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BAHCESEHIR UNIVERSITY

GRADUATE SCHOOL

DEPARTMENT OF ECONOMICS

IMPROVING DATA-CENTRIC DECISION-MAKING PROCESS IN EU SUPPLY CHAINS DATA NETWORKS BY ENHANCING DATA MANAGEMENT USING DISTRIBUTED LEDGER TECHNOLOGY WITH EU COMMON DATASPACES

MASTER'S THESIS

IBRAHIM OSAMA ABDELWAHAB MOHAMED RAYIS

ISTANBUL 2024

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MASTER THESIS APPROVAL FORM

Program Name:	**FINANCIAL TECHNOLOGY**
Student's Name and Surname:	**Ibrahim Osama Abdelwahab Mohamed**
Name Of The Thesis:	**Improving Data-Centric Decision-Making Process in EU Supply Chains Data Networks by Enhancing Data Management Using Distributed Ledger Technology with EU Common Dataspaces**
Thesis Defense Date:	

This thesis has been approved by the Graduate School which has fulfilled the necessary conditions as Master thesis.

Assoc. Dr. Yücel Batu SALMAN

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This thesis was read by us, quality and content as a Master's thesis has been seen and accepted as sufficient.

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ABSTRACT

IMPROVING DATA-CENTRIC DECISION-MAKING PROCESS IN EU SUPPLY CHAINS DATA NETWORKS BY ENHANCING DATA MANAGEMENT USING DISTRIBUTED LEDGER TECHNOLOGY WITH EU COMMON DATASPACES

Ibrahim Osama Abdelwahab Mohamed
Master's Program in Financial Technology
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2024

As data becomes increasingly influential in all aspects of life, the EU Commission's digital strategy aims to achieve a digital age. Addressing the growing complexity and data management issues within supply chains is imperative, as these challenges lead to various risks and disruptions. This study explores and analyze the potential of Distributed Ledger Technology (DLT) and EU Common Data Spaces to enhance data-centric decision-making. It examines the readiness of the current EU supply chain, identifies its challenges, and evaluates the benefits and barriers to adopting these emerging technologies. The analysis delves into how these innovative technologies could impact industrial supply chain, The goal is to equip policymakers, industry leaders, researchers, and stakeholders with tools to identify and leverage opportunities from technological advancements, driving transformation and improvement of data centric decision making in the supply chain sector.

Key Words: Blockchain, Supply chain network, Data spaces, Data driven decision Making, Open data.

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ÖZ

AB Tedarik Zinciri Veri Ağlarında Veri Merkezli Karar Alma Süreçlerini Güçlendirmek İçin AB Ortak Veri Alanları Kullanılarak Dağıtılmış Defter Teknolojisi ile Veri Yönetimini Geliştirmek

Ibrahim Osama Abdelwahab Mohamed
Finansal Teknoloji Yüksek Lisans Programı
Tez Danışmanı: Dr. Öğr. Üyesi Levent AKSOY
2024

Veriler yaşamın tüm yönlerinde giderek daha etkili hale geldikçe, AB Komisyonu'nun dijital stratejisi dijital bir çağa ulaşmayı hedeflemektedir. Tedarik zincirlerinde artan karmaşıklık ve veri yönetimi sorunlarını ele almak zorunludur, çünkü bu zorluklar çeşitli riskler ve aksamalara yol açmaktadır. Bu çalışma, Veri Merkezli Karar Alma süreçlerini geliştirmek için Dağıtık Defter Teknolojisi (DLT) ve AB Ortak Veri Alanlarının potansiyelini araştırmakta ve analiz etmektedir. Mevcut AB tedarik zincirinin hazır olup olmadığını incelemekte, karşılaşılan zorlukları belirlemekte ve bu yeni teknolojilerin benimsenmesinin faydalarını ve engellerini değerlendirmektedir. Analiz, bu yenilikçi teknolojilerin endüstriyel tedarik zincirine nasıl etki edebileceğini irdelemektedir. Amaç, politika yapıcıları, sektör liderlerini, araştırmacıları ve paydaşları teknolojik gelişmelerden kaynaklanan fırsatları belirleyip değerlendirebilecek araçlarla donatarak, tedarik zinciri sektöründe dönüşümü ve veri merkezli karar alma süreçlerinin iyileştirilmesini sağlamaktır. Anahtar Kelimeler: Blockchain, Tedarik zinciri ağı, Veri alanları, Veriye dayalı karar alma, Açık veri.

ACKNOWLEDGEMENTS

I am thankful to my supervisor, Prof. Dr. Levent Aksoy, for his exceptional guidance, insightful support, constructive feedback, motivation, and extensive knowledge throughout my research journey.

My heartfelt appreciation goes to my parents, Osama Rayis and Sara Omer, and my grandfather, Ibrahim Omer for their unwavering support throughout my life. Their empathy and relentless backing have been crucial in my pursuit of higher education and the successful completion of this research. I also want to thank my brothers, sisters, and entire family for their support during this challenging time, standing by me and motivating me every step of the way.

Additionally, I express my appreciation to Alexander Duisberg, Hubert Tardieu, Carsten Claussen, Douwe Lycklama, Holger Drees, Volker Berkhout, Charlotte Ducuing, Sara Aljazar, and all the experts who contributed to the completion of this research.

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Term	Definition
BDV	Big Data Value
Fintech	Financial Technology.
DAPP	Decentralized application
LC	Letter of Credit.
CAD	Cash Against Document
P2P	Peer to Peer network
RDF	Resource Description Framework.
GVC	Global Value Chain.
IOT	Internet of Things.
AI	Artificial Intelligence.
AML	Anti-money laundering.
API	Application Programming Interface.
DMP	Digital Manufacturing platforms
ERP	Enterprise resource planning.
MES	manufacturing execution system
KYC	Know Your Customer.
SME	Small and Medium-sized Enterprise.
MSME	micro, small and medium-sized enterprises.
GDPR	General Data Protection Regulation.

Chapter 1

Introduction

1.1 Motivation

Since its inception, the European Union has been actively engaged in efforts to digitize and integrate its economy (Szczepański, 2015). This century, the European Union resolved to develop a new Digital strategy that aims to create a holistic digital transformation that suits all citizens, businesses, and stakeholders (Maria Del Mar, 2021).

The commission's vision, is derived from European values and fundamental rights and the conviction that the human being must remain at the centre (European Commission, 2020), to be able to actually realise Europe's "Digital Decade" (European Commission, 2021a), and to become a role model and a leader for data-empowered societies, thus to achieve this, on preparing into this new era, Europe is strengthening its digital sovereignty and setting standards for openness to keep pace with the global digital revolution, recently, the EU released a new strategies and methods to contribute to economic development – EU digital compass, digital decade, SDM, Multi-countries projects (Madiega, 2022), and pushed new legislations, laws and regulations to the public on its data strategy – GDPR and "The big five" (DSA, DMA, DGA, DA and AI reg) – (Vagelis Papakonstantinou & Paul de hert, 2021). The European Union, in collaboration with its affiliated institutions, is allocating funds based on policy options to achieve the expected functional scenarios (Micheletti Giorgio, Raczko Nevena, Moise Cristina, & Osimo David, 2022; Rohmann Katrin, Klein Florian, & Lux Annina, 2019) that it has allocated a significant investments exceeding $30 billion towards emerging technologies such as blockchain, AI, and cloud through programs like Horizon 2020 and Europe Horizon (Stan Higgins, 2017) Additionally, private sector EU companies have contributed an investment of eight hundred million dollar towards the development of innovative solutions in these emerging technology domains (Smit Sven et al., 2022). These investments showcase the dedication of the EU and its affiliated institutions to explore and leverage the potential of emerging technologies for various applications.

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However, despite significant efforts and investments, the European Union still faces a significant challenge regarding the availability of data (Commission Staff, 2022), The data economy in the EU is characterized by disparities in data distribution and control, resulting in an imbalanced landscape where US and foreign companies manage 90 percent of the EU's data (Stolton Samuel, 2021). This unequal distribution of data has far-reaching implications for the overall development of the EU's economy, particularly in the context of data-driven processes like decision-making. The disparities in data access and utilization introduce complexities and uncertainties, especially within the supply chain sector. These discrepancies hinder the establishment of a level playing field and impede the EU's ability to fully harness its data resources for inclusive and equitable economic growth. Recognizing the pivotal role of supply chains in driving the EU economy, there is an increasing need to establish a robust and secure framework that enables efficient data management, allowing the EU to regain control over its data and enhance data-centric decision-making within the context of supply chains. With approximately 30 percent of European value-added dependent on well-functioning cross-border supply chains (Ollagnier, Timmermans, & Brueckner, 2022), the European Parliamentary Research Service (EPRS) together with European Regional Development Fund (ERDF) supported various policy options to address future challenges, reduce uncertainties, and promote effective data management. One such initiative is the EU common dataspaces, which aims to create specialized environments for efficient and secure data management within specific sectors. Hence, our project focuses on identifying and evaluating the needs and requirements for developing a DLT-based framework that moderates data management in EU supply chains networks, facilitating data-driven operations for decision-makers by enhancing data culture, governance, and integration through cutting-edge technologies. This endeavour contributes to the EU's strategic target for 2030 in Europe while providing opportunities to leverage digitalization for innovative solutions that ensure trust, effectiveness, efficiency, transparency, and security in monitoring and tracking goods within the EU supply chain. Ultimately, the framework aims to enforce and control EU regulations and policies effectively.

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1.2 Research Problem

The research problem revolves around data uncertainty, operational complexity, unfair management practices, and lack of transparency in EU supply chains networks These issues lead to data silos and an inequitable allocation and access of data, resulting in suboptimal decision-making processes. The research “Improving Data-Centric Decision Making in EU Supply Chains Networks by Enhancing Data Management using Distributed Ledger Technology (DLT) with EU Common Data Spaces" aims to explore and address this problem.

1.3 Research Gap

While the European Union acknowledges the importance of data management practices and the establishment of common data spaces to enhance decision-making processes, there is a notable research gap in evaluating and studying the potential of implementing DLT and EU common data spaces within supply chains. Current research and development efforts in this area are still in their early stages, as existing studies predominantly focus on specific aspects of data management or individual technologies. This fragmented approach fails to provide a comprehensive framework that encompasses the data management issues at entire data-centric decision-making process within supply chains. The contribution of this research by identifying the status, challenges, risks, and benefits of technology adoption, and by analysing the relationship between micro and macro factors to enhance decision-making processes tailored to the unique requirements of EU supply chain networks. Policymakers, practitioners, and researchers can benefit from this comprehensive framework, as it offers valuable insights for enhancing data management strategies and fostering growth in EU supply chains.

1.4 Research Aim and Objectives

The aim of this thesis is to explore the benefits, risks, and challenges associated with utilizing Distributed Ledger Technology (DLT) and the European Union (EU) Common Data Space to enhance data-centric decision-making within the EU supply chain networks, thereby supporting the European Union's vision (European Commission, 2020). Additionally, the thesis seeks to understand the relationship between contextual dimensions to improve the dynamic capabilities of organizations

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within the supply chain, thereby enabling them to adapt, seize opportunities, and facilitate decision-making.

The designed architecture aims to enforce the policies mandated in EU member states and promote standardization, which is fundamental for generating reliable data and metrics that assist EU stakeholders in their decision-making processes. Furthermore, the architecture is intended to manage and forecast the flow of goods within the EU supply chain in a transparent and immutable manner. It will also aid firms and businesses in creating secure channels to expedite settlements and exchanges, and to authenticate and legalize legitimate trade between parties. Finally, the goal of this thesis can be broken down into three ***objectives***:

- Identify the advantages and risks of adopting the proposed new technologies, understand the current status of the EU supply chain data space development, and examine the readiness, essential requirements, attributes, and dimensions necessary for the successful implementation of a DLT-based supply chain.
- Evaluate and analyze how micro and macro contextual factors and their corresponding dimensions within the supply chain context align with existing regulations, legislation, and policymaking processes, ensuring compliance and seamless integration within the current framework.
- Assess the implications of applying this framework in a specific use case, and its broader impact on macro-level phenomena, such as the creation of data markets and the establishment of a single market.

By accomplishing these objectives, this research aims to provide valuable insights and guidance for the development and implementation of a DLT supply chain Data space within the European Union, facilitating improved data management, decision-making processes, and the realization of EU's strategic goals.

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1.5 Purpose and Research Questions

Research question 1: *Is there a necessity for the stakeholders EU supply chain networks to adopt distributed ledger technology?*

The question aims to identify the challenges that the stakeholders face and drivers that support the reform or enhancement of the current system approach using DLT and to determine whether there is a justifiable reason for implementing these changes.

Research question 2: *How to Improve the decision-making process using DLT-based architecture for EU supply chain networks?*

This question aims to explore the specific ways in which a DLT-based architecture can enhance the decision-making process within EU supply chains networks. It seeks to identify the key components and functionalities of DLT that can address issues related to data certainty and uncertainty and enhancing it using data sharing, data governance, and data interoperability.

Research question 3: *What are the impacts and macro-level phenomena of adopting a DLT-based architecture on EU supply chain networks?*

This question aims to explore and understand the future implications of adopting a DLT-based architecture within the context of the EU 2030 vision and its impact on the digital agenda. It seeks to evaluate the broader economic, social, and regulatory effects that such an adoption may have on the overall efficiency, transparency, and robustness of EU supply chain networks. Furthermore, it examines how this adoption will affect relationships for further cooperation and development between the similar European initiative and other around the world. The objective is to provide insights into how these macro-level changes align with and support the strategic goals outlined in the EU's 2030 vision and digital agenda, thereby fostering global collaboration and advancement in supply chain management practices.

1.6 Research Importance

The research conducted in this thesis holds significant importance as it aims to address the gaps and challenges related to data management and decision-making processes in EU supply chains networks. By leveraging DLT within EU common dataspaces, the proposed framework seeks to improve data interoperability, data quality, and data governance. This advancement will contribute to the establishment of a robust and efficient supply chain ecosystem, aligning with the EU's vision for 2030 and its strategic objectives. Furthermore, the research outcomes will support the realization of a single data market, enable multi-country projects, and foster the development of a data-driven culture and business ecosystems within the EU. Ultimately, the implementation of this framework will enhance the overall efficiency, transparency, and competitiveness of EU supply chain networks, while reducing costs and creating new opportunities for innovation and growth.

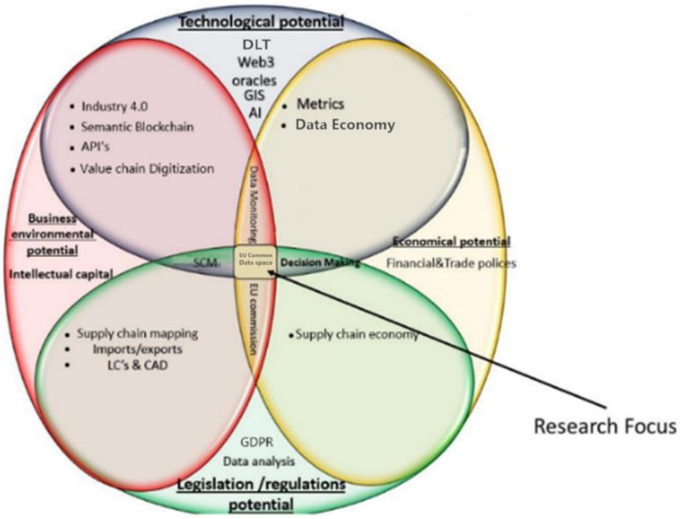

Figure 1. Research focus

1.7 Thesis Scope and Limitation

The scope of this explore is the how will a design of a new architecture will assist EU governments, businesses, and individuals in managing their data, from the supply chain and associated facilities, to make wiser decisions. Additionally, as a proof of concept, the creation of a prototype using accessible tools and technologies is also included. The thesis is carried out from grey and academic literature, focusing on recent releases and studies from EPRS, STOA, BBVDA, OpenDEI, IDC, IDSA, Deloitte, CCAF, IBM, HPE, TFG, WTO and The Lisbon Council, as well as other prominent research institutions and scholarly articles on the topic. It also covers a variety of established-related projects, as well as tools for working with and developing such architecture. Aside from that, the research only falls short when it comes to prototype competence because the researcher is limited by time and resources. Additionally, the study does not fully delve into setting regulations and legal requirements. While the research methodology employs convenience sampling and cross-sectional surveys, the findings may not be generalizable to all countries within the EU, leading to potential limitations in generalization.

1.8 Outline

This thesis is structured into five chapters. Chapter One provides an overview of the project, detailing the research questions, scope, focus, and significance. Chapter Two offers a literature review and theoretical framework, examining current and past approaches to the issue, the impact of emerging technologies on supply chains, the current state of the field, case studies, notable projects, and related research. Chapter Three defines the thesis context and outlines the research methodology. Chapter Four presents the research findings, and Chapter Five concludes by summarizing the findings and discussing their implications.

1.9 Chapter Summary

In this chapter, a summary of the thesis is presented, along with an explanation of the main issue and the proposed solution. The goals, limitations, and emphasis of the project are also discussed, as well as the research approach and structure, before ending with some key concepts.

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Chapter 2

Literature Review

2.1 Introduction

The European Union (EU) is an alliance consisting of twenty-seven member states that are chiefly located on the European continent, operating together as a single entity in political and economic affairs (EU Commission, 2022a; Kristin Archick, 2022). The core mission of this collective is to enhance the economic well-being of its members by pursuing sustainable development characterized by equitable economic expansion and stable prices. Additionally, it seeks to cultivate an extremely competitive market economy that promotes job creation and social improvement (Rohmann Katrin et al., 2019).

Today, the EU finds itself at the Centre of what is swiftly becoming a digital storm. The decisions taken today by public and private stakeholders, both individually and collectively, will shape the world we live in the future. While it is difficult to foresee the future, methods and technologies such as policy options, impact assessment and scenario analysis may provide considerably deeper insights into probable future development by cutting through complexity and capturing fruits of uncertainties. Based on driving factor-freedom or security - today's actions of the European Union, - EUtopia, EUsed, EUssr, and EUniformity - are the four different scenarios that were constructed to address the issue of what digital transformation may look like in 2035 (Rohmann Katrin et al., 2019) . To realize the EUtopia or EUniformity, which are the ideal functional scenarios, Europe must successfully and effectively master digital transformation and should employ data using appropriate and required technologies to navigate in the correct direction.

Data as itself is inartistic, data without a context lacks real value, The European data strategy is woven into its dynamic data-centric economy, acknowledging that data has the capacity to revolutionize every industry and unlock extensive growth possibilities for businesses of all scales (Snowflake, 2022; Susha, Janssen, & Verhulst, 2017; Zhong, Bertok, Mirchandani, & Tari, 2011).

There is a big misconception between Dataspaces with data lakes and regular databases, dataspaces are not another data silos, Data space is different than storing and processing data in one central cloud instance at one central cloud solution, data spaces are a new paradigm for federated data architecture, with the attributes of data co-existence, data visiting, data networks.

According to (EU Commission 2022) addressed some essential characteristics of its shared data spaces: An infrastructure that prioritizes security and privacy for pooling, accessing, sharing, processing, and utilizing data. It includes a transparent and fair structure for accessing and using data, while also respecting European rules and values such as personal data protection, consumer protection legislation, and competition law. Data holders have the option to grant access to or share personal or non-personal data in the data space, and the data made available can be reused for compensation or for free. Participation is open to a wide range of organizations and individuals.

As software development increasingly moves towards platform-centric ecosystems (Katz & Shapiro, 1994), the future role of dataspaces becomes a pertinent question: Will dataspaces emerge as the platforms of the future? Addressing this query, Malte, a policy officer at the European Commission, delves into the potential of dataspaces as future platforms in “chapter three” of the discussion. Malte emphasizes that if dataspaces gain substantial traction, they could hold significant economic influence over digitized products and their related services. However, caution is advised regarding the platformization effects of certain digitization trends. While maintaining a sense of optimism, it is crucial to approach dataspaces without fostering unrealistic expectations (Beyer, 2021).

The data economy encompasses the overall impact of the data market on the economy, including the various processes enabled by digital technologies such as generation, collection, storage, processing, distribution, analysis, and exploitation of data. Unlike the narrower concept of the data market, the data economy considers the value and wealth generated in the broader economy, beyond just businesses, through data exploitation.

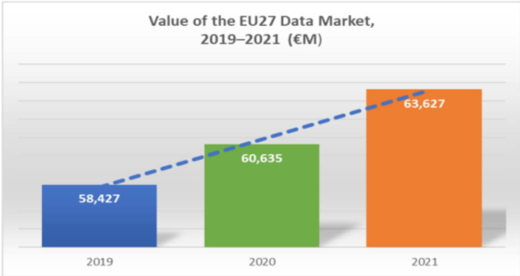

Figure 2. Value of the EU27 Market, 2019-2021(Deloitte LLP, 2021)

According to Deloitte in the figure above, Driving the Digital Economy and Society Index (DESI) score to 90 by 2027, would result in a GDP increase per capita of 7,2% across the EU.

Currently, the EU is placing significant importance on establishing a robust framework for data spaces. This involves laying the necessary groundwork for data sharing, exchange, and governance (European Commission, 2020), which are vital elements shaping the data economy. To prevent any European member state from falling behind in the digital transformation, it is crucial for the EU to ensure effective data sharing and management. Failure to do so could lead to a situation referred to as "EUsed," where only a few member states have successfully dealt with digital change (Rohmann Katrin et al., 2019). By emphasizing data sharing, the EU aims to empower the data economy and prioritize contextual data at its core. The European Commission has set up data.europa.eu to implement EU open data and reuse policies in accordance with legal acts adopted by EU institutions and member states (Inmaculada Farfan Velasco, 2022).

Globally, there is a shift towards data sharing in public authorities and organizations, such as the US Department of Defence, which has transitioned from a "Need to Know" approach to a "Responsibility to Provide" data sharing. Recognizing the advantages of data cooperation, both the public and private sectors are increasingly embracing data-sharing ecosystems. In fact, 48 percent of organizations and companies plan to establish new data-sharing ecosystems in the near future, with 84 percent intending to do so within the next three years.

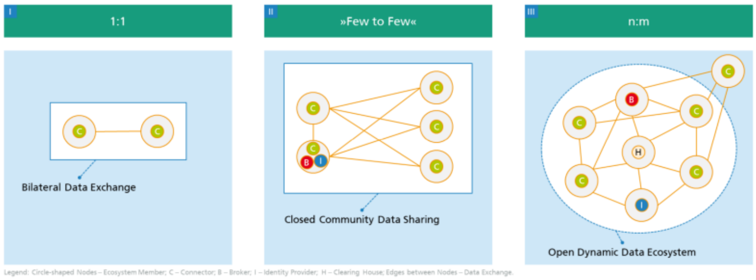

Figure 3. Evolvement stages of business ecosystems (2020 Fraunhofer ISST)

Despite the potential benefits, the sharing of information in current supply chains is not yet widespread. Typically, the flow of information ceases after the production and sale of the product due to outdated infrastructure within supply chain networks product (Akbarieh, Jayasinghe, Waldmann, & Teferle, 2020; Scruggs, Nimpuno, & Moore, 2016; Xu et al., 2011),

Open data represents a transformative force in supply chains, enhancing transparency and enabling immediate visibility into inventory and production dynamics. The incorporation of external data enhances capabilities in demand forecasting and risk management, thereby minimizing disruptions. Furthermore, it plays a role in ensuring compliance with regulations and achieving sustainability objectives. Through the integration of varied datasets, organizations have the potential to optimize their performance, enabling well-informed and efficient decision-making for the continuous enhancement of their supply chain processes. However, according to the union report (Corcho & Simper, 2022) on challenges and opportunities from data.europa.eu and the European Common Data Spaces selected from information sources (Gaia-X, IDSA and Open DEI), there is no indication that the supply chain, logistics, or manufacturing sectors within the region are utilizing or incorporating any form of open data.

DLT presents a straightforward solution for modernizing outdated and fragmented supply chain systems burdened by extensive paperwork. Through the digitization of these systems on a shared IT infrastructure and the implementation of automation, DLT and blockchain technologies enhance operational efficiency. Additionally, they enable data standardization among supply chain stakeholders, ensuring consistent data sharing and reducing disparities in data distribution among member states in EU supply chains.

In combination with DLT and machine-readable, legally compliant smart contracts, participant behaviour can be affected in such a way that both data quality and quantity are improved for the whole Data Space.

However, challenges arise in situations where participating stakeholders have diverse incentives “e.g. fear of tragedy of the common (Hardin, 1968)”, particularly when they represent different companies. This can lead to a decreased motivation to provide comprehensive information, resulting in information asymmetry. To overcome this challenge, the EU's common dataspaces initiative aims to foster trust and cultivate a cooperative environment that encourages win-win scenarios scenarios (Berg, Dickhaut, & McCabe, 1995).

Data sharing within dataspaces revolves around enabling applications to create, use, transfer, and exchange data effectively. This necessitates the establishment of data exchange APIs and data models. Standardizing shared data is crucial to enhance interoperability among stakeholders. The EU promotes the use of DCAP-AP for dataset standardization and CAN for government website standardization, which contribute to achieving interoperability and improving data quality.

Interoperability is defined by ISO/IEC 2382 Information Technology Vocabulary as the capability to communicate, execute programs, or transfer data among various functional units without requiring extensive knowledge of their unique characteristics (ISO, 2000). Other definitions, such as Lueders' definition, emphasize that interoperability enables the exchange of data and the sharing of information and knowledge within IT systems and supporting business processes.

As the EU envisions extensive digital transformation in businesses, interoperability plays a critical role. Interoperability between businesses facilitates rapid data interchange, fostering growth and prosperity. The European Council, in its conclusions of 25 March 2021, acknowledged the need to accelerate the creation of common data spaces, emphasizing access to and interoperability of data.

Semantic interoperability ensures that participating systems understand the meaning of data models within a specific subject area. Behavioral interoperability focuses on achieving the expected outcomes when using data exchange APIs. Policy interoperability ensures interoperability while complying with legal, organizational, and policy frameworks applicable to participating systems.

Interoperability in distributed systems is closely linked to the challenge of achieving "consensus," which is a fundamental concern in distributed computing. (Lamport, Shostak, & Pease, 1982) extensively discussed this challenge in the context of the Byzantine General Problem. This problem underscores the necessity for nodes to reach a consensus in order to establish trust in the received information and make decisions accordingly. Successfully addressing the Byzantine General Problem and attaining fault tolerance lay the groundwork for the development of robust distributed ledger systems.

Previous definitions reflect the enduring belief that information should be universally shared, regardless of the technology employed for its storage, processing, or distribution. Historical milestones such as the invention of the press in 1440 and the establishment of ARPANET, which evolved into the Internet, founded in 1969, have paved the way for our present. However, the future lies in the concept of the Internet of Value.

The essential role of cross-sector data interoperability in establishing a unified EU data economy. To achieve this interoperability, it is crucial to develop suitable standards at the European level. These standards will streamline and standardize data interpretation, thereby addressing a significant barrier to information exchange. The coordination and cooperation among stakeholders, as well as the involvement of European Standardization Organizations, are pivotal in the development and visibility of these standards. This collaborative effort will enhance interoperability within and across industrial ecosystems and European data spaces, facilitating the realization of a cohesive EU data economy.

Data-Driven, data-first approach involves building applications and workflows that prioritize data analysis and interpretation. By adopting a data-driven strategy, businesses can enhance their understanding of client and consumer needs, allowing for improved services. By contextualizing data, companies can personalize their communications and adopt a customer-centric approach.

This paradigm emphasizes making decisions based on data analysis rather than purely on intuition (Provost & Fawcett, 2013). A data-driven company operates by starting with data, analyzing it, and then making informed decisions. In contrast, a data-centric company begins with its business model, analyzing how data can support that model and contextualizing it to effectively serve its objectives. This approach includes launching new data-monetization services to achieve all business goals.

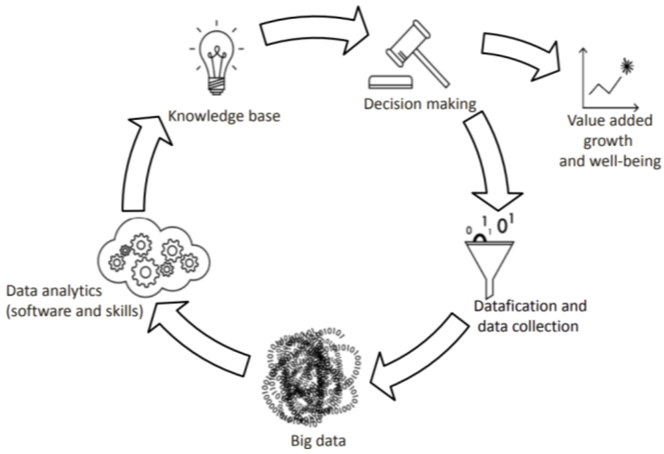

Figure 4. Creation of data economy

Data-driven Decision Support Systems (DSS) is recognized as one of the major types of computerized decision support systems, as noted by (Power, 2008). These systems exhibit unique features that differ across specific implementations. In addition to data-driven DSS, the other four types of DSS include communications-driven DSS, document-driven DSS, knowledge-driven DSS, and model-driven DSS (Power, 2002).With the advancement of technology, a new type of DSS is emerging, known as data-centric decision support systems. These systems prioritize the central role of data in the decision-making process, leveraging advanced technologies to enhance data-driven insights and decision-making capabilities. Despite the rapid progress in its development, the systematic and comprehensive frameworks or methodologies for data-driven decision making for supply chain networks are ignored in the current literature (Long, 2018).

Although adopting a data-driven approach is a great starting point for companies aiming to leverage data, unleashing the full power of data requires becoming a data-

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centric company. This involves integrating data into the core of the business model, contextualizing it to meet specific needs, and leveraging it to drive all aspects of the business.

Data Centric approach “Not all Big Data are Valuable Data”: Industries are increasingly transitioning towards data ecosystems, which involve an integrative and collaborative approach to data management and sharing. The global data production is rapidly expanding, projected to reach 175 zettabytes by 2025, with approximately 80 percent of it remaining unused 2025 (Ilka Jussen, Julia Schweihoff, Valentin Dahms, Frederik Möller, & Boris Otto, 2023). A study conducted in 2018 estimated the potential value of non-personal data usage in manufacturing to be €1.5 trillion by 2027 (European Commission, 2020).

The true value of big data lies not in the data itself, but in the narratives, it can reveal (Kristian J. Hammond, 2013), Adopting a Data-Centric Architecture treats data as a valuable and versatile asset rather than an expensive afterthought. This approach simplifies security, integration, portability, and analysis, enabling faster insights throughout the data value chain (Kevin Doubleday, 2020).

Considering the immense volume of data that the EU's supply chain would generate, it is essential to store the obtained data on platforms such as the cloud or IPFS. However, a significant portion of this data may be deemed worthless. To fully harness its potential and transform it into valuable knowledge, a data-centric approach is crucial. It not only supports future innovation but also aids in error detection.

Data-sharing systems and data-centricity are interrelated. For sustainable growth, data-sharing systems must adopt a data-centric approach. While temporary solutions may address some challenges, a data-centric approach provides scalability and higher chances of success in developing a value data-sharing ecosystem.

A definition of the Internet of Value (IoV) is suggested as the “instant transfer of assets that can be expressed in monetary terms over the Internet between peers without the need for intermediaries”.

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The Internet of Value can enable the exchange of any asset that is of value to someone, including stocks, votes, frequent flyer points, securities, intellectual property, music, scientific discoveries, and more.

A value chain is a business model that describes the entire process of creating a product or service (TARDI, n.d.). A value chain is the sequence of processes that a company takes to get a product from conception to distribution, including the procurement of raw materials, production functions, and marketing activities.

Porter coined the term -value chain as the set of linked activities performed by an organization that impact its competitiveness(Porter, 1985), Having a comprehensive dynamic shareable value chain map for EU authorities might be quite beneficial. This is due to the fact that a value chain generates a sharable understanding of how value is created.

Technology development plays a pivotal role in value chain development as it has a profound impact on all aspects of the value chain, encompassing both primary and supporting activities, as it empowers the linkages between activities. The integration of technology not only enhances the final product but also optimizes the manufacturing process, resulting in higher quality output and streamlined operations.

Moreover, technological advancements serve various vital functions in value chain development, spanning areas like telecommunications, accounting systems, and management systems such as ERP. Many of these operations have now been automated on blockchain platforms, which further enhances transparency and reliability within the value chain.

The data value chain acknowledges the interconnectedness of stages, spanning from raw data to decision-making, and highlights their interdependence (Miller & Mork, 2013). By embracing blockchain technology, along with its distributed nodes, the EU can establish connections and unify disparate data silos into a singular, accessible, and immutable decentralized database "EU Data Value Chain Map".

Internet of Value (IoV) and value chain: The emergence of the Internet of Value allows for the representation of assets as they move over the internet without the need for intermediaries, thanks to DLT. This innovative approach has the potential to reshape and enhance existing value chain concepts. Blockchain technology plays a significant role in enabling this transformation by facilitating a new generation of web patterns, known as the Internet of Value. This digital network operates on open standards and enables the seamless transfer of value across various entities.

Blockchain can simplify methods of establishing proof of ownership and accelerate patent registration, resulting in more efficient IP monitoring and new opportunities. Global IP management is done electronically. Blockchain technology can store, manage, and secure IP resources like trademarks, domain names, brand recognition, reservations, patents, copyrights, and goodwill (Kumar & Mallick, 2018). "Hashing" and "proof of existence" make blockchain patentable. Blockchain could improve the invention process by recording a patent's hash and proving its existence without revealing its content (Di Gregorio & Nustad, 2017). Blockchain technology could improve additive manufacturing, anti-counterfeiting, and copyright. Distributed cloud storage and blockchain are compatible. By integrating the technology into the cloud, cloud nodes can record data in a fault-tolerant, cryptographically secure distributed network.

EU Data Value Chain Dynamic Map (EUvcdm): The European Commission's launch of the Digital Single Market Strategy in May 2015 marked a significant step towards harnessing the potential of DLT (Szczepanski, 2015). By adopting this technology, the EU can enhance the Digital Single Market and improve the efficiency of the entire value chain system. EU companies can now benefit from improved traceability and monitoring of inbound and outbound logistics, as well as the ability to trace and verify original equipment manufacturers (OEMs) used in operational processes and enhance new product introduction (NPI) processes.

Technological advancements have the power to drive change and influence competitive advantage in markets, generating new markets, jobs, fostering innovation, cost reduction, and eliminating redundant work. However, it is crucial to acknowledge that technology also carries the potential to disrupt markets, leading to economic downturns, job losses, and misalignment within businesses, ultimately impacting costs and margins.

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The integration of the EU Data Value Chain Dynamic Map (EUvcdm) significantly simplifies the mapping of intellectual capital for governments and countries. Thus, it enables effective steering, guidance, and allocation of necessary skills at the right time and place, optimizing internal linkages within the value chain and positively impacting the overall performance of firms. Furthermore, companies can leverage the EUvcdm for strategic decision-making and planning, such as developing Target Operating Models (TOMs), ensuring comprehensive coverage in major change initiatives, and assessing acquisition fit.

The establishment of harmonized data spaces is hindered more by coordination and scaling challenges rather than technological limitations. While the necessary technology and process knowledge exist to create data spaces that empower users and enable cross-sector interoperability, concerted engineering efforts and continuous maintenance under sound European governance are now required (Nagel & Lycklama, 2022). By seamlessly integrating activities and leveraging appropriate technologies for communication while adopting data centric architecture (Brock, Bachmann, Kortsch, & Ritter, 2022), EU markets can achieve a competitive edge through enhanced coordination and optimization. This strategic orchestration of complex and innovative technologies facilitates the production of sophisticated products, generating substantial value for customers, suppliers, employees, and shareholders alike.

However, these emerging technologies are not immune to issues and debates. Pertinent concerns, such as GDPR and other regulatory frameworks, prompt the questions such: Will GDPR square the adoption of DLT? (IDSA, 2021) concerns about right to be forgotten (Article 17), etc, do not necessarily hinder the integration of DLT in supply chain digitalization. In fact, incorporating DLT within supply chain networks can align with GDPR requirements and effectively address crucial considerations related to data governance, efficiency, collaboration, security, and innovation. solution for this concern lies in permissioned DLTs, which can be utilized instead of public blockchains. DLTs offer various solutions to tackle real-world challenges, such as processing and storing personal data in an off-chain, changeable database, which is then connected to DLTs using a hash reference. By doing so, data can be effectively managed and even destroyed while the DLT simply reflects its existence at a specific moment. Traceability advantages of DLT align with GDPR's focus on accountability

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and transparency. Selective storage of relevant information on the blockchain allows for data minimization and purpose limitation. By developing compliance frameworks and collaborating with legal experts, organizations can strike a balance between innovation and GDPR compliance, thereby fully harnessing the benefits of DLT in supply chains while ensuring the protection of individuals' rights and fostering trust. IBM has addressed key areas associated with GDPR, demonstrating the advantages and risks of using DLTs in relation to EU Data Subject Rights, Security of Processing, Lawfulness and Consent, Accountability of Compliance, and Data Protection by Design and by Default (Cindy Compert, Maurizio Luinetti, & Bertrand Portier, 2018). DLTs provide accountability and transparency for value chain actors while maintaining privacy and confidentiality. More significantly, DLTs may aid in the elimination of friction points in conventional business processes. Although DLTs may not be a solution to all GDPR concerns, DLTs can be perceived to effectively control and manage the utilization of personal data, highlighting the importance of embracing GDPR and DLTs at present.

The coordination between the technological stack and regulatory frameworks is crucial for embracing the correct structure for building information within the digital supply chain, Regulations and legislation including the data act plays a pivotal role in establishing standards and creating a framework to adopt emerging technologies like DLT. Defining the appropriate properties for DLT can significantly contribute to establishing robust data management and information building within the digital supply chain, effectively addressing challenges related to interoperability, data sharing, productivity, efficiency, sustainability, and safety in the industry. Stakeholders, including manufacturers, suppliers, and contractors, recognize the benefits of Building Information Modelling (BIM) and the importance of collaborative efforts and data sharing, leading to positive transformations, streamlined workflows, and improved environmental sustainability and safety (Priego Pujol Laia & Osimo David, 2021).

The supply chain serves as the backbone of the economy, any congestion or disruptions within it can have far-reaching impacts on the entire economic system. For the EU, managing such a massive supply chain poses unique challenges, and any inefficiencies could hinder the achievement of its primary goals. To ensure effective decision-making, the digitalization of the EU's supply chain through appropriate technologies becomes paramount. Supply Chain Management involves actively overseeing supply chain activities and relationships to maximize customer value and gain a sustainable competitive advantage (Bozarth & Handfield, 2008). Responding to the complexities of supply structures and the dynamic relationships between supply chain members, the concept of Supply Chain Network (SCN) emerged, emphasizing the interdependence and continuous evolution of these relationships (Borgatti & Li, 2009).

Supply Chain Traceability refers to the completeness of the information about every step in a process chain. It refers to the capability of an application to track and trace the state of objects, discover information regarding its past states and potentially estimate future states (Abdulrab, Itmi, Poletaeva, & Saleh, 2012).

The contemporary supply chain serves as a network where manufacturers and service providers collaborate to deliver products or services to end-users (Bozarth & Handfield, 2006). In the retail supply chain, various stakeholders are interconnected, facilitating the physical flow of goods from producers to consumers. As globalization continues to advance, traceability within supply chains has gained paramount importance. Today's consumers exhibit a strong preference for goods that align with sustainable and ethical standards, fuelling the demand for increased transparency in supply chains. Nonetheless, the growing complexity of modern supply chains poses challenges for manufacturers in their sourcing endeavours (Gualandris, Klassen, Vachon, & Kalchschmidt, 2015). we encounter numerous products in our daily lives, sourced from regional, national, or global supply chains, the lack of comprehensive information about their journey underscores the urgent need for enhanced traceability and transparency within these supply chains.

Decision-making within supply chain networks is concentrated on generating impartial and efficient decisions to enhance overall performance. In practice, a significant portion of these decisions relies heavily on the domain knowledge or extensive experience of decision-makers within their respective supply chain network fields (Provost & Fawcett, 2013). The current challenges in today's supply chain center around the effective identification, tracking, and tracing of elements or products as they progress through different stages. The threat of counterfeiting and fraudulent goods poses substantial risks to consumer safety, as well as potential harm to the reputation and revenues of involved companies. To address these challenges, various techniques and strategies have been developed over time. DLT holds immense promise in improving supply chain traceability and is already integral to the digitalization of supply chain processes. By synergizing these crucial elements, the EU has the potential to achieve efficient supply chain operations, optimize value creation, and uphold its competitive edge in the global market. Subsequently, we will delve into the discussion of technologies that the EU should prioritize.

2.2 Enhancement of Supply Chain Management with Emerging Technologies Stack (Advanced Technologies for Industry)

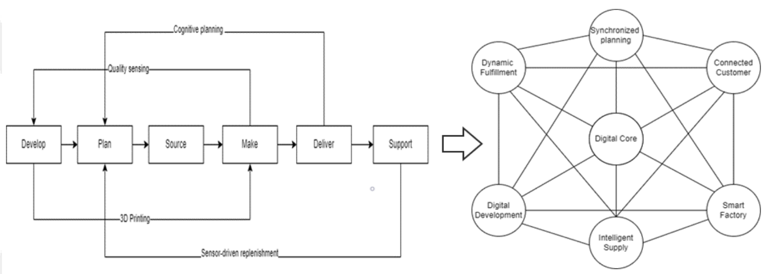

Figure 6. The interaction of technologies supply chain

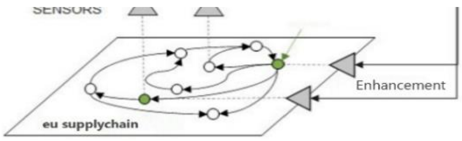

Figure 5. circular value chain improvement

Over the course of the last few decades, digital technologies, such as IOT, AI, and more recently, DLTs, have been progressively making their way into supply chains, international trade, and trade finance. Those advanced technologies are paving the road for digitalizing supply chains and ushering in what is being known as the Fourth Industrial Revolution (industry 4.0) (Murata Christina, Pant Nikhil, Iyer Sarayu, Veitch Jacob, & Campbell Michael, 2020), Accordingly, the Update of the 2020 New Industrial Strategy explains that an industrial (Manufacturing) data space will lead to more flexible and resilient supply chains (European Commission, 2021b).

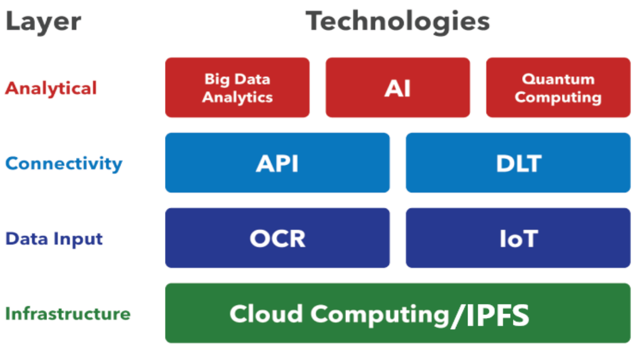

Figure 7. Digital technologies stack

The nine technologies emphasized in the figure can be thought of as existing within the framework of a technology stack. Each layer can be used to facilitate and enhance the layers above it. The following sections will explore certain layers and technologies from this stack and then illustrate how these certain technologies can interplay, resulting in a better outcome.

2.3 Edge Technologies and their Value Proposition

2.3.1 Artificial Intelligence (AI).

AI plays a critical role in enabling supply chain digitalization by acting as the brain behind automation technologies like autonomous objects, robots and RPA. These AI-driven technologies automate repetitive and error-prone tasks, enhancing the efficiency and accuracy of supply chain processes. One of AI's powerful advantages is its ability to strengthen data collection and distribution operations for IoT devices. In case of failure of oracles, AI can intelligently choose suitable replacements. Moreover, AI facilitates the connection of ontologies on semantic networks of supply chains, offering significant benefits to decentralized digital supply chains. By leveraging AI, supply chains can achieve greater automation, data-driven decision-making, and seamless connectivity, ultimately enhancing overall supply chain performance.

There are significant linkages between blockchains, FinTech applications and artificial intelligence, by exploiting valuable big data with AI, the usage of blockchains in business helps with product and process innovation, utilizing the favourable influence of the supply chain, which effects the functionality of blockchains and payment systems via its machine learning patterns (Dujak & Sajter, 2019; Korpela, Hallikas, & Dahlberg, 2017; Saberi, Kouhizadeh, Sarkis, & Shen, 2018).

2.3.2 Cloud Computing Federated Cloud.

Cloud computing has emerged as a well-defined technology that evolved from distributed computing on a large scale (Bharathi Murthy, Shri, Kadry, & Lim, 2020). It offers various benefits, including reducing the processing burden on users, enabling remote and on-the-go operations through cloud-based applications and data. Cloud service providers (CSPs) manage the underlying infrastructure, leading to cost savings for businesses by eliminating the need for dedicated servers and equipment while ensuring automatic network backups. Cloud computing encompasses three main

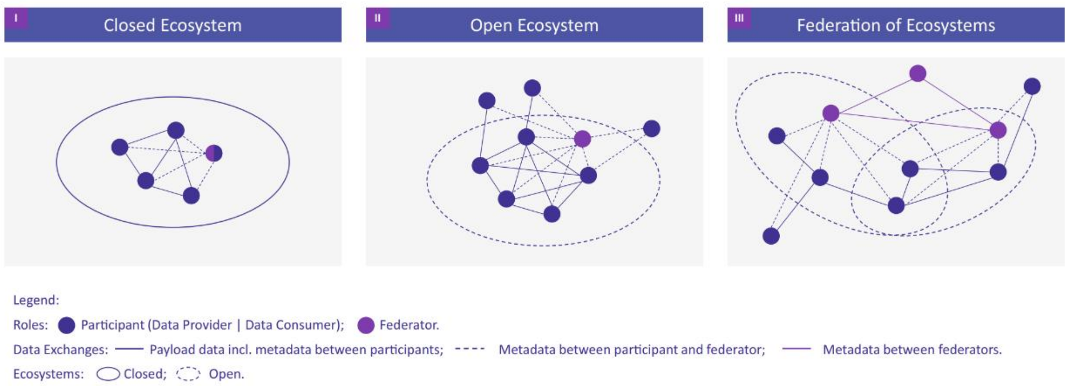

Figure 8. Ecosystem evolutionary stages

(2021, Fraunhofer ISST)

delivery models: Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS). It is widely used as an infrastructure technology in blockchain technology, allowing cloud infrastructure to adapt to changing computing resources and capacity demands. CSPs continuously upgrade their offerings, granting users access to the latest technologies. The concept of federated cloud plays a vital role in creating data spaces and federated ecosystems, facilitating seamless data sharing and collaboration across different platforms and organizations. This approach empowers organizations to harness the power of data and cutting-edge technologies collectively, leading to increased efficiency and value across various industries and domains. (Otto, 2022)

2.3.3 Distributed Ledger Technology (DLT).

Traditional databases have historically served as centralized data storage for transaction data. In contrast, DLT offers a decentralized and distributed record of

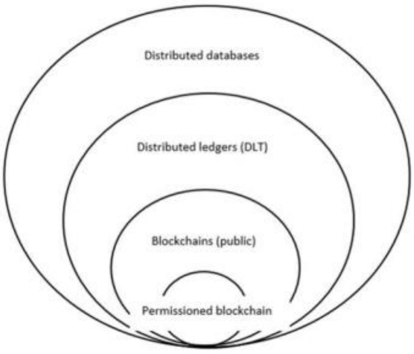

Figure 9. Blockchains and DLTs are types of distributed databases

transactions that all network participants can trust, allowing for easy traceability. DLT has the potential to be as revolutionary as the invention of double-entry bookkeeping in fourteenth-century Italy. Before delving into this thesis, it is important to address and clarify misconceptions, differentiate between intertwined concepts, and define the specific layer being worked on. The figure above illustrates the difference between database types.

Blockchain Trilemma Blockchains are a sort of distributed ledger that is created by decentralized, generally shared groups of individuals rather than known centralized parties. Consensus is achieved by making the ledger viewable and verifiable. A ledger should ideally: (i) properly record all information; (ii) be cost efficient; and (iii) be entirely decentralized to minimize any concentration of authority.

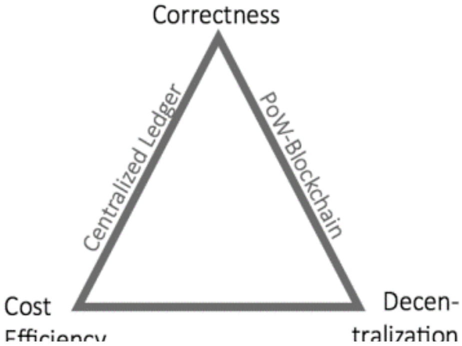

Figure 10. The blockchain Trilemma

(Abadi & Brunnermeier, 2018)

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According to (Avyan, 2022) the blockchain trilemma, a blockchain may only have two of three potential traits, but never all three at the same time, hence it is impossible for any ledger to completely meet the three attributes depicted in Figure 1 concurrently (Abadi & Brunnermeier, 2018). So that:

A blockchain is safe if it is decentralized. However, in order to maintain security, it cannot be scaled and hence has a lower throughput. If a blockchain is scalable and decentralized, there is a risk that it will not be secure because validators will face a barrier to entrance. If a blockchain is scalable and safe, it is not likely to be decentralized.

Monolithic and Modular Blockchains In the realm of blockchain technology, there are two main types of architectures: monolithic and modular blockchains. A modular blockchain is one part of a larger modular stack, where specialized blockchains are organized in layers to create a cohesive and comprehensive system. On the other hand, monolithic blockchains have been in existence for more than a decade, but they are constrained by handling all functions within a single layer. As a result, to improve aspects like throughput, security, or decentralization, certain trade-offs need to be made. In contrast, modular blockchains offer numerous advantages over monolithic ones, including the efficient creation of new blockchains, promoting sovereignty, and enhancing scalability within the system.

2.3.4 Internet of Things (IoT).

The Internet of Things (IoT) refers to a network of physical objects, or “things” that are equipped with sensors, software, and other technologies to connect and share data with other devices and systems via the internet. (oracle, n.d.)

The main benefit that IoT brings to the supply chain is that it offers transparency and enables information to be communicated from and about each section of the physical supply chain thanks to the data generated by sensors and other devices. This adds a sense of secure flexibility to the supply chain because devices can behave as oracles for DLT-powered chaincodes (Smart Contracts), offering a strong data input solution. Thus, events reported by oracles can be used as triggers for chaincodes.

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Looking back at the 2008 financial catastrophe, it becomes evident that despite having seemingly robust financial products and standards in place that functioned well for a period, the root issue lay in neglecting to assess or update the foundational level, particularly the data inputs.

Thus, IoT also can play a crucial role in equipment interoperability, particularly in cases of large-scale applications like smart cities. By combining DLTs and IoT, a reliable connectivity/communication layer is established, enabling seamless interactions and efficient data exchange in complex settings such as smart city infrastructures. The integration of DLTs and IoT opens up new possibilities for enhancing various industries, including supply chain management and smart city initiatives(Tocco & Lafaye, 2022).

2.3.5 DLT's Oracles.

The term "oracle" derives from the Latin term "oraculum", which meaning "divine announcement". These so-called oracles provided such pronouncements in ancient times, and since they were believed divine, everyone trusted them. People did not usually doubt oracles, preferring to accept that their own interpretation was incorrect, regardless of how events ended out. What makes the oracle concept interesting and applicable to blockchain is that the trust people placed in their oracle stemmed from the fact that once the oracle made a prophecy, they could not easily change it. Altering a prophecy after it has been made would essentially make an oracle appear fraudulent.

So, Oracle ensures, as these markets grow so quickly and so much capital is pushed b ehind them, that as these different products and services are built, in a way that keeps the scientific standards of the data at the center of these markets.

Failure to manage the data properly could lead to inadvertently experiencing a situation reminiscent of the 2008 financial crisis. In this scenario, there would be no room for pointing fingers or assigning blame, as the root cause would be directly tied to the lack of infrastructure resulting from insufficient collaboration among the private sector, capital markets, and scientific communities.

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2.3.6 Trusted Execution Environments (TEE) and Zero-knowledge (ZK)Proofs.

Confidential Computing, a safeguarding method for data in use utilizing hardware-based Trusted Execution Environments (TEE), addresses the three states of data - in transit, at rest, and in use. Notably, blockchain spending in Europe is expected to triple from 2020 to 2024, making it an intriguing market for confidential computing. By integrating blockchain technology, this emerging solution can comply with European laws governing communication confidentiality, boosting trust in transactions among network partners (Hefny Mohamed & Dragov Radoslav, 2021). European players lag significantly behind the EU's global economic influence in crucial technology sectors such as processors, web platforms, and cloud infrastructure. For instance, US companies manage around 90 percent of the EU's data, less than 4 percent of the top online platforms are of European origin, and European-made microchips account for less than 10 percent of the European market. However, confidential computing offers opportunities to enhance the value chain by improving marketing campaigns and accessing customer data without compromising privacy. This approach also benefits customers by reducing data sharing across organizations and increasing transparency in campaign cycles. Furthermore, confidential computing can work in tandem with Trusted Execution Environments (TEE) to ensure privacy when linking sensitive data within the EU data space, effectively serving as a “clean room” for secure processing. Looking ahead, it is anticipated that all chips will integrate TEE, thereby advancing data protection to new levels.

Zero-knowledge proofs first appeared in a 1985 paper, “The knowledge complexity of interactive proof systems”, A zero-knowledge proof is a way of proving the validity of a statement without revealing the statement itself. The “prover” is the party trying to prove a claim, while the “verifier” is responsible for validating the claim.

Zero-knowledge proofs marked an important advancement in applied cryptography, as they promised to improve the confidentiality of information for individuals. Consider how you might convince another party of a claim (e.g., “I am a citizen of X country”) (e.g., a service provider). Your claim must be backed by “proof,” such as a national passport or driver's license, this approach has drawbacks, most notably the lack of privacy. Personally Identifiable Information (PII) exchanged with third-party services is stored in vulnerable central databases. As identity theft becomes an increasing concern, there are requests for more secure methods of communicating sensitive information. Zero-knowledge proofs eliminate the requirement to disclose information to validate statements, hence overcoming this issue. The zero-knowledge approach employs the statement (called a "witness") as input to build a minimal validation proof. This proof provides strong assurance that a statement is accurate without revealing the information required to create it. Returning to our earlier scenario, the only evidence required to prove citizenship is a zero-knowledge proof. To be convinced that the underlying proposition is also true the verifier just needs to check that certain components of the proof are valid (ethereum.org, n.d.).

With ***zero-knowledge proof***, businesses are likely able to initiate preliminary eliminations, which check participants' eligibility and compliance, and cut down on wasted time by removing non-compliant parties from the equation at an earlier stage. Therefore, it functions more like a trustless "Blackbox" technique, in which all participants place their reliance on the specific output without providing more than necessary.

2.3.7 Containerization and Virtualization.

A container functions as a confined environment that runs software independently within the host operating system. These containers are established on the foundation of the host operating system's kernel and serve as compact entities housing lightweight operating system APIs and user-mode services. In contrast, virtual machines

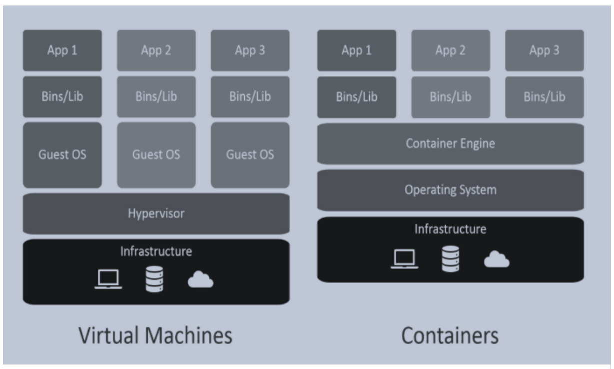

Figure 11. Containerization vs Virtualization

(IBM Cloud Education, 2021)

encompass an entire operating system, complete with their own kernel. The technology of containerization is surpassing virtualization and is swiftly emerging as the favored choice among IT experts. Through virtualization technology, multiple operating systems and software applications can function simultaneously, sharing resources from a single physical computer. For instance, an IT company could operate both Windows and Linux, or numerous operating system versions, along with various applications on a singular server. Each application, along with its relevant files, libraries, dependencies, and a copy of the operating system, is bundled together within a virtual machine (VM). Employing multiple virtual machines on one physical computer can lead to substantial cost savings in terms of capital, operational, and energy expenses. Concurrent operation of multiple operating systems and software applications, and resource sharing, is facilitated by virtualization technology. On the other hand, containerization optimizes the utilization of computational resources. A container represents a unified executable software package combining application code with essential configuration files, libraries, and dependencies required for its operation; notably, containers do not contain a copy of the operating system. Instead, the container runtime engine is integrated into the host machine's operating system, serving as a common interface through which all containers on the computing system share the identical OS. Consequently, multiple containers can perform on the equivalent computing capacity as a single VM, boosting server efficiency and further reducing costs associated with servers and licenses. (IBM Cloud Education, 2021)

2.3.8 Containerization and Microservices.

Microservices break complex applications into a series of smaller, more specialized services, each with their own business logic. That interacts through APIs and REST (like HTTP). Microservices allow development teams to update individual parts of a program without affecting the whole, speeding up development, testing, and deployment. Both microservices and containerization turn programs into smaller, portable, scalable, efficient, and easier-to-manage services or components. Microservices and containerization pair perfectly. Containers provide a lightweight encapsulation of any application, whether it's monolithic or modular. A microservice written inside a container enjoys all of the inherent benefits of containerization, including developer agility, fault isolation, server efficiency, automation of installation, scaling, and maintenance, and levels of security. Today's communications are migrating to the cloud, where users may construct apps quickly in the cloud. Containers, microservices, and cloud computing are enhancing application development and delivery. Next-generation techniques make the software development lifecycle more flexible, efficient, reliable, and safe. This speeds up the delivery of applications and improvements to end users and the market.

2.4 Current Status

The COVID-19 pandemic has emphasized the importance of data, digital technologies, and infrastructures in our daily lives, showing how our societies and economies can continue to gain from digital solutions. Even though the supply chain has become more digital, the COVID-19 pandemic has exposed gaps in supply chain networks, especially in terms of data visibility and integrity.

The European Union values openness and transparency in its member relationships, However, this raise concerns that can create challenges. In this context, and regarding

Figure 12. EU maturity curve (regulatory and business)

(EBSI, 2020)

the medical sector a well-functioning common European data space for health was initiated , a priority initiative for the European Council, which will be essential in addressing future health pandemics exposed infrastructure issues. The EBSI 2020 report provides figures on the blockchain regulatory maturity of member states.

2.5 Importance of Distributed Ledger Technology in Supply Chain

Today, DLT is being used in supply chains by businesses all around the world. The usage of DLT is rapidly expanding, and forward-thinking businesses are using it to digitally alter outdated supply chain operations across a wide range of use cases:

Legacy System Digitization: Blockchain's trust, security, and automation capabilities have the potential to convert paper-based back-office procedures into entirely digital systems that cut costs and boost productivity.

Building Resilience: When supply networks are disrupted, opaque old systems make it harder to adapt. Transparent, digital procedures developed on top of blockchain strengthen supply chain communication.

Modernizing Trade Finance: The interchange of huge volumes of secure data between various parties is required for trade finance. Because of DLT's inherent openness and security, these operations may be automated, drastically decreasing funding times.

Complying with Regulations: Businesses are subject to a slew of regulations controlling product procurement, safety, and quality. The auditability and traceability of blockchain-based solutions make it simple to demonstrate that goods and processes are compliant.

Guaranteeing Quality: When purchasing goods from numerous vendors, businesses need to ensure that their requirements are being fulfilled. Because DLT transactions are traceable, firms may discover suppliers who are falling short.

Streamlining Dispute Resolution: When difficulties develop, determining where the breakdown occurred and who is to blame is a time-consuming, laborious procedure. Blockchain allows for faster dispute resolution by offering a common source of truth.

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2.6 Importance of Distributed Ledger Technology in Trade

In trade, DLT is often utilized for two purposes: 1) track-and-trace, to improve transparency on how items are handled, and 2) digitalization of trade operations. Track-and-trace serves three goals. For starters, it may be utilized to promote consumer transparency and trust. This is accomplished by offering the client with access to DLT-verified records of the steps that a specific product takes to get into their hands. Second, it may be used to establish the legitimacy of certain items, therefore combating the trafficking of counterfeit goods. Third, companies can use it to quickly check for and find contaminated items. This lets them find problems quickly and fix them.

2.7 Case Studies and Prominent Established Projects

This section examines a number of well-established blockchain-based businesses, The table below depicts and illustrates the mentioned projects with an elaborate description.

Table 1

Case Studies and Prominent Established Projects

Project	Description
We.trade	Is s a European-based trade finance consortium founded by a coalition of Europe's largest banks, connects buyers, sellers, and their banks using IBM blockchain technology to facilitate international trade.
Korean trade Korean Customs Service, SAMSUNG SDS Co. and KCNET consortium	A collaboration between the Republic of Korea's customs and e-commerce companies to implement a pilot of a Blockchain-based customs platform that makes it easier to share documents and get information, as well as to test new ways to speed up the customs clearance of goods from these companies, share information in real-time, send automated reports to the authorities about import customs clearance, and stop fraud and smuggling.
EBSI	The first EU-wide blockchain infrastructure, led by the public sector, in full respect of European principles and rules. EBSI is a market-friendly distributed blockchain network that is built on open standards and transparent governance style. The European Blockchain Partnership (EBP), which includes all of the EU member states as well as Norway and Liechtenstein, is behind the Enterprise Blockchain Support Initiative (EBSI).(EBSI, 2021) in-memory support for intelligent, real-time applications and next-generation analytics.

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Table 1 (cont.d 1)

Project	Description
TradeLens	A collaboration between IBM and Maersk, connects the whole supply chain ecosystem. The platform facilitates end-to-end supply chain shipping information and documentation exchange across the many different and interdependent stakeholders participating in typical supply chain transactions. TradeLens limits supply chain information visibility to authorized parties, ensuring privacy and security. Hyperledger Fabric supports the platform.
Syncfab	delivers NPI & OEM parts production procurement for agile supply chain management & parts pedi gree with digital thread compliance & blockchain cybersecurity, as well as ERP/PLM Compatibility, SyncFab Digital Parts Inventorying, Smart Contract Trust and Responsiveness.
Modum	Is a project that combines IoT sensors and blockchain technology to secure data integrity in physical commodities transactions, hence optimizing su pply chain operations. Originally intended to monitor pharmaceuticals, it is also appropriate for tracki ng food, electronics, art, and valuables.
Port of Rotterdam	Consortium members will be engaged in testing applications focused on facilitating the exchange of logistical and contractual information among involved parties. Within this initiative, the Port of Rotterdam is striving to leverage Blockchain technology to enable the structuring of extensive networks, chains, and markets in a decentralized manner, eliminating the necessity for a dominant or third-party regulator.
Legaltestbed	Digital testbed is currently being created to explore automated business processes. The aim of the Legal Testbed is to provide policymakers and companies with recommendations for action regarding new legal standards.

2.8 Hyperledger Technologies' Dominance in Enterprise Blockchains

The widespread adoption of cryptocurrencies and their underlying technology has reformed companies and industries worldwide. Many of the businesses in the figure derive their innovative models from investing in new technologies and transacting in crypto marketplaces. As a result, they made blockchain technology a

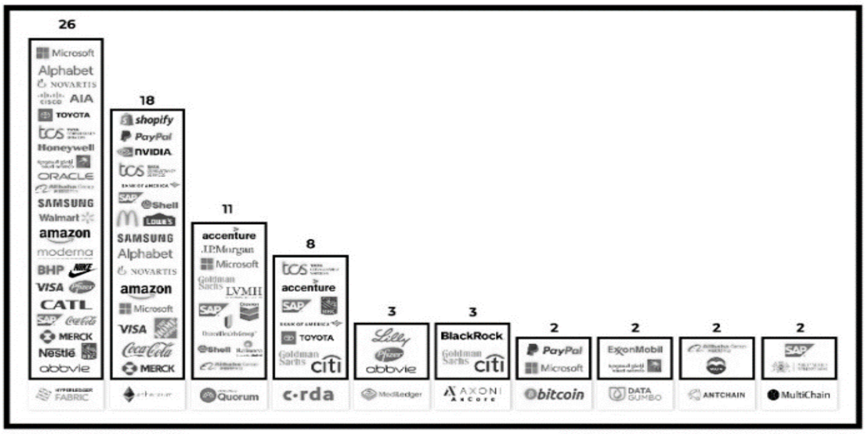

Figure 13. Hyperledger Fabric's Market Dominance (Hyperledger Foundation, 2020)

pillar of their business operations. At least 13 of the companies on this year's list have established strategic networks using Hyperledger technologies, far outnumbering any other technology or platform in these types of deployments.

2.9 Chapter Summary

This chapter begins with a theoretical introduction, then moves to discuss a number of emerging technologies and their interactions with supply chains, followed by some definitions and their value propositions. Then it proceeds to discuss the current state of digital supply chains. Next, the chapter sheds light on some notable established projects before delving into a review of storing methods with their advantages and disadvantages on blockchain. Finally, it presents the functionalities of Hyperledger fabric tools for working with Hyperledger fabric.

Chapter 3

Methodology

3.1 Introduction

In this chapter, we outline the methodological framework guiding our inquiry into achieving the research objectives and addressing key questions. Our focus is on assessing the necessity, benefits, challenges, and broader impacts of adopting DLT and data space structure in supply chains.

To data collection and to gather insights, we conducted in-depth semi-structured interviews with experts in related fields to cover the topic, structured around three pivotal research questions. This method helps us understand real-world experiences and perspectives, enriching our study and contributing to a comprehensive framework for improving decision-making processes in the context of the EU supply chain.

We employ reflective thematic analysis for data interpretation, a qualitative approach combining literature review insights with expert interviews. This method aligns with our study objectives and addresses the complexities of data management and DLT integration in supply chains.

We also recognize the limitations of our approach, particularly regarding the prototype's scope and the generalizability of our results. Ethical considerations and steps to ensure research integrity are discussed.

By the end of this chapter, readers will understand the methodologies used to explore the benefits of DLT in EU supply chains and the rigorous procedures followed throughout the research.

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3.2 Research Design

The study employed a qualitative research approach, utilizing in-depth interviews with a selection of experts in various aspects of the field to gain a comprehensive and focused understanding. The interview guide was developed after thorough literature review, A total of over hundred experts from prestigious international institutions were invited to participate in online interviews via university email. However, most of them didn’t respond , So due to time constrain, Only nine experts were interviewed, with eight of them being based in the EU and affiliated with EU institutions. The remaining expert was from outside the EU but possessed relevant expertise in the field. The selection of this topic was driven by its significance and originality in advancing decision-making in the EU supply chain.

This research is considered exploratory as it represents the initial attempt to assess the potential of an immersive concept aligned with the EU Digital Strategy. The use of expert interviews was deemed suitable for this evaluation strategy, as suggested in the literature for new research initiatives. This decision was a logical choice for this exploratory study. Conducting interviews allowed for valuable insights and perspectives from experts in the field, contributing to addressing the research questions.

The interviews were carried out via online platforms such as Zoom and Microsoft Teams at the agreed-upon time and date. Eight of the interviews were recorded, while one interviewee expressed apologies due to position restrictions, but detailed notes were taken instead. The remaining eight interviewees consented to being recorded. A semi-structured interview technique was employed during the interviews.

All interviewees possessed prior knowledge of European common data space and DLT and were related to the topic, and detailed explanations were provided whenever clarification was needed, fostering an interactive and discussion-oriented atmosphere during the interviews.

The primary objective of using this approach was to introduce new questions as required, backed by a wide range of comprehensive and diverse question types and sections within the topic, such as open-ended questions and agree/disagree statements.

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This approach aimed to make the participants' experience conversational and elicit detailed information through free association. On average, the interviews lasted 45 minutes and were structured to cover various topics such as Data Management Challenges in the EU, Challenges in Integrating DLT in Supply Chains, Contributions of EU Common Data Spaces, Impact of Regulatory Frameworks, Technological and Strategic Considerations for DLT Integration, Future Trends in DLT and Data Spaces, Agreement on Premises, EU's Strategic Vision, and International Influence.

Following a recommendation from a scholarly source, transcripts were promptly created or within a few days after each interview using transcription software. Subsequently, all transcript data were inputted into the NVivo software program. The analysis and data extraction from these interviews followed a reflective thematic review analysis approach as outlined by (Braun & Clarke, 2006), which consists of six steps for analysis: familiarization with the data, generating initial codes (inductive and deductive), generating themes (grouping codes with similar meanings to create themes), reviewing potential themes, defining and naming themes, and producing the report. Further details regarding the analysis and the interview content are elaborated upon in the findings and dissection sections.

3.2.1 Research Philosophy: Pragmatism/ Interpretivism.

Adopting pragmatism as the research philosophy underpinning this study signifies a commitment to a practical approach where the research is driven by its real-world applications and consequences. Pragmatism eschews the dichotomy between positivist and interpretivist paradigms, allowing for a flexible research methodology that can adapt to the evolving needs of the study. This philosophy is particularly pertinent to the investigation of DLT in supply chains, where technological innovation intersects with complex human and organizational behaviours.

3.2.2 Research Type: Inductive Approach Using Qualitative Method.

The inductive research type is selected to enable the derivation of new theories from the data collected and patterns observed. Using a qualitative methodology, this study combines qualitative insights, which will provide depth and context to the research and generalizability to the findings.

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3.2.3 Research Strategy: Exploratory.

The exploratory research strategy was adopted to investigate the emerging field of DLT within supply chains. This approach is particularly suited for areas with limited existing research, allowing this study to build foundational knowledge and uncover novel insights that can influence future research directions.

In the initial phase of the research, a comprehensive exploration was conducted to define the thesis focus. Several terms that were most appropriate for this initial phase of research were identified, such as: Blockchain, Supply chain, EU Digital Decade, Data space, Data quality, etc, see appendix. These terms which were used as follows: – supply chain and (quality OR DLT OR Data Quality OR EU OR Digitalization) – (supply chain OR DLT OR data quality) AND (Data space OR Digital decade OR Blockchain OR Open data), Key topics relevant to the study were identified to establish a common understanding of the subject's opportunities and challenges. The research gap was then defined, leading to the formulation of objectives and research questions. Subsequently, a second research phase was initiated to gather literature and build theoretical foundations for the study's design.

Each component of the main research questions was individually analyzed and defined to ensure a clear and shared understanding of the research questions and title for the literature review. This process laid a foundation for the subsequent development of the expert list, question guides, and further research analyses. Additionally, the identification of the technological stack, drivers with high uncertainty and impact, and challenges helped define contextual factors for the interview guide

Identification of driving and contextual factors was vital in guiding the exploration of relevant future drivers and developments. This enabled a detailed analysis of driving forces with objectivity and efficiency, leading to the creation of a list of the most relevant trends and developments shaping the chosen key topics and the technological stack. Understanding how the EU works, and its expectations and assumptions was crucial in mitigating any intrinsic biases and gaining a comprehensive understanding of the key topic. Previous studies were deeply analyzed from different angles, including technological, regulatory, legislative, and cultural aspects.

3.2.4 Time Horizon: Cross-Sectional.

A cross-sectional time horizon is selected to accommodate the study's time limitations and focus. This strategy enables the analysis of data at a specific moment, which is advantageous for capturing the immediate impacts and dynamics arising from the integration of DLT in supply chain networks. Data is gathered at a singular instance from a diverse sample of individuals (nine interviewees from various domains), offering a snapshot of the participants' viewpoints and characteristics at that particular juncture. Through these interviews with the nine distinct participants, valuable insights are gained into their perspectives regarding the incorporation of DLT in the supply chain of the European Union (EU) within a specific timeframe.

3.2.5 Sampling Strategy: Purposive Sampling.

The study employed Purposive sampling, a pragmatic choice given the constraints of accessibility and resources. This strategy involved selecting readily available subjects that fit the criteria of the study, ensuring that the research could be conducted efficiently without compromising the quality of the data.

3.2.6 Data Collection: Qualitative Approaches.

Qualitative Data approve was conducted on two stages first collecting Secondary data from academic and grey literature was used objectives define answer research questions. Second stage is conducting semi structure interview with field experts. This data also included insights from industry professionals obtained through workshops and interviews. This step was crucial for using the data for generalizing sample purposes.

3.2.7 Analysis Methods and Techniques.

Reflective thematic analysis was utilized to gather more evidence of the evolution and benefits of data sharing. This method, rooted in the work of (Braun & Clarke, 2006) involves a rigorous process of coding and identifying patterns or themes within qualitative data. The analysis was conducted through a continuous reflexive process, ensuring that the researcher's perspectives and potential biases were considered and mitigated. This approach facilitated a comprehensive understanding of the various dimensions of data sharing, capturing nuanced insights into its development and the advantages it offers within the context of supply chains. By systematically analyzing the data, reflective thematic analysis helped to uncover underlying themes and relationships, thereby providing a rich, detailed account of the potential under study.

3.2.8 Validation of the Research Design.

To ensure the validity and reliability of the research design, the research design will also be subjected to peer review and scrutiny by experts in the field to confirm that the methodology is sound and capable of answering the research questions.

In conclusion, the research design is meticulously planned to yield a comprehensive understanding of the potential benefits and challenges of implementing DLT in EU supply chains decision-making. The qualitative, inductive, and exploratory approach, underpinned by a interpretive philosophy and a cross-sectional time horizon, is well-suited to the complex and multifaceted nature of the research problem. The convenience sampling and mixed data collection strategies are designed to balance depth with breadth, ensuring a nuanced yet generalizable set of findings, contributing valuable insights to the field of supply chain management and technology adoption.

3.3 Limitation

While the approach used in this research is thorough and reliable, it does have specific limitations due to the number of participants and time constraints related to data collection that need to be considered. Recognizing these restrictions is crucial for a comprehensive understanding of the extent and significance of the study's results.

Qualitative Data Collection Methodology The primary qualitative data for this research was intended to be collected through interviews with experts in the EU supply chain domain. However, due to various constraints such as accessibility and the willingness of experts to participate, this method could not be fully implemented as planned.

Mitigation Strategy: To address this limitation, the strategy was adapted by extending the number of participants to gain greater insights and adopting a more in-depth approach by opening channels with participants' institutions. This adjustment aimed to provide a broader and more comprehensive understanding of the subject matter by incorporating a wider range of perspectives and insights from additional participants.

3.4 Chapter Summary

Chapter three introduces the methodology of the thesis, which focuses on understanding how to improve data-centric decision-making in the EU supply chain network. The research adopts a pragmatic, qualitative approach, primarily employing semi-structured interviews for data collection and Reflective Thematic Analysis for data interpretation. It also combines qualitative and quantitative data collection methods, including literature reviews and workshops. The study is exploratory and inductive, with a cross-sectional time horizon and uses convenience sampling to select participants. Despite challenges such as limited expert access and the nascent stage of the framework, the chapter outlines mitigating strategies like extending participant numbers and engaging institutions. Additionally, it discusses validation strategies and proposes future research directions to address identified limitations and further develop the framework.

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Chapter 4

Findings

4.1 Introduction

This chapter outlines the findings of the research aimed at investigating the potential effects of implementing DLT and EU common data spaces within EU supply chains networks. The results are structured to align with the research questions posed in the study.

The categorization of experts was based on their specific areas of expertise. It is essential to provide detailed insights into decision-making processes, data management challenges, government regulations, and the role of the union in supply chian management and development from the perspective of the participating experts. As shown in Table 1, all nine interviewees possess a profound understanding of their respective fields. However, each expert represents different aspects of the macro factors discussed. This diversity allows us to comprehend decision-making processes within the EU supply chain involving government, private, and individual participants, either fully or partially engaged in the sector - an approach that facilitates a holistic interpretation.

To achieve a balanced sample distribution, a number of experts from related organizations based on various macro and micro factors (technology regulation, supply chain, economy and data management) were interviewed.

Table 1 represents summarization of expert's profile that:

Participant A focuses on digital economy frameworks, EU legal and digital regulations, providing insights into the legal aspects of blockchain, cybersecurity, data spaces, AI, and the digital economy.

Expert B specializes in digital strategy for cloud infrastructure and data interoperability, offering perspectives on global finance, consulting, systems integration, and cloud infrastructure (GAIA-X Project).

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Expert C brings expertise in AI, data analytics, and digital business transformation, sharing knowledge on business informatics, digital markets, and data analytics.

Expert D is adept in digital transactions, fintech, and digital identity, providing insights into fintech, payments, digital identity, data sharing, Web3, and collaborative innovation.

Expert E has a focus on the legal implications and regulations of data governance and new technologies, offering perspectives on Regtech, cybersecurity, data governance, and digital law.

Expert F specializes in digital infrastructure and connects transportation solutions, offering insights into transport and digital infrastructure.

Expert G provides expertise in government digital transformation, discussing data interoperability between public and private sectors and digital transformation strategies.

Expert H focuses on supply chain management and value chains, providing insights into the digital transformation of supply chains and logistics.

Expert I is knowledgeable in digitalization within the renewable energy sector, sharing insights on energy data space solutions and digitalization.

This comprehensive approach ensures an in-depth understanding of how decision-making occurs across different segments of the EU supply chain, bolstered by insights from a diverse range of expert perspectives.

Table 2

Benefit, Risks and barriers and perspective of adopting DLT and data space technologies according to Experts

Expert	Perspectives on DLT and data space supply chain Adoption	Benefits of adoption	Risks of adoption	Challenges and Barriers in EU SC for adoption
A	Positive about the adoption, Not mature, coordination and scalability, still in use case phase; data spaces advanced early stages, no issues in the technical stack, we should start small. Companies are at ahead of authorities and regulations.	1. Fosters Data economy 2. Data consistency 3. Reliable Information for third parties 4. Traceability 5. Monitoring goods 6. Federated cloud 7. Data interoperability 8. data standardization 9. Data sovereignty 10. Identity verification 11. Data sharing 12. Immutability 13. Imposing regulations 14. Dispute settlement 15. Resilience against cyberattacks	1. Block time 2. Energy consumption	1. Influence and control of gatekeepers (big tech companies) 2. DLT controllers 3. Ununified decision-making base 4. Old regulations 5. Different regulations 6. Data silos 7. Governance 8. Security, 9. Regulation (GDPR, DATA ACT) 10. Technological stack 11. Bad resource allocation 12. Readiness

Table 2 (cont.d 1)

Expert	Perspectives on DLT Adoption	Benefits of adoption	Risks of adoption	Challenges and Barriers in EU SC for adoption
B	Negative about DLT, positive data space, contradiction between trust concept in the two technologies.	1. Reduce supply chain disruption 2. Carbon footprint 3. Data interoperability 4. Quality assurance 5. Mult- hoping	1. Cost of transaction 2. Concept of building trust Cost of transaction	1. Awareness 2. Gatekeepers 3. Unified TCP protocol 4. Participation in business processes 5. Coordination with existing technologies
C	Positive	1. Fostering data economy 2. Decentralization 3. Data analysis 4. Impose regulations 5. Standardization 6. Joint understanding about contracts 7. Data exchange	1. Cost of transaction	1. Gatekeepers 2. Companies afraid of Scandal 3. Digitalization (paper-based process) 4. Data standardization issues 5. Legal steps 6. Resource management 7. Political will 8. Coordination with existing technologies 9. Concept of building trust 10. No data availability
D	Positive	1. Reducing data silos 2. Data traceability 3. Immutability 4. Thrustless systems 5. Digital identity 6. Digitalization 7. Awareness 8. Data market 9. monetization	1. Large data processing	1. Awareness 2. Gatekeepers 3. Unified identity for legal entities 4. Unified TCP protocol 5. Participation in business processes 6. availability

Table 2 (cont.d 2)

Expert	**Perspectives on DLT Adoption**	**Benefits of adoption**	**Risks of adoption**	**Challenges and Barriers in EU SC for adoption**
E	Positive, Not matured yet, we need realistic goals, regulations side is behind the schedule	1. Digital passport 2. Data market 3. Lower transaction costs using smart contracts 4. Circular economy 5. Role management for data protection 6. Data exchange DLT Governance of data spaces	1. Cost of transaction	1. No unified goals 2. Compatibility issues 3. Transparency 4. Political will 5. Unrealistic regulations 6. Conflict of interest 7. Coordination with existing technologies 8. Concept of building trust
F	Positive, Following the vision of 2030, mobility data space is up to date.	1. Fosters data economy 2. Reducing data silos 3. Market penetration for EU companies	1. Cost of trust	1. Awareness 2. Hesitance in data sharing Confidentiality 3. Reliance on legacy systems, Legislation
G	Significance/Positive	1. Fostering data economy 2. Reducing supply chain disruption	1. Immutability	1. Awareness 2. Unified decision-making base, 3. Bureaucratic procedures 4. Scalability 5. Interoperability

Table 2 (cont.d 3)

Expert	Perspectives on DLT Adoption	Benefits of adoption	Risks of adoption	Challenges and Barriers in EU SC for adoption
H	Significance/Positive coordination and scalability	1. Real time authentic data 2. Compliance 3. Completeness 4. Transparency 5. Traceability 6. Fosters Data economy 7. Market opportunities 8. Regulated framework 9. Avoiding stockouts 10. Forecast accuracy 11. Strategic relationships	1. Privacy	1. Monopoly risk 2. Data availability 3. Data accessibility 4. Confidentiality 5. Data accuracy 6. Timing 7. Quality 8. Infrastructure 9. Awareness 10. Gatekeepers 11. Unified decision-making base
I	Significance/Positive coordination and scalability	1. Reducing supply chain disruption Authentication 2. Unifying identity 3. Producing certificates 4. Data monetization	1. Cost of transaction 2. Another data silo	1. Gate keepers 2. Economical potential (conflict of interest) 3. Political will 4. Simplification of technology 5. Cost of compliance 6. Coordination with existing technologies 7. Concept of building trust

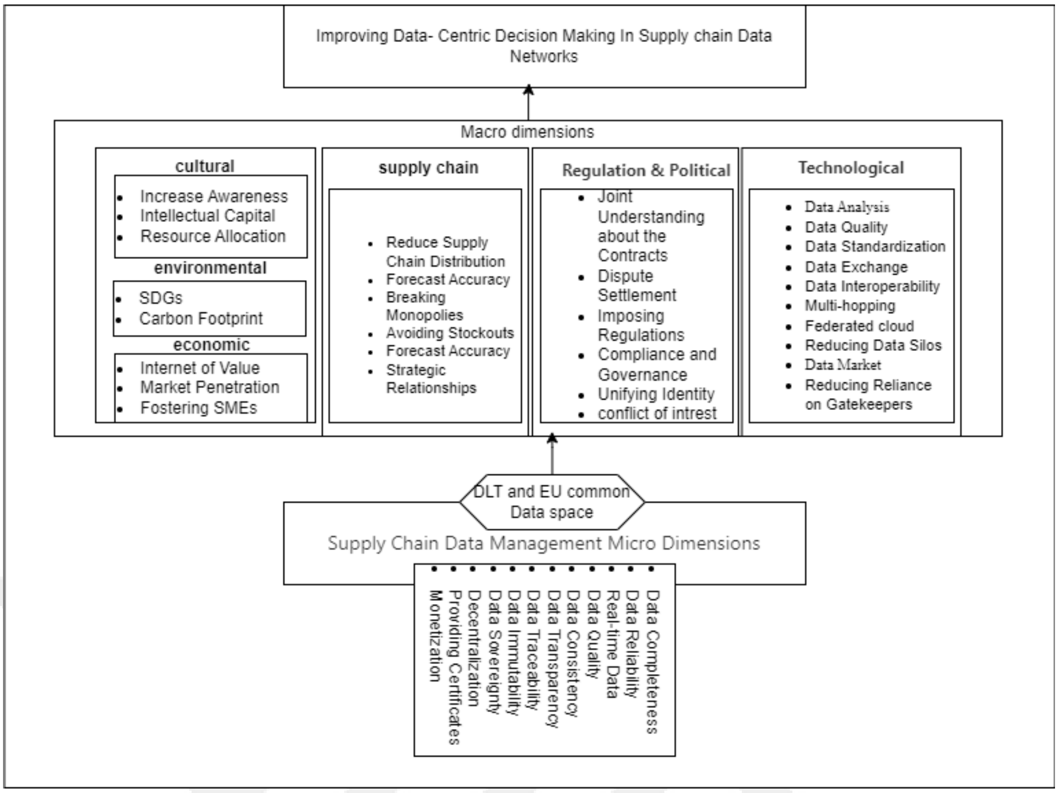

Figure 14. Micro and Macro Dimensions integrations

4.2 Benefits, Risks and Challenges

The primary objective of this section is to identify the benefits, challenges, and risks associated with adopting DLT within the EU supply chain networks. Additionally, it aims to assess the status of the EU's digital and regulatory landscape to determine the essential requirements, attributes, and dimensions necessary for successful DLT implementation.

Table 2 is coded and categorized according to Research Question 1 (RQ1): Is there a necessity for stakeholders in EU supply chains networks to adopt DLT? Table A2 summarizes the benefits of adoption, challenges within the supply chain, and the current status of supply chain digitalization benefits from the perspectives of all nine interviewees. By assessing these factors, we can determine whether there is a necessity for adoption, using the given qualitative data to design a theoretical framework.

The "Benefits of Adoption" section outlines the advantages of utilizing both DLT and data spaces from the experts' perspectives. The "Risks of adoption", "Barriers of Adoption" sections highlights the current difficulties faced by the EU supply chain in terms of its further development and digitalization risks comes upon it. The "Perspectives on DLT and Data Space Framework Adoption/Current Status" section provides a synthesized view of the experts' opinions on adoption and offers insights into the current state of development and its progress according to commission vision of 2030.

Combining these insights gives us a cohesive understanding to measure and decide the necessity of adoption. However, we cannot ensure a definitive decision without further empirical data analysis.

When asked about the status of common data space development within the EU, experts generally agreed that it is not yet mature. Some experts, such as Experts E, D, A, H, and C, noted that progress is lagging, while others like Experts I and F observed that some advancements are being made. However, some experts found the question difficult to answer due to various data challenges, including data silos (e.g., Expert A). Data silos remain a significant challenge, which data spaces and DLT aim to address. Concerns were raised by some experts (e.g., Expert C) about data spaces potentially becoming new silos if interoperability is not ensured (e.g., Expert H). Conversely, others argued that data spaces can't become new silos due to their regulatory roles rather than becoming new stakeholders. These issues often lead to disruptions in the supply chain, such as stock shortages (Expert H). The EU's common data spaces are seen as a promising solution for data sharing, standardization, interoperability, and digital transformation, but they require integration with DLT to be effective (e.g., Experts A and G). Expert I emphasized that interoperability should be established at multiple levels to ensure well-coordinated systems (macro-level coordination).

Currently, nine sectors of the EU common data space have been announced (referencing the commission). Expert A stated that each data space is being developed differently, with various regulations and technological frameworks. Therefore, it is essential for all data spaces to align. The development of the supply chain data space is expected in the next few years. Experts unanimously stated that the overarching goal of creating sectoral data spaces is to establish a European alternative that ensures data sovereignty, reducing dependency on large platform providers or "gatekeepers" (Experts C, B). The EU aims to create a non-American data space. Expert D mentioned that the goal is to create a legal framework that imposes regulations and holds users accountable. Expert B noted that the primary reason for creating data spaces is to manage the supply chain more effectively. Expert B also pointed out that the creation of data spaces is driven more by industrial needs than political decisions. Thus, coordination should be business-driven, requiring business alignment and shared interoperability layers (Expert I) using the IDSA reference model (reference). Expert E highlighted the importance of aligning EU goals holistically rather than pursuing multiple divergent objectives simultaneously. According to various experts (Experts C, E, A), political guidance is crucial for the union to benefit appropriately and steer in the right direction. Expert I also believes that the potential economic benefits of using data could raise political issues. Expert D thinks that one of the most fundamental challenges with data sharing is creating a unified identity of legal entities. Expert A mentioned a funded project within the union working to address this issue by providing a legal testbed for performing digital contracts, facilitated by DLT technologies using smart contracts.

While data spaces are considered a technological and regulated framework aimed at fostering a data economy (according to Experts A, C, F, G, H), DLT has the potential to tackle supply chain challenges by improving standardization and addressing accessibility issues. Experts such as H and C believe that DLT can disrupt data monopolies controlled by gatekeepers like big tech companies (e.g., Google and Amazon) through smart contracts. Expert (I) believes it opens up opportunities for new companies to enter new markets and suggests that gatekeepers don't need to be replaced but should adhere to EU data regulations, becoming "GAIA-X compliant". Data availability is another challenge facing the current supply chain. This issue represents a significant obstacle in creating data spaces, as data availability is currently low (Experts D, H). Improving data availability through the proposed framework will enhance data-driven decision-making and improve interoperability between people and help facilitate data exchange (Expert D). Expert H also sees challenges in the current supply chain related to data accuracy, accessibility, storage, transparency (Expert E), time span, completeness, and confidentiality. These issues lead to market shortages, stockouts, inaccurate forecasts, and monopolies in the supply chain. Expert C sees that addressing helps improving data analysis with supply chain network.

Only one expert, Expert B, expressed skepticism about DLT, citing the concept of trust in DLT as contradictory to the trust built in data space concepts. Expert C noted that companies might resist digitalization due to fears of exposure if they are not committed to standards. Expert H believes this could close backdoors for non-compliant companies but could open new fair market opportunities for SMEs if they comply with standards against the gatekeepers. Expert B emphasized the importance of building interoperable systems by developing technological stacks that support data interoperability, fostering seamless information exchange.

Expert B emphasizes the role of the EU common data space in accurately calculating and recreating carbon footprints. By implementing this solution, particularly in the automotive sector's supply chain, it becomes possible to trace back and accurately calculate emissions that he stated *"If you take for instance, the case for typically one of the main examples which has been used to demonstrate the value of data space is calculating the carbon footprint in a car, So in a car you do have 30%, which is created by the car manufacturer and 70% which is delivered by part manufacturer, So in order to know what is the carbon footprint, you need to have a carbon footprint of every element of the car, including parts, So the data remain in value, remain in BMW, remain in Bosch, And through interoperability and data exchange, you manage to capture with definitions which are the one used by the data connector with all the various definitions which exist within parts, And you recreate the carbon footprint by letting the data where it is, using telecommunication to make it happen".*

Expert (C) mentioned that APIs could help in achieving SDGs and circular economy goals and highlighted the need to address this using DLT. Expert G pointed out that awareness levels among users and policymakers need to be raised to ensure collective understanding and cohesive objective-setting, as differing perspectives can lead to conflicts of interest. Expert A sees that companies and businesses are ahead of the Data Act, suggesting that the Data Act should be modified. Smart contracts could be beneficial in legal areas (e.g., Expert E) and can assist with GDPR compliance and other regulations. Expert A sees it helping in dispute settlements and gave a use case example of the legal testbed under development. He also highlighted another example, such as the Port of Rotterdam, illustrating significant progress. When discussing the use of DLT in supply chains, Expert A highlighted its significance but stressed the need for clear control mechanisms. Expert B suggested that GAIA-X nodes could become those intermediaries or controllers.

The technological stack should not be the main concern; rather, coordination, clear regulation, and a defined roadmap are crucial. UAE is of effective coordination (e.g., Expert C) due to its decision-making mechanism. Another challenge mentioned was the cost of transactions, with concerns about DLT increasing these costs due to its trustless concept (e.g., Expert B). The consensus mechanism could define the eventual transaction cost, making the selection of a low-cost consensus mechanism essential for adoption within the EU (e.g., Experts D and I). Expert I also noted that additional service requirements in the transition phase could temporarily drive costs higher, though these would likely decrease over time.

Experts agreed that incentivizing data provision and addressing identity management issues would be necessary steps facilitated by DLT adoption. Expert (I) believes DLT could be beneficial in authentication processes. Smart contracts, for instance, could automate transactions, reducing costs and enhancing trust (e.g., Experts E and I). In essence, implementing DLT and data spaces can offer significant benefits, such as data monetization, enhanced data stratification, improved legal dispute resolution, effective identity management, and provision of verified data to third parties. However, several challenges and risks must be addressed, including Data Controller Responsibilities, Experts debated whether data controllers should be GAIA-X nodes or other entities.

Experts B, C, E, I expressed their fears about the cost of transactions, noting that the solution could involve significant power consumption and initial costs related to EU incentives and service adoption. These costs also pertain to coordination with existing technologies.

Expert A highlighted the challenge of mismanagement of resource allocation, suggesting that existing resources should be invested wisely. Additionally, there are intellectual capital costs and the need to increase awareness levels across stakeholders.

Experts A, G, H, E pointed out that another challenge is the lack of unified decision-making, which stems from ineffective coordination and robust regulations. It's critical to mitigate this to reduce fragmentation and ensure a unified approach.

In summary, while the technological infrastructure is essential, the overarching issue remains coordination. Clear regulations, a strategic roadmap, and consistent objectives are pivotal for successful DLT and data space integration within the EU supply chain.

Several European data spaces have been announced by the Commission. Each data space is being developed differently, with varying regulations and technological blocks. However, there is no supply chain data space as of now. It is essential that all data spaces align together, including the development of the supply chain data space in the coming years. According to Expert B, the creation of data spaces is more of an industrial than a political decision. Therefore, businesses need to align and share a common interoperability layer using the IDSA reference model (I). Expert A sees that companies and businesses are ahead of the Data Act and suggests that it should be modified.

Experts acknowledge that the slow progress in creating data spaces is due to fragmented decision-making. Experts A and D proposed an enforcement phase to accelerate the maturity stage and make it compulsory. Expert F and I agree on the importance of mobility and industrial data space in establishing the supply chain data space. Expert B suggests that the creation of all data spaces culminates in the actual supply chain data space. Experts (I and B) outlined reference guides to assist companies in transitioning towards the new framework, ensuring compliance with initiatives like GAIA-X.

An obstacle discussed is that organizations might not open up due to compliance and awareness issues, which could lead to scandals. Another awareness barrier is that organizations are afraid of the digitalization process and leaving paperwork behind. All these cultural barriers underscore the main reason to create a regulated data framework. Expert G sees huge ignorance about the topic and suggests training sessions to increase awareness among stakeholders, even within policymakers.

Since it is not easy to earn money from data (Expert F), experts believe DLT represents a great opportunity for data monetization, turning it into what is called data as a service flourishing in the Internet of Value (Expert I).

In conclusion, ambiguities are expected in the beginning stages, but clarity will improve as things progress. The pressing need to address current inefficiencies, coupled with the substantial benefits DLT promises, justifies the effort to overcome existing barriers and readiness challenges. The potential for improved decision-making, data integrity, reduction in disruptions, and fostering a data-driven economy makes a strong case for its adoption despite the hurdles present. Strategic initiatives to enhance awareness, simplify regulatory frameworks, and ensure political backing will further support this transition.

4.3 Chapter Summary

Chapter four illustrates benefits, risks, and challenges associated with adoption as expressed by the interviewees. Additionally, it presents the insights and perspectives of experts on enhancing data-centric decision-making. The chapter also outlines the relationships between the micro dimensions under analysis, providing a comprehensive view leading to more informed decision-making. This synthesis of findings offers valuable insights into the complexities and nuances surrounding the research area, contributing to a deeper understanding of the dynamics at play in the context of data-centric decision-making. Overall, the findings suggest that the adoption of DLT in EU supply chains networks could lead to more robust and reliable supply chain operations, ultimately benefiting all stakeholders involved.

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Chapter 5

Discussions and Conclusions

5.1 Discussions

This exploratory study investigates how DLT data spaces can facilitate data-centric decision-making in European supply chain networks. The study aims to comprehend various technological, regulatory, cultural, economic, and political aspects, while also focusing on supply chain management covering both micro and macro dimensions affecting the improvement of data-centric decision-making processes within EU supply chains networks, we will investigate this using common supply chain management theories. Despite the originality of the scope, similar generalized findings were found regarding the immaturity of the system, awareness, and political will in previous studies(Dursun, Ulker, & Gunalay, n.d.) . These barriers need to be overcome to unlock the potential of these technologies. Data space opens great opportunities for other technologies to prosper, such as AI, strengthening the foundational layer for data. DLT, in combination with IoT, represents a promising solution for many supply chain issues.

In this section, the research results are discussed under three headings following the analysis levels to answer the research questions. Firstly, DLT and data space risks are interpreted as found in Table 2. Secondly, the relationship between data space, DLT, and supply chain management is discussed, focusing on how it can improve data-centric decision-making at both theoretical and practical levels, as stated in Tables 3 and 4. Finally, the macro-emergence of the phenomena is discussed, studying the relationship between various stakeholders.

5.1.1 Necessity of adoption.

The study comprehensively investigates the status, benefits, and barriers before identifying the necessity of adoption to address the first research question. Interviews with experts revealed that while the objectives of the thesis align with the EU digital agenda, adoption is expected in the near future but not immediately. Table 2 reveals the benefits and barriers of DLT and data space in detail, providing a concrete answer to RQ1, our main findings suggest that experts agree that data space is still immature and under development, with many use case level ongoing programs such as the Rotterdam port and legaltestbed. However, findings indicate that the problem lies not in technology but in scalability and coordination. Most experts see DLT as a complementary technology within the data space technological stack, bringing transparency, confidentiality, and real-time information, which promotes standardization, improves data quality, and enhances decision-making in supply chain networks, thereby reducing disruptions. This outcome supports previous studies' findings predicting that DLT adaptation will increase supply chain efficiency and performance. Another finding is the role of European initiatives like Gaia-X in promoting and establishing data space and managing DLT and data space data controllers, emphasizing how EU initiatives and companies are leading the digitalization process.

Although DLT has great potential and benefits, the current barriers and low readiness status in the EU supply chain networks make it less necessary for companies to adopt DLT immediately. By focusing on reducing barriers and improving readiness, the necessity for adopting DLT in the future will increase, making it more imperative for companies to do so.

To mitigate cultural risks associated with data-centric decision making and to enhance readiness and the maturity of EU common data space and EU supply chain network for the proposed solution, The research suggests focusing on reducing coordination complexities, managing initial costs, and addressing awareness issues. Analyzing this through Upper Echelon Theory (UET), which relates to upper management issues, we see from Table 2 (challenges section) that all upper management issues connect to the cultural macro dimension (see Figure 14). That according to UET, top management plays a crucial role in overcoming organizational challenges. The research suggests that increasing decision-makers' awareness is vital. According to the findings in the benefits section, addressing regulation macro dimensions and proposing solutions helps impose regulation and establish governance, which in turn applies institutional pressure. This benefits the organization by correctly modifying and enhancing their dynamic capabilities. According to Resource Orchestration Theory (ROT), developing a big data culture through a skilled group and appropriate resource allocation is

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essential (Dubey et al., 2019) This approach also addresses regulation and political macro dimension challenges, such as ununified decision-making, and helps reduce coordination and scalability issues mentioned by the interviewed experts. The relationship between cultural dimensions and data-centric decision making is intertwined. A supportive organizational culture enhances the adoption and effectiveness of data-driven practices, ultimately leading to better decision-making outcomes and organizational success.

5.1.2 Enhancing data-centric decision making.

To examine the impact of DLT and data space adoption on Supply Chains (SC) and the way businesses adapt to these changes, it is essential to draw upon established theoretical frameworks. The Information Processing Theory (IPT) is particularly pertinent for understanding how micro-level aspects of supply data management are influenced. IPT provides insights into how information is processed, decisions are made, and adaptations occur within supply chains, thus illuminating the consequences of adopted solutions on SCs and how companies respond to these shifts.

This theory effectively demonstrates how organizations can gain a competitive advantage by managing information flow, especially in environments characterized by high uncertainty (Jia, Blome, Sun, Yang, & Zhi, 2020). IPT addresses the link between information processing, environmental uncertainty, and the necessity for organizational adaptation (Saberi, Kouhizadeh, Sarkis, & Shen, 2019). Additionally, the correlation between big data processing capabilities and the development of swift trust has been established (Dubey et al., 2019), By leveraging big data analytics, our findings confirmed that DLT and data space can reduce behavioural uncertainty through enhanced data sharing among supply chain members and, Furthermore, increased transparency fosters swift trust and enhances SC collaboration(Dubey, Gunasekaran, Bryde, Dwivedi, & Papadopoulos, 2020). Therefore, DLT-based data management mitigates opportunistic behaviors within the SC by providing access to reliable and visible (Karamchandani, Srivastava, Kumar, & Srivastava, 2021), This was also discussed in Table 2 concerning gatekeepers and breaking monopolies intervened experts.

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To provide a concrete answer to the RQ2 regarding decision making enhancement, we evaluated the expert's findings from Table 3, The table attempts to examine potential solutions for interviews to analyze them from the perspective of Information Processing Theory (IPT), by querying all interviewees about their insights.

Do you agree that reducing data uncertainty directly enhances data quality?

IPT suggests that the quality of input data directly affects the efficiency of information processing and the accuracy of outputs. Reducing data uncertainty aligns with the idea of improving the quality of input data, thereby enhancing the overall data processing cycle. High-quality data with reduced uncertainty is easier to process, leading to more reliable and accurate decision-making. Depict from table 3 all expert confirmed and agreed on that expect for expert (E) which coming from legal background, her concern was only about the ***purpose***.

Would you say there is a positive correlation between the value of data and the level of data certainty, particularly as data value increases?

IPT posits that higher-quality information (with greater certainty) is more valuable because it reduces ambiguity and aids in decision-making. This question explores the link between data certainty and perceived value, which is critical in IPT as more certain data contributes to better information processing and consequently higher decision quality. Depict from table A3 also all experts confirmed on that only for expert (E) for the same previous reason.

Do you believe that improving data quality through DLT and data spaces enhances decision-making in supply chains?

DLT and data spaces aim to improve data integrity, reliability, accessibility and other Table 2 Benefits of Adoption. IPT emphasizes the need for high-quality, organized, and accessible information for effective processing and decision-making. By improving data quality through DLT and data spaces, you enhance the fundamental inputs of the IPT framework, leading to better analysis and outcomes in supply chain decision-making. Depict from table 3 all experts confirmed that only for expert (b)which have criticism on DLT, but he agreed on data space context, experts (E) had the same previous that she has concern on the context.

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Do you think that the adoption of DLT effectively addresses the complex challenges within dynamic and evolving supply chain networks?

IPT deals with processing vast amounts of information, adapting to changes, and managing complexities. The adoption of both data space with DLT provides a structured approach to manage and verify large volumes of data across decentralized networks. Addressing the dynamic and complex nature of supply chains through DLT fits within the IPT framework as it supports the efficient handling of complex information flows and enhances the adaptability and responsiveness of the supply chain.

Depict from table A3 Expert (A, C, D, G, H, I) Agreed on that, experts (B, E) said it depends on the context, expert(F) say he is neutron about that, expert (I) said he don't know.

Utilizing the Dynamic Capability View (DSV) theory and the adoption benefits outlined in Table 2, we can see how the proposed solution strengthens the dynamic capabilities of organizations within a supply chain network. By improving the traceability, interoperability, and monitoring of data, this solution promotes better collaboration and data sharing among network participants. Consequently, this enhances swift trust, which ultimately strengthens the organization's dynamic capabilities. This facilitation empowers the organization to adeptly sense, seize, and reconfigure resources as required (Teece, 2007).

5.1.3 Macro emergences.

What are the impacts and macro-level phenomena of adopting a DLT-based architecture on EU supply chain networks?

When asked about the EU's potential to achieve its goals in the digital age and establish a digital single market for data across multiple countries, all interviews agreed that it will achieve its goals, but they differed on the timing and implementation phases. Expert D emphasizes that the EU's vision is more than just a framework; it's an ecosystem.

When asked about the implications of the newly imposed data regulations and their impact on EU initiatives and companies compared to international ones, Expert D stated that *they are stopping it, but they are giving a direction,* On the other hand,

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Expert I expressed the belief that these regulations are crucial for the development of the data space. Meanwhile, Expert E expressed concern that the regulations are stifling EU companies, preventing them from flourishing and potentially driving them to operate outside the EU, these regulations could push EU to becoming EUniformity (Rohmann Katrin et al., 2019) .

When questioned about the role of EU initiatives in the digitization of the supply chain and navigating the digital age, most experts emphasized the significance of initiatives like Catana X. They noted its pivotal role in digitalizing the automotive sector within the supply chain, underscoring its importance. Additionally, another crucial initiative highlighted was Gaia X, often referred to as the backbone of the European data space. These initiatives are instrumental in achieving high interoperability across various levels, as noted by expert I, and facilitating multi-hopping, as highlighted by Expert B. Furthermore, they aid in fostering data exchange and collaboration with initiatives beyond the EU. Expert I stated *that I think Gaix provides very far developed architecture in how you could set up the database*, which leads and helps on establishing onto what so called ***data markets.***

When asking the experts *Do you think the EU is on track with its vision for the Digital Single Market and its broader digital agenda?*

Most experts agree that the European Union (EU) will eventually achieve its digital agenda, facilitated by the EU common data space and DLT, leading to the establishment of a digital single market. Experts D, B, and A emphasize the need for an enforcement phase to accelerate the pace of this transformation. According to expert B, this phase will necessitate a change in stakeholder behavior throughout the entire supply chain's upper echelon to adapt to a data-centric approach. This behavioral shift is expected to reduce costs for any data-driven business model or application, as highlighted by expert I.

The findings indicate that advancing into the digital age will entail establishing reference model architectures, such as the International Data Space (IDSA) Reference Model, to regulate the interaction between EU member states and other nations. The partnership with IDSA is marked by collaborative agendas and shared roadmaps, with upcoming reference models identifying common data space and DLT technologies to facilitate and initiate cross-border projects.

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Regarding similar initiatives underway in Arabian Peninsula countries, most experts admit their limited knowledge about them. Nevertheless, they emphasize that any forthcoming collaboration will prioritize interoperability. Expert C underscored the rapid development in the region, attributing it to the decision-making mechanism in place. This mechanism faces challenges related to political and regulatory macro dimensions, as noted in Table 3.

5.2 Conclusions

This study explored the potential of DLT and Data Spcaes technologies, in addressing key challenges within supply chain management. Through in-depth interviews and the application of supply chain management theories, valuable insights were gained regarding the benefits, risks, and challenges associated with DLT-based solutions.

The findings suggest that DLT, when integrated with smart contracts, offers significant promise in enhancing data exchange interoperability, reducing uncertainty, and stabilizing supply chains within the manufacturing sector. Leveraging DLT-based data spaces could streamline processes, foster trust among stakeholders, and facilitate more informed decision-making.

Moreover, the discussion on macro-level phenomena, such as the digital single market and international project relations, underscores the importance of considering broader contextual factors when implementing DLT solutions in supply chain management.

A notable highlight is the EU's progress towards achieving EUniformity, In this process, there is a preference for a closed approach in the current phase to establish a robust foundation. This strategy aims to diminish the influence of gatekeepers and foster a fair market environment, allowing EU initiatives to compete on an equitable basis. Leading a step towards harmonization and integration facilitated by common data spaces and emerging technologies. This vision of a more interconnected and standardized digital infrastructure suggests a future where cross-border transactions and collaborations are more efficient and sustainable.

In conclusion, while challenges and uncertainties persist, the findings of this study point towards a promising future where DLT-based solutions contribute to optimizing supply chain networks, fostering resilience, efficiency, and trust among stakeholders. Continued research and collaboration will be crucial in realizing the full potential of these technologies and achieving a more unified and sustainable supply chain ecosystem.

Despite the promising direction indicated by our findings, our qualitative analysis suggests that DLT is still nascent and cannot operate effectively as a standalone solution without a supporting framework. Moreover, it necessitates robust communication with industry stakeholders. A significant barrier to adoption is the reluctance of many supply chain actors, such as manufacturers, to move away from their established legacy systems. However, this resistance may wane as the European Union advances regulations and legislation aimed at encouraging these entities to venture beyond their comfort zones. This initiative aligns with the Union's broader digital strategy objectives. Thus, a pivotal question emerges: Will innovative approaches or traditional legacy systems and their advocates dominate the landscape?

5.3 Thesis Limitation

This study encompasses several limitations that merit acknowledgment.

- Time Horizon: The research was conducted within a constrained timeframe, which may have impacted the depth of analysis and breadth of data collection.
- Data collection should be expanded to encompass a larger number of interviewees in order to capture more insights from macro-level dimensions.
- Data Spaces Development: The data spaces under consideration are still in the process of being developed and have not reached completion. This evolving nature means that the study's findings may not fully reflect the final capabilities and characteristics of these data spaces.
- Scope of Discussion: The study did not encompass discussions on security measures and other related aspects that are crucial to the understanding and implementation of data spaces.

These limitations highlight areas for further inquiry and suggest that the conclusions drawn from this study should be considered as part of an ongoing dialogue rather than definitive answers.

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