiness for AI adoption, with employees expressing a willingness to learn and engage with new technologies. This aligns with the TAM, where employees' positive attitudes toward AI adoption suggest a higher likelihood of successful integration within procurement processes. However, challenges such as training and the integration of AI systems with existing tools, AI hallucination and reliability could affect perceived ease of use, an area that requires further attention (Venkatesh et al., 2003; Venkatesh & Davis, 2000)
- 3. Technology, Organization & Environment (TOE):** From a strategic perspective, the development of procurement maturity within the organization can be understood through the lens of the TOE framework (Oliveira & Martins, 2011). The technological component—reflected in the company's AI trials—appears to be advancing, but

organizational and environmental factors, such as financial investment (including licensing and training costs) and the readiness of staff and suppliers, may be limiting factors in achieving a higher level of maturity. Organizationally, there is strong support for AI from senior leadership, and cross-departmental collaborations are encouraged, however a holistic approach to integrate technological, organizational, and environmental changes will be necessary for the company to move towards higher stages of maturity, as suggested by Pleuger (2003) and supported by other scholars in the field (Peter Kraljic, 1983).

Critical Analysis

In relation to the case study, these models help unpack the complex readiness landscape for AI adoption. Internally, positive staff attitudes and openness to experimentation reflect a strong cultural foundation for change. However, challenges such as limited technical training, unclear role definitions, and AI's reliability issues—including hallucinations—signal a need for targeted capability building. While early-stage initiatives and cross-functional collaboration show promise, the pace of adoption varies significantly across regions. With a global supplier and operational network, the uneven diffusion of AI-related practices underscores the influence of local context and market maturity. This unevenness demands more than top-down enthusiasm; it requires localized support structures and context-aware implementation strategies. Technologically, the organization shows intent and early investment, but organizational and environmental readiness are still catching up. These findings suggest that while the environment is conducive in principle, realizing AI's full potential will require better alignment across operational silos, regulatory adaptation, and clearer long-term investment plans.

Based on the critical review of findings, several key recommendations emerge to support the organization's journey toward AI-enabled procurement. First, addressing supplier-related and design challenges requires a more structured feedback loop and early-stage collaboration between procurement, technical teams and suppliers. Second, the organization should actively monitor the procurement maturity to assess its current standing and guide strategic development over time. Third, AI applications—particularly IoT—should be scaled in controlled pilots to enable predictive analytics and monitoring, which can reduce recurring costs. Moreover, exploratory work on blockchain can be explored to investigate its alignment with real operational needs. Finally, prioritizing training, clear governance, and locally adapted plans is key to enhancing organizational readiness. Aligning technological investments with workforce capabilities and environmental support will ensure sustainable AI integration in procurement. The following figure, constructed using NVivo, illustrates the mind map of four research questions (RQ).

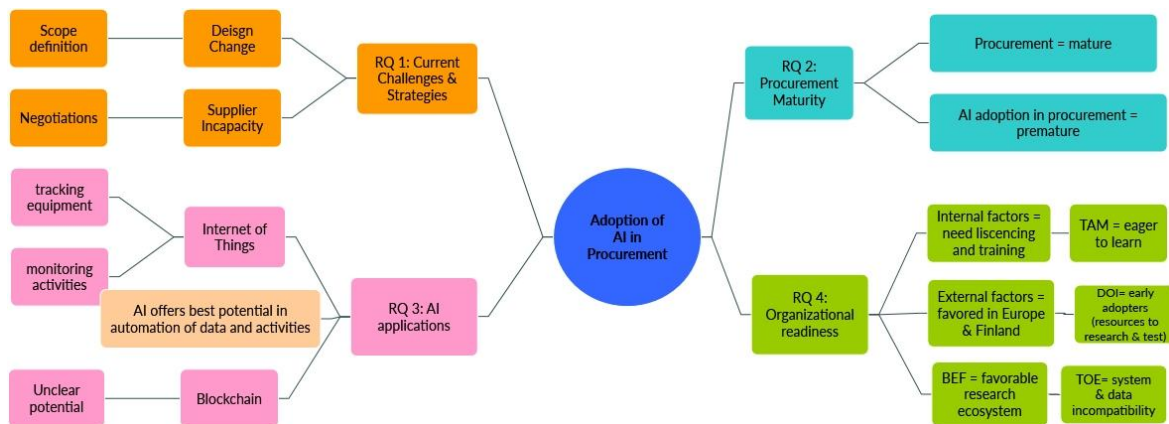


Figure 21. Mind Map of Research Findings (Created by the author using NVivo)

7 Conclusion

In conclusion, the adoption of AI in procurement presents a transformative opportunity to enhance efficiency, decision-making, and overall procurement performance. As highlighted by previous studies (A. Bhardwaj, 2021; Felemban et al., 2024; Shyla Awasthi, 2024), AI technologies, particularly when integrated with the Internet of Things (IoT) and blockchain, can revolutionize procurement by automating routine tasks, improving predictive analytics, and enabling real-time decision-making. However, successful integration of AI requires addressing both internal and external factors, such as organizational readiness, workforce capabilities, and environmental support (Rogers, 1983; Venkatesh & Davis, 2000). Organizations should prioritize fostering a culture of continuous learning and innovation to ensure employees possess the necessary skills to leverage AI effectively (Davenport, 2013, 2018). Additionally, clear governance structures, tailored implementation strategies, and controlled pilot programs are essential for scaling AI initiatives in a sustainable manner (Teece, 2018). By aligning technological investments with organizational capabilities and adapting to industry-specific challenges, procurement functions can unlock the full potential of AI while navigating barriers such as high costs and system compatibility (Judy Chen, 2025; Luo et al., 2023).

“Smart Procurement, Strong Supply Chain”. -author

While this research provides a foundational understanding of technology adoption in procurement, several avenues remain open for future exploration. Longitudinal studies can examine the integration of blockchain with IoT to make supply chains resilient and intelligent. Furthermore, comparative research across different industries or geographical regions may reveal context-specific insights. Future studies can conduct a Cost-Benefit analysis on AI applications. Moreover, future studies can focus on developing frameworks or models to support companies in overcoming implementation barriers or investigate the human-centric challenges such as digital literacy, resistance to change, and ethical concerns in AI-driven decision-making.

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Appendices

Appendix 1. Introduction Letter

Laraib Akhtar
Strategic Project Management
(Master's student) University of Vaasa



I am writing to formally confirm my intention to undertake my master's thesis for a maritime company as part of my Master's program in Strategic Project Management at the University of Vaasa. I am grateful for the opportunity to engage with the company, which will provide an invaluable learning experience and insights into the industry.

The potential title for my thesis is "Procurement 4.0: Investigating AI adoption for Intelligent and Resilient Supply Chains." A key component of this research will be understanding how AI can enhance resilience and reduce disruptions. Potential outcomes from the literature include insights into best practices of Artificial Intelligence integration, evidence-based frameworks for enhancing delivery timeliness of capital goods, and comparative analyses on the effectiveness of AI adoption in mitigating supply chain delays. By investigating these factors, the study aims to provide recommendations that align with company goals and contribute to improved on-time deliveries and overall supply chain performance.

I am pleased to inform you that Dr. Aurangzeab Butt, a Lecturer and Researcher at the School of Technology & Innovation has agreed to supervise my thesis. Dr. Aurangzeab Butt has a distinguished background in industrial management & project portfolio management, and he can be reached at aurangzeab.butt@uwasa.fi for any further questions related to this collaboration. This opportunity to conduct my thesis with the case company has been made possible through the support of my university, which encourages students to engage in industry-relevant projects that provide practical experience and contribute to their academic growth.

I understand the importance of research practices under the guidelines of the Finnish National Board on Research Integrity and the handling of personal data as per EU Data Protection (GDPR) guidelines. Furthermore, I acknowledge that my limited access to the company information will be subject to signing a non-disclosure agreement (NDA). I look forward to your support and collaboration on this project. Please let me know if any further steps are necessary to proceed. Thank you again for this opportunity.

Yours sincerely,

Laraib Akhtar (2302978)
X4788048@student.uwasa.fi
 Strategic Project Management

A handwritten signature in blue ink that reads "Laraib".

Student's Signature
 12.07.2024

Marko Makiluoko
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A handwritten signature in blue ink that reads "Marko Makiluoko".

Head of the Degree Program
 12.07.2024

Appendix 2. List of Interviewees

1

Table 6. List of Interviewees

Interviewee	Role	Experience in SCM
P-M	Director, PM Supply Chain and Development	20 Years
P-N	Manager, Project Purchasing	19 Years
P-E	Manager, Project Purchasing & Documentation	7 Years
P-T	General Manager, Delivery	12 Years
P-S	Supply Manager	20 Years

Background Information:

Interview type: Focused-group interview

Number of Interviews: 5

Duration of the interview: 1 hour and 10 minutes.

Department: Supply Chain & Development.

Industry: Maritime industry.










1 Focused-group interview with all 5 participants

Appendix 3. Interview Questionnaire

1. Which area of your procurement process do you find most challenging or prone to causing delays?
2. In your opinion, what are the biggest threats to procurement today, and how do they impact supply chain efficiency? Do you think AI or advanced analytics can help predict and prevent these threats?
3. In your opinion, which procurement area offers most and least potential for AI integration? And why?
4. How do you typically monitor and track activities within your procurement process to ensure efficiency and compliance?
5. What specific measures do you have in place to protect sensitive data, such as supplier information or financial records?"
6. How would you rate your organization's readiness to adopt AI in procurement based on technological, organizational, and environmental factors? Or what are the key challenges in implementing or integrating AI in procurement processes?
7. How would you describe your organization's current procurement maturity level, and what steps are being taken to advance it?
8. How do factors like regulations, competition, and technology in Finland affect AI adoption in industries compared to the rest of Europe?
9. To what extent do you believe AI is replacing human expertise and where is human intervention still crucial?
10. How do you see the future role of AI in transforming procurement practices and supply chain resilience?

Appendix 4. NVivo Data Structures

Table 7. NVivo Data Structures

Sr.	Name	Files	References	
1	Procurement & AI	0	0	
1.1	Most challenging area of procurement	1	3	
1.1.1	Impact	1	2	
1.1.2	Mitigation steps	1	3	
1.1.3	use of AI to mitigate	1	5	
1.2	Least suitable procurement area for AI	1	2	
1.3	most suitable procurement area for AI	1	3	
2	procurement monitoring	1	4	
2.1	IoT, tracking tags and sensors	1	1	
2.2	Power BI	1	3	
3	Data Security	1	3	
3.1	Blockchain	1	4	
4	AI	0	0	
4.1	AI & Finland	1	3	
4.2	AI & Future	1	3	
4.3	AI & Human	1	1	
5	Organizational readiness	0	0	
5.1	External, DOI	1	3	
5.2	Internal factors, TAM	1	4	
5.3	Current maturity level	1	2	
5.4	TOE	1	3	