An Empirical Investigation of

Factors Influencing the Adoption of Secure Blockchain Technology in the Saudi Manufacturing Sector

by

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to

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, *Mahasen Alsolmy* declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy in the Faculty of Engineering and Information Technology in the school of Computer Science at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualification at any other academic institution.

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Abstract

A blockchain technology can be a transformative solution across various sectors, with the potential of its use in the manufacturing industry receiving increasing attention. This study explores the adoption of blockchain technology in the manufacturing sector of Saudi Arabia, a critical element of the nation's Vision 2030 to enhance technological capabilities and economic growth. Despite the acknowledged advantages of blockchain, including enhanced accuracy of information, lower transaction costs, and improved compliance with standards, its adoption faces significant challenges. These include complexities in technology implementation and resistance in organisational structures. To address the scarcity of research on blockchain adoption in developing countries, particularly by IT employees, this study develops and examines a blockchain adoption framework based on the technology-organisation-environment (TOE) framework.

Using a quantitative approach, this research analyses data collected from 332 valid responses out of 379 surveyed IT employees in the Saudi manufacturing sector. The study employs structural equation modelling to test hypotheses regarding the influence of seven key factors: relative advantage, compatibility, complexity, top management support, organisational readiness, current regulations and laws, and government support on the behavioural intention to adopt blockchain. The findings indicate a strong model fit, with these factors explaining 84% of the variance in behavioural intentions, significantly surpassing previous models. The results highlight government support as having the most substantial positive impact on adoption intentions. This study fills a significant gap in the existing literature and provides a practical roadmap to facilitate blockchain integration in manufacturing, aligning with the 2030 Vision national goals.

DEDICATION

To my dearest mother, thank you for always loving and supporting me. Your inspiring and motivating words have always been my source of inspiration, and without your support, I would not have reached this point.

To my dear father, thank you for teaching me the value of hard work, determination, and resilience. My sincere gratitude goes out to you for always encouraging and supporting me.

To my loving husband, I thank you for your endless love, patience, and understanding. Thank you for standing by my side and being my biggest cheerleader.

To my dear children, thank you for giving me a reason to strive for excellence every day. Your love and support have been my driving force and I am honoured to be your role model.

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This study could not have been conducted without the participation of the survey participants.

List of Publications

Related to the Thesis :

1. Alsolmy, M., Hussain, F. K. (2023, November). Blockchain Adoption in Saudi Manufacturing: The Conceptual Model and Research Hypotheses. In 2023 IEEE International Conference on e-Business Engineering (ICEBE) (pp. 199-204). IEEE.

2. Alsolmy, M., Hussain, F. K. (2024, November). Advancing Blockchain Integration in Manufacturing: A Roadmap aligned with Saudi Vision 2030. In 2024 IEEE International Conference on e-Business Engineering (ICEBE) (pp. 199-204). IEEE.

Abbreviations

TOE: Technology-Organisation- Environment framework.

DOI: Diffusion of Innovation.

TAM: The Technology Acceptance Model.

UTAUT: The Unified Theory of Acceptance and Use of Technology.

TPB: The Theory of Planned Behavior.

TRI: The Technology Readiness Index.

ISS: Information Systems Success Model.

TTF: Task-Technology Fit.

ANP: Analytic Network Process.

RFT: Regulatory Focus Theory.

PMT: Protection Motivation Theory.

TRA: Theory of Reasoned Action.

RED: Organisational Readiness.

RAD: Relative Advantage.

CB: Compatibility.

CX: Complexity.

TMS: Top Management Support.

RL: Regulation and Laws.

GS: Government Support.

BI: Behavioural intention.

SLR: Systematic literature review.

IoT: Internet of Things.

SMEs: Small and medium-sized enterprises.

CFA: Confirmatory Factor Analysis.

SEM: Structural Equation Modelling.

SPSS: Statistical Package for the Social Sciences.

EFA: Exploratory Factor Analysis.

AVE: Average Variance Extracted.

VIF: Variance Inflation Factor.

AGFI: Adjusted goodness-of-fit index.

CFI: Comparative Fit Index.

TLI: Tucker-Lewis index.

ROI : Return on investment.

SAMA : Saudi Arabian Monetary Authority (SAMA).

CST : Communications Space and Technology Commission.

KPIs: Key performance indicators.

RMSEA: Root Mean Square Error of Approximation.

IFI: Incremental Fit Indice.

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CHAPTER 1

INTRODUCTION

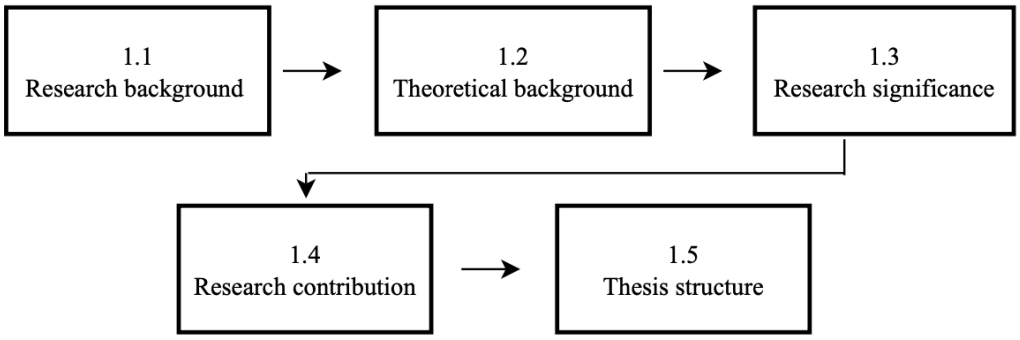

Figure 1.1: Chapter 1 outline.

1.1 Reserch Overview

Historically, governments have taken a significant part in recognising and assessing emerging technological trends, whether in science, engineering, industry, or other areas of innovation. By doing so, they have engaged in strategic planning to leverage these trends for economic development, societal progress, and national security. So, Saudi Arabia's Ministry of Industry and Mineral Resources is focusing on several initiatives to achieve Saudi Vision 2030 [192]. Their main objective is to improve the industrial and logistics services in the country by enhancing the initiatives related to Industry 4.0

technologies.

Technology has become a driving force for improving the efficiency and performance of organisational processes by offering innovative solutions to complex problems. Digital innovations, such as blockchain technology, exemplify how technological advancements can significantly impact various industries and sectors. Blockchain technology, known for its decentralised and secure ledger system, has demonstrated transformative potential across numerous fields. For instance, in the services sector, blockchain is expected to revolutionise the payment industry by enabling faster, more secure, and transparent financial transactions, reducing costs and enhancing trust among participants [110], [162]. Similarly, in the healthcare industry, it can improve data sharing, enhance patient privacy, and streamline administrative processes, fostering better healthcare outcomes [106]. In the supply chain industry, blockchain technology enables greater traceability, transparency, and efficiency in tracking goods and managing logistics [37], [23]. Blockchain technology has shown significant potential for a variety of applications, but adoption rates have fallen short of predictions [152]. The adoption of technology by organisations has been extensively researched, but blockchain as an emerging technology has received comparatively little attention. Blockchain technology offers substantial benefits to the manufacturing sector by enhancing operational efficiency, data integrity, and transparency. Its decentralised nature improves data reliability and security, while features like traceability and real-time data access support better decision making and fraud prevention. The integration of smart contracts and IoT further optimises processes, reduces costs, and fosters collaboration among stakeholders [56], [104], [193].

Successful technology adoption depends on identifying the factors influencing an organization's decision-making process. To determine if an organization is likely to adopt blockchain technology, it is essential to identify the factors influencing the adoption process. Numerous theories and models within the information systems field can help pinpoint the specific factors that significantly or insignificantly impact the adoption of IT innovations in organisations.

The purpose of this research is to gain a deeper understanding of how blockchain is being adopted in Saudi Arabia's manufacturing sector. The key factors for blockchain adoption will be determined in this research and we will develop an understanding of this through an investigation of the relationship between these factors and IT employees' and decision makers' intention to adopt. The technology-organization-environment (TOE) framework was selected from among the various theories and models regarding information systems (IS). This framework helps pinpoint the specific determinants that may

either encourage or hinder the adoption of innovative technologies within organisations.

1.2 Theoretical Background

Numerous models and theories have been developed across various research contexts to identify factors influencing IT adoption. Integrating factors from multiple adoption theories, however, can offer deeper insights into the potential drivers of IT adoption. To address the research issues identified, this study employs the technology-organization-environment (TOE) framework as the foundation for developing a theoretical model (see Chapter 4 for further details).

Many disciplines and organisations use the TOE framework as an adoption model. Several researchers have used it to analyse the adoption of a variety of IS and IT innovations such as RFID [24], the Internet of Things [79], cloud computing [96], and AI-powered industrial robots (InRos) [149].

The TOE framework outlines three key contexts that impact an organisation's adoption and implementation of technological innovations: technological, organisational, and environmental. Technological factors include relative advantage, compatibility, and complexity. Organisational factors include top management support and organisational readiness, while environmental factors involve regulations, laws, and government support.

1.3 Research Significance

The manufacturing sector generates vast amounts of data across various stages of production, quality control, supply chain management, and more. However, challenges such as data fragmentation, inconsistent data accessibility across multiple facilities, and limited traceability pose significant obstacles. These issues can lead to inefficiencies, operational delays, and increased costs. Additionally, security concerns, data manipulation risks, and a lack of transparency further hinder seamless operations. Blockchain technology can tackle these challenges by providing a secure, transparent, and decentralized approach to data management and process optimization.

This study aims to bridge the gap in understanding the adoption of blockchain technology within the manufacturing sector, focusing on how it can resolve critical issues like data integrity, supply chain visibility, and process automation. By developing a comprehensive framework grounded in the TOE model, this research contributes theoretically by

enhancing existing adoption models and practically by providing actionable insights for manufacturing decision makers. Specifically, it helps organisations assess their readiness, identify key adoption determinants, and formulate strategies to implement blockchain technology effectively.

The practical significance of this study extends to IT managers and organisational leaders in manufacturing, offering a structured approach to blockchain adoption that can optimise operations, reduce costs, and improve collaboration between supply chain stakeholders. As a result of its improved data security, traceability and efficiency, the findings of this study can drive innovation and increase competitiveness within the Saudi manufacturing industry and beyond.

1.4 Research Contribution

The main contribution of this study lies in creating a framework designed to evaluate the adoption of blockchain technology in the manufacturing sector. This framework aims to help manufacturing organisations assess the key factors influencing blockchain adoption, facilitating decision-making processes. A thorough review of the literature reveals that most prior studies on blockchain adoption have concentrated on regions like India and China, with minimal focus on the Middle East and Arab countries. Therefore, a significant contribution of this research is identifying the determinants impacting blockchain adoption in Saudi Arabia's manufacturing sector, marking it as the first comprehensive study in this specific context.

The study examines and validates the suitability of different theoretical models to understand the factors affecting blockchain adoption, specifically employing the TOE framework. The study develops and validates a theoretical framework based on the perspectives of IT employees' in the manufacturing sector using the TOE framework as a foundation for understanding blockchain adoption. Unlike previous studies that may lack a structured theoretical foundation, this research examines blockchain adoption in the manufacturing sector through a robust theoretical lens.

The findings from this study offer practical benefits for Saudi government officials, industry leaders, and manufacturing decision makers by providing deeper insights into the facilitators and inhibitors of blockchain adoption. Manufacturers can use these findings to better understand how blockchain technology can be implemented within the Saudi context.

1.5 Thesis Structure

Chapter 1 provides an introduction to the research topic, encompassing the research and theoretical background, the study's significance, and its relevance to the field. It also highlights the research contributions and concludes with an overview of the thesis structure.

Chapter 2 delivers a comprehensive literature review on blockchain technology, including its general background, definitions, characteristics, and benefits. It also discusses the manufacturing industry in general, with a focus on the Saudi manufacturing context, and includes a systematic review to identify the key factors influencing blockchain adoption.

Chapter 3 defines the research problems and outlines the research questions and objectives. It also clarifies the key terms relevant to the study.

Chapter 4 explains the research methodology, adopting a deductive approach and a quantitative research design. It discusses the conceptual framework based on the TOE model, exploring seven key factors influencing blockchain adoption in the manufacturing sector: relative advantage, compatibility, complexity, top management support, organizational readiness, regulations and laws, and government support.

Chapter 5 details the data collection process, including the development of an online questionnaire as the primary tool for gathering data on blockchain adoption. It also discusses the sampling design, sample size, and ethical considerations.

Chapter 6 presents the data analysis and results. It describes the statistical methods used to evaluate the influence of various factors on blockchain adoption, covering response rates, data screening, and descriptive statistics. Reliability and factor analyses were performed for measurement validation. Subsequently, structural equation modeling (SEM) was employed to test the research model and hypotheses.

Chapter 7 provides a discussion of the results, offering an in-depth analysis of the findings. It revisits the conceptual framework and examines the identified determinants influencing blockchain adoption. Additionally, it explores potential manufacturing applications and services that can transition to blockchain technology.

Chapter 8 concludes the study by summarizing the key findings, highlighting its theoretical and practical contributions, and addressing its limitations. It proposes a blockchain adoption roadmap and suggests directions for future research.

CHAPTER 2

LITERATURE REVIEW

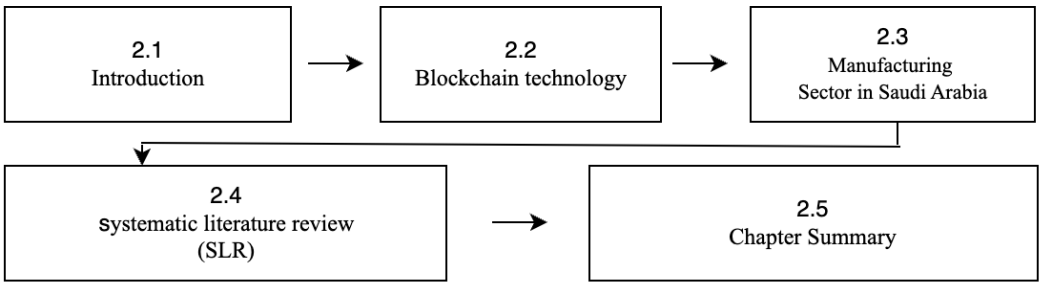

Figure 2.1: Chapter 2 outline

2.1 Introduction

The introduction chapter establishes a comprehensive foundation for understanding the topic and delineates what is currently known about blockchain technology adoption in the manufacturing sector, while highlighting critical knowledge gaps. This chapter comprises several sections, starting with an overview of blockchain technology, including essential definitions, characteristics, and a concise explanation of its mechanisms. Additionally, the application of blockchain technology in the manufacturing industry is discussed, with an emphasis on its advantages and its potential to address key challenges. The chapter then provides an overview of the manufacturing sector in Saudi Arabia, highlighting the sector's strategic initiatives and growth potential, and aligning them with the national

development goals articulated in Vision 2030. Finally, a systematic literature review identifies and analyses the key factors influencing blockchain adoption, serving as the foundation for the study's research framework and objectives.

2.2 Blockchain Technology

Blockchain technology first emerged in the context of the Bitcoin market (introduced by Nakamoto in 2008 [133]. Initially, blockchain was designed to facilitate secure and transparent Bitcoin transactions. However, its applications quickly expanded beyond cryptocurrency. Blockchain's unique capabilities, such as data immutability, decentralisation, and transparency, proved valuable in a wide range of other fields, including supply chain management, finance, healthcare, and manufacturing, where secure and verifiable data management is essential.

2.2.0.1 Blockchain Technology Definitions

Blockchain technology is defined as A technology that ensures data immutability and integrity by maintaining a record of transactions within a system across multiple distributed nodes connected through a peer-to-peer network. [191].

2.2.0.2 Blockchain: How it Works

The Harvard Business Review [85] outlines the following five basic principles of blockchain technology.

1. Distributed database: In a blockchain, each participant has access to the entire database and its complete transaction history. There is no central authority controlling the data; instead, all participants (or nodes) can verify records on their own, without relying on a middleman. This makes the system more resilient and transparent.

2. Peer-to-peer transmission: Blockchain uses a peer-to-peer network, meaning that communication occurs directly between participants rather than through a central hub. Each node on the network stores data and shares it with other nodes, ensuring that all participants have the same information and that the network operates without a single point of failure.

3. Transparency with pseudonymity: Every transaction on a blockchain is visible to all users on the network, ensuring transparency. However, participants are identified by unique alphanumeric addresses rather than personal information, allowing users to remain pseudonymous. They can choose to remain anonymous or provide proof of identity if desired, but all transactions occur between these addresses, not individual names.

4. Irreversibility of records: Once a transaction is recorded on the blockchain, it cannot be altered or deleted. This is due to the 'chain' structure, where each transaction is linked to the previous one. This immutability ensures a permanent, secure, and chronological record of all actions, which can be verified by all users on the network.

5. Computational logic: Blockchain can use computational algorithms and logic, which means transactions can be programmed to execute automatically when specific conditions are met. This is often implemented with "smart contracts," which are self-executing contracts that trigger transactions between nodes based on predefined rules.

2.2.0.3 Blockchain Technology Characteristics

The following fundamental characteristics make blockchain technology secure, reliable, and suitable for various applications.

1. Decentralisation: Unlike traditional databases managed by a central authority, blockchain distributes data across multiple nodes, enhancing security, and reducing single points of failure [116].

2. Immutability: Once recorded, the data on the blockchain cannot be altered or deleted. This permanence ensures data integrity and trust, as records remain verifiable and consistent over time [209], [116].

3. Transparency: Blockchain allows participants to access and view transaction histories, promoting accountability, and enabling all parties to track the movement and origin of information [2], [116].

4. Security: Blockchain uses cryptographic techniques to secure data, ensuring that only authorised participants can access information, reducing the risks of tampering or fraud [116].

5. Consensus mechanisms: Blockchain relies on various consensus protocols, such as Proof of Work (PoW) or Proof of Stake (PoS), which enable network participants to agree on the validity of transactions, enhancing reliability without a central governing entity [148].

6. Open source: Blockchain platforms are open source, which means that their underlying code is publicly accessible and can be viewed, modified, and shared by anyone [2], [116].

2.2.1 Blockchain Technology in Manufacturing

Manufacturing systems play a crucial role in creating value and wealth in the economies of countries, shaped by the nature of their activities. These systems rely on the generation and exchange of high-precision information, which is often shared across departments within a company or with external partners in the supply chain. However, the geographically and organizationally distributed structure of manufacturing makes this information exchange vulnerable to errors and inconsistencies. To ensure enterprise success and continuous process improvement, every transfer or transformation of information needs to be accurately recorded in a way that is permanent and tamper-proof. Blockchain's capability for secure, immutable data storage across distributed networks makes it a strong candidate for supporting these critical needs in the manufacturing sector [93].

2.2.1.1 Advantages Of Blockchain Technology in Manufacturing

Blockchain technology has many benefits for the manufacturing sector, enhancing various operational facets and making it an attractive solution. Decentralised data recording distributes data across multiple nodes, improving redundancy and reliability, and ensuring system continuity even if parts of the network fail [56]. Data immutability means that it cannot be altered or deleted once entered into the blockchain. This improves the integrity and credibility of the data, making it trustworthy for all involved parties [154],[193],[133]. Traceability features enable the detailed tracking of products or transactions from their origin, fostering accountability and transparency, which is particularly beneficial in complex supply chains [105],[193]. This technology also closes information gaps, enhancing visibility across the network and reducing information asymmetry [105],[193]. In contrast, the rapid availability of real-time information facilitates better decision making and quicker responses to market changes [199]. The integration of IoT with blockchain (BioT) prevents data manipulation from IoT sensors [151],[180],[104].

Blockchain is a deterrent against fraud by preventing the circulation of counterfeit materials and identities, thus securing the manufacturing environment [154], [29]. It supports data confidentiality through role-based access controls [56], [16] and utilises consensus-based decision making to distribute power and enhance decision efficiency [83],[193]. Smart contracts automate contract execution based on predefined criteria, eliminating intermediaries and reducing costs [51],[193]. The technology also enables manufacturers to directly connect with a wide range of stakeholders, enhancing collaboration and communication [127]. At the same time, its ability to remove non-value-adding intermediaries simplifies processes and reduces costs [127]. Blockchain further simplifies audits by allowing them to be conducted remotely [127],[1], [83], and implementing it can lead to significant cost reductions in various areas such as transactions, verification, and contracting [127], [155].

2.3 Manufacturing Sector in Saudi Arabia

The manufacturing sector in Saudi Arabia is advancing steadily, fueled by the ambitious vision to diversify the economy beyond oil dependence. The Kingdom is expanding its industrial base by investing heavily in sectors such as oil and gas while fostering growth in emerging and competitive industries, including military manufacturing, automotive, pharmaceuticals, and food production. This strategic expansion aligns with the Saudi Vision 2030 goals, aiming to establish a sustainable and diversified industrial economy that can drive long-term growth and employment [192].

At the core of this transformation is the National Industry Development Program (NIDP), a pivotal initiative that seeks to position Saudi Arabia as a global industrial hub and a central platform for logistics services [135]. By focusing on high-growth industries and enhancing logistical frameworks, the NIDP envisions Saudi Arabia as a leader in advanced manufacturing and an attractive destination for international investment. Through these efforts, the Kingdom is building a foundation for a prosperous industrial future, integrating advanced technologies and innovation to boost competitiveness and resilience in the global market.

Saudi Arabia's vision for the manufacturing sector outlines ambitious targets aimed at achieving substantial economic diversification and bolstering the nation's industrial capabilities. A central goal is to drive growth by 84% in non-oil industries, demonstrat-

ing a strong commitment to reducing reliance on oil and expanding other productive sectors. Furthermore, the vision includes an emphasis on increasing the local content in manufacturing to 55%, which will strengthen domestic supply chains, stimulate local innovation, and enhance economic self-reliance [192].

In addition to growth and localization, the vision prioritizes job creation within the manufacturing sector, aiming to generate 230,000 employment opportunities. This focus on workforce development aligns with broader socioeconomic goals, supporting a more skilled and diverse labour force. Through these objectives, Saudi Arabia's industrial vision aspires to transform the Kingdom into a resilient, globally competitive industrial power that contributes substantially to sustainable national growth.

The National Industrial Development Center (NIDC) plays a pivotal role in advancing Saudi Arabia's industrial landscape by fostering industrial clusters and spearheading development initiatives across high-growth sectors targeted for export. Key areas of focus include automotive manufacturing, minerals and mining operations, water desalination and energy spare parts, chemical and pharmaceutical industries, and biotechnology. These sectors represent strategic priorities for diversifying Saudi Arabia's industrial base and enhancing its global competitiveness. To achieve its mission, the NIDC leverages technical expertise and coordinates closely with government agencies and private sector partners to promote industrial investment, prioritize development initiatives, and implement effective policies [30].

The Saudi Ministry of Industry has prioritized the establishment of industrial cities and technical zones, aligning with national development goals through collaborations with both public and private sectors. This effort led to the creation of the Saudi Authority for Industrial Cities and Technology Zones (MODON) in 2001, which is tasked with developing industrial lands and building integrated infrastructure to support industrial growth [128]. Currently, MODON oversees 36 industrial cities that are either operational or under development across the Kingdom. These cities host over 4,000 factories in various stages of production, construction, and establishment, alongside a total of 6,587 industrial, investment, service, and logistical contracts [138]. Spanning more than 200 million square meters of developed industrial land, these industrial hubs have become key drivers of economic diversification and job creation, employing 517,242 people, including 185,840 Saudi men and 16,825 Saudi women [150].

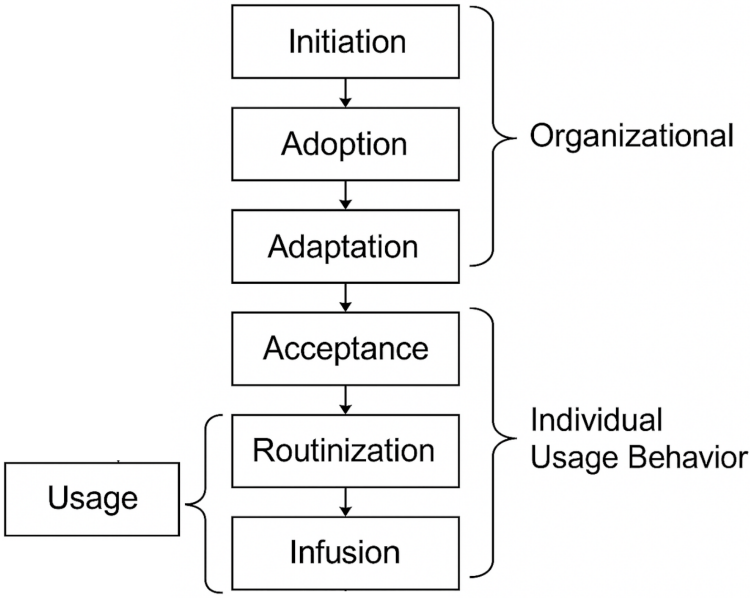

Figure 2.2: IT implementation stages [42]

2.4 Technology Adoption

An organisation moves from the initial exploration of an IT solution to its full integration and optimal use. Figure 2.2 shows how, starting with finding a suitable IT solution, the organisation works through stages of adoption, implementation, acceptance by employees, and eventually, routine use and full integration, where the technology is fully embedded in the organisation's operations and leveraged for maximum benefit [42]. It is important to note that organisations may choose from off-the-shelf, customised, or bespoke IT solutions during this process. The stages described are broadly applicable regardless of the type of solution selected.

1. In the initiation stage, the organization begins by examining its challenges and opportunities, either proactively or as they arise, to identify potential IT solutions. The drive for change may stem from internal requirements (pull) or technological advancements (push). Ultimately, this stage results in identifying an IT solution that meets the organization's specific needs.

2. In the adoption stage, the organization engages in internal discussions and negotiations to build support for the IT implementation, working to secure the required

approvals and resources. This stage concludes with a formal decision to invest in the IT application, enabling the organization to proceed with implementation.

3. In the adaptation stage, the IT application is developed, installed, and set up for ongoing maintenance. Organisational processes are modified to align with the new system, and employees receive training on both the updated procedures and the IT application itself. At the end of this stage, the IT application is fully prepared for use within the organisation.

4. In the acceptance stage, initiatives are taken to motivate employees to incorporate the new IT application into their work routines, resulting in employees beginning to use the application in their everyday tasks.

5. In the routinization stage, the IT application becomes an integral part of daily organisational activities, seamlessly incorporated into standard operations. It is now embedded within the organization's governance structure and is perceived as a regular component of workflows rather than an independent or novel tool.

6. In infusion stage, the organisation aims to enhance its effectiveness by using the IT application in a fully integrated and comprehensive way, supporting more advanced and complex tasks. As a result, the application is leveraged to its maximum potential, optimising organisational efficiency and overall effectiveness.

The phases of technology adoption are addressed by several theories and models, including the Technology Acceptance Model (TAM) [45], the Diffusion of Innovation (DOI) theory [157], the Unified Theory of Acceptance and Use of Technology (UTAUT) [189], and the Technology-Organisation-Environment (TOE) framework [179]. In addition to these, other influential models such as the Theory of Reasoned Action (TRA) [5], the Theory of Planned Behavior (TPB) [6], the Motivation Model (MM) [46], and the Social Cognitive Theory (SCT) [19] offer valuable insights into user behaviour and decision-making processes. These frameworks help explain how individuals and organisations decide to adopt technology and how they continue to engage with it after initial implementation. The models collectively offer a comprehensive view of the lifecycle of technology adoption, from initial awareness and decision making to sustained use and integration. They help researchers and practitioners understand both the motivations behind adoption and the factors that influence continued use, satisfaction, and optimisation.

2.5 Systematic Review of Blockchain Technology Adoption

This thesis utilises a systematic literature review (SLR) method, as defined by Kitchenham and Charters (2007), to establish a broad perspective on key research questions and to uncover significant research gaps [97]. The main objective of this SLR is to synthesise current research trends in blockchain adoption, focussing on the various determinants critical to its success. This approach facilitates the identification and evaluation of the latest knowledge on this topic, ensuring a comprehensive understanding of the field [98]. Unlike traditional reviews, the systematic method applied here allows for a more structured collection and analysis of the literature, significantly reducing bias and increasing reliability.

2.5.1 Research method

Kitchenham and Charters' guidelines for systematic reviews were followed to ensure a rigorous and transparent process [97]. The research method used in this study is a systematic approach, involving the identification of relevant research, the selection of primary studies, assessment of study quality, data extraction, and data synthesis.

2.5.1.1 Identification of research

This phase involves determining the databases used in the research and the search terms used to search the database.

Databases used in the research: A systematic search was conducted across six digital libraries, namely ACM Digital Library, Scopus, Springer Link, ProQuest, IEEE Explore, and Web of Science. The search targeted research articles and encompassed titles, keywords, and abstracts. Table 2.1 lists the names of databases and their websites.

Terms used in the search: Key terms were used to search the literature in the databases. The keywords were chosen to capture the literature on blockchain adoption as well as manufacturing. Boolean operators "AND" and "OR" were employed to create effective search strings. The search queries included combinations such as: *(Acceptance "OR" adoption) "AND" (Blockchain "OR" Block chain) AND (Manufacture "OR" Manufacturing*).

The query strings for each scientific database, as shown in Table 2.2, were systematically applied across the selected digital libraries. The initial search yielded a total

Table 2.1: Database website

Scientific database	Database website
ACM Digital Library	https://dl.acm.org/
Scopus	https://www.scopus.com/
ScienceDirect	https://www.sciencedirect.com/
ProQuest	https://www.proquest.com/
IEEE Explore	http://ieeexplore.ieee.org
Web of science	https://www.webofknowledge.com/

of 1,884 articles, which were then filtered based on predefined inclusion and exclusion criteria.

Table 2.2: Searches in the databases

Scientific database	Query strings
ACM Digital Library	Adopt* OR Accept* AND Blockchain AND Manufacture*
Scopus	adopt* OR accept* AND blockchain AND manufacture*
ScienceDirect	(Adopt OR Accept) AND (Blockchain) AND (Manufacture)
ProQuest	Blockchain Accept* OR Blockchain Adopt* AND Manufacture*
IEEE Explore	Blockchain Accept* OR Blockchain Adopt* AND Manufacture*
Web of science	Adopt* OR Accept* AND Blockchain AND Manufacture*

2.5.1.2 Inclusion and exclusion criteria:

The initial search yielded a total of 1,884 articles, which were then filtered based on predefined inclusion and exclusion criteria. In this phase, our objective was to pinpoint primary studies that directly addressed our research question. To achieve this, we defined a set of inclusion and exclusion criteria.

Criteria for selecting papers: The criteria for selecting papers are detailed in Table 2.3. The inclusion criteria included a focus on blockchain adoption topics, only journal papers and conference proceedings published in English, as well as online access to the full text. Exclusion criteria were established to filter out non-academic papers and duplicated content, as well as survey papers and literature reviews.

Procedure for selecting papers: The initial screening phase aimed to eliminate studies that did not meet the core criteria such as language, type of publication and their connection to blockchain adoption. Each study was meticulously screened to ensure that it met the inclusion criteria, including a focus on blockchain adoption topics, and

Table 2.3: Criteria for selecting papers

Inclusion Criteria	Exclusion Criteria
Blockchain adoption topics	Non-academic papers
Journal papers	Duplicated content
Conference proceedings	Survey papers and literature reviews
Peer-reviewed publications	Non English papers

the availability of the full text online. A first screening reduced the sample to 621. The details of these papers were exported using Excel to help in further filtering and removing duplicates. Following the initial screening phase evaluation, the remaining articles were subjected to a more detailed evaluation, which involved reading the title and keywords of the articles in the first stage, abstracts in the second stage, and full-text papers in the third stage.

In the first stage, the titles and keywords of all 621 papers were reviewed to assess their relevance to the research topic. If the title was clear and provided enough information to determine that the paper was relevant, it was retained for the next stage. If the title was clear and indicated that the content was not relevant, the paper was excluded. However, if the title was ambiguous or did not provide enough information to make a confident judgment, the paper was also retained for further screening. As a result, 102 articles progressed to the second stage.

In the second stage, the abstracts of these 102 papers were read to determine how closely they aligned with the study's aims. Papers that matched well were advanced to the final stage, totalling 84 articles.

In the third stage, the full texts of these 84 papers were thoroughly read to ascertain their relevance and contribution to the research topic. Following this detailed review, 59 papers were selected as being most pertinent to the research.

The stages and results of the paper selection process are detailed in Table 2.4, which summarises how the papers were filtered at each stage.

2.5.1.3 Study quality assessment

Quality assessment describes the process used to assess the rigour and relevance of the articles selected from the systematic review filtering process. Five specific criteria were established to assess the quality of each shortlisted article. Table 2.5 outlines the specific criteria that were used to assess the quality of the selected articles.

Table 2.4: Paper selection stages.

Database	The initial screening stage	First stage	Second stage	Third stage
ACM Digital Library	144	12	8	4
Scopus	73	20	15	12
ScienceDirect	53	12	12	10
ProQuest	122	19	15	9
IEEE Explore	162	15	14	13
Web of Science	67	24	20	11
Total	621	102	84	59

Table 2.5: Criteria used for quality assessment.

	Criteria used for quality assessment.
QA.1	Does this study focus on blockchain adoption?
QA.2	Is the theoretical model of the study clearly defined?
QA.3	Does the study address the factors that influence blockchain adoption?
QA.4	Does the study evaluate the factors that affect blockchain adoption?
QA.5	Does the study examine blockchain adoption in the manufacturing domain?

Based on these criteria, papers were rated on a scale. When a paper met a specific criterion, it scored 1 or a 0 if it did not meet the criterion. An article must meet at least three out of the five criteria, or receive a score of three or higher, to be considered for further analysis. Table 2.6 lists the scores of the 59 articles shortlisted according to these criteria, ranked according to the five quality benchmarks.

Table 2.6: Papers that meet the quality assessment criteria

No.	**Paper**	**QA.1**	**QA.2**	**QA.3**	**QA.4**	**QA.5**	**Overall**
A1	[204]	✓	✓	✓	✓	✗	4
A2	[203]	✓	✓	✓	✓	✗	4
A3	[194]	✓	✓	✓	✓	✗	4
A4	[195]	✓	✓	✓	✓	✗	4
A5	[183]	✓	✓	✓	✓	✓	5
A6	[174]	✓	✓	✓	✓	✓	5
A7	[3]	✓	✓	✓	✓	✗	4
A8	[36]	✓	✓	✓	✓	✗	4

Continued on next page

Table 2.6 – continued from previous page

No.	Paper	QA.1	QA.2	QA.3	QA.4	QA.5	Overall
A9	[39]	✓	✓	✓	✓	✗	4
A10	[92]	✓	✓	✓	✓	✗	4
A11	[23]	✓	✓	✓	✓	✗	4
A12	[66]	✓	✓	✓	✓	✗	4
A13	[152]	✓	✓	✓	✓	✗	4
A14	[124]	✓	✓	✓	✓	✗	4
A15	[142]	✓	✓	✓	✓	✗	4
A16	[164]	✓	✓	✓	✓	✗	4
A17	[8]	✓	✓	✓	✓	✗	4
A18	[153]	✓	✓	✓	✓	✗	4
A19	[112]	✓	✓	✓	✓	✗	4
A20	[33]	✓	✓	✓	✓	✗	4
A21	[32]	✓	✓	✓	✓	✗	4
A22	[146]	✓	✓	✓	✓	✗	4
A23	[129]	✓	✓	✓	✓	✗	4
A24	[166]	✓	✓	✓	✓	✗	4
A25	[144]	✓	✓	✓	✓	✗	4
A26	[109]	✓	✓	✓	✓	✗	4
A27	[86]	✓	✓	✓	✓	✗	4
A28	[91]	✓	✓	✓	✗	✗	3
A29	[190]	✓	✓	✓	✓	✗	4
A30	[115]	✓	✓	✓	✗	✗	3
A31	[110]	✓	✓	✓	✓	✗	4
A32	[111]	✓	✓	✓	✗	✗	3
A33	[114]	✓	✓	✓	✓	✗	4
A34	[167]	✓	✓	✓	✓	✗	4
A35	[184]	✓	✓	✓	✓	✗	4
A36	[198]	✓	✓	✓	✓	✗	4
A37	[74]	✓	✓	✓	✓	✗	4
A38	[60]	✓	✓	✓	✗	✗	3
A439	[11]	✓	✓	✓	✓	✗	4
A40	[106]	✓	✓	✓	✓	✗	4

Continued on next page

Table 2.6 – continued from previous page

No.	Paper	QA.1	QA.2	QA.3	QA.4	QA.5	Overall
A41	[185]	✓	✓	✓	✓	✗	4
A42	[37]	✓	✓	✓	✓	✗	4
A43	[34]	✓	✓	✓	✓	✗	4
A44	[145]	✓	✓	✓	✓	✗	4
A45	[122]	✓	✓	✓	✓	✗	4
A46	[125]	✓	✓	✓	✓	✗	4
A47	[123]	✓	✓	✓	✓	✗	4
A48	[7]	✓	✓	✓	✓	✗	4
A49	[61]	✓	✓	✓	✓	✗	4
A50	[117]	✓	✓	✓	✓	✗	4
A51	[169]	✓	✓	✓	✓	✗	4
A52	[208]	✓	✓	✓	✓	✗	4
A53	[9]	✓	✓	✓	✓	✗	4
A54	[15]	✓	✓	✓	✓	✗	4
A55	[28]	✓	✓	✓	✓	✗	4
A56	[170]	✓	✓	✓	✓	✗	4
A57	[162]	✓	✓	✓	✓	✗	4
A58	[134]	✓	✓	✓	✓	✗	4
A59	[90]	✓	✓	✓	✓	✗	4

2.5.1.4 Data synthesis

Data extraction is a fundamental process to collect the necessary information, address specific research inquiries, and establish quality standards [97]. The data collected were meticulously organised and analysed using Excel, enhancing our ability to systematically review and interpret the gathered information. This approach was instrumental in delineating a coherent overview of the extracted data.

During the data synthesis phase, information from the 59 selected studies was synthesised and structured in tables. This crucial step facilitated a comprehensive understanding of various aspects of the collected data, including context, methodologies, theoretical frameworks, applications, and factors identified within the associated literature. Subsequently, these elements were systematically classified, providing a structured analysis that enhances the clarity and depth of our research findings.

2.5.2 Results

The systematic search and selection process resulted in the inclusion of 59 studies to provide answers to our research questions.

2.5.2.1 Search result

As a result of the systematic review, 59 relevant studies were identified, spanning 2018 to 2023, as summarised in Table 2.7. In general, these studies were sourced from peer-reviewed journals and several conference papers were also included, underscoring the interdisciplinary and evolving nature of blockchain research. The publications mainly originate from diverse global contexts, including notable contributions from countries such as India, Australia, and China, which are leading in blockchain exploration and implementation in various sectors. The research spans multiple domains with a significant emphasis on supply chain management.

Table 2.7: An overview of the selected studies

No.	Paper	Year	Country	Category	Domain
A1	[204]	2020	Malaysia	Journal	Supply chain management
A2	[203]	2020	Malaysia	Journal	Multi-sector
A3	[194]	2019	Brazil	Journal	Supply chain
A4	[195]	2020	India and the US	Journal	Supply chain management
A5	[183]	2021	Pakistan	Journal	Manufacturing and service
A6	[174]	2023	Bangladesh	Journal	Manufacturing
A7	[3]	2022	France	Journal	Multi-sector
A8	[36]	2020	Korea	Journal	Supply chain
A9	[39]	2019	Ireland	Journal	Multi-sector.
A10	[92]	2018	India	Journal	Supply chain
A11	[23]	2021	India	Journal	Supply chain
A12	[66]	2021	Turkey and U.K.	Journal	Supply chain management
A13	[152]	2019	India and USA	Journal	Supply chain
A14	[124]	2021	Australia	Journal	Multi-sector
A15	[142]	2020	Nigeria	Journal	Freight logistics
A16	[164]	2021	India	Journal	Agri-food supply chain
A17	[8]	2021	Australia	Journal	Supply chain
A18	[153]	2020	Brazil	Journal	Supply chain management

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Table 2.7 – continued from previous page

No.	Paper	Year	Country	Category	Domain
A19	[112]	2022	China	Journal	Construction
A20	[33]	2021	India	Journal	Multi-sector
A21	[32]	2022	China	Journal	Engineering-construction
A22	[146]	2022	India	Conference	banking
A23	[129]	2021	South Africa	Conference	ICT and Telecommunications
A24	[166]	2019	Canada	Conference	Research
A25	[144]	2023	Indonesia	Conference	Banking
A26	[109]	2021	India	Conference	Higher education
A27	[86]	2022	Iraq	Conference	Small and medium-sized enterprises
A28	[91]	2021	Malaysia	Conference	Government
A29	[190]	2020	Netherlands	Conference	Multi-sector
A30	[115]	2022	China	Conference	Electricity industry
A31	[110]	2023	India	Journal	Financial services
A32	[111]	2020	South Africa	Conference	Information
A33	[114]	2020	Hong Kong	Journal	Multi-sector
A34	[167]	2021	Canada	Journal	Business
A35	[184]	2021	Malaysia	Journal	Education
A36	[198]	2022	China	Journal	Construction industry
A37	[74]	2022	Spain	Journal	Information and Communications
A38	[60]	2018	USA	Journal	Supply chain
A39	[11]	2023	Malaysia	Journal	Multi-sector
A40	[106]	2019	India	Journal	Healthcare
A41	[185]	2020	Iran	Journal	Energy
A42	[37]	2023	U.K	Journal	supply chain management
A43	[34]	2023	India	Journal	Multi-sector
A44	[145]	2020	Korea	Journal	Logistics industry
A45	[122]	2021	DACH region	Journal	Multi-sector
A46	[125]	2022	U.K	Journal	Technology
A47	[123]	2022	Australia	Journal	Organisation
A48	[7]	2022	Malaysia	Journal	Software development
A49	[61]	2023	Australia	Journal	Agricultural
A50	[117]	2021	China	Journal	Food

Continued on next page

Table 2.7 – continued from previous page

No.	Paper	Year	Country	Category	Domain
A51	[169]	2021	China	Journal	Small and medium-sized enterprises
A52	[208]	2023	Pakistan	Journal	Supply chain management
A53	[9]	2023	Saudi Arabia	Journal	Supply chain and logistics
A54	[15]	2021	South Africa	Journal	Logistics and transport
A55	[28]	2023	USA and China	Journal	Supply chain management
A56	[170]	2021	Thailand	Journal	Supply chain and finance
A57	[162]	2021	Australia	Journal	Finance
A58	[134]	2022	Bangladesh	Journal	Supply chain
A59	[90]	2022	U.K	Journal	Supply chain

2.5.2.2 Regional Distribution

The geographical distribution of the relevant articles is shown in Figure 2.3. The regional distribution of the selected studies indicates a concentration of blockchain research in specific countries. India leads with the highest number of studies, closely followed by China and Malaysia, indicating a strong focus on blockchain technology in Asia. Blockchain technology has attracted research interest throughout the world, as evidenced by the geographical distribution.

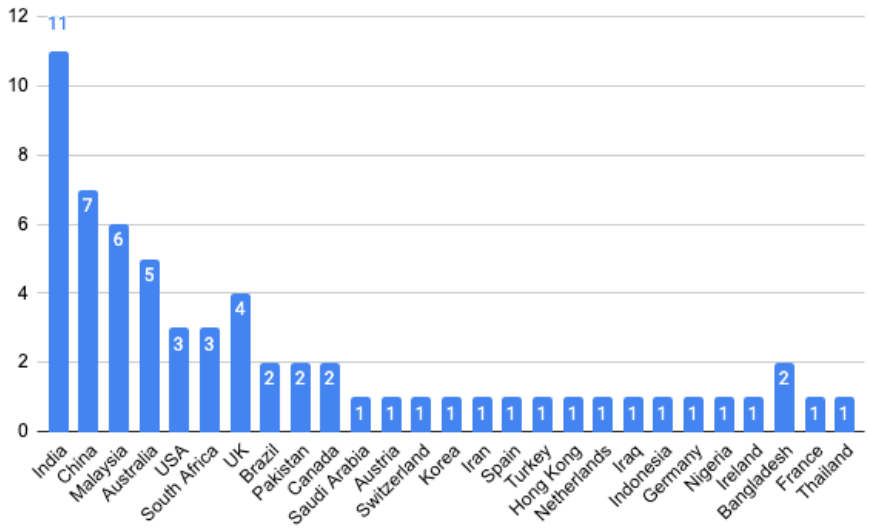

Figure 2.3: Geographic Distribution of Studies by Country

2.5.2.3 Publication year

From 2018 to 2023, there were significant trends in blockchain-related research activity, as shown in Fig. 2.4. The data show that there was a steady increase in publications from 2018,

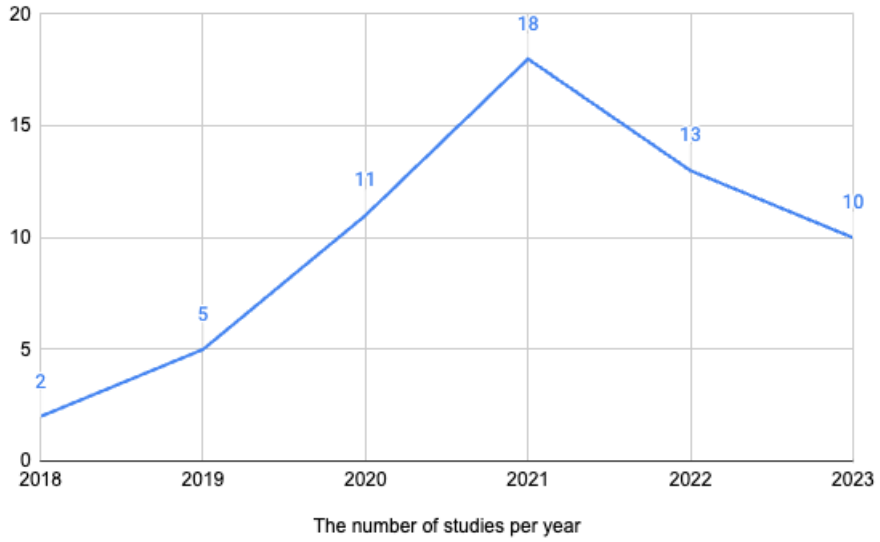

Figure 2.4: Publication year of the selected papers

culminating in a peak in 2021. This peak reflects the increasing academic interest in blockchain technology.

2.5.2.4 Application fields of the selected studies

The analysis of the selected studies reveals a variety of application areas for blockchain technology, with a primary focus on supply chain management, as investigated in 16 studies. This was followed by the multisector category with ten studies, which covered more than two sectors in each study. Specific sectors such as construction and education were covered by three studies each. Critical sectors such as logistics, SMEs, and manufacturing were covered by two studies each. Figure 2.5 illustrates the distribution of research studies by domain.

2.5.2.5 Theories/models used in the studies

Table 2.8 provides an overview of the empirical and conceptual theories used in blockchain adoption studies, classified by the number of empirical and conceptual studies for each

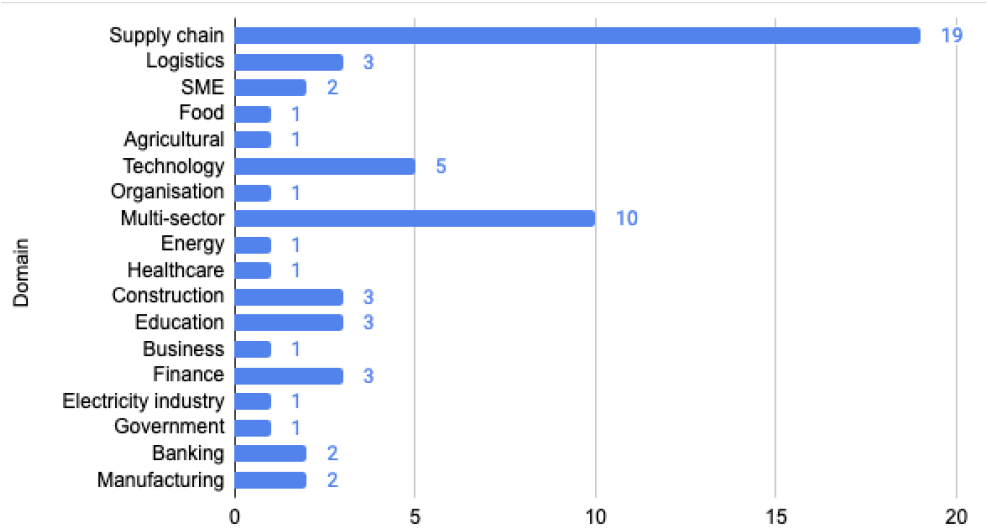

Figure 2.5: Distribution of Research Studies by Domain

theory. This study explores the factors that influenced blockchain adoption from a theoretical perspective through 14 different theories. The TOE framework is the most frequently used, with 25 total studies, including 23 empirical and 2 conceptual studies. The technology acceptance model (TAM) was utilized in 20 empirical studies, while the unified theory of acceptance and use of technology (UTAUT) was utilized by 15 studies, including 13 empirical and 2 conceptual. Other frameworks such as the diffusion of innovation (DOI), the theory of planned behavior (TPB), the technology readiness index (TRI), and the information systems success model (ISS) were used less frequently, highlighting the dominance of the TOE, TAM, and UTAUT models in blockchain adoption research.

2.5.2.6 Factors affecting blockchain adoption

A total of 49 factors were extracted from the TOE framework. It was chosen for the extracted factors due to its wide application and proven effectiveness in previous research on blockchain adoption, as highlighted in Table 2.8. The TOE framework was used in 25 studies, making it the most widely applied theoretical model in the investigation of blockchain adoption. The following table 2.9 provides an overview of the factors identified as influential in the adoption of blockchain technology, categorised into technological, organisational, and environmental factors. Technological factors such as relative advantage, were most frequently cited in 14 studies, along with complexity, compatibility, security, and others, which primarily address the technical benefits and challenges associated with blockchain implementation. Organisational factors including

Table 2.8: An overview of the empirical and conceptual theories

N.	Used Theory	Empirical	Conceptual	Total	Studies
1	TOE	23	2	25	[90], [134], [162], [170], [15], [9] , [7], [123], [122], [145] , [34] , [74] , [198], [111], [115], [190], [91], [129], [112], [124] , [66], [23], [39] , [174], [203].
2	TAM	20	-	20	[28], [61], [37], [185] , [106], [11], [74] , [198], [184], [167], [109] , [166], [146], [33], [23], [92] , [195], [183], [174], [36].
3	UTAUT	13	2	15	[208], [145], [37], [60], [110], [115], [86], [144], [153] , [8], [164], [152], [195], [194], [204]
4	DOI	6	-	6	[9] ,[184], [129], [23], [36], [3],
5	TPB	5	-	5	[117], [61], [32], [92] , [183].
6	TTF	3	-	3	[106], [146], [8].
7	TRI	3	-	3	[183], [92] , [61].
8	ISS	2	-	2	[8],[117].
9	ANP	1	-	1	[142].
10	RFT	1	-	1	[32].
11	PMT	1	-	1	[125].
12	TRA	1	-	1	[114]
13	Trust	1	-	1	[91]
14	Complexity	1	-	1	[169]

top management support, organisational readiness, and cost critically assess a company's internal capabilities and readiness to embrace new technologies. Environmental factors such as competitive pressure, regulations, and government support highlight external forces that influence blockchain adoption. Table 2.9 lists the factors that are supported by the studies, with the total number of studies.

2.5.3 SLR discussion

2.5.3.1 Theories Used in Blockchain Adoption

This section discusses the theories and models of technology adoption. It is important to note that TOE, TAM, and UTAUT are the most commonly used models in blockchain technology adoption studies.

1. ***Technology-Organisation-Environment Framework***
   TOE was introduced by Tornatzky and Fleischer (1990) [179] and describes the factors that impact the adoption of technology by an organisation. The TOE model identifies the various contexts of a firm that impact the process by which it implements and adopts technological innovation [39], namely the technological context, which describes both external and internal technologies relevant to a firm, the organisational context, which includes descriptive measures such as size, scope, and

Table 2.9: Influencing factors on blockchain adoption based on literature review

N.	Factors	Studies	Total
	Technological Factors		
1	Relative advantage	[15],[9], [122], [34], [74], [198], [129], [112], [66], [23], [174] , [203],[162],[134].	14
2	Complexity	[15], [7], [122], [74], [190], [129], [112] , [124], [66], [23] ,[203]	11
3	Compatibility	[15], [123], [122], [34], [198] ,[129], [112] , [124], [66], [23], [134].	11
4	Security	[7], [34], [23] , [170]	4
5	Trust	[34], [190], [66], [162]	4
6	Trialability	[7], [122], [112]	3
7	Perceived benefits	[123], [129], [124]	3
8	Information transparency	[123], [124]	2
9	Perceived risks	[123], [124]	2
10	Observability	[122]	1
11	Technological maturity	[198]	1
12	Interoperability	[190]	1
13	Perceived Disintermediation	[124]	1
14	Data integrity	[170]	1
15	Operational efficiency	[170]	1
16	Scalability	[66]	1
17	Uncertainty	[162]	1
	Organisational Factors		
18	Top management support	[15] [9] [122] [34] [74] [190] [129] [112] [124], [66] [23], [39], [174] [203] [162] [170]	14
19	Organizational readiness	[15], [122], [198], [129], [112] , [66], [39] , [174], [162] , [170]	11
20	Cost	[7], [11], [190], [66] , [23], [203]	6
21	Organisational size	[122], [34], [112] , [66], [39]	5
22	Innovativeness	[7], [123], [190], [124]	4
23	Organisational learning capability	[123], [124]	2
24	Openness to innovation	[9]	1
25	Facilitating conditions	[7]	1
26	Organizational age	[122]	1
27	Firms' IT resources	[34]	1
28	Monetary Resources	[34]	1
29	Competence	[74]	1
30	Employees' knowledge	[174]	1
31	Suitable application	[162]	1
	Environmental Factors		
32	Competitive pressure	[15], [34], [74] , [198], [190],[129], [112], [66] , [174], [203], [162]	11
33	regulations	[23] ,[112] ,[34] ,[7] ,[162] ,[36],[203], [15], [198], [66], [170]	11
36	Government support	[9],[129], [124], [142], [36], [23], [134]	7
35	Business partner pressure	[34], [112], [66] , [174],	4
37	Competition intensity	[123],[122],[124]	3
38	External support	[15],[122]	2
39	Standardisation	[190] ,[66]	2
40	Vendor orientation and support	[9], [23]	2
41	Market dynamics	[7], [203]	2
42	Partner readiness	[7], [124]	2
43	Standards uncertainty	[123], [124]	2
44	Pre-existing collaboration with stakeholders	[122], [170]	2
45	Regulatory uncertainty	[122],	1
46	Competitors influence	[9]	1
47	Scope of the business ecosystemy	[122]	1
48	Inter-organisational trust	[66]	1
49	Network effect	[170]	1

managerial structure of the organisation; and the environmental context, which includes competitors and industry. It also presents opportunities and constraints for technological innovation.

The TOE framework proved important due to its wide application and proven effectiveness in research on blockchain adoption in the supply chain [170], [90], [134], [66], [23], in finance [162], [170] in logistics and transport [15] in supply chain and logistics [9], in information technology[111], [7], [129], in organisations in general [123] and in construction [112]. Some studies covered multiple sectors [122], [34], [190], [124], [39], [203].

TOE was integrated with various theories in several studies to provide a more complete understanding of the adoption of blockchain technology, such as TAM in information and communications [74], in the construction industry [198], in supply chains [23], in manufacturing [174]. Also, UTAUT was utilised in the logistics industry [145], and in the electricity industry [115]. It is worth mentioning that the DOI theory can be seen as a component of the TOE framework, particularly within the technological dimension. TOE complements DOI by adding organisational and environmental perspectives. Thus, all TOE studies include DOI theory.

2. ***The Technology Acceptance Model (TAM)***
   TAM, introduced by Davis (1989) [45], is one of the most popular theories. It is based on the Theory of Reasoned Action (TRA) [5]. Davis (1989) proposed TAM to understand individual behaviours. in the acceptance of an information system. According to Szajna (1996) [171], TAM is an IS theory to understand the acceptance and use of emerging technology by users in the workplace.

   Numerous studies on the acceptance of blockchain technology have used TAM such as studies on supply chain management [28], agriculture [61], energy [185], and education [109],[166],and multiple sectors have been covered in some studies [11], [33].

   A significant level of integration has occurred between TAM and other theories to gain a better understanding of the adoption of blockchain technology, for instance, TAM and UTAUT in supply chain management [37], TAM and DOI in supply chains [36] and education [184], TAM and TTF in banking [146] and healthcare [106], TAM and the Trust model in business [167], and TAM, TRI and TPB in supply chains [92].

3. ***Unified Theory of Acceptance and Use of Technology (UTAUT)***

   The UTAUT is an IS model that analyses the behaviour and intentions of technology users' [145]. It was formulated by Venkatesh et al. in 2003 [189]. It is among the common theories used to explain how people adopt and embrace new technology when it is available. In addition, it combines the models of the theory of planned behavior (TPB), the theory of reasoned action (TRA), the motivation model (MM), the TAM model, the social cognitive theory (SCT) and the innovation diffusion theory (IDT). Several constructs in UTAUT play a significant role in predicting an individual's acceptance. These paradigms include social influence, performance expectancy, facilitation conditions, and effort expectancy.

   Studies on the acceptance of blockchain technology have used UTAUT, including research on supply chain management [204], [194], [152], [153], [208], agri-food supply chains [164], banking and financial services [110], [144], and small and medium enterprises [86].

2.5.3.2 Key Influencing Factors

This section presents a detailed summary of the factors that influence the adoption of blockchain technology. The factors were selected on the basis of two criteria. First, all factors were evaluated on the basis of the TOE framework, which is the most widely used for blockchain adoption studies (see Table 2.8). In addition, each factor was empirically tested in seven or more studies. As a result, seven factors are included, namely compatibility, complexity, relative advantage, top management support, organisational readiness, regulations and laws, and government support. While competitive pressure can be a motivating factor, the focus of this study is on internal factors (e.g., organisational readiness, top management support) and external enablers (e.g., government support, regulations) rather than the competitive dynamics of the market. As shown in Figure 2.6, the factors are classified into three contexts: technological, organisational, and environmental.

1. ***Technological factors:*** In the technological dimension, we focus on the characteristics of the technology itself. In blockchain adoption studies, complexity, compatibility, and relative advantage are the most important factors.

   A total of 14 studies examined the influence of relative advantage on blockchain adoption, and the results were consistent across these studies [15],[9], [122], [34], [74], [198], [129], [112], [66], [23], [174] , [203],[162],[134]. Specifically, they found

Figure 2.6: Selecting blockchain adoption factors based on the SLR.

that relative advantage, the perceived benefits or improvements that blockchain technology offers over existing systems, plays a significant and positive role in influencing organisations or individuals to adopt blockchain.

A total of 11 studies explored the effect of complexity on blockchain adoption [15], [7], [122], [74], [190], [129], [112] , [124], [66], [23] ,[203]. In these 11 studies, researchers found that the complexity of blockchain technology can act as a barrier to its adoption. Specifically, if blockchain is perceived as difficult to understand, implement, or integrate with existing systems, organisations or individuals are less likely to adopt it. Blockchain adoption is therefore negatively influenced by its complexity.

Lastly, 11 studies investigated the role of compatibility in blockchain adoption [15], [123], [122], [34], [198] ,[129], [112] , [124], [66], [23], [134]. Organisations are more likely to adopt blockchain technology when it is compatible with their current systems, processes, and technologies. The compatibility of a blockchain can, therefore, positively affect its adoption.

2. ***Organisational factors:*** Two internal factors, top management support and organisational readiness, are addressed in the organisational context.

   A total of 14 studies investigated how top management support affects blockchain adoption [15] [9] [122] [34] [74] [190] [129] [112] [124], [66] [23], [39], [174] [203] [162] [170]. These studies found that strong support from senior leadership plays a positive role in the decision to adopt blockchain technology, further emphasising the importance of management's role in technological innovation.

A total of 11 studies examined how organisational readiness impacts the adoption of blockchain technology [15], [122], [198], [129], [112] , [66], [39] , [174], [162] , [170]. These 11 studies explored how being well prepared (in terms of resources, skills, and infrastructure) influences whether or not an organisation decides to adopt blockchain technology.

3. ***Environmental factors:*** We focus on two external factors in the environmental context: regulations and government support.

   A total of 11 studies examined how regulations affect the adoption of blockchain technology [23], [112], [34], [7], [162], [36], [203], [15], [198], [66], [170]. Understanding how regulations impact the decision to adopt blockchain is crucial to identifying legal and compliance issues that can slow the rate of adoption.

   A total of 7 studies examined how government support affects blockchain adoption [9], [129], [124], [142], [36], [23], [134]. Government support for blockchain adoption provides positive insight into how state-backed initiatives facilitate or encourage blockchain adoption.

2.6 Chapter summary

This chapter provides a foundational understanding of the study topic and explores what is currently known about blockchain technology adoption in the manufacturing sector, while clarifying critical knowledge gaps. It begins with an overview of blockchain technology, outlining its definitions, characteristics, and operational mechanisms. The discussion then extends to blockchain's applications and benefits within the manufacturing industry, with a focus on its capacity to address key sectoral challenges. Subsequently, the chapter introduces the manufacturing sector in Saudi Arabia, emphasising its strategic priorities and development trajectory in the context of national economic initiatives. Finally, a systematic review of the relevant literature is presented to identify and analyse the key determinants influencing the adoption of blockchain technology, thereby laying the groundwork for the research framework and study objectives discussed in the following chapter.

CHAPTER 3

PROBLEM DEFINITION

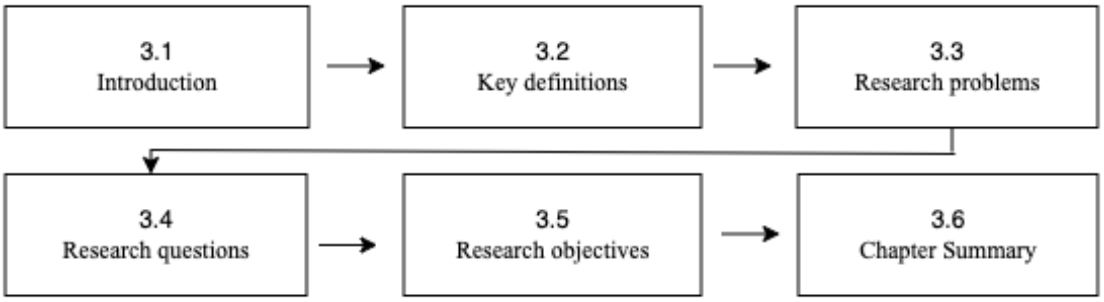

Figure 3.1: Outline of chapter 3

3.1 Introduction

This chapter defines the foundational elements of the study, starting with the key definitions to clarify the essential terms and concepts. It then presents the research problem, pinpointing gaps in the existing knowledge that the research aims to address. Following this, the research questions are formulated to explore these gaps thoroughly. Finally, the research objectives and aims provide a clear overview of the research. The structure of this chapter is illustrated in Figure 3.1

3.2 Key Definitions

- **Blockchain** is a distributed ledger technology that allows data to be stored on multiple servers across the globe simultaneously. Each 'block' in the blockchain contains a number of transactions, and every time a new transaction occurs on the blockchain, a record of that transaction is added to the ledger of every participant [133]. It uses cryptographic techniques to ensure that once a transaction is recorded, it cannot be altered or deleted, offering high levels of security and transparency [173].

- **Technology adoption** is defined as the process through which individuals and organizations accept and begin utilising a new technology [95]. The purpose of studies on technology adoption is to understand, predict, and explain the factors influencing adoption at the personal and organisational levels of technological adoption [63].

- **Theories and models** describe and predict the factors influencing the acceptance, use, and diffusion of new technologies within individual, organisational, or societal contexts. They typically identify the determinants of adoption and categorise them into various constructs that can influence an individual's or group's decision to embrace and utilise a technology. Prominent examples include the technology acceptance model (TAM), (UTAUT), (DOI) and (TOE) framework [179] [189] [45] [156].

- **Information technology employees** Information technology (IT) employees engage in a diverse range of roles across multiple industries, handling tasks related to both IT hardware and software. These roles include CIOs, software and hardware engineers, IT support, programmers, IT security personnel, online content managers etc. Their functions are essential across various sectors and are not limited to only the IT industry [55]. The study participants are those in the manufacturing sector working in management, administration, professional, or technician roles.

- **Manufacturing** refers to an An industrial production process that converts raw materials into finished products ready for sale in the market. [53]. In this study, we emphasize the inventory of raw materials as a critical aspect of manufacturing, which consists of items purchased from suppliers which are then used as inputs in the manufacturing process [178].

3.3 Research Problems

Adopting IT innovations profoundly affects both the internal and external operations of companies, signaling significant transitions across various industrial activities [197] [89]. Several technological advancements, from the digitisation of processes to the adoption of cutting-edge methods aligned with the fourth industrial revolution, facilitate expansions and transformations within industries. Of these evolving technologies, blockchain has emerged as a particularly noteworthy trend, garnering considerable attention from academics, practitioners, and national development agencies alike [39].

Blockchain technology, known for its transformative capabilities, offers multiple benefits that enhance manufacturing operations. These include real-time transparency, cost reductions, improved decisions in supply chain financing, and increased sustainability [102]. Its applications extend to tracking goods movement, assessing product quality, ensuring regulatory compliance, and enhancing manufacturing processes through real-time data monitoring and analysis. In addition, blockchain helps reduce the risks of fraud and counterfeiting by maintaining a secure and transparent record of transactions [25].

Despite these significant advantages, blockchain technology adoption in manufacturing has been relatively slow, especially in developed and developing countries [90],[134]. This is even more pronounced in the Saudi Arabian manufacturing sector, where the implementation of blockchain technology is still at an early stage, and empirical research on this subject remains scarce.

To address this identified gap in the literature, this study proposes to develop a conceptual framework specifically tailored for the adoption of blockchain technology in the Saudi manufacturing industry. This framework focusses in particular on the management of raw material inventories. This framework will be empirically tested through a quantitative approach that uses the technology-organisation-environment (TOE) framework. This research aims to provide a comprehensive understanding of the factors that influence blockchain adoption. It also identifies the key drivers and barriers in this context. In doing so, the study aims to facilitate a broader and more effective integration of blockchain technology into Saudi Arabia's manufacturing processes, potentially leading to enhanced operational efficiencies and competitiveness in the sector.

3.4 Research Questions

In light of the comprehensive review of the existing literature and the identified gaps, the purpose of this study is to advance our understanding of blockchain adoption in manufacturing in Saudi Arabia. The following research questions have been developed to direct the focus of this investigation and ensure a structured approach to uncovering new insights:

How can Saudi manufacturing sectors successfully implement blockchain technology?

Three sub-questions were developed to address this main research question more effectively:

Sub-question 1: What are the factors that influence the adoption of blockchain technology in Saudi manufacturing?

Sub-question 2: What relationships exist between these factors?

Sub-question 3: What applications are being selected by IT employees to drive blockchain adoption in manufacturing?

3.5 Research Aims and Objectives

This research aims to examine the factors that influence the adoption of blockchain technology in manufacturing in Saudi Arabia. The following objectives were established to achieve the primary purpose of this research:

1. Objective 1: Determine the factors that influence blockchain adoption in Saudi manufacturing.

2. Objective 2: Develop a conceptual framework based on the relevant theoretical frameworks for studying the factors affecting Saudi manufacturing's adoption of blockchain technology .

3. Objective 3: Validate the proposed research model by empirically testing it through a survey questionnaire of IT employees in the Saudi manufacturing sector.

4. Objective 4: Propose the specific blockchain applications being selected by IT employees to determine future directions in blockchain adoption within the sector.

3.6 Chapter Summary

This chapter lays the foundation for the study by defining key terms and concepts, ensuring a unified understanding. It highlights significant gaps in the existing literature through the research problem and outlines specific inquiries via the research questions. Precise research objectives were established to directly address these gaps.

CHAPTER 4

RESEARCH MODEL AND HYPOTHESES DEVELOPMENT

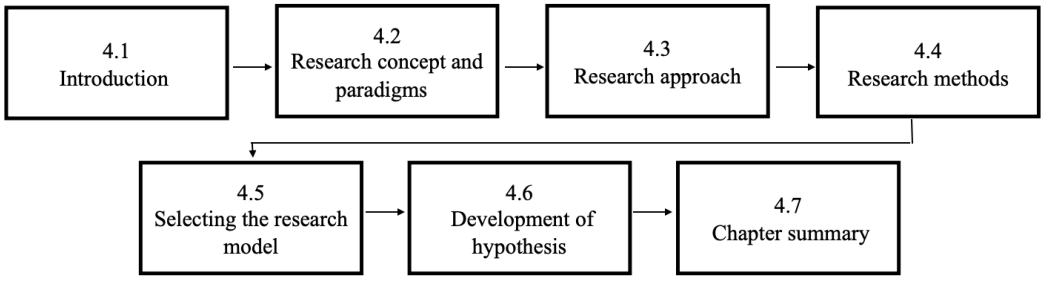

Figure 4.1: Chapter 4 outline

4.1 Introduction

This chapter provides an overview of the methodology used to address the research questions outlined in this study. The investigation methodology determines how the data will be collected and analysed. This section explores the research paradigms, strategies, and methods to investigate the adoption of blockchain technology. In addition, the chapter presents a conceptual model, research hypotheses, and a scientific rationale for the chosen methodology. Figure 4.1 provides an overview of this chapter.

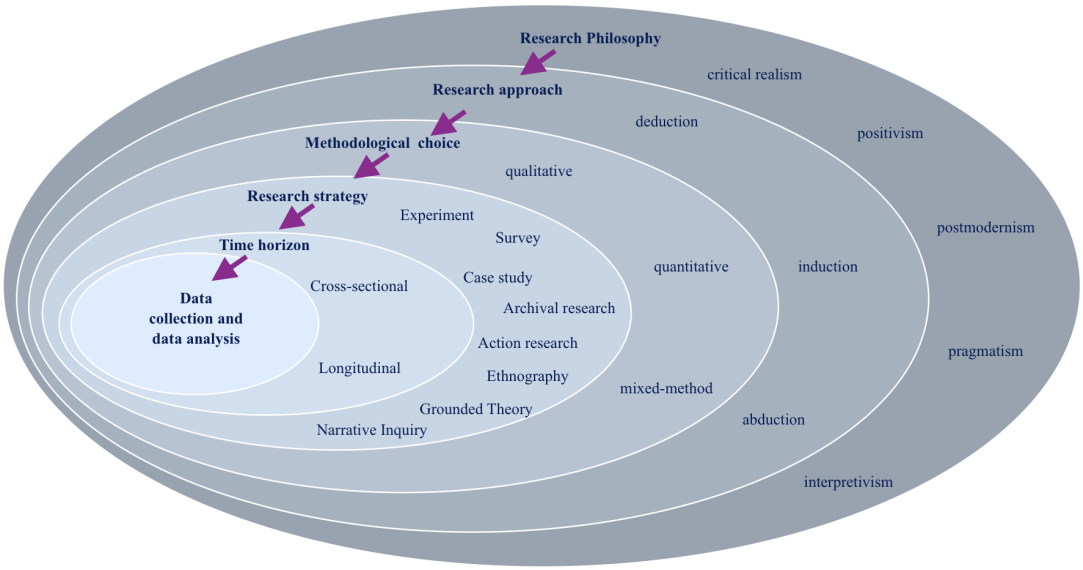

Figure 4.2: The research onion

4.2 Research Concept And Paradigms

Creswell [43] described research as a series of steps undertaken to gather and analyse information, enhancing our understanding of a specific topic or issue. Paradigms are characterised by specific assumptions about fundamental aspects such as ontology, epistemology, and methodology [69][202]. Epistemology refers to our understanding of knowledge, while ontology refers to our existence, and methodology refers to research design and methods [76].

The research paradigms represent scientific philosophies [186]. Guba and Lincoln [69] define a paradigm as a basic set of beliefs or a worldview that guide a research action or an investigation. Five categories of research paradigms exist: critical realism, positivism, postmodernism, pragmatism, and interpretivism [159].

This study employs a positivism approach which promotes the use of quantitative research methods to allow researchers to accurately describe and interpret data, thus understanding the relationships within the analysed data [99]. Positivism begins with a theory, collecting data to verify it and revising it before conducting a further assessment. A positivist approach ensures that factors such as bias do not influence the outcome during the process [43]. Figure 4.2 serves as a widely used and valuable tool for guiding decisions related to the philosophy, approach, method, strategy, time frame and techniques of research. [159].

4.3 Research Approach

Choosing the appropriate approach to answer the research questions is important to achieve a successful research objective [158]. In theory development, there are three main approaches: deduction, induction, and abduction. Deduction involves formulating a theory and hypotheses followed by designing a research strategy to test these hypotheses. In contrast, induction involves collecting data first and then deriving a theory based on the analysis of these data. Abduction, on the other hand, employs data to investigate a phenomenon, recognise patterns, and elucidate themes, aiming to generate a new theory or refine an existing one. Subsequently, this theory is subjected to testing, often involving additional data collection [159].
This study employs a deductive approach characterised by a highly structured methodology which focusses on repeated analyses to ensure reliability. Furthermore, this approach involves formulating concepts that allow quantitative data measurement. Since a deductive approach emphasises generalisation, careful sample selection and sufficient sample size are necessary preconditions to facilitate a broader application [159].

4.4 Research Methods

According to Creswell [43], research designs are structured plans and procedures that guide the research process, encompassing decisions ranging from broad assumptions to the specific methods used for data collection and analysis. Choosing a research design involves selecting a method to investigate a problem. Creswell [43] argues that the design should be chosen based on the nature of the problem, the audience for the study, and the researcher's personal experiences. The research designs are divided into qualitative, quantitative, and mixed methods [159]. An overview of the strategies, methods, and expected results for qualitative, quantitative, and mixed-method research is provided in Table 4.1 [43].

The choice of a quantitative research design for this study is grounded in several key considerations. First, using academic literature to identify key technological, organisational, and environmental factors for successful blockchain adoption, this research aims to validate a model for blockchain adoption in Saudi Arabia's manufacturing sector. The main instrument for collecting data for this study will be a structured questionnaire designed to collect statistical data from decision makers in the Saudi manufacturing sector. The data will be analysed and verified. Furthermore, a substantial body of literature

Table 4.1: Research Methods

	Quantitative
The strategies	Surveys and Experiments.
methods	Closed-ended questionnaire Numeric data collection Analysis of existing research data Use of deduction.
outcomes	Statistical hypothesis evaluation based on numerical standards.
	Qualitative
The strategies	Grounded theory, case study, focus group, narrative and phenomenology.
methods	Open-ended questionnaire, expert opinions, field observation.
outcomes	Understanding of the interrelationships and the phenomena.
	Mixed Methods
The strategies	Hybrid of quantitative and qualitative methods.
methods	Quantitative techniques combined with qualitative techniques with the purpose of improving the quality of the results.
outcomes	Integration of both qualitative and quantitative research to inform the research.

indicates that the quantitative survey method is particularly effective for assessing the adoption of new technologies like blockchain [195], [92], RFID [207], cloud computing [96], broadband mobile applications [35]. According to Creswell [43], the quantitative approach provides a comprehensive data set that facilitates the testing of theories and the exploration of relationships between various variables. Additionally, quantitative research specifically examines the influence of selected independent variables on dependent variables [176]. Moreover, Creswell and Clark [44] suggest that quantitative methods allow findings to be generalized to a larger population, provided that an appropriate response rate is achieved. The use of predefined, reliable measures and the inclusion of a large participant pool enhance the ability to generalize the results of this study.

Based on these factors and consistent with the study's objectives as well as similar research documented in the literature, a quantitative research approach has been adopted for this investigation, as illustrated in Figure 4.3.

4.5 Justification for the Selection of the Research Model

The technology-organisation-environment (TOE) framework was selected as the theoretical foundation to study the adoption of blockchain technology in this study. It was chosen specifically from numerous theoretical frameworks discussed in the literature on information systems (IS) [179]. This choice is based on its suitability for exploring how technological, organisational, and environmental factors influence blockchain adoption.

Technology adoption at the organisational level has been extensively studied using

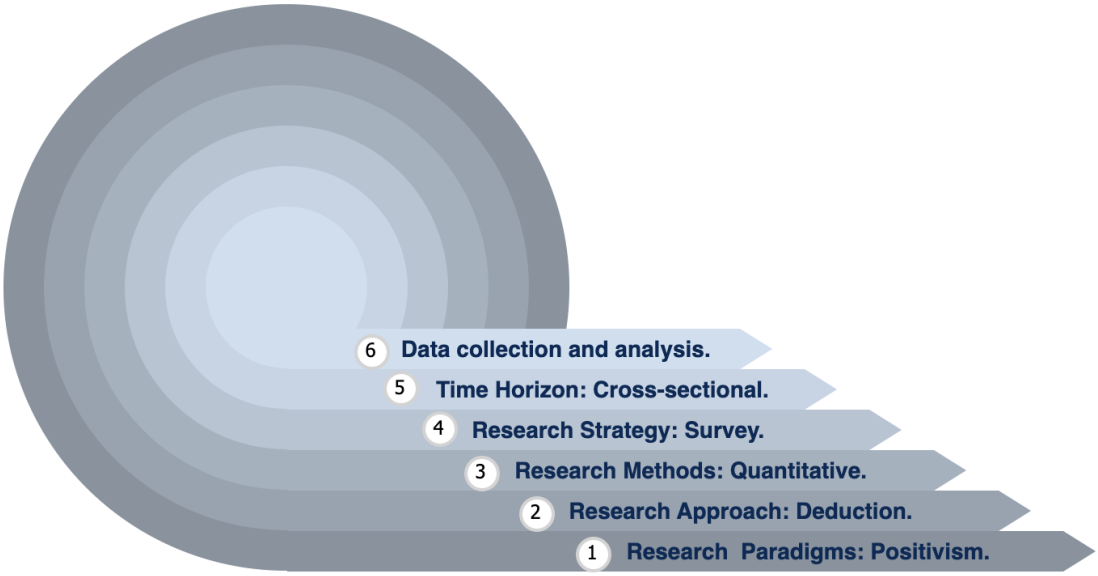

Figure 4.3: The selected research design

diffusion of innovation (DoI) and institutional theory. Environmental considerations are a major component of institutional theory, which has already been incorporated into the TOE framework [50]. The DoI theory, on the other hand, examines the role of technology characteristics and organisational readiness in the adoption process [139]. The TOE framework also discusses the characteristics of technological and organisational influences within technological and organisational contexts [188].

The TOE framework has been widely used to examine the adoption of new technologies in organisations, including AI-powered industrial robots (InRos) [149], cloud computing [140] and RFID [200]. TOE also encourages the adoption of blockchain technology in a range of industries, including operations and supply chain management (OSCM) [203], supply networks [36], supply chain management [66], Australian organisations [124], freight logistics [142] and the construction industry [112].

As a result, the TOE framework provides a more comprehensive explanation. This is due to the specific technological, organisational and environmental dimensions that have a direct impact on the decision-making and implementation capabilities of an organisation.

4.5.1 The TOE framework

The TOE framework is a theoretical model used to analyse the process of adopting and implementing technological innovations within firms [179]. It posits that the decision to adopt an innovative technology is influenced by three contexts. The technology context refers to the internal and external technologies relevant to the organisation, including existing technologies and those that can be adopted. It encompasses the technological infrastructure in place and the potential benefits and costs associated with adopting new technology. This context helps to understand how technological readiness and the perceived attributes of a new technology, such as its relative advantage, compatibility, complexity, and observability, influence the adoption decision. The organisational context includes the characteristics and resources of the organisation. These characteristics include size, degree of centralisation, formalisation, managerial structure, human resources, and the amount of slack resources. It examines how the organisational structure, resource constraints, and internal needs and processes affect its capacity and willingness to adopt new technologies. The environmental context covers the influence of the external setting in which the company operates. It includes industry characteristics, competitive pressure, trading partner pressure, and the regulatory environment. The environmental context helps to assess how external pressures, such as market demand, legislation, and competition, motivate or limit the adoption of technology, as depicted in Figure 4.4. While the TOE framework provides a robust structure for analysing technology adoption at the organisational level, it does have limitations. One key limitation is that it does not account for individual-level behavioural factors that may influence decision-making within organisations [139].

4.6 Hypotheses Development

This study proposes a conceptual model that can be applied in the Saudi Arabian context to understand the adoption of blockchain technology in the manufacturing sector. Technology, organisation, and the environment are considered. There are seven constructs to adopt blockchain serving as the dependent variable and the seven determinants acting as independent variables using the TOE framework. The proposed model is shown in Figure 4.5. Each labeled hypothesis (H1-H7) corresponds to the constructs explained in detail in Section 4.6.1 below.

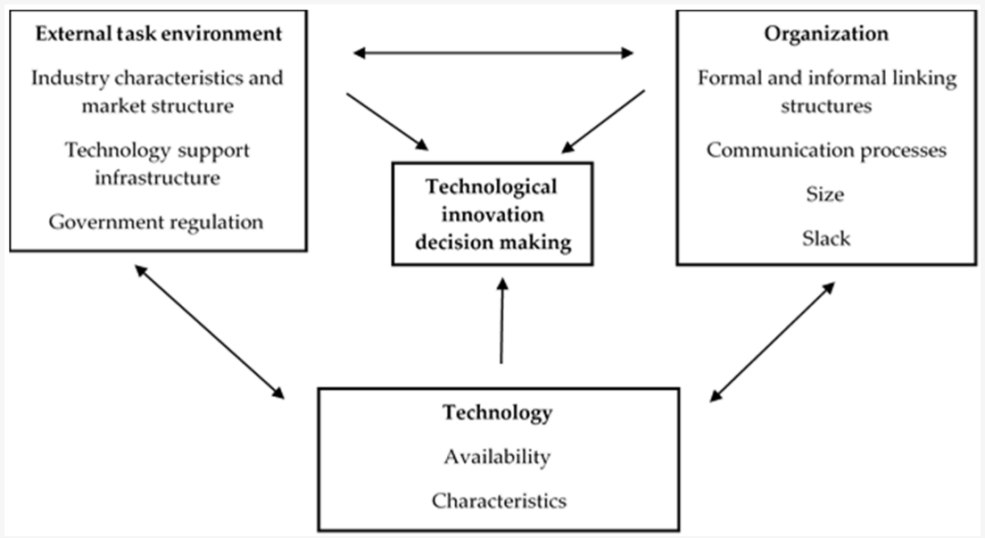

Figure 4.4: The TOE framework

4.6.1 Technology Context

4.6.1.1 Relative Advantage (RAD)

Following Rogers' theory [157], relative advantage refers to an innovation's perceived benefits or advantages over existing alternatives. Relative advantage refers to the extent to which blockchain technology is perceived as being superior to previous technologies or methods within the manufacturing sector. Manufacturing organisations consider factors such as increased efficiency, transparency, security, reduced costs, improved traceability, and other potential benefits that blockchain technology offers compared to traditional systems. Numerous studies have shown that the perceived relative advantage of a blockchain exerts a favourable influence on its adoption trajectory [66],[203], [23]. Therefore, the hypothesis is as follows: .

H1: Relative advantage positively impacts the implementation of blockchain technology in the manufacturing sector.

4.6.1.2 Complexity (CX)

Complexity refers to the level of difficulty in understanding and using innovation [157]. Manufacturing organisations might defer or slow the adoption of blockchain technology if they perceive it as complex and difficult compared to their current methods. Interestingly, there is no positive association between complexity and blockchain technology adoption; instead, there is a negative correlation. The existing literature highlights that the

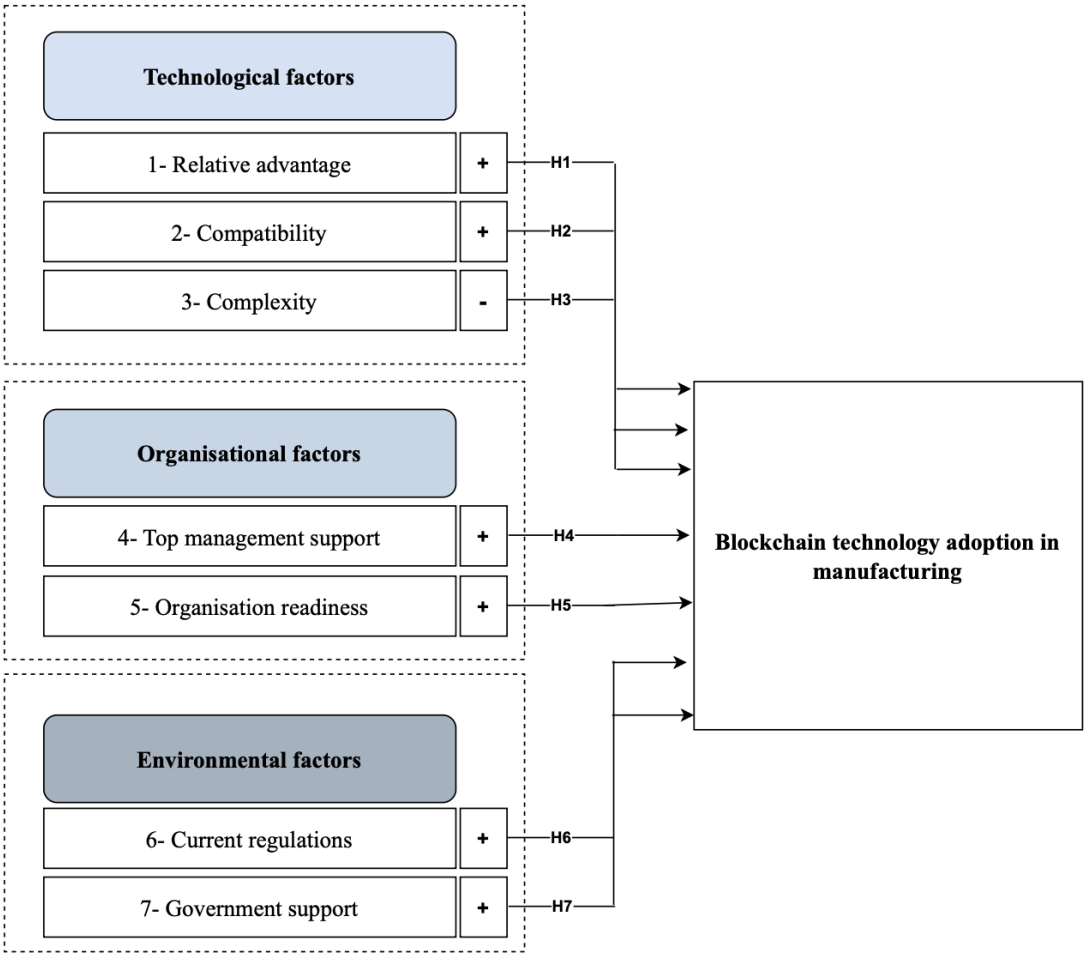

Figure 4.5: A proposed blockchain adoption model for Saudi manufacturing

complexity of blockchain is considered a critical factor influencing organisational adoption [36], [23], [124], [66], [203]. Understanding and addressing this complexity will be crucial in promoting the widespread adoption and integration of blockchain technology in manufacturing. Therefore, the second hypothesis is as follows:

H2: Complexity has a negative impact on the implementation of blockchain technology in the manufacturing sector.

4.6.1.3 Compatibility (CB)

Compatibility is another important aspect of technological adoption. It refers to how innovation fits the values, needs, practices, and infrastructure of potential adopters [157]. To successfully adopt innovations, organisations must ensure that the innovation

process, management requirements, and corporate culture are compatible [140]. The adoption of blockchain technology is strongly influenced by compatibility, as evidenced by several relevant studies [36], [23], [124], [142], [66]. For blockchain to be embraced by an organisation, it needs to seamlessly integrate with existing systems, align with organisational goals, fit within the cultural context, demonstrate interoperability with other technologies, and be assessed in terms of cost and resource considerations to enhance compatibility. These factors are pivotal in determining whether an organisation will adopt blockchain technology. Therefore, based on the insights from previous research, we propose the following hypothesis:

H3: Compatibility positively impacts the implementation of blockchain technology in the manufacturing sector.

4.6.2 Organisational Context

4.6.2.1 Top Management Support (TMS)

Top management support, as defined by Kulkarni et al. [108], encompasses managerial beliefs about technological initiatives, active participation in these initiatives, and the extent to which top man agement advocates technological advancement. This support is pivotal in the successful adoption of IT innovations, including blockchain technology. Research has shown that providing top management support for IT innovations is essential to secure the necessary resources, make informed decisions, align the organisation with innovation objectives, overcome resistance to change, establish a clear vision and strategy, mitigate potential risks, establish external relations and advocate for the benefits of innovation [200], [62]. Specifically, in the context of blockchain adoption, numerous studies have consistently identified top management support as a key factor that positively influences the decision to embrace this transformative technology [66], [124], [142], [23], [39]. Hence, the backing of top-level executives becomes a critical determinant for the successful integration and widespread adoption of blockchain technology within organisations. Based on these insights, we propose the following hypothesis:

H4: Top management support positively impacts the implementation of blockchain technology in the manufacturing sector.

4.6.2.2 Organisational Readiness (RED)

The concept of organisational readiness, as defined by Lacovou et al. [84], refers to the ability of an organisation to adapt to new IT innovations. Empirical studies in

the field have consistently shown that organisational readiness plays a significant role in influencing the adoption of blockchain technology [112], [39], [66]. Assessing an organisation's readiness involves various factors, including the presence of employees with IT skills and knowledge, the availability of financial resources dedicated to IT innovations (such as the IT budget), and the existing infrastructure capable of supporting blockchain applications [200], [201]. These indicators collectively contribute to gauging an organisation's readiness to embrace and integrate blockchain technology. Accordingly, we propose the following hypothesis:

H5: Organisational readiness has a positive impact on the implementation of blockchain technology in the manufacturing sector.

4.6.3 Environmental Context

4.6.3.1 Regulations and Laws (RL)

Government policies and regulations play a crucial role in regulating and overseeing the incorporation of new technologies in industries, making them a central factor in the diffusion of innovation [211]. Furthermore, these policies offer organisations adopting blockchain technology a sense of clarity and guidance, ensuring adherence to legal requirements and addressing concerns related to security [70]. In particular, Gokalp [66] recognised the importance of current regulations in influencing the adoption of blockchain technology. The impact of government regulations is far reaching; they can either encourage or discourage businesses from embracing new technologies [140]. Hence, regulations and laws directly affect the willingness and feasibility of technology adoption within organisations. Accordingly, we propose the following hypothesis:

H6: The current regulations and laws positively impact the implementation of blockchain technology in the manufacturing sector.

4.6.3.2 Government Support (GS)

Government support is a pivotal catalyst in expediting the adoption of blockchain technology. Beyond its influential role, the government assumes the position of a convener, displaying a strong political commitment, and adopting an overarching strategy to drive the adoption of this transformative technology [182]. This support takes on multifaceted forms, including the allocation of direct or indirect funds to research, development and the integration of emerging technologies such as blockchain [182]. In addition, government support can educate organisations, change organisational behaviour, and establish

a conscious relationship with the environment [17]. In particular, its significance spans the adoption of sustainable technology in manufacturing [17]. The government's pivotal role in advancing technological innovation and fostering an enabling atmosphere for adoption remains underlined. Multiple studies underscore the substantial impact of government involvement in shaping the adoption landscape of blockchain technology [66], [23], [124],[142]. Government support plays a crucial role in this process, as suggested by the following hypothesis:

H7: Government support positively impacts the implementation of blockchain technology in the manufacturing sector.

4.7 Chapter Summary

The chapter presents the foundational elements of the research framework adopted for the study. This framework centres on an objectivist epistemology that supports an external, realist view of knowledge. The research employs a deductive approach, starting with theoretical propositions and moving towards empirical validation. A quantitative method is selected to facilitate the statistical analysis of the relationships between variables. The justification for selecting the TOE framework as the theoretical underpinning lies in its comprehensive ability to assess technology adoption within organisations. Within this framework, hypothesis development is structured around eight constructs that represent blockchain technology adoption, serving as the dependent variable. These are influenced by seven determinants, categorised as independent variables, which comprehensively cover the technological, organisational, and environmental aspects posited by the TOE framework to affect adoption outcomes.

CHAPTER 5

DATA COLLECTION

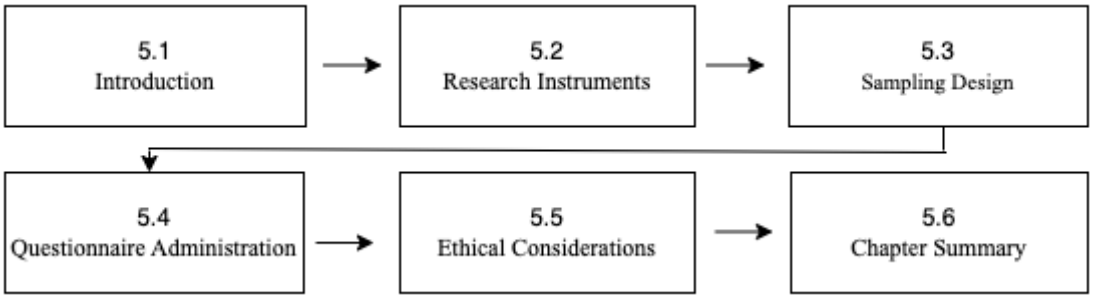

Figure 5.1: Chapter 5 outline

5.1 Introduction

An overview of the research instrument and survey strategy is provided in the following chapter. It details the development and implementation of the questionnaire, including its design, pre-testing, translation, and coding processes. Additionally, the chapter outlines the sampling design, discussing the target population, sample size, and sampling methods used. Ethical considerations are taken into account to ensure a comprehensive understanding of the research framework. Figure 5.1 shows the organisation of this chapter.

5.2 Research Instruments

In academic research, a research strategy acts as a fundamental plan, guiding how a researcher will address and answer the primary research question [159]. Of the various strategies, the survey strategy stands out, particularly in studies that adopt a deductive research approach. This method often employs tools like questionnaires, alongside structured observations and interviews, to gather data systematically [159].

Survey strategies, especially those using questionnaires, are popular due to their effectiveness in collecting large volumes of data. A questionnaire is defined as a pre-formulated written set of questions where respondents mark their answers within predefined options [161]. This instrument is particularly useful for several reasons. Firstly, it allows for the standardised collection of data across a significant portion of the population, which is both cost-effective and efficient. In addition, questionnaires are generally well-regarded and accepted by the public, making them a reliable tool that respondents can easily understand and researchers can easily explain [159].

Furthermore, the use of questionnaires facilitates the analysis of relationships between variables by providing a solid data set that can support the development of models to explain these relationships. This can suggest potential reasons for specific patterns observed in the data [159]. This capacity to standardise and scale makes questionnaires a powerful tool for survey-based research.

5.2.1 Questionnaire Development

The questionnaire items outlined in this section are derived from the factors identified in the proposed TOE-based model. These factors include relative advantage (RAD), with five items focused on the adoption of blockchain; compatibility (CB), comprising three items; complexity (CX), with four items; top management support (TMS), with four items; organizational readiness (RED), with four items; regulations and laws (RL), with three items; government support (GS), with three items; and behavioural intention (BI), with three items, reflecting the intent to adopt blockchain. All these factors and their respective items are detailed as follows:

Relative Advantage (RAD)

- **RAD 1:** Blockchain technology speeds up the process of managing the inventory of raw materials [130].

- **RAD 2:** Blockchain technology will make the process of managing the inventory of raw materials easier [130].
- **RAD 3:** Blockchain will increase the productivity of managing the inventory of raw materials [140].
- **RAD 4:** Blockchain will increase control of managing the inventory of raw materials. [130]
- **RAD 5:** Blockchain technology effectively checks the inventory of raw materials [130].

Compatibility (CB)

- **CB 1:** Blockchain technology is compatible with managing the inventory of raw materials [130].
- **CB 2:** Blockchain technology fits with checking the stock of raw materials [130].
- **CB 3:** Blockchain technology is compatible with the goals and values of the factory related to managing the inventory of raw materials [210].

Complexity (CX)

- **CX 1:** Blockchain technology is hard to understand [36].
- **CX 2:** The skills necessary for using blockchain technology are too complicated for our staff [23].
- **CX 3:** Blockchain technology is difficult to use in raw material inventory management [36].
- **CX 4:** The tools of blockchain technology are not easy to use [23].

Top Management Support (TMS)

- **TMS 1:** Our top management provides sufficient information and courses when applying new technology such as blockchain [23].
- **TMS 2:** Our top management provides strong leadership when it comes to technology adoption, such as blockchain [140].
- **TMS 3:** Our top management considers the adoption of blockchain technology in raw material inventory management as strategically important [200].
- **TMS 4:** Top management supports the implementation of new technologies in the factory [23].

Organisational Readiness (RED)

- **RED 1:** Our factory is flexible in allocating adequate IT infrastructure resources necessary to adopt blockchain technology in raw material inventory management [119].
- **RED 2:** Our factory is flexible in allocating adequate financial resources necessary to adopt blockchain technology in raw material inventory management [119].
- **RED 3:** Our factory understands how blockchain technology can support raw material inventory management [23].
- **RED 4:** Our factory is flexible in allocating adequate human resources necessary to adopt blockchain technology in raw material inventory management [119].

Regulations and Laws (RL)

- **RL 1:** The regulations and laws in Saudi Arabia protect the use of blockchain [140].
- **RL 2:** The regulations and laws in Saudi Arabia are sufficient to protect the use of blockchain [140].
- **RL 3:** The regulations and laws in Saudi Arabia support blockchain issues [211].

Government Support (GS)

- **GS 1:** The Saudi Ministry of Industry offers the facilities to promote blockchain adoption [124].

- **GS 2:** The Saudi Ministry of Industry is willing to adopt blockchain [124].

- **GS 3:** The Saudi Ministry of Industry provides economic incentives to encourage blockchain adoption [124].

Behavioral Intention (BI)

- **BI 1:** Our factory intends to adopt blockchain technology to actively manage the inventory in the future [45].

- **BI 2:** Our factory expects to use blockchain technology to manage the inventory of raw materials in the near future [45].

- **B1 3:** Our factory is likely to use blockchain technology to manage the inventory of raw materials on a regular basis in the near future [23].

The question structures within each factor follow previous research methodologies, where similar items are grouped together to improve the reliability and validity of the model. This approach is supported by Davis and Venkatesh [187], who advocated grouping similar items to achieve more reliable model validation. Table 5.1 lists the questionnaire items and key literature sources used for each factor.

Table 5.1: Measurement Items

Construct	ID	Items
Relative Advantage (RAD)	RAD 1	Blockchain technology speeds up the process of managing the inventory of raw materials.[130]
	RAD 2	Blockchain technology will make the process of managing the inventory of raw materials easier.[130]
	RAD 3	Blockchain will increase the productivity of managing the inventory of raw materials. [140]
	RAD 4	Blockchain will increase control of managing the inventory of raw materials. [130]
	RAD 5	Blockchain technology effectively checks the inventory of raw materials.[130]
Compatibility (CB)	CB 1	Blockchain technology is compatible with managing the inventory of raw materials [130].
	CB 2	Blockchain technology fits with checking the stock of raw materials [130].
	CB 3	Blockchain technology is compatible with the goals and values of the factory related to managing the inventory of raw materials [210].
Complexity (CX)	CX 1	Blockchain technology is hard to understand [36].
	CX 2	The skills necessary for using blockchain technology are too complicated for our staff [23].
	CX 3	Blockchain technology is difficult to use in raw material inventory management [36].
	CX 4	The tools of blockchain technology are not easy to use [23].
Top Management Support (TMS)	TMS 1	Our top management provides sufficient information and courses when applying new technology such as blockchain [23].
	TMS 2	Our top management provides strong leadership when it comes to technology adoption, such as blockchain.[140]
	TMS 3	Our top management considers the adoption of blockchain technology in raw material inventory management as strategically important. [200]
	TMS 4	Top management supports the implementation of new technologies in the factory. [23]
Organisation Readiness (RED)	RED 1	Our factory is flexible in allocating adequate IT infrastructure resources necessary to adopt blockchain technology in raw material inventory management [119].
	RED 2	Our factory is flexible in allocating adequate financial resources necessary to adopt blockchain technology in raw material inventory management [119].
	RED 3	Our factory understands how blockchain technology can support raw material inventory management [23].
	RED 4	Our factory is flexible in allocating adequate human resources necessary to adopt blockchain technology in raw material inventory management [119].
Regulation and Laws (RL)	RL 1	he regulations and laws in Saudi Arabia protect the use of blockchain [140].
	RL 2	The regulations and laws in Saudi Arabia are sufficient to protect the use of the Blockchain [140].
	RL 3	The regulations and laws in Saudi Arabia support blockchain issues [211].
Government Support (GS)	GS 1	The Saudi Ministry of Industry offers the facilities to promote blockchain adoption [124].
	GS 2	The Saudi Ministry of Industry is Willing to adopt blockchain [124].
	GS 3	The Saudi Ministry of Industry provides economic incentives to encourage blockchain adoption [124].
Behavioral Intention (BI)	BI 1	Our factory intends to adopt blockchain technology for managing the inventory actively in the future [45]
	BI 2	Our factory expects to use Blockchain technology for managing the inventory of raw materials in the near future. [45]
	BI 3	Our factory is likely to use blockchain technology in managing the inventory of raw materials on a regular basis in the near future [23].

5.2.2 Pre-Testing and Pilot Study

This section describes the pre-testing and pilot study phases of the research, which are crucial for ensuring the validity and effectiveness of the survey instruments.

5.2.2.1 Pre-test

Pre-testing involves the use of a small number of respondents to test the appropriateness of the questions and their comprehension [161]. During the pre-testing stage of the questionnaire development, the on-line questionnaire link was emailed to nine selected PhD students and individuals with expertise in the manufacturing sector, blockchain technology, and information systems to validate its content and format. Based on their feedback, several key recommendations were made to enhance the questionnaire's effectiveness and reliability. The changes implemented included eliminating confusing terminology, rephrasing complex questions to make them clearer, and simplifying the language. Based on this feedback, the researcher adjusted the questionnaire.

5.2.2.2 Pilot study

After pre-testing and redeveloping the questionnaire, a pilot study was conducted with 26 participants from two groups. Hertzog (2008) states that a pilot study should have a sample size of at least 25 participants [75]. The first group comprised Ph.D. students who were asked about any difficulties they experienced and their suggestions. They provided specific feedback on the length of time needed to complete the given tasks, the time needed to complete the questionnaire, the clarity of the statements and the instructions, and the layout of the questionnaire. The second group comprised IT employees working in manufacturing. These participants assessed the validity and clarity of the questions. A pilot test was conducted to refine the questionnaire so that respondents would have no difficulty answering the questions and that data would be easily recorded [159].

5.2.3 Questionnaire Translation

Translating a questionnaire requires careful attention to ensure that the original and translated versions remain consistent, allowing respondents to interpret and answer as intended [159], [161]. The questionnaire was initially formulated in English, as detailed in Appendix A. Since Arabic is the official language in Saudi Arabia, it was essential that the questionnaire be translated into Arabic. The researcher employed a parallel

translation method to ensure the clarity and accuracy of the questionnaire's wording in the target language[159]. This approach involved two independent translators, both English teachers in the Saudi Ministry of Education, who separately translated the source questionnaire into the target language. After completing their translations, the translators compared the two versions of the target questionnaire. Through this comparison, they collaborated to resolve any discrepancies and consolidate their translations into a final version. Carefully modifying the respondents' primary language was crucial to ensure that all participants could understand and respond accurately to the survey.

5.2.4 Questionnaire Design

Data was collected using a questionnaire which was divided into six sections:

- Section 1: The questionnaire cover letter: As part of the questionnaire cover letter, comprehensive information was provided to ensure participants were fully informed about the study. The purpose of the study was explained, highlighting its aim to identify the factors motivating the adoption of blockchain technology in managing raw material inventory in Saudi Arabia's manufacturing sector in line with the country's 2030 vision and the National Industry Development Program. Information about the researcher and supervisor was provided for any questions or concerns, along with the Research Ethics Officer's email address. The UTS Research Ethics and Integrity Policy is also provided as part of the cover letter, including an ethics approval number (ETH22-7537) to ensure ethical standards are followed See Appendix A.

- Section 2: Consent form: Participants were informed on the consent form that participation in the study was completely voluntary and that they could choose not to participate. Participants who chose to take part were invited to complete an online survey, designed to be completed in approximately 15 minutes. Participants were assured that they could withdraw at any time without consequences. Also, the participants were told that their identities would remain anonymous during data collection.

- Section 3: A brief explanation of blockchain technology: Given the newness of this technology, a brief explanation of blockchain technology was provided to ensure that all participants have a basic understanding of the key concepts. This section includes a simple and concise overview of blockchain technology. This foundational

knowledge is crucial for participants to accurately respond to subsequent questions related to blockchain technology adoption.

- Section 4: Demographic information: This section gathers demographic information from the participants, such as their age, education level, city in which their industry is located, current job title, years of work experience, and the number of employees in their factory. It also includes questions to assess their knowledge of blockchain technology.

- Section 5: The questionnaire body: This section contains questions exploring the factors affecting blockchain adoption. These questions are based on the TOE model, which covers three contexts:technological, organisational, and environmental. The concepts are relative advantage (RAD), compatibility (CB), complexity (CX), top management support (TMS), organisational readiness (RED), regulations and laws (RL), government support (GS), and behavioral intention (BI). Each concept includes several scale items grouped together based on existing research. There were 29 items addressing the following groups:

  1. RAD regarding the adoption of blockchain (5 items);
  2. CB regarding the adoption of blockchain (3 items);
  3. CX regarding the adoption of blockchain (4 items);
  4. TMS regarding the adoption of blockchain (4 items);
  5. RED regarding the adoption of blockchain (4 items);
  6. RL regarding the adoption of blockchain (3 items)
  7. GS regarding the adoption of blockchain (3 items); and
  8. BI regarding the intention to adopt blockchain (3 items).

  The researcher asked a question about the potential applications of blockchain-based manufacturing in the future and provided a list of responses from which the participants could choose.

- Section 6: Closing the questionnaire: The participants were thanked for their time and effort in the closing section.

5.2.5 Questionnaire Coding

The study used a seven-point Likert scale as an ordinal scale, in which respondents were asked to express their level of agreement or disagreement with specific statements. The scale ranged from "strongly disagree" to "strongly agree" as follows:

- Option 1: Strongly disagree.
- Option 2: Disagree.
- Option 3: Somewhat disagree.
- Option 4: Neutral.
- Option 5: Somewhat agree.
- Option 6: Agree.
- Option 7: Strongly agree.

Using a seven-point format improves the sensitivity of the measurement, allowing for a more nuanced capture of attitudes and opinions compared to scales with fewer response options [120].

5.3 Sampling Design

This section describes the population and sampling methodology employed in the study, including details on the target population and the rationale behind the chosen sampling technique. It also explains how the sample was identified and selected.

5.3.1 Target Population

According to the Ministry of Saudi Industry, in 2023, Saudi Arabia had 11,110 factories. The population, as defined by Saunders (2016) [159], is the complete set of cases or elements from which a sample is drawn. The Communications and Information Technology Commission (2015) estimates that there are between 20,000 and 50,000 IT professionals in the manufacturing sector. Therefore, the target population for this study comprises IT professionals within the Saudi manufacturing sector. Given the size and scope of this population, conducting a survey of the entire group is not feasible due to budget and time constraints [159]. Consequently, it is necessary to sample a subset of the population to carry out research effectively within the available resources.

5.3.2 Sample Size

Sample size refers to the number of subjects selected to serve as a representative sample, reflecting the characteristics of the population.[161]. In this study, the sample size calculation was based on the data analysis method used, which is the structural equation model (SEM). SEM is a statistical technique for extracting information from observed and latent variables by examining their complex relationships. The determination of the minimum sample size for SEM in this study was guided by Nunnally (1967) [136], who recommended maintaining at least ten cases per variable to ensure sufficient statistical power for accurate parameter estimation. Following this rule requires at least 290 participants (10 cases x 29 indicators) since our model includes 29 indicators.

5.3.3 Sampling Method

Sampling techniques provide a range of methods that enable the researcher to reduce the amount of data which needs to be collected by considering only data from a subset rather than all possible cases or elements [158]. Probability or representative sampling and non-probability sampling are two approaches used to select samples from a population [159]. In probability sampling, every member of the target population has a known and usually equal chance of being selected [159]. On the other hand, non-probability sampling involves selecting cases without knowing the chance or probability of choosing them [158]. Probability sampling requires a sampling frame, which can significantly extend the duration and complexity of the research process. Furthermore, in scenarios where it is not feasible to construct a sampling frame, non-probability sampling becomes the necessary choice [159].

For this study, the snowball sampling approach was selected. This is a non-probability method that effectively uses initial respondents' social networks to identify and recruit additional participants. This method operates on the principle of referrals, where participants suggest other potential respondents within their circle of contacts. This facilitates access to a larger number of suitable participants [13]. To minimise potential biases associated with snowball sampling such as the overrepresentation of specific networks or perspectives efforts were made to initiate the process with a diverse group of initial participants from various regions. This approach was particularly effective for this study, which targeted IT employees within the Saudi manufacturing sector a population that is often difficult to access through conventional sampling methods. By beginning

with a varied group of IT professionals, the method helped ensure that subsequent referrals remained within the same professional context, thereby preserving both the relevance and focus of the target population. The choice of snowball sampling was also driven by practical challenges encountered during the study. The ongoing COVID-19 pandemic posed significant obstacles in reaching and engaging participants through more conventional sampling methods.

5.4 Questionnaire Administration

A comprehensive approach was adopted to ensure a representative sample of IT professionals and decision makers for the study. For the data collection process, the target population is IT professionals working in Saudi manufacturers. Data were collected using online questionnaires. We sent the questionnaire to IT workers from the managerial level to the technician level, such as the Chief Information Officer (CIO), IT manager, IT administrators, computer engineers, IT consultants, IT technicians, etc. We selected IT professionals because they play an essential role in determining how the organisation operates and making strategic decisions. The IT staff of these manufacturers have a solid understanding of technology and are crucial in introducing new technologies to their firms. The survey was distributed by email and through social media platforms such as WhatsApp, Twitter, and LinkedIn, which helped to increase visibility and participation. In addition, a snowball sampling technique was used, in which initial respondents were encouraged to refer other qualified individuals. This method expanded our reach and facilitated the identification of additional participants. Data collection spanned 10 months, from July 1, 2022, to April 30, 2023. In addition, Qualtrics software was used to design and develop the online survey, improving the efficiency and accessibility of the data collection process.

5.5 Ethical Considerations

Gaining the approval of the Ethics Committee was essential to ensure that the research method adhered to ethical standards, particularly regarding the protection of the study participants. The researcher implemented several measures to uphold these standards. First, participation was voluntary, allowing individuals to freely decide whether to participate without pressure. Participants were also able to withdraw at any time, with no consequences. Confidentiality was strictly maintained; participants' identities were

kept anonymous. The researcher communicated that the collected data would only be used for research purposes and that any findings would be published solely in academic publications. As well, the research purpose was clearly communicated, emphasising the importance of blockchain in inventory management in manufacturing. This clarification helped the participants understand the scope and aim of the survey. Furthermore, providing contact details for both the researcher and the supervisor offered participants direct lines of communication to express any concerns or request further clarification about the research. The researcher also explicitly asked individuals whether they would like to participate, providing a clear and respectful invitation that respected participants' autonomy. Ethics approval was obtained from the University of Technology Sydney on 05/09/2022 under reference number ETH22-7537 to ensure ethical data collection.

5.6 Chapter Summary

This chapter summarises the research strategy, focusing on the development and administration of the questionnaire. It reviews the processes of designing the questionnaire, pre-testing, translation, and coding, as well as detailing the sampling strategies. Ethical considerations are addressed to ensure research integrity. The comprehensive approach facilitates a robust analysis of the data collected.

CHAPTER 6

DATA ANALYSIS AND RESULTS

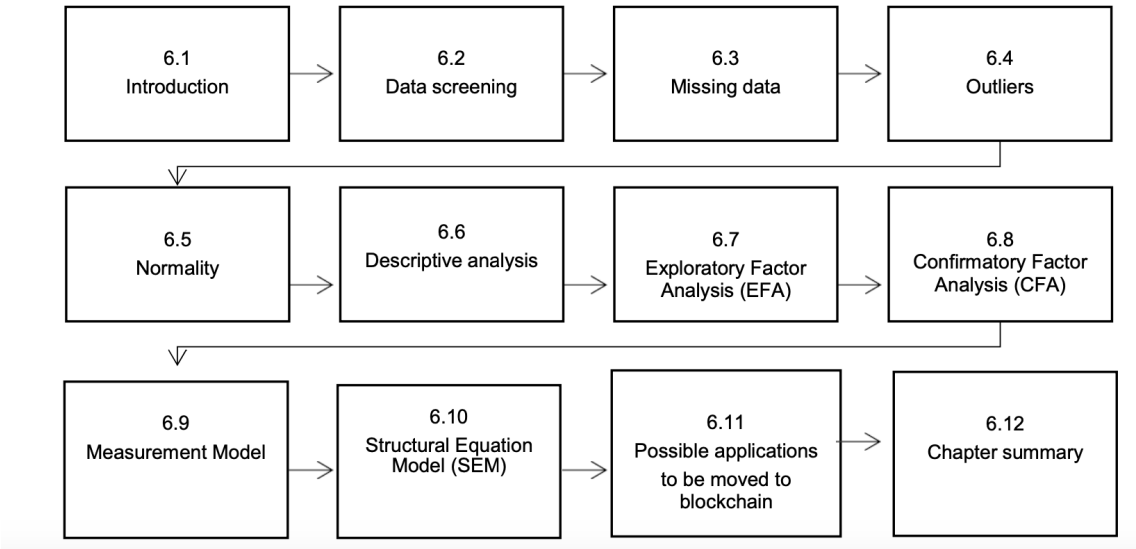

Figure 6.1: Chapter 6 outline

6.1 Introduction

This chapter presents the quantitative findings obtained from the questionnaire survey. It also highlights the challenges faced during data collection, including missing responses, lack of participant motivation, and outlier data points. In addition, it paints a picture of

the participants' profiles and backgrounds. The chapter details the measurement scales used and provides justifications for their reliability and validity. It explains the selected SEM multivariate analysis method which allows for a comprehensive evaluation of the research model by ensuring that the measurements are reliable and valid. Lastly, it thoroughly dissects the findings, uncovering respondents' perspectives on which applications or services they recommend migrating to blockchain technology. Figure 6.1 illustrates the chapter's organisational structure.

6.2 Data screening

Data screening plays a crucial role in preparing the data for analysis. It involves a series of checks to ensure the data is accurate, complete, and ready for meaningful interpretation. This includes verifying correct data entry, identifying and handling missing values, detecting outliers, and examining the distribution of variables. Data cleaning significantly impacts the final statistical results. Inconsistent data or missing values can lead to skewed findings and flawed conclusions. Therefore, careful consistency checks and treatment of missing data are essential, as the goal of data screening is to prevent model estimation failures and software crashes. The initial size of the sample of participants who attempted the survey questions was N = 379 participants which changed after removing incomplete responses from the collected data. By taking the time to thoroughly clean the data, we can pave the way for reliable and insightful analysis. This section details the data screening process.

6.3 Missing data

Our research faced the challenge of missing data for some variables. This missing information could have biased the results [10]. While missing demographic details were deemed unlikely to significantly impact the analysis, we needed a strategy to handle missing data in our core research constructs. To address this, we followed the cautious and reliable approach of listwise deletion used in a study by Musil et al.[132]. Listwise deletion removes entire responses with missing data, ensuring only complete records remain [132]. This approach, while conservative, ensures consistency across variables and avoids the complications that can arise from imputation or pairwise deletion, particularly in multivariate statistical techniques like SEM. While this eliminated 37 responses

from our initial set of 379, it resulted in a final dataset of 342 valid responses for further analysis.

6.4 Outliers

Despite safeguards such as multiple choice questions and Likert scales, outliers, defined as data points that deviate sharply from the norm [65], can still emerge. Although its likelihood is minimised, vigilance is crucial. There are two types: univariate, isolated anomalies within a single variable, and multivariate, those deviating across multiple variables simultaneously. A careful examination of these potential outliers is essential for accurate data analysis.

6.4.1 Univariate outliers

Data can be deceptive, masking outliers - unusual data points that deviate significantly from the norm. These outliers can wreak havoc on statistical analyses, distorting results, and leading to misleading conclusions. Researchers have tools such as boxplots at their disposal that visually depict the distribution of data and identify potential outliers. In this instance, 10 such outliers were identified. These univariate outliers were identified using boxplot analysis, where values falling outside 1.5 times the interquartile range (IQR) above the third quartile or below the first quartile were classified as outliers. To neutralise these potential threats, they were replaced with their closest neighbours, effectively transforming the boxplot into a haven free of outlier disruptions, resulting in a final dataset of 332 valid responses for further analysis.

6.4.2 Multivariate outliers

Data points can sometimes exhibit unusual combinations of values in multiple variables, known as multivariate outliers. These outliers can significantly impact statistical analyses, so identifying them is crucial.The Mahalanobis distance helps us quantify this unusualness and measures the distance of each data point from the average, considering all variables simultaneously. Large distances suggest potential outliers. Similarly, Cook's distance assesses how much each data point influences the regression model's predictions. High values indicate points with a potentially substantial impact. However, in our case,

Table 6.1 does not reveal evidence of multivariate outliers. The Mahalanobis distances range from 0.437 to 49.741, well within the expected range. Similarly, Cook's distances fall between 0.000 and 0.145, with an average below the typical threshold of 1. This suggests that the data are free of concerning outliers, as defined by these metrics.

Table 6.1: Mahalanobis and Cook's distance measures for multivariate outliers.

Variable	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**N**
Predicted Value	4.4271	5.9277	5.1637	.19966	332
Std. Predicted Value	-3.689	3.827	.000	1.000	332
Standard Error of Predicted Value	.075	.446	.168	.057	332
Adjusted Predicted Value	4.5716	5.9840	5.1658	.20122	332
Residual	-3.42712	2.22244	.00000	1.12737	332
Std. Residual	-3.008	1.950	.000	.989	332
Stud. Residual	-3.176	1.974	-.001	1.002	332
Deleted Residual	-3.82091	2.27753	-.00218	1.15574	332
Stud. Deleted Residual	-3.221	1.983	-.002	1.005	332
Mahal. Distance	.437	49.741	6.979	6.129	332
Cook's Distance	.000	.145	.003	.010	332
Centered Leverage Value	.001	.150	.021	.019	332

a. Dependent Variable: Behavioral Intention (BI)

6.5 Normality

Checking normality is an important early step in almost every multivariate analysis. Normality can be examined at both the univariate and multivariate level. As discussed by Hair et al. [65], normality measures the data that is normally distributed across the population sample to detect if there are any excessively high or low scores from a few respondents which can then skew the overall result. A lack of normality will adversely affect the suitability indices and standard errors [21]. Two component values used to assess data normality are skewness and kurtosis. Skewness judges the symmetry of the distribution, whereas kurtosis assesses the peakedness of a distribution. A positive skew represents a distribution that is shifted or skewed to the left and a negative skew reflects a distribution skewed to the right. A negative kurtosis value denotes a flatter distribution, whereas a positive kurtosis value reveals a peaked or taller distribution [172]. Data distribution with either a highly skewed nature or with high kurtosis indicates non-normality, which has random effects on specification or estimation [59]. Hair et al. [54] suggested that all skewness values should fall within an acceptable range of -1 to +1.

Although an absolute value of skewness 1.0 or lower indicates that the data is normally distributed, if the sample size is greater than 200, the absolute skewness could increase to 1.5 [4]. On the other hand, the value of the standardised kurtosis index should be within the range of -3 to +3 [100]. The absolute values of the kurtosis index from about 8.0 to over 20.0 have been described as indicating extreme kurtosis or may suggest a problem [48]. For this study, the normality test result is presented in Table 6.2. The results demonstrate that all values for the items fall within the acceptable range of skewness +1 to -1 and meet a lenient +3 to -3 range of kurtosis. Therefore, the empirical measures of skewness and kurtosis for all constructs from the questionnaires confirm no issues of multivariate non- normality in the data set.

Table 6.2: Normal distribution detection for the research model construct (N=332)

Variable	**N**	**Min**	**Max**	**Mean**	**Std.**	**Skew**	**Kurt.**
Relative Advantage (RAD)	332	1.00	7.00	5.5120	1.04195	-1.713	2.284
Compatibility (CB)	332	1.00	7.00	3.5080	1.64577	0.276	-1.038
Complexity (CX)	332	1.00	7.00	3.2154	1.53715	0.546	-0.756
Top Management Support (TMS)	332	1.00	7.00	5.1777	1.24161	-1.078	1.020
Organisational Readiness (RED)	332	1.00	7.00	5.4910	1.10714	-1.362	2.091
Regulation and Laws (RL)	332	1.00	7.00	5.2189	1.14402	-1.138	1.915
Government Support (GS)	332	2.00	7.00	5.1878	1.13442	-0.694	0.597
Behavioral Intention (BI)	332	1.00	7.00	5.1637	1.14492	-0.772	0.393

6.6 Descriptive Analysis

The demographic characteristics of the samples are presented in Table 6.3, showcasing a diverse, yet focused group with varying levels of blockchain awareness. An understanding of their profiles provides a valuable context for interpreting the study's findings and assessing the potential impact of blockchain in Saudi Arabia's industrial sector.

Table 6.3: Demographic summary of respondents (332)

Characteristic	**n**	*%*
Age		
18 to 24	42	12.7
25 to 34	95	28.6

Table 6.3: Demographic summary of respondents (332)

Characteristic	**n**	**%**
35 to 45	145	43.7
46 to 60	44	13.3
60+	6	1.8
Education level		
High school or lower	66	19.9
Diploma	65	19.6
Bachelor	159	47.9
Post-graduate degree	42	12.7
In which industrial city do you work?		
A central industrial city	98	29.5
A western industrial city	150	45.2
An eastern industrial city	28	8.4
A southern industrial city	39	11.7
A northern industrial city	17	5.1
What is your current job?		
Chief Information Officer	16	4.8
IT Manager	58	17.5
IT Administrator	12	3.6
Computer Engineer	16	4.8
IT Consultant	7	2.1
IT Technician	36	10.8
Other IT Staff	187	56.3
Years of work experience		
<5 years	91	27.4
5–9 years	51	15.4
10–15 years	87	26.2
>15 years	103	31.0
How many employees work in the factory?		
Less than 100	99	29.8
100–200	54	16.3
More than 200	179	53.9

Table 6.3: Demographic summary of respondents (332)

Characteristic	**n**	*%*
What is your level of knowledge about blockchain?		
Advanced knowledge	22	6.6
Intermediate knowledge	192	57.8
Beginner knowledge	118	35.5

6.6.1 Age

The age breakdown offers a glimpse into the study's participants, with the largest number of participants (43.7%) falling between 35 and 45 years old, followed by 28.6% in the 25-34 age group. The study leans toward a mid-career demographic. A total of 12 participants are younger adults aged 18-24 (12.7%), suggesting some new perspectives, while individuals over 60 represent a smaller group at 1.8%. This distribution potentially indicates a workforce with experience and potential interest in exploring how blockchain could impact their established workflows.

6.6.2 Educational level

The data reveal a varied landscape in terms of the educational level of the 332 participants. The majority (47.9%) have a Bachelor's degree, indicating that they are well educated and knowledgeable. However, a significant portion (19.9% + 19.6% = 39.5%) possess a high school diploma or lower, suggesting a diverse range of educational backgrounds. Interestingly, 12.7% hold a post-graduate degree, indicating some of the participants are highly specialised.

6.6.3 Geographic Distribution

Saudi Arabia's industrial landscape is represented in Table 6.3 by a wide range of participants. Nearly half (45.2%) come from western industrial cities such as Jeddah and Makkah, highlighting the prominence of the region in the industrial sector. The next most prominent group are those from the Central Industrial Cities (29.5%), which encompass Riyadh and other central hubs. This balanced distribution suggests that the study captured perspectives from various industrial centres throughout the country. Interestingly, Eastern Industrial Cities (Dammam, Al-Ahsa) have low representation (8.4%), despite housing major industrial players. This could indicate lower participation

from these areas or potential differences in their knowledge of blockchain compared to other regions. Almost (11.7%) of participants come from Southern Industrial Cities. And smaller number of participants come from Northern Industrial Cities (5.1%), reflecting their potentially smaller industrial footprint or unique industry compositions.

6.6.4 Job role

Table 6.3 reveals a workforce heavily concentrated in the IT realm, with most of the participants employed as IT staff (56.3%). This suggests a solid technical foundation within the study group, indicating a high potential for understanding and adopting blockchain technology. The second highest percentage of participants are IT managers at (17. 5%), further solidifying the tech focus. Other roles include Computer Engineer (4.8%) and IT Technician (10.8%), suggesting that there is diverse technical expertise within the group. Chief Information Officers (CIOs) (4.8%) represent a smaller, yet strategic segment, potentially offering valuable insights from leadership positions. While IT Administrator (3.6%) and IT Consultant (2.1%) make up smaller groups, their perspectives could shed light on the broader organisational implications of blockchain adoption.

6.6.5 Experience

Table 6.3 reveals an experienced workforce, with over half (57.2%) having at least 10 years of work experience. The largest segment falls within the over 15 years range (31.0%), followed closely by those with within the 10-15 year range (26.2%). Interestingly, over a quarter (27.4%) of the participants have less than 5 years of experience, suggesting a mix of experienced and younger professionals. This diverse pool of experience could offer valuable insight into both established practices and evolving needs within the industrial sector.

6.6.6 Company size

Over half (53.9%) work in companies with more than 200 employees, suggesting a predominance of larger players within the industrial sector. This aligns with the established industrial landscape of Saudi Arabia, where larger companies often hold significant influence. Participants from smaller companies with 100-200 employees make up a notable portion (16.3%), highlighting a diverse industrial ecosystem. Interestingly, nearly a third (29.8%) work in companies with less than 100 employees, indicating the presence of

smaller players contributing to the industrial landscape. This diverse size distribution provides a valuable snapshot of the industrial sector and could potentially influence the adoption and impact of blockchain technology within different company scales.

6.6.7 Blockchain knowledge

The level of awareness of blockchain among the respondents is varied, suggesting that both opportunities and challenges exist in relation to its industrial adoption in Saudi Arabia. Although only 6.6% possessed advanced knowledge, a sizeable 57.8% reported having intermediate knowledge. This suggests that there is a baseline understanding, paving the way for further education and targeted solutions. However, 35.5% reported they had beginner knowledge which highlights a knowledge gap that needs to be addressed for broader acceptance and effective implementation. This diverse pool of the levels of awareness underscores the importance of tailoring blockchain applications and communication strategies to cater to varying degrees of understanding within the industrial sector.

6.7 Exploratory Factor Analysis (EFA)

To explore the underlying structure of the factors through the item reduction process of 29 indicators, a sequence of EFAs were executed using IBM SPSS with principal axis factoring (PAF) as an extraction method and oblique rotation with the Promax method. PAF is one of common factor extraction methods to explore interrelationships between a large number of variables and to clarify these variables in terms of their underlying pattern constructs (factors) [57]. The cutoff point used to investigate the factor structure solution was determined as recommended by Hair et al. [54] by specifying that the factor loadings should be at or above.30 which is considered the minimal level for explaining factorial structure. Also, this criterion for factor loadings was chosen to ensure that enough items are retained during this exploration of the underlying factor structure. The recommended number of identified measured items (i.e. three or more) was used as a guideline. This recommendation was explained by Hair et al. [54] as an identification process of the measured items to be either just-identified (i.e. three items) or overidentified (i.e. more than three items) for identifying a factor solution with enough information to be examined for the SEM method. Therefore, the identified limit of the factor loadings for each variable is specified to be poor when the factor loading is close to

.30, and good when above .35. Furthermore, the items with cross-loadings are treated using the guidelines suggested by Hair et al. [54], namely principal component analysis and a rotation method called Promax with Kaiser normalization. This rotation method aids in better separating the factors and improving interpretability. Eight factors were extracted that cover the 29 items with loadings greater than 0.30. RAD: All five variables related to RAD have strong loadings on component 1, CB: Similar to RAD, the three CB variables have strong loadings on component 2, CX: The four CX variables have strong loadings on component 3, TMS, RED, RL, GS: These constructs each have their own dedicated component . BI: The three BI variables have strong loadings on component 8, forming their own factor as shown in Table 6.4. Overall, this EFA suggests that the data can be understood through eight distinct factors. Each factor groups together variables that share a common underlying theme.

6.8 Confirmatory Factor Analysis (CFA)

Using the SEM approach through a two-stage method, the first stage is to examine a measurement model (CFA) to test the overall measured model fit and establish data reliability and convergent and discriminant validity to ensure that the measurement model accurately confirms the EFA findings. The second stage is to examine a structural model which specifies the relationships among the latent constructs to estimate path coefficient significance (hypotheses testing).
In total, SEM enables researchers to assess the theoretical assumptions concerning how factors are theoretically associated [160]. The SEM method was executed using AMOS 28 to handle the 7-point Likert scale items for data collection to compute the CFA tests and evaluate the structural model. The CFA is a multivariate statistical method to examine whether the measured observed variables of the latent constructs are consistent with the result of the underlying structure of the EFA of the latent constructs [54]. As indicated above, this phase of data analysis focuses on examining the overall model fit and the construct validity and reliability of the measured model resultant from the EFA,Äôs factor solution by underpinning the number of cutoff criteria. To assess the overall CFA model fit, we used a number of criteria as thresholds specified by Hu and Bentler [81] such as CMIN/DF, CFI, SRMR, and RMSEA.
For goodness model fit indices, the CMIN/DF should be between 1 and 3, the CFI should be acceptable when exceeding 0.90 and excellent when exceeding 0.95, the SRMR should

Table 6.4: Pattern Matrix of Exploratory Factor Analysis (EFA).

Item	**Component**							
	1	2	3	4	5	6	7	8
RAD1	.674							
RAD2	.877							
RAD3	.826							
RAD4	.756							
RAD5	.820							
CB1		.762						
CB2		.724						
CB3		.685						
CX1			.854					
CX2			.878					
CX3			.866					
CX4			.942					
TMS1				.792				
TMS2				.934				
TMS3				.911				
TMS4				.746				
RED1					.862			
RED2					.949			
RED3					.780			
RED4					.599			
RL1						.854		
RL2						.937		
RL3						.879		
GS1							.902	
GS2							.855	
GS3							.882	
BI1								.888
BI2								.905
BI3								.870

Extraction Method: Principal Component Analysis Rotation Method: Promax with Kaiser Normalization Rotation converged in 6 iterations.

not exceed 0.08, and the RMSEA value below 0.06 typically suggests a good fit. Figure 6.2 and Table 6.5 show the results of CFA and standardized regression weights.

Table 6.5 presents the standardised regression weights from CFA. An examination of these values provides insight into the relationships between individual items and their respective constructs. All standardised regression weights fall within the range

of 0.600 to 0.923, indicating strong to moderate positive relationships between items and their assigned constructs. This suggests good convergent validity, meaning that the items successfully measure the intended constructs. Most values are greater than 0.70, exceeding conventional thresholds for acceptable loadings [54]. This further strengthens the evidence for convergent validity.

Table 6.5: CFA results.

Variable	**Standardized Regression Weights**
RAD1	.600
RAD2	.832
RAD3	.763
RAD4	.731
RAD5	.752
CB1	.782
CB2	.785
CB3	.824
CX1	.901
CX2	.907
CX3	.777
CX4	.842
TMS1	.719
TMS2	.888
TMS3	.825
TMS4	.765
RED1	.830
RED2	.800
RED3	.733
RED4	.696
RL1	.827
RL2	.896
RL3	.785
GS1	.818
GS2	.818
GS3	.825
BI1	.810

Continued on next page

Table 6.5 continued from previous page

Variable	Standardized Regression Weights
BI2	.923
BI3	.752

6.9 Measurement Model

An investigation into the research model's effectiveness requires an assessment of its inner workings – reliability and validity. Before diving into the results, this first requires an examination of how the study measures the impact of the nine chosen constructs. Reliability gauges an entity's internal construct consistency, meaning its items measure the same underlying concept consistently [67]. Conversely, validity ensures each set of items accurately reflects its respective theoretical construct, acting as a mirror to the abstract idea. The next subsections explore the findings of these tests, illuminating the model's foundation before evaluating its effectiveness.

6.9.1 Reliability

To investigate the proposed framework for blockchain adoption in Saudi manufacturing, this study employed seven independent scales and one dependent scale (BI) behavioural intention to use blockchain technology in Saudi manufacturing sector. The independent scales assessed key factors influencing adoption, including: relative advantage (RAD), compatibility (CB), complexity (CX), top management support (TMS), organisational readiness (RED), regulations and low (RL), and government support (GS). To ensure the scales accurately capture the intended constructs, their internal consistency and inter-item correlations were analysed. This assessment, detailed in the following subsection, demonstrates the scales' reliability and ability to measure the targeted constructs.

6.9.2 Internal consistency

Measuring the internal consistency of the survey instruments using multi-item scales is vital, and a key method is the Cronbach's alpha test [38]. This test, also known as the coefficient alpha, assesses the reliability of a dataset by evaluating whether all items within a scale reliably measure the same underlying construct [49]. In essence, reliability refers to the degree to which a test consistently measures what it intends to

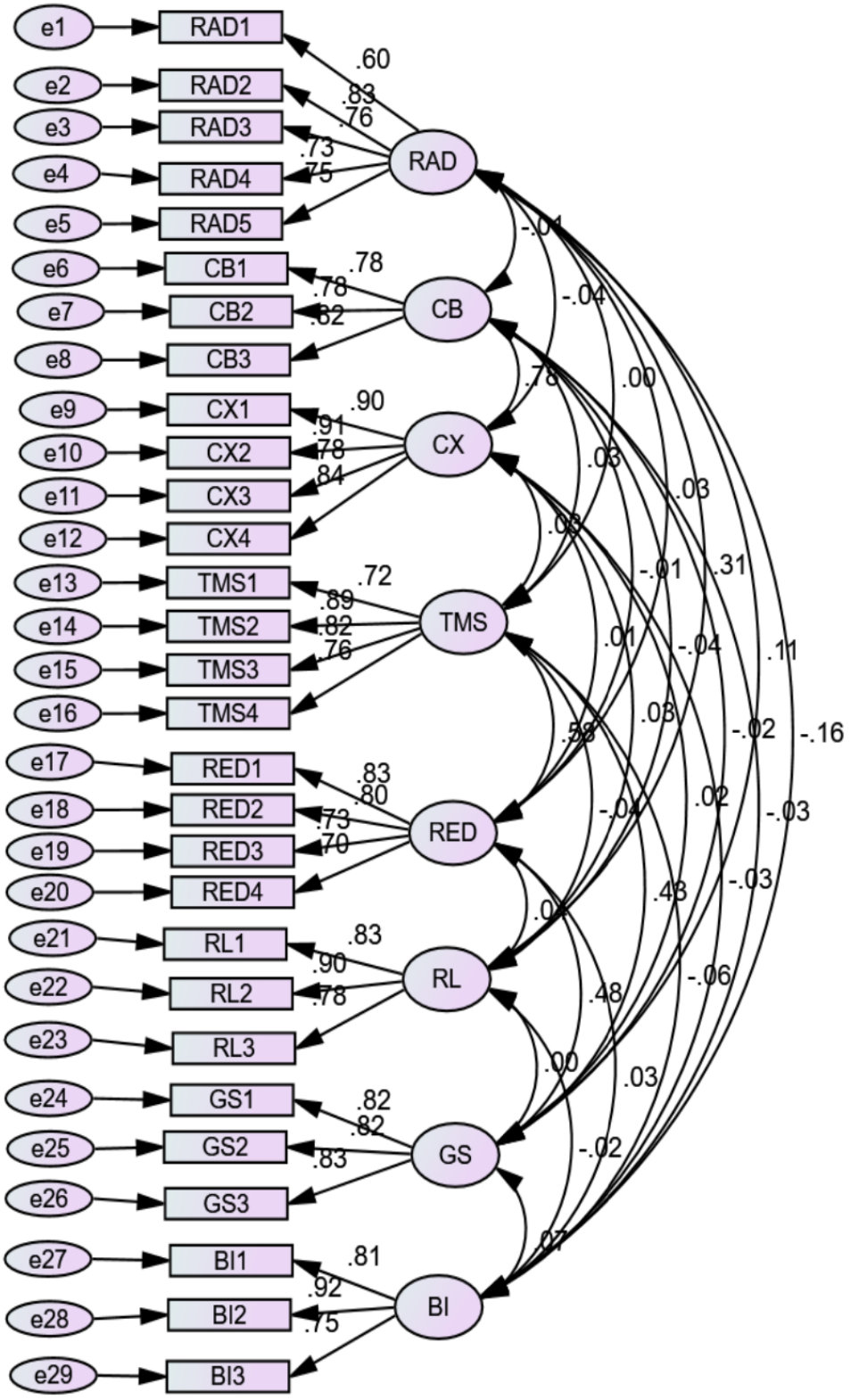

Figure 6.2: Measurement model with standardized estimates

[49]. Therefore, for researchers using multi-item scales, employing Cronbach's alpha is an essential step to ensure the instrument's data holds up to scrutiny.
To assess data reliability for the research, Cronbach's alpha helps gauge internal consistency. Typically, values between 0.70 and 0.95 suggest reliable data. Lower values as Tavakol and Dennick (2011) explain, could indicate a lack of questions, weak item connections, or mixed underlying concepts [175].
Hence, in this study, this test was used to determine whether the scales used are reliable. Table 6.6 shows the values of the Cronbach's alpha test which ranged between 0.85 and 0.95, therefore suggesting good internal consistency [143]. This is in line with Nunnally (1978), who established that an alpha α of 0.70 or above provides evidence for the internal consistency and reliability of a scale's items [137].

Table 6.6: Reliability results

Construct	**Items**	**Cronbach's Alpha**	**Result**
Relative Advantage (RAD)	5	0.85	High reliability
Compatibility (CB)	3	0.95	Excellent reliability
Complexity (CX)	4	0.93	Excellent reliability
Top Management Support (TMS)	4	0.87	High reliability
organisational Readiness (RED)	4	0.85	High reliability
Regulation and Laws (RL)	3	0.87	High reliability
Government Support (GS)	3	0.86	High reliability
Behavioral Intention (BI)	3	0.87	High reliability

6.9.3 Inter-item correlations

To delve deeper into scale analysis, inter-item correlation plays a crucial role. It assesses the degree to which individual item scores within a scale are interlinked [40]. In simpler terms, it gauges how consistently respondents answer different items supposedly measuring the same underlying concept. This, in turn, unveils the strength and nature of the relationship between these indicators.
Generally, a low correlation value suggests weak internal consistency of the scale, implying the items might capture disparate constructs. Conversely, a strong correlation indicates reliable measurement. Researchers like Hair et al. [65] advise an acceptable minimum threshold of 0.30. Values below this raise concerns about whether the observed variables truly tap into the intended construct. Computing the inter-item correlation

matrix is a key step in reliability analysis, as it ensures that the items collectively measure the construct as intended. This step is particularly useful during questionnaire validation and refinement. The exact procedure and detailed results are further discussed in the following sections.

6.9.3.1 Analysis of relative advantage

The concept of relative advantage focuses on how much better an innovation is perceived to be compared to its predecessor [130]. In this study, we investigate its potential impact on the Saudi manufacturing sector's adoption of blockchain technology. We measure relative advantage using four established factors from past research [177]. These factors assess how much more beneficial respondents believe blockchain is compared to existing practices within the Saudi manufacturing sector. Table 6.7 displays the inter-item correlation matrix for these factors. All values exceed 0.30, ranging from 0.382 to 0.639. This strong correlation suggests high reliability within the constructed measure.

Table 6.7: Correlation Matrix of Items for the Relative Advantage Construct

Relative Advantage (RAD)	**RAD1**	**RAD2**	**RAD3**	**RAD4**	**RAD5**
RAD1					
Pearson Correlation	1	.520**	.465**	.382**	.432**
Sig. (2-tailed)		<.001	<.001	<.001	<.001
N	332	332	332	332	332
RAD2					
Pearson Correlation	.520**	1	.630**	.595**	.639**
Sig. (2-tailed)	<.001		<.001	<.001	<.001
N	332	332	332	332	332
RAD3					
Pearson Correlation	.465**	.630**	1	.579**	.556**
Sig. (2-tailed)	<.001	<.001		<.001	<.001
N	332	332	332	332	332
RAD4					
Pearson Correlation	.382**	.595**	.579**	1	.565**
Sig. (2-tailed)	<.001	<.001	<.001		<.001
N	332	332	332	332	332
RAD5					
Pearson Correlation	.432**	.639**	.556**	.565**	1
Sig. (2-tailed)	<.001	<.001	<.001	<.001	
N	332	332	332	332	332

** Correlation is significant at the 0.01 level (2-tailed).

6.9.3.2 Analysis of compatibility

In his seminal work, Rogers (1995) defined compatibility as The degree to which an innovation aligns with users' values, past experiences, and needs[156] (p. 224). This characteristic plays a crucial role in blockchain adoption. These indicators assess the perceived consistency between blockchain and the Saudi manufacturing sector's requirements. As reflected in Table 6.8, all three indicators yielded values exceeding 0.30, ranging from 0.878 to 0.942. This robust range signifies a strong, reliable association between compatibility and blockchain adoption within the Saudi manufacturing sector.

Table 6.8: Inter-item correlation matrix for compatibility construct

Compatibility (CB)	**CB1**	**CB2**	**CB3**
CB1	1	.921**	.878**
Sig. (2-tailed)		<.001	<.001
N	332	332	332
CB2	.921**	1	.942**
Sig. (2-tailed)	<.001		<.001
N	332	332	332
CB3	.878**	.942**	1
Sig. (2-tailed)	<.001	<.001	
N	332	332	332

** Correlation is significant at the 0.01 level (2-tailed).

6.9.3.3 Analysis of complexity

The intricate nature and perceived difficulty of understanding and using an innovation play a key role in its adoption [179]. This study explores how complexity hinders technology adoption. To gauge the perceived level of complexity associated with blockchain and its subsequent impact on adoption, three established measures were adapted from previous research [36], [177]. As reflected in Table 6.9, these measures demonstrated

strong internal consistency, with correlation values exceeding 0.30 and ranging from 0.713 to 0.872, emphasizing the reliability of their interrelationships.

Table 6.9: Inter-item correlation matrix for the complexity construct

Complexity (CX)	**CX1**	**CX2**	**CX3**	**CX4**
CX1				
Pearson Correlation	1	.872**	.716**	.806**
Sig. (2-tailed)		<.001	<.001	<.001
N	332	332	332	332
CX2				
Pearson Correlation	.872**	1	.713**	.757**
Sig. (2-tailed)	<.001		<.001	<.001
N	332	332	332	332
CX3				
Pearson Correlation	.716**	.713**	1	.739**
Sig. (2-tailed)	<.001	<.001		<.001
N	332	332	332	332
CX4				
Pearson Correlation	.806**	.757**	.739**	1
Sig. (2-tailed)	<.001	<.001	<.001	
N	332	332	332	332

** Correlation is significant at the 0.01 level (2-tailed).

6.9.3.4 Analysis of top management support

A company's leadership perspective on technology, their active participation in tech initiatives, and their commitment to fostering innovation are collectively known as top management support [107]. To quantitatively evaluate the impact of strong leadership endorsement on blockchain adoption, three criteria were adapted from prior studies by Li (2008) and Teo et al. (2003). These criteria were assessed for reliability using a correlation matrix [113] [177]. As shown in Table 6.10, all correlation coefficients exceed 0.30, ranging between 0.605 and 0.744, indicating strong internal consistency

and reliability of the measurements.

Table 6.10: Correlation Matrix of Items for the top management support Construct

Top Management Support (TMS)	**TMS1**	**TMS2**	**TMS3**	**TMS4**
TMS1				
Pearson Correlation	1	.625**	.605**	.536**
Sig. (2-tailed)		<.001	<.001	<.001
N	332	332	332	332
TMS2				
Pearson Correlation	.625**	1	.744**	.688**
Sig. (2-tailed)	<.001		<.001	<.001
N	332	332	332	332
TMS3				
Pearson Correlation	.605**	.744**	1	.605**
Sig. (2-tailed)	<.001	<.001		<.001
N	332	332	332	332
TMS4				
Pearson Correlation	.536**	.688**	.605**	1
Sig. (2-tailed)	<.001	<.001	<.001	
N	332	332	332	332

** Correlation is significant at the 0.01 level (2-tailed).

6.9.3.5 Analysis of organisational readiness

The results presented in Table 6.11 support the high reliability of the three items used to measure the organizational readiness construct. All correlation coefficients between the items (RED1, RED2, RED3, and RED4) exceed 0.30, ranging from 0.472 to 0.607. Importantly, all correlations are statistically significant at the 0.01 level (2-tailed), indicating a strong positive relationship between each pair of items. This finding aligns with the established criteria for acceptable internal consistency in research. According to Hair et al. (2014), correlation coefficients above 0.30 suggest good reliability, while values above 0.70 indicate excellent reliability [54]. Therefore, the results in Table 6.11 demonstrate that the chosen items effectively capture a single underlying construct of organisational readiness and are suitable for further analysis.

6.9.3.6 Analysis of regulations and laws

In this factor, we examines the legal and policy environment surrounding blockchain adoption. It encompasses both government-imposed regulations and organisational poli-

Table 6.11: Correlation Matrix of Items for the the organisational readiness construct

Organization readiness (RED)	**RED1**	**RED2**	**RED3**	**RED4**
RED1				
Pearson Correlation	1	.723**	.546**	.567**
Sig. (2-tailed)		<.001	<.001	<.001
N	332	332	332	332
RED2				
Pearson Correlation	.723**	1	.607**	.472**
Sig. (2-tailed)	<.001		<.001	<.001
N	332	332	332	332
RED3				
Pearson Correlation	.546**	.607**	1	.575**
Sig. (2-tailed)	<.001	<.001		<.001
N	332	332	332	332
RED4				
Pearson Correlation	.567**	.472**	.575**	1
Sig. (2-tailed)	<.001	<.001	<.001	
N	332	332	332	332

** Correlation is significant at the 0.01 level (2-tailed).

cies designed to support or control the implementation of new technologies [82] , [163]. To assess the influence of legal and regulatory frameworks on blockchain adoption, three variables were adapted from previous research [36], [71]. As demonstrated in Table 6.12, all correlation coefficients between these variables exceed 0.30, ranging from 0.634 to 0.741, with all correlations statistically significant at the 0.01 level (2-tailed). These results suggest a strong internal consistency and reliability for the chosen measures, indicating their effectiveness in capturing the essence of the regulations and laws construct.

6.9.3.7 Analysis of government support

This study analysed government support for blockchain adoption in Saudi Arabia using three adapted measures derived from previous research [36], [124]. These measures capture the extent to which government policies, programs, and incentives facilitate technology adoption, reflecting the country's broader transformation goals [94]. As shown in Table 6.13 , all correlation coefficients between the items (GS1, GS2, and GS3) surpassed 0.30, ranging from 0.670 to 0.679. Moreover, all correlations were statistically significant at the 0.01 level, indicating strong internal consistency and reliability. This confirms that the chosen measures effectively capture a unified construct of government support

Table 6.12: Correlation Matrix of Items for the regulations and laws construct

Regulations and Laws (RL)	**RL1**	**RL2**	**RL3**
RL1			
Pearson Correlation	1	.741**	.634**
Sig. (2-tailed)		<.001	<.001
N	332	332	332
RL2			
Pearson Correlation	.741**	1	.711**
Sig. (2-tailed)	<.001		<.001
N	332	332	332
RL3			
Pearson Correlation	.634**	.711**	1
Sig. (2-tailed)	<.001	<.001	
N	332	332	332

** Correlation is significant at the 0.01 level (2-tailed).

for blockchain adoption.

6.9.3.8 Analysis of behavioural intention

This section examines the willingness and determination of IT employees in the Saudi manufacturing sector to adopt blockchain technology. Drawing on established indicators from Venkatesh et al. (2003), the analysis employs a set of three items designed to capture their behavioural intention [189]. As evidenced by the correlation matrix in Table 6.14, all values exceed 0.30, ranging from 0.683 to 0.779. This demonstrates strong internal consistency and reliability among the chosen items, signifying their effectiveness in measuring the targeted construct.

6.9.4 Validity

Validity is defined as a scale's ability to measure what it is supposed to measure [212]. To ensure this ability, Nunnally and Bernstein (1994) propose three key criteria for a valid construct [137]. First, the construct should accurately capture the real-world phenomena (domain) it represents. Second, it should demonstrate consistency with alternative mea-

Table 6.13: Correlation Matrix of Items for the government support construct

Government Support (GS)	**GS1**	**GS2**	**GS3**
GS1	1	.670**	.679**
Sig. (2-tailed)		<.001	<.001
N	332	332	332
GS2	.670**	1	.670**
Sig. (2-tailed)	<.001		<.001
N	332	332	332
GS3	.679**	.670**	1
Sig. (2-tailed)	<.001	<.001	
N	332	332	332

** Correlation is significant at the 0.01 level (2-tailed).

sures of the same concept. Finally, the construct should exhibit meaningful relationships with other relevant constructs. Following these guidelines, this thesis explores various elements of validity, including content validity, convergent validity, and discriminant validity.

6.9.5 Convergent validity

Convergent validity is achieved when all factor loadings are statistically significant and the standardised loading estimate is 0.50 or higher [65]. According to Sekaran (2003), convergent validity examines whether the measures of the same construct are highly correlated [161]. Average variance extracted (AVE) is used as an indicator for supporting convergent validity [58]. In addition, computing the AVE for each construct can verify the convergent validity. To verify the convergent validity, the AVE value must be greater than or equal to 0.50 to achieve an adequate level [58],[65]. Retaining the low factor loadings in a model could lead to convergent validity failure [14]. Lastly, convergence was also reflected by the composite reliability (CR) measure, which is greater than 0.6 and higher than the construct AVE value. Table 6.15 shows that all AVE values are greater than 0.50.

Table 6.14: Correlation Matrix of Items for the behavioral intention Construct

Behavioral Intention (BI)	**BI1**	**BI2**	**BI3**
BI1			
Pearson Correlation	1	.747**	.618**
Sig. (2-tailed)		<.001	<.001
N	332	332	332
BI2			
Pearson Correlation	.747**	1	.693**
Sig. (2-tailed)	<.001		<.001
N	332	332	332
BI3			
Pearson Correlation	.618**	.693**	1
Sig. (2-tailed)	<.001	<.001	
N	332	332	332

** Correlation is significant at the 0.01 level (2-tailed).

Table 6.15: Convergent validity results

Construct	**Composite Reliability**	**Average Variance Extracted (AVE)**
Relative Advantage (RAD)	0.85	0.63
Compatibility (CB)	0.95	0.80
Complexity (CX)	0.93	0.78
Top Management Support (TMS)	0.87	0.64
Organisational Readiness (RED)	0.85	0.63
Regulations and Laws (RL)	0.87	0.64
Government Support (GS)	0.86	0.62
Behavioral Intention (BI)	0.87	0.64

6.9.6 Discriminant validity

Discriminant validity refers to the extent to which a test is not related to other tests that measure different constructs. Fornell and Larcker (1981) assessed discriminant validity by comparing the square root of each AVE to the correlation coefficients between the constructs [58]. AVE is a measure of how much variance in a construct is explained by its indicators. The square root of AVE in every latent variable should be more than the other correlation values among the latent variables [54]. Table 6.16 shows that for each construct, the square root of the AVE on the diagonal is higher than the correlation

coefficients (off diagonal) for each construct in the related rows and columns. For instance, the AVE for relative advantage is 0.794, while the correlation coefficients (off-diagonal) for the support construct range between 0.376 and 0.629, all of which are less than 0.794. Hence, discriminant validity is confirmed using the criteria of Fornell-Larcker.

Table 6.16: Discriminant Validity using the Fornell-Larcker Criterion

-	**RAD**	**CB**	**CX**	**TMS**	**RED**	**RL**	**GS**	**BI**
Relative Advantage (RAD)	**0.794**							
Compatibility (CB)	0.574	**0.894**						
Complexity (CX)	0.576	0.479	**0.883**					
Top Management Support (TMS)	0.556	0.525	0.577	**0.800**				
Readiness (RED)	0.629	0.492	0.400	0.463	**0.794**			
Regulations and Laws (RL)	0.530	0.436	0.688	0.516	0.337	**0.800**		
Government Support (GS)	0.485	0.542	0.454	0.505	0.378	0.461	**0.787**	
Behavioral Intention (BI)	0.376	0.425	0.381	0.488	0.256	0.407	0.607	**0.800**

6.10 Structural Equation Modeling (SEM)

SEM is a set of statistical techniques used to analyze and explore the relationships between measured variables (observable data) and latent variables (unobservable constructs) [65]. SEM enables researchers to test hypotheses by estimating path coefficients, which represent the strength and direction of the relationships between indicators (measured variables) and their respective latent constructs [78]. This method is particularly critical in behavioral sciences and is widely utilized in information systems and information technology research [78]. According to Kline (2010), SEM is divided into two main components: Measurement Model: This part defines the relationship between latent constructs and their indicators (observed variables). Structural Model: This component maps the hypothetical relationships among the latent constructs used in path analysis[101]. As a multivariate statistical approach, SEM is able to simultaneously analyse the measurement model and the structural model. In this study, SEM was applied in a two-stage process: First stage: The measurement model was analysed to estimate the relationships between the observed variables and their corresponding latent constructs. Second stage: The structural model was evaluated to test the hypothesised relationships (correlations)

between the latent constructs [54]. Both stages were performed using Analysis of Moment Structures (AMOS) version 28, a specialised IBM software designed for SEM path analysis and Confirmatory Factor Analysis (CFA). AMOS provides a user-friendly interface for specifying, estimating, and evaluating SEM models, making it a preferred tool for research involving complex statistical relationships.

6.10.1 Goodness-of-fit (GOF)

In SEM, there are a series of goodness-of-fit (GOF) indices to determine the fit of the model. GOF specifies how well the model reproduces the observed covariance matrix among the indicators or first-order items [65]. Based on the literature, there are between four to six fit indices that can assess the model fit [100],[126]. Currently, there is no agreement among scholars as to which fitness indices should be reported. Hair et al. (2010) and Holmes-Smith, Coote and Cunningham (2006) recommend the use of at least three fit indices by including at least one index in each category: absolute fit, incremental fit and parsimonious fit. The selection of indices used in the study and the acceptable cut-off values reported in the study may vary depending on which study is being referred to. For this study, the model fit category used, the selected indices and level of acceptance are presented in Table 6.17. In the next sub-sections, each category of the GOF measures is discussed [65], [77].

6.10.2 Absolute Fit Indices

Chi-square $\tilde{\chi}^2$ tests the difference between the model's predicted and observed covariance matrices. It is sensitive to sample size, as larger samples tend to reject models even if they fit well [65].
Goodness-of-fit (GFI) measures the amount of variance and covariance explained by the model. It can be biased by sample size and model complexity [27].
Root Mean Square Error of Approximation (RMSEA) assesses model fit in the population, considering error approximation. Values less than 0.05 indicate a close fit and 0.08 is generally acceptable [26].
Root Mean Square Residual (RMR) and Standardized RMR (SRMR) is the square root of the difference between observed and predicted covariance. SRMR is less sensitive to scale differences. Values less than 0.05 are good, 0.08 is acceptable [80].

6.10.3 Incremental Fit Indices

Adjusted Goodness-of-Fit Index (AGFI) adjusts GFI for degrees of freedom, penalizing complex models. Values above 0.80 indicate a good fit but are sensitive to sample size [27].

Normed Fit Index (NFI) compares the model's fit to a baseline null model. It is sensitive to sample size and is not recommended for sole reliance [22].

Comparative Fit Index (CFI) compares the model's predicted covariance to the observed covariance [22].

Tucker-Lewis Index (TLI) is similar to CFI, but is preferable on simpler models. Both CFI and TLI range from 0 (poor) to 1 (perfect), with 0.90 or higher generally recommended [65].

6.10.4 Parsimonious Fit Index

Normed Chi-square ($\tilde{\chi}^2$/df) evaluates model fit relative to the number of estimated parameters. Values less than 2.0 to 5.0 are considered acceptable but should be used in conjunction with other indices [65].

Table 6.17 presents the results of the fit indices which show a good degree of fit.

Table 6.17: The results of the goodness of fit indices

Fit index	Recommended Value	Research Model	Comments
$\tilde{\chi}^2$/df	<5.0	1.513	Meets the recommended value
GFI	>0.90	0.923	Meets the recommended value
CFI	>0.90	0.972	Meets the recommended value
IFI	>0.90	0.973	Meets the recommended value
TLI	>0.90	0.968	Meets the recommended value
RMSEA	<0.08	0.039	Meets the recommended value

6.10.5 Multicollinearity

Independent variables should be individually linked to the dependent variable, but not excessively correlated with each other. This phenomenon, known as multicollinearity, can distort regression results and reduce the meaningfulness of individual coefficients [54].

To assess this risk, we analysed the variance inflation factors (VIFs) and tolerances for each independent variable. Tolerance reflects the unique explanatory power of a

variable, while VIF indicates its inflation due to multicollinearity. According to established guidelines, tolerance values above 0.1 and VIFs below 10 suggest an absence of multicollinearity concerns [54]. Table 6.10.5 presents the multicollinearity assessment.

Table 6.18: Multicollinearity assessment.

	Multicollinearity*	
	Tolerance	VIF
Relative Advantage (RAD)	.895	1.117
Compatibility (CB)	.454	2.205
Complexity (CX)	.453	2.208
Top Management Support (TMS)	.670	1.493
Organisational Readiness (RED)	.647	1.545
Regulations and Laws (RL)	.900	1.111
Government Support (GS)	.782	1.279

* Dependent Variable: BI.

6.10.6 Testing the research hypotheses

Following the successful evaluation of the measurement model in the previous stage, the subsequent stage involves assessing the structural model to test the remaining research hypotheses:

Relative advantage (RAD), H1: Relative advantage positively impacts the implementation of blockchain technology in the manufacturing sector.

Compatibility (CB), H2: Compatibility positively impacts the implementation of blockchain technology in the manufacturing sector.

Complexity (CX), H3: Complexity has a negative impact on the implementation of blockchain technology in the manufacturing sector.

Top management support (TMS), H4: Top management support positively impacts the implementation of blockchain technology in the manufacturing sector.

Organisational readiness (RED), H5: Organisational readiness has a positive impact on the implementation of blockchain technology in the manufacturing sector.

Regulations and laws (RL), H6: The current regulations and laws positively impact the implementation of blockchain technology in the manufacturing sector.

Government support (GS), H7: Government support positively impacts the implementation of blockchain technology in the manufacturing sector.

The path coefficient estimates were examined along with the overall model fit indices to test hypotheses H1 to H7. Parameter estimates are important to SEM analysis because they are used to generate the estimated population covariance matrix for the model [172]. In this section, the hypothesised relationships are assessed and confirm the structural model of the study. A path analysis was used to analyse the relationships between variables related to behavioral intention. P-values were calculated for each path, indicating the statistical significance of the hypothesized relationships. A 5% significance level was used, meaning a p-value less than 0.05 suggests a statistically significant relationship. The details of the structural model evaluation of this thesis are discussed in the following.

Table 6.19: Results of structural relationships

Hypothesis	**Structural path**	**SRW**	**t-value**	**p-value**	**Result**
H1	RAD → BI	0.21	-2.695	.001	Supported
H2	CX → BI	-0.15	2.247	.021	Supported
H3	CB → BI	0.25	1.877	.001	Supported
H4	TMS → BI	0.26	2.344	***	Supported
H5	RED → BI	0.18	2.631	.002	Supported
H6	RL → BI	0.17	2.407	.003	Supported
H7	GS → BI	0.29	1.707	***	Supported

Note: SRW= Standardised regression weight, RAD=Relative advantage, CB=Compatibility, CX=Complexity, TMS=Top management support, RED= Organisational readiness, RL=Regulations and laws, GS=Government support, BI=Behavioral intention to use blockchain technology in the Saudi manufacturing sector.[***] = $p < 0.001$.

The path analysis conducted to determine the main predictors of IT employees' behavioral intention towards blockchain adoption in the Saudi manufacturing sector reveals that all hypotheses are supported. As shown in Table 6.19 , all seven hypotheses (H1-H7) regarding the relationships between various factors and behavioral intention have statistically significant p-values (less than 0.05). Positive influences found for factors like relative advantage (RAD), compatibility (CB), top management support (TMS), organisational readiness (RED), regulations and laws (RL), and government support (GS) all have

a positive impact on the intention to adopt blockchain technology, while complexity (CX) had a negative impact on behavioral intention, suggesting that a perceived difficulty in understanding or implementing blockchain technology discourages its adoption. Returning to the strength of relationships, the path analysis results provide strong evidence that various factors influence the behavioral intention to adopt blockchain technology in the Saudi manufacturing sector. Of these, government support (GS) and top management support (TMS) demonstrate the strongest positive influence, highlighting their critical roles in driving technology adoption.

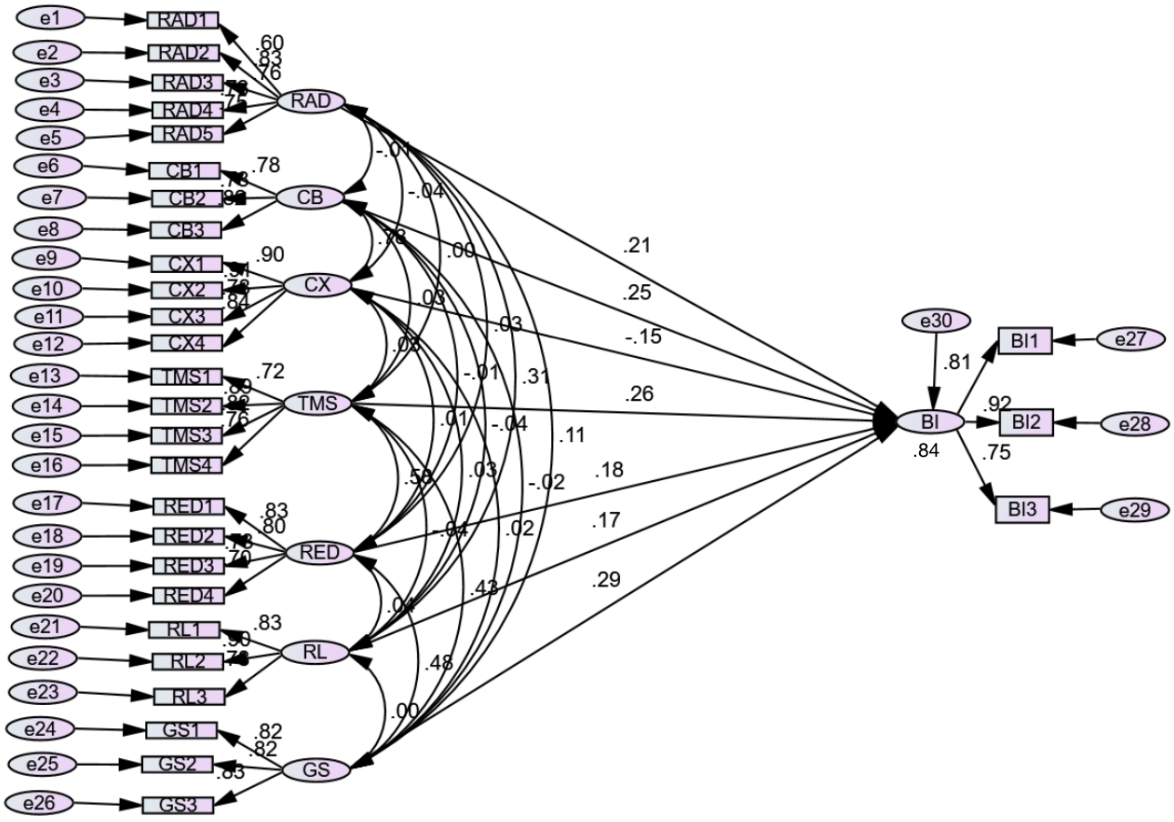

Figure 6.3: Structural model

Additionally, while complexity (CX) was found to have a negative impact, its effect was less pronounced compared to other factors. This suggests that addressing complexity concerns can be beneficial but might not be the most crucial factor for promoting adoption in this context. These findings offer valuable insights for stakeholders involved in blockchain implementation within the Saudi manufacturing sector. By focusing on fostering strong leadership support, securing government backing, and addressing poten-

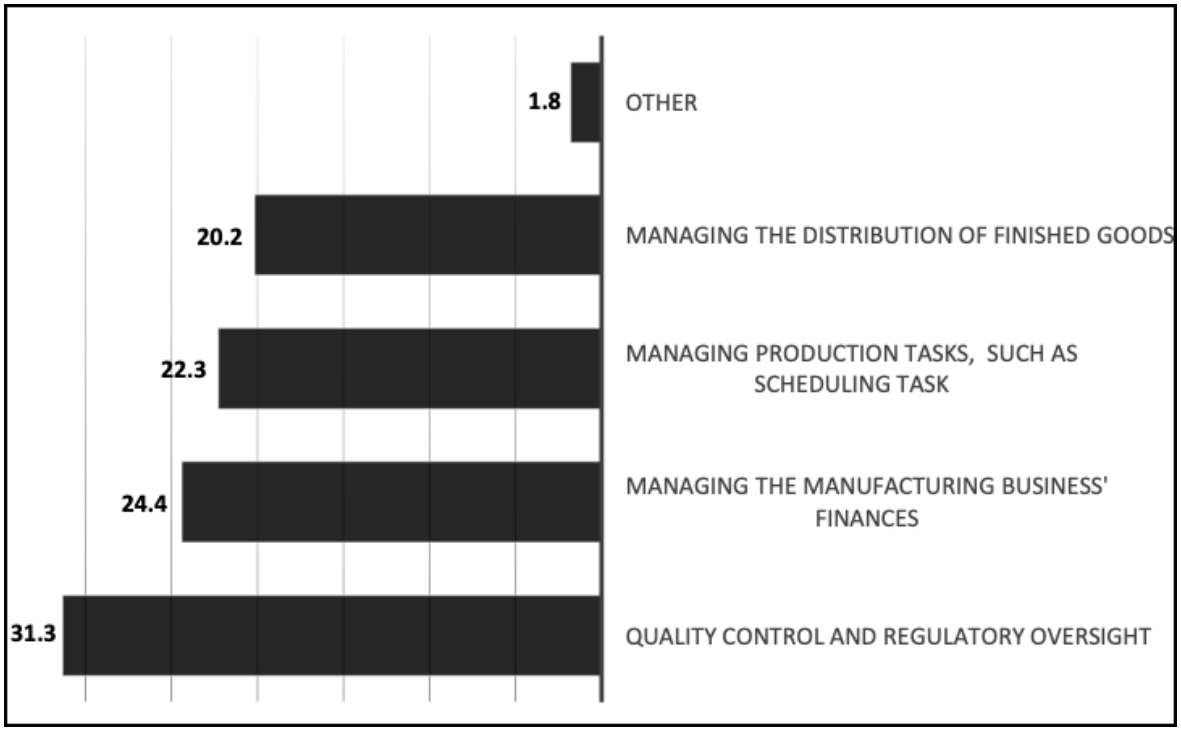

Figure 6.4: Potential applications of blockchain-based manufacturing

tial complexity concerns, stakeholders can create a more favorable environment for the successful adoption of this transformative technology. The analysis confirms all hypothesized relationships between the proposed factors and behavioural intention to adopt blockchain technology was significantly associated with ($p < 0.05$). This finding provides strong empirical support for the proposed model, visualized in Figure 6.3. The model explains 84% of the variance in behavioral intention, as evidenced by the R-squared value of 0.84.

6.11 Potential applications of blockchain-based manufacturing in the future

Participants envisioned several applications for blockchain technology within the Saudi manufacturing sector. Quality control and regulatory oversight topped the list (31.3%), highlighting the perceived value of blockchain in tracking product quality, verifying materials, and ensuring regulatory compliance. Managing financial transactions for manufacturing businesses closely followed at 24.4%, suggesting potential cost reductions and security enhancements through blockchain-based payments, trade finance, and

other financial activities. Production task management, such as scheduling, came third at 22.3%, emphasizing the appeal of secure and tamper-proof records for improving efficiency and traceability in production processes. Managing the distribution of finished goods ranked fourth at 20.2%, reflecting the perceived benefit of transparent and secure tracking throughout the supply chain. Other diverse applications represented 1.8% of suggestions.

6.12 Chapter Summary

This chapter analysed the survey data collected from IT professionals in the Saudi manufacturing sector to understand their perspectives on blockchain adoption. To ensure a reliable and representative dataset, we meticulously cleaned the data by removing missing entries, inconsistencies, and outliers. Additionally, we analysed the respondents' demographics to provide context. Next, we evaluated the quality of the survey instrument using robust statistical tests. The internal consistency of our scales was confirmed through reliability analysis in SPSS, followed by confirmatory factor analysis (CFA) in AMOS 28 to establish both convergent and discriminant validity. This guarantees that the measures accurately capture the intended concepts. Then, we explored the hypothesised relationships between various factors and the intention to adopt blockchain technology. Each hypothesis proposed was statistically significant, solidifying their influence on adoption intent. Interestingly, government support emerged as the strongest factor. These compelling findings set the stage for the next chapter, where we explore these key factors and their combined impact on blockchain adoption within the Saudi manufacturing landscape. This deeper analysis will ultimately fulfil the research objective of pinpointing the key drivers of blockchain adoption in this specific context.

CHAPTER 7

DISCUSSION

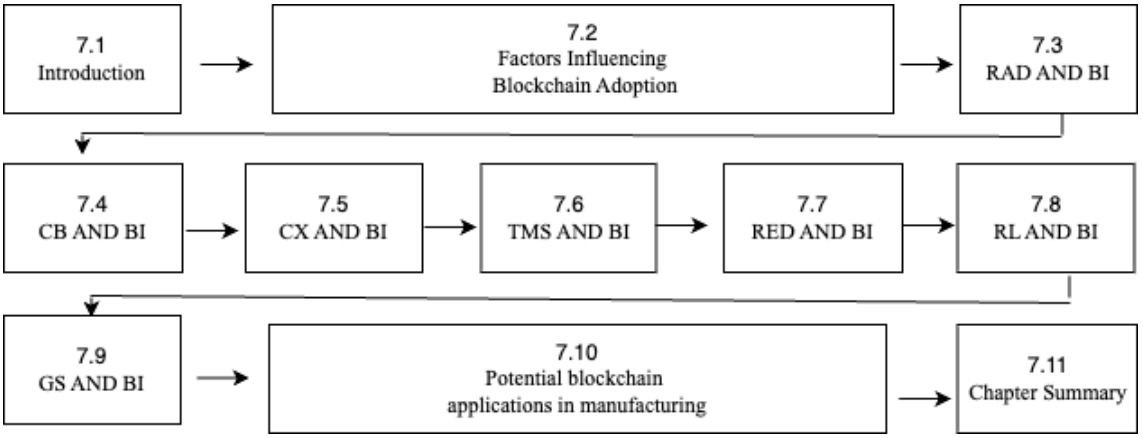

Figure 7.1: Chapter 7 outline

7.1 Introduction

The findings of this research are discussed in this chapter. Building on the data presented in the preceding chapter, this discussion connects the empirical results with the established literature, aligning them closely with the research questions posited at the beginning of this study. Key to this discussion is an analysis of the constructs of the original technology-organisation-environment (TOE) framework as they pertain to blockchain adoption in the manufacturing sector. In addition, the chapter explores the impact of various factors that were hypothesised in the revised model presented earlier

in this work. The discussion extends to evaluate which manufacturing information system applications could be optimally transitioned to blockchain technology, based on the findings. Figure 7.1 illustrates the organisation of this chapter.

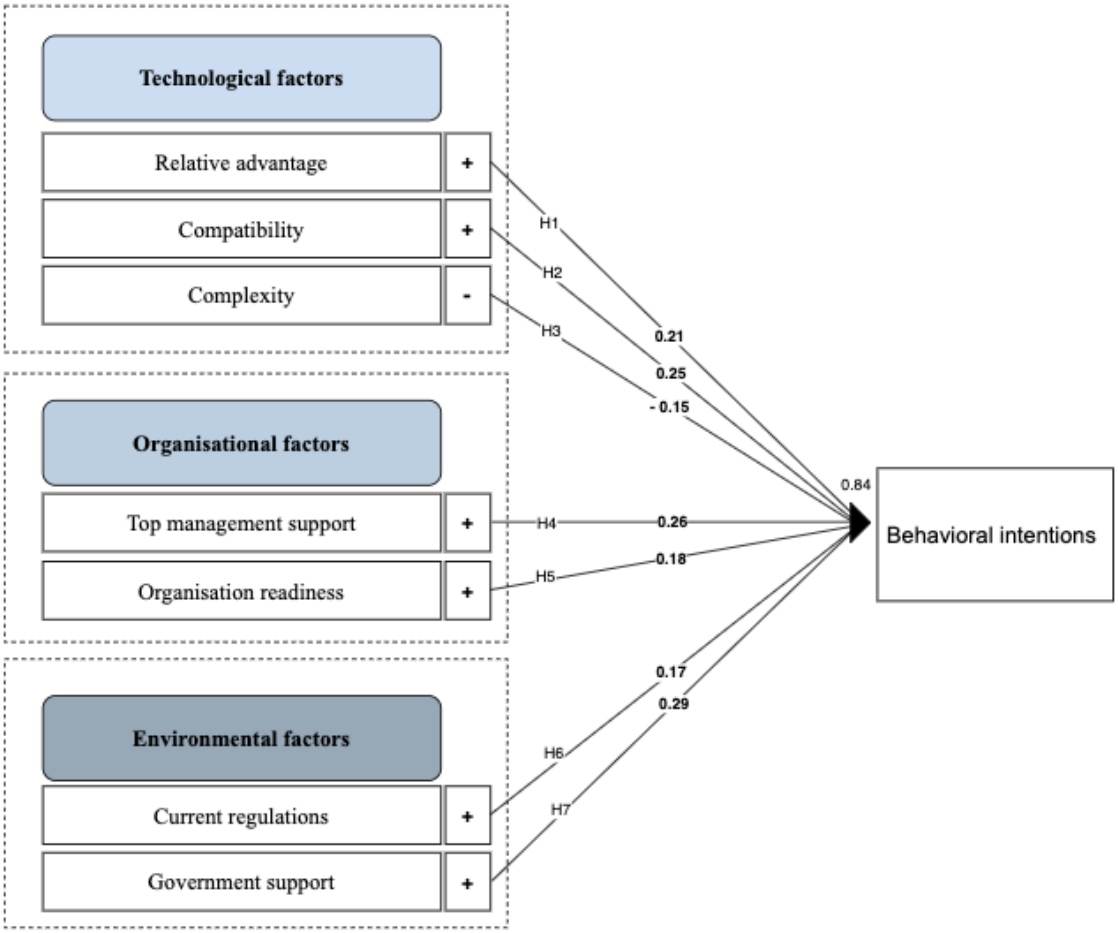

Figure 7.2: Hypotheses that have been confirmed in the research framework

7.2 Factors Influencing the Adoption of Blockchain

This section discusses the key factors that influence the adoption of blockchain in Saudi Arabia's manufacturing sector, framed within the original TOE framework. The study evaluates the constructs of relative advantage, compatibility, complexity, top management support, organisational readiness, regulations and lows, and government support, and their impact on the dependent construct of behavioural intention.
Using a quantitative approach, the proposed model explains 84% the variance in be-

havioural intention, as indicated by the R-squared value of 0.84. This substantial percentage suggests that the variation in organisational receptiveness to blockchain adoption can be largely attributed to these TOE factors, highlighting a significant goodness of fit for the model.

Compared to other models or frameworks used in previous blockchain studies, such as indicated by the R-squared values of 0.48 in [203] and 0.79 in [36], this framework provides a better and more comprehensive understanding. Figure 7.2 outlines the path coefficients of seven factors and their collective influence on the behavioural intentions towards blockchain adoption in the manufacturing sector.

The discussion in the following sections is structured around the seven hypotheses developed from the research model, each corresponding to a key factor from the TOE framework. These hypotheses were designed to answer the core research questions outlined in Chapter 3, particularly the main question: "How can the Saudi manufacturing sector successfully implement blockchain technology?". Each section discusses one hypothesis, interpreting the statistical results in light of the literature and practical implications for the Saudi manufacturing sector.

7.3 RAD AND BI (H1)

Relative advantage refers to the extent to which the advantages of a technology are viewed as superior to those of its predecessors [156]. This concept is crucial in the TOE framework, as it directly influences the adoption decision. In the context of blockchain in manufacturing, assessing the relative advantage involves comparing blockchain's capabilities with traditional manufacturing information systems.

The analysis of the data underscores that relative advantage is a robust predictor of blockchain adoption in manufacturing. This is confirmed by our hypothesis (H1: Relative advantage positively impacts the implementation of blockchain technology in the manufacturing sector) being strongly supported. The impact of relative advantage on adoption is both significant and substantial, evidenced by a beta value of 0.21 and a p-value of 0.001, indicating a highly significant positive influence. This study aligns with the existing literature, including studies [203], [66], [23], [112], which also recognised relative advantage as an important factor in the adoption of blockchain.

The study results indicate that the adoption of blockchain technology in raw material inventory management in the manufacturing sector typically increases when relative advantages are clearly recognised, such as enhanced transparency, increased accuracy,

improved security, and potential cost savings. Therefore, decision makers can enhance the adoption of blockchain technology by conducting a thorough cost-benefit analysis. In this analysis, reduced inventory shrinkage, reduced administrative overhead, and faster and more accurate order fulfilment should be considered. In addition, it is also important to consider educating stakeholders about blockchain technology and its specific applications in inventory management by organising workshops and seminars. In these sessions, common misconceptions can be addressed and insights into how blockchain can solve raw material management problems can be provided.

These results are expected, as firms are more likely to adopt new technologies when clear advantages such as improved transparency, cost savings, and efficiency are perceived. In a rapidly transforming industrial environment like Saudi Arabia's, perceived value directly drives adoption.

7.4 CB AND BI (H2)

Compatibility describes the extent to which an innovation aligns with the existing values, past practices, and current needs of its potential adopters. [118]. Compatibility, in the context of the adoption of blockchain technology in the manufacturing sector, is defined as the degree to which blockchain is perceived as consistent with the existing technological infrastructure, production processes, organisational values, and strategic goals of manufacturing firms. It measures how seamlessly blockchain can be integrated into current systems without significant changes in equipment, workflows, or corporate culture.

The findings demonstrated that compatibility exerts a significant positive influence on the adoption of blockchain technology within the manufacturing sector, corroborating our initial hypothesis (H2: Compatibility positively impacts the implementation of blockchain technology in the manufacturing sector). Through quantitative analysis, it was concluded that the compatibility determinant strongly affects blockchain adoption, showing a highly significant positive impact with a beta value of 0.25 and a p-value of 0.001. The findings of our research align with the broader literature, which consistently indicates that compatibility is a key factor in the adoption of blockchain technology. Several studies across various references [36], [23], [124], [142], [66], [204] have also highlighted the significant role of compatibility in supporting blockchain integration into different sectors.

Inventory management in traditional information systems lacks the capabilities to

handle modern needs, such as real-time tracking and data integration. Hence, blockchain adoption must be compatible with hardware infrastructure, including servers and secure network capabilities, as well as being compatible with existing software applications to ensure seamless data flow. Also, blockchain must be integrated smoothly with current IT systems to enhance manufacturing efficiency. So, we recommend considering compatibility when adopting blockchain technology; a thorough evaluation is necessary to determine how well the technology aligns with the organisation's specific goals and requirements.

This strong influence is logical, as organisations are more inclined to adopt innovations that do not disrupt existing systems or require major operational changes. In Saudi manufacturing, seamless integration is a key enabler of adoption.

7.5 CX AND BI (H3)

Complexity is defined as the extent to which an innovation is perceived as challenging to understand and use.[118]. The complexity of blockchain technology refers to the difficulty manufacturing firms perceive in understanding and implementing it. It encompasses the technical intricacy and the required expertise to operate and maintain blockchain systems. It also encompasses the complexity of integrating these systems with existing manufacturing processes and IT infrastructure.

The findings from our study demonstrated that complexity exerts a significant negative influence on the adoption of blockchain technology within the manufacturing sector. This corroborates our initial hypothesis (H3: Complexity has a negative impact on the implementation of blockchain technology in the manufacturing sector). Through quantitative analysis, it was concluded that the complexity determinant strongly affects blockchain adoption. It shows a highly significant negative impact with a beta value of -0.15 and a p-value of 0.021. Several studies have shown that complexity plays an important role in the adoption of blockchain technologies [203], [66], [124], [36], [23].

In this study, participants indicated that blockchain technology seemed confusing to manufacturers without technical knowledge. This is because of a lack of ability within the organisation to effectively implement and manage it. Addressing these concerns and encouraging the adoption of blockchain in managing raw materials inventory by providing comprehensive training and educational resources to all levels of the organisation can demystify the technology and reduce anxiety related to its use. This includes workshops, seminars, and training courses that explain blockchain technology. Also, collaborating

with blockchain technology experts and consultants can provide the necessary expertise and guidance.

The negative impact of complexity is understandable, given that blockchain requires a level of technical knowledge and infrastructure that many firms may currently lack. This reinforces the idea that perceived difficulty can be a barrier to adoption in resource-constrained settings.

7.6 TMS AND BI (H4)

Top management support pertains to senior management's beliefs about technological initiatives, their active involvement in these efforts, and their commitment to fostering technological advancement [103]. The findings of the study indicate that top management support significantly influences the adoption of blockchain technology in the manufacturing sector, validating our initial hypothesis (H4: Top management support positively impacts the implementation of blockchain technology in the manufacturing sector). The quantitative analysis revealed that the determinant of top management support has a significant impact on blockchain adoption, evidenced by a beta value of 0.26 and a highly significant p-value of less than 0.001. Studies in the literature consistently demonstrate the critical role that top management plays in the successful adoption of blockchain technologies, such as [39], [142], [66], [124],[23], [112].

Top management support is critical for the successful implementation of blockchain adoption of raw material inventory management systems in the manufacturing sector. Support can take a number of forms, such as setting policies, providing skilled personnel, supporting the hiring or training of staff, and allocating sufficient funds to establish blockchain. Blockchain technology may change the industrial hierarchy. Companies that successfully implement blockchain technology are more likely to achieve higher profits [102]. Hence, decision makers at the upper management level in the manufacturing sector recommended collaborating with the Ministry of Industry to achieve Vision 2030 and to contribute to the achievement of initiatives that encourage the manufacturers to adopt new technologies, especially blockchain.

This finding is consistent with expectations, as strategic initiatives like blockchain adoption often require leadership commitment to secure resources and foster organisational change. In the Saudi context, executive endorsement is particularly crucial to align with national digitalisation goals.

7.7 RED AND BI (H5)

Organizational readiness refers to the extent to which a manufacturing firm is prepared to implement blockchain technology. This encompasses the availability of the necessary human, financial, and technological resources.

The findings of our study demonstrated that organisational readiness exerts a significant positive influence on the adoption of blockchain technology within the manufacturing sector. This corroborates our initial hypothesis (H5: Organisational readiness has a positive impact on the implementation of blockchain technology in the manufacturing sector). Through quantitative analysis, it was concluded that the determinant of organisational readiness strongly affects blockchain adoption. It shows a highly significant positive impact with a beta value of 0.18 and a p-value of 0.002. Several studies in the literature have shown that organisational readiness plays a crucial role in the adoption of blockchain technologies [23], [39],[66].

Participants in this study indicated a high probability of organisational readiness. Organisations are likely to be ready if they focus on strategic, cultural, cognitive, resource, and IT readiness aspects [119]. However, to ensure that the organisation is well prepared, we recommend addressing IT infrastructure, such as choosing a blockchain platform and consensus protocol, and developing the architecture. We recommend starting with raw materials inventory management as a pilot study to explore the weaknesses and strengths of organisations' readiness to apply blockchain.

These results are justified, as firms that are better equipped with technical infrastructure, skilled personnel, and financial resources are more capable of undertaking complex implementations like blockchain. Organisational preparedness is essential to reduce adoption risk.

7.8 RL AND BI (H6)

Regulations and laws refer to the framework of policies, legal standards, and government directives that govern the deployment and use of new technology [72]. This includes any local, national, or international regulations that affect how blockchain can be implemented in the manufacturing industry.

Our study demonstrated that regulations and laws exert a significant impact on blockchain technology adoption in the manufacturing sector. This corroborates our initial hypothesis (H6: The current regulations and laws positively impact the implementation

of blockchain technology in the manufacturing sector). Through quantitative analysis, it was concluded that the factors that influence regulations and laws have a significant impact on blockchain adoption. It shows a highly significant positive impact with a beta value of 0.17 and a p-value of 0.003. Several studies have shown that regulations and laws plays a crucial role in the adoption of blockchain technologies [23], [36].

Understanding blockchain is crucial to establishing regulations and laws [121]. As blockchain is still in its infancy, regulations and laws in Saudi Arabia are in the early stages. It is recommended that the Communications, Space and Technology Commission pay more attention to laws and regulations relating to blockchain technology since it falls under their jurisdiction. It would also be helpful for the Ministry of Industry to collaborate with the Communications, Space and Technology Commission to create regulations and laws related to blockchain under the Improvement Regulations and the Legislative Environment of the Industrial Sector Initiative. In addition, we recommend establishing clear and precise legal frameworks around blockchain and offering financial incentives to companies that take a proactive step to adopt blockchain technology .

This finding aligns with the regulatory uncertainty that exists around blockchain in many countries, including Saudi Arabia. Clear laws and supportive regulatory frameworks are often prerequisites for confident investment in emerging technologies.

7.9 GS AND BI (H7)

Government support is defined as the comprehensive assistance provided by government entities to promote the adoption and integration of emerging technologies like blockchain. This support encompasses the allocation of direct and indirect funds for the research and development of these technologies. In addition, it includes educational initiatives aimed at shifting organizational behavior towards more innovative practices and establishing environmentally conscious approaches [182].

Our study demonstrated that government support exerts a significant positive influence on blockchain technology adoption in the manufacturing sector. This corroborates our initial hypothesis (H7: Government support positively impacts the implementation of blockchain technology in the manufacturing sector). Through quantitative analysis, it was concluded that the factor of government support has a significant impact on blockchain adoption. It shows a highly significant positive impact with a beta value of 0.29 and a p-value of less than 0.00.

According to several studies, government support of blockchain technologies plays

an important role [23] [124] [142] [66]. Transferring knowledge and technology, and enhancing innovation in local industries is one of the most essential pillars of Vision 2030 economic diversification, Initiatives have been numerous and varied in consistency and the integration between them to improve the strength and growth of manufacturing in the Kingdom and provide the potential for its development and prosperity. The Saudi Industry Ministry launched a number of initiatives such as the Manufacturing Technology Consolidation and Acquisition Initiative, the Industrial Capacity Development Centre Initiative, Improvement Regulations and the Legislative Environment of the Industrial Sector Initiative, etc. These initiatives are in line with the potential stages of the Saudi government's intention to apply blockchain technology. The Saudi government should support educational strategies for blockchain adoption, identify blockchain use cases in manufacturing, and support feasibility studies. Furthermore, we recommend establishing the infrastructure, encouraging manufacturers to implement pilot projects, and seeking regulatory alignment for blockchain.

This finding aligns with the regulatory uncertainty that exists around blockchain in many countries, including Saudi Arabia. Clear laws and supportive regulatory frameworks are often prerequisites for confident investment in emerging technologies.

7.10 Potential applications of blockchain technology in manufacturing

A Manufacturing Information System (MIS) is an integrated system designed to manage and coordinate all the information associated with manufacturing processes. This type of system encompasses a wide range of functionalities, including the planning, tracking, and execution of manufacturing operations [73].It involves the management of quality control, manufacturing accounting, production scheduling, distribution management, and others [2]. We requested participants to select an application that they would recommend transitioning to blockchain technology, based on their personal perspectives regarding the MIS applications they felt were the most suitable for this change.

Quality control and regulatory oversight received the highest preference, indicating that participants see significant potential for blockchain in this area. The immutable and transparent nature of blockchain could be particularly advantageous for maintaining rigorous quality standards and compliance with regulations, which is critical in manufacturing [205]. The high percentage suggests a strong belief that blockchain can improve traceability, accountability, and security in these areas.

The second highest preference was for financial management applications. Blockchain's capabilities in providing secure, tamper-proof transactions and reducing fraud risks make it an attractive option for managing financial operations [87]. This indicates an acknowledgement of the efficiency and transparency blockchain can bring to financial processes.

The third highest preference is the application of blockchain for managing production tasks, including scheduling. Blockchain could potentially streamline production workflows by improving the coordination of tasks, improving data accuracy, and facilitating real-time updates across various production stages [18].

The use of blockchain for managing the distribution of finished goods also ranked highly. Blockchain technology can provide significant improvements in supply chain transparency and the real-time tracking of goods [12]. Although there is some interest in exploring new areas for blockchain applications, the focus remains primarily on core operational aspects. Only a small percentage chose other applications.

7.11 Practical Recommendations

Based on the findings of this study, the following actionable recommendations are proposed for policymakers and industry practitioners to support the adoption of blockchain technology in the Saudi manufacturing sector:

- Policymakers should raise awareness of blockchain's benefits through national campaigns and pilot case studies. Industry leaders should prioritise cost-benefit analyses to justify blockchain investments in areas such as inventory management and traceability.

- Firms should assess the compatibility of blockchain platforms with their existing IT infrastructure. Government agencies can develop integration toolkits and provide funding for legacy system adaptation.

- To reduce perceived complexity, training programmes and technical workshops should be organised for IT staff and managers. Collaboration with blockchain experts and universities can also facilitate internal capacity building.

- Industry associations should engage executives through strategic forums that highlight blockchain's return on investment (ROI). Executive endorsement can be encouraged through targeted leadership programmes.

- Organisations should begin with small-scale blockchain pilot projects (e.g., raw material tracking) to test internal readiness. Policymakers may offer readiness assessment tools and infrastructure grants.
- Regulatory bodies should establish a clear legal framework for blockchain use in manufacturing, supported by consultation with industry stakeholders. Sandbox initiatives can allow for safe experimentation with new solutions.
- Government entities should expand support for blockchain innovation through R&D incentives, national strategies, and feasibility funding. Industry-specific blockchain use cases should be identified and promoted under Vision 2030 initiatives.
- Develop blockchain-based modules for traceability and compliance tracking. Encourage standardisation of quality metrics on blockchain ledgers to improve audits and inspections.
- Use blockchain for secure and immutable financial transactions to reduce fraud and enhance real-time financial reporting. Financial authorities can promote this via sandbox trials.
- Deploy blockchain to manage production task allocation and scheduling. It can serve as a trusted system of record for production timelines and resource usage across departments.
- Implement blockchain-based supply chain tracking for end-to-end visibility. Government agencies can encourage this through logistics digitalisation initiatives and traceability mandates.
- Encourage local IT solution providers to develop blockchain add-ons for existing MIS platforms to support smooth adoption without complete system overhauls.

These recommendations aim to bridge the gap between theory and practice and provide targeted guidance to support strategic adoption of blockchain in Saudi manufacturing.

7.12 Chapter summary

This chapter analyses the quantitative findings of the study, focussing on how the primary constructs of the TOE framework affected blockchain adoption in manufacturing.

It integrates these findings with established literature to increase the understanding of blockchain's integration into manufacturing processes. According to the proposed model, approximately 84% of manufacturing decision makers intend to use blockchain. The chapter evaluates potential blockchain applications in manufacturing information systems, identifying optimal areas for the technology transition. Finally, it proposes new directions for future research and policy development, with the aim of supporting the implementation of strategic technologies in the manufacturing sector.

CHAPTER 8

CONCLUSION

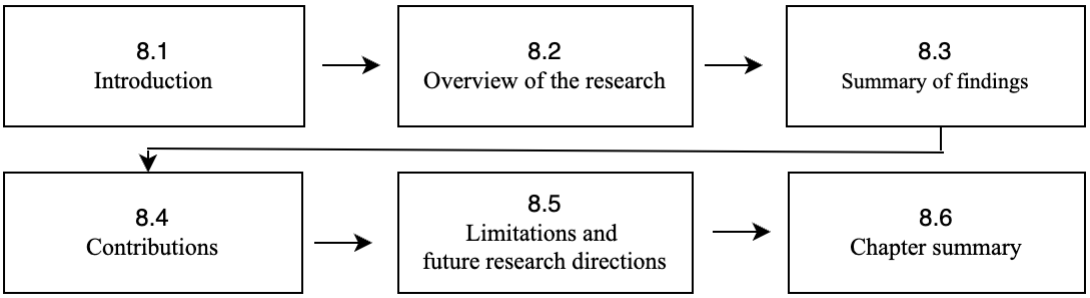

Figure 8.1: Chapter 8 outline

8.1 Introduction

The objective of this study is to examine the factors influencing the adoption of blockchain technology within the Saudi Arabian manufacturing sector. Beginning with a systematic literature review, the study identifies and analyses models and frameworks that impact blockchain adoption at the organizational level. It focuses on Saudi manufacturing firms, which face challenges like the need for standardized data management, real-time data analysis, managing complex processes, and mitigating the security risks associated with smart and IoT devices. The research posits blockchain as a critical tool for enhancing business agility and managing costs, thus improving competitive positioning globally. The primary objectives include identifying the critical factors affecting blockchain adoption,

developing and empirically validating a conceptual framework based on the technology-organization-environment (TOE) model and exploring specific blockchain applications as identified by IT employees. This study is motivated by a significant gap in the literature regarding blockchain adoption in developing countries, particularly within the Saudi context and aims to provide a thorough understanding through the collection and analysis of data from 332 IT employees. This introduction sets the stage for a detailed exploration of the findings and contributions of this research, discussed in subsequent sections.

8.2 Overview of the Research

This research investigates the factors driving the adoption of blockchain technology within the manufacturing sector in Saudi Arabia. Designed to improve adoption rates, the study begins with a systematic literature review method (SLR) to identify prevalent models and frameworks that influence the adoption of blockchain at the organisational level. The focus is on Saudi manufacturing firms, which are grappling with challenges such as the need for standardised data management approaches, real-time data analysis, the management of process complexities, and the increasing security risks from the use of smart and IoT devices.

Given these challenges, this study highlights blockchain's potential to manage costs and improve business agility, making it a pivotal tool for competitive global positioning. The objectives of this research are as follows:

1. to identify and analyse the critical factors that influence the adoption of blockchain in Saudi manufacturing, providing a comprehensive landscape overview.

2. to develop and validate a conceptual framework grounded in the TOE model, adapted for the specific context of Saudi manufacturing, and validate it through empirical testing using a survey of IT employees.

3. to investigate specific blockchain applications chosen by IT employees to pinpoint future adoption trajectories within the sector.

The motivation for this study is driven by a significant research gap in understanding the factors affecting the adoption of blockchain in developing countries, particularly within the Saudi context. Using quantitative methods, data was collected from 332 IT employees, ensuring the rigorous empirical testing of the proposed model. This included

an open-ended question within the survey to uncover potential innovative applications of blockchain technology. A summary of the findings is presented in subsequent sections.

8.3 Summary of Findings

This section synthesizes the findings from a study focused on the determinants influencing blockchain adoption within Saudi Arabia's manufacturing sector, framed using the TOE framework. The study identified seven key factors: relative advantage, compatibility, complexity, top management support, organizational readiness, current regulations, and government support, all significantly impacting the behavioral intention toward adopting blockchain. The quantitative analysis revealed that these factors collectively explain 84% of the variance in behavioral intention, showcasing a strong fit of the TOE model in this context. This high explanatory power, indicated by an R-squared value of 0.84, not only reaffirms the robustness of the TOE framework but also surpasses the explanatory capabilities of previous models utilized in blockchain research, which reported lower R-squared values. Each factor's path coefficient further detailed their individual contributions to behavioral intention, providing a clear map of how each influences blockchain adoption decisions in the manufacturing sector.

8.4 Contributions

This thesis makes significant theoretical and practical contributions to the understanding of blockchain technology adoption within the manufacturing sector, particularly focusing on the Saudi Arabian context. These contributions aid in theoretical advancement and also guide practical implementation, setting a precedent for future blockchain integration in manufacturing within the region and beyond.

8.5 Contributions to Theory

- This thesis significantly advances the theoretical knowledge on the adoption of blockchain in manufacturing. Through a meticulous review of 59 studies from seven leading scientific databases, a critical gap in the existing literature is identified: the lack of a comprehensive framework to analyse the determinants of blockchain adoption in manufacturing. This study fills this gap by proposing a novel evaluative framework that also rigorously assesses the influence of each determinant.

- This study makes a significant theoretical contribution by adapting and empirically validating the TOE framework in the context of blockchain technology acceptance within the manufacturing sector. It confirms the robustness and suitability of the TOE framework as a theoretical model to explore the dynamic relationships of technological, organisational, and environmental factors that influence the adoption of innovation in manufacturing. The research identifies specific determinants within these contexts that are pivotal in driving blockchain adoption, thus supporting the findings of previous studies across various domains. This validation underscores the comprehensive explanatory power of the TOE framework and also broadens its applicability, making it a valuable model for understanding organisational innovation adoption across different sectors.
- This research expands the geographic scope of blockchain studies by introducing empirical data from the Middle East, a region previously under-represented in blockchain adoption research. This study significantly contributes to the existing body of knowledge by being the first to empirically investigate blockchain adoption in the manufacturing sector of Arab countries, particularly Saudi Arabia. This contribution is particularly valuable given that Saudi Arabia is interested in adopting and applying new technologies in Vision 2030.
- A set of survey questions adapted from prior research specifically for the study of blockchain technology adoption was adapted and validated for this study, which enhances the methodological tools available to researchers. The present research contributes to the body of knowledge by delivering a well-validated questionnaire about blockchain technology adoption for future research.
- This study contributes to the knowledge of the most potential use cases for blockchain applications from an IT employee's perspective. To the best of the researcher's knowledge, this is the first study to explore blockchain applications in the manufacturing sector from the perspective of IT employees.

8.6 Contributions to Practice

The Ministry of Industry's main objective in the 2030 Vision is to improve industry and logistics services in the country. The ministry wants to make Saudi Arabia one of the leading industrial powerhouses and a major global hub for logistics. Their efforts are designed to increase the economic value and variety of the industrial sector and to make

this sector more attractive to investors. So we encourage the Ministry of Industry to adopt blockchain to achieve these goals.

8.6.1 Blockchain Roadmap

Implementing blockchain technology in the manufacturing sector in Saudi Arabia can be a transformative strategy, aligning with national priorities under Vision 2030 to improve technological capabilities and economic growth. To achieve this, organisations will need new strategies and organisational models, as well as changes in their physical infrastructure, manufacturing operations and technologies, human resources, and management practices [64]. This study develops a roadmap detailing the resources and efforts required to support the transformation of the Saudi industry for blockchain adoption, as shown in Fig. 8.2. The proposed road map consists of seven phases that are explained as follows:

- **Phase 1: Educational strategies for the adoption of blockchain in manufacturing**

Blockchain, similar to other Industry 4.0 technologies, requires employees to have considerable technical knowledge and appropriate qualifications [64]. The initial phase of the roadmap focusses on establishing a strong foundation of knowledge and support for blockchain technology among decision makers and IT teams. It is essential to thoroughly engage and educate all key stakeholders [88]. This can be achieved effectively by conducting targeted workshops, seminars, and training sessions on blockchain technology. Researchers in universities are encouraged to conduct in-depth research on blockchain technology [165]. A study of its potential applications, the development of existing blockchain systems, or the improvement of existing ones could contribute to its practical applicability to manufacturing.

- **Phase 2: Identify blockchain use cases in manufacturing and feasibility studies**

To develop a successful information technology strategy, it is important to conduct a feasibility study with high-quality feasibility indicators [47]. Blockchain technology in the manufacturing sector needs to undergo feasibility studies to identify and prioritise practical applications. A feasibility study will assess the impact, return on investment and technical viability of incorporating blockchain into various manufacturing processes [52]. Furthermore, use cases that can benefit significantly from blockchain should be

identified, such as inventory management, maintenance and tracking, payments and tax compliance, identity and credential management, privacy [181], controlling financial transactions between and within companies, asset and product tracking during and after manufacturing, and controlling quality and tests [2].

- **Phase 3: Regulatory alignment for blockchain in Saudi manufacturing**

Governments should be encouraged to implement supportive blockchain policies to develop a successful information technology strategy [88]. It is essential to collaborate with key regulatory bodies such as the Saudi Arabian Monetary Authority (SAMA), the Ministry of Industry, and the Communications Space and Technology Commission (CST). The CST recently established the Digital Regulatory Academy to deal with digital regulatory environments, conduct necessary analyses, and support decision-making processes [41]. This collaboration will improve the understanding of blockchain and potentially influence regulations that affect blockchain applications in the manufacturing industry. There must be clear and well-managed standards that organisations should follow[196]. Furthermore, developing a comprehensive compliance checklist specific to the use of blockchain in manufacturing will facilitate the smooth and legal integration of this technology by ensuring that all implementations meet the relevant regulatory requirements.

- **Phase 4: Establishing technology foundations for blockchain in manufacturing**

A comprehensive approach is required to establish the technology infrastructure and partnerships required to implement blockchain in the manufacturing industry, starting with a review of the existing IT infrastructure, such as computing power, storage and networking. Blockchain technology operates on the basis of several core components: consensus rules, a peer-to-peer network, and security functions such as cryptography and hash functions. These elements are not stored within the blockchain's data structure, but are implemented through supporting hardware and software that manage and validate the blockchain's operations [141]. A robust network architecture must be designed to support decentralised blockchain operations, taking into account the configuration and redundancy of the nodes. Investment in high-performance hardware and the selection of suitable software tools, such as development platforms and system interfaces like Ethereum and Hyperledger Fabric, are critical to ensure blockchain applications run efficiently [206]. Implementing advanced security measures, including firewalls and

encryption technologies, will protect blockchain data and operations [168]. It is also necessary to develop or update existing systems to ensure the seamless integration of blockchain applications with traditional manufacturing systems. Planning for scalability is vital to accommodate future expansions and the evolution of blockchain use cases [31]. Furthermore, forming strategic partnerships with blockchain technology providers, industry consortiums, and research institutions will improve the deployment and effectiveness of blockchain technology within the sector [131].

- **Phase 5: Implementing pilot projects for blockchain in manufacturing**

To effectively test and refine blockchain applications in manufacturing settings, it is essential to initiate pilot projects for selected use cases. Developing smaller and more focused projects accelerates the process of turning an idea or concept into an actual application in the real world [88]. These pilot projects allow the effectiveness, scalability, and ability of the technology to integrate seamlessly with existing systems to be evaluated. By gathering and analysing feedback from these pilot implementations, refinements and optimisations can be made to blockchain applications, ensuring that they meet the specific needs and challenges of the manufacturing sector. This iterative process is essential to fine-tune the technology prior to wider deployment [20].

- **Phase 6: Phased implementation and scaling of blockchain in manufacturing.**

Scaling often involves optimising system performance, improving infrastructure, and ensuring that the system can effectively handle growing demands, upgrading hardware, improving software efficiency, or implementing distributed architectures to improve system capacity and responsiveness [147]. Many blockchain projects are still in the pilot stage. Few have advanced beyond the pilot stage to full implementation [131]. In the implementation and scaling stage of the adoption of blockchain technology in the manufacturing sector, the overarching goal is to systematically implement successful blockchain applications across the industry. The approach involves gradually expanding the scope of blockchain applications, starting with pilot projects that test the technology's effectiveness in smaller, controlled settings. Based on the success of these pilots and the valuable learning outcomes they provide, the deployment can then be scaled to full-scale operations. This phased expansion ensures that each step is informed by previous experiences, optimising the integration process, and enhancing the overall impact of blockchain technology in manufacturing.

- **Phase 7: Continuous improvement and monitoring of blockchain performance in manufacturing**

In the final stage of the blockchain adoption roadmap, the focus shifts to monitoring, evaluation and continuous improvement with the objective of ensuring long-term success and optimisation of blockchain applications in the manufacturing sector. Key actions include establishing key performance indicators (KPIs) that will help monitor the performance and impact of blockchain implementations [68]. This allows stakeholders to measure its effectiveness and identify areas for improvement. Furthermore, fostering a culture of continuous improvement is essential; this involves regularly using data collected from ongoing operations to refine and improve blockchain applications. This proactive approach ensures that blockchain technology continually adapts and evolves in response to operational needs and emerging industry trends.

8.7 Limitations and Future Research Directions

This study, while comprehensive in its approach to examining the factors influencing blockchain technology adoption in Saudi Arabia, encounters several limitations and provides directions for future research:

- Primarily, it utilized snowball sampling, a non-probability technique, which may introduce sample bias. Future research should consider using probabilistic sampling methods, such as stratified or simple random sampling, to secure a more representative sample. This approach would likely improve the generalisability of the findings.

- Currently, there is a lack of studies examining the factors influencing blockchain adoption by IT employees in the Saudi manufacturing sector. This study examined seven factors influencing blockchain adoption. Future research should explore additional factors to provide a more comprehensive understanding of blockchain adoption in manufacturing.

- As a result of time constraints, this study used a cross-sectional design to capture the intention to adopt blockchain at one point in time. To assess the long-term impacts and sustainability of blockchain solutions in manufacturing, future research should employ longitudinal methods. Such studies would also clarify how initial perceptions and adoption decisions change over time.

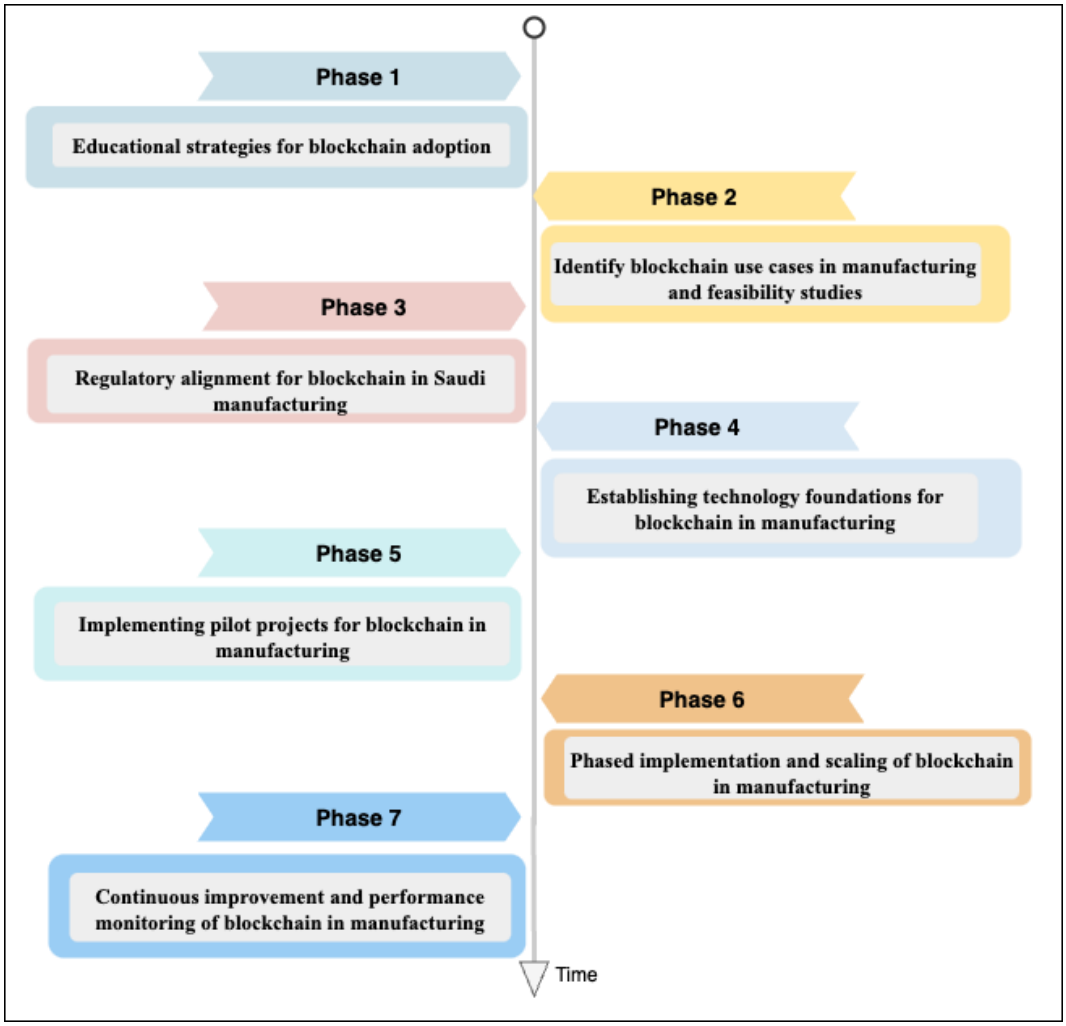

Figure 8.2: Proposed blockchain adoption roadmap phases

- While the survey-based quantitative approach of this study provides robust statistical insights, it does not capture the specific motivations behind blockchain adoption as effectively as qualitative methods might. Future research should incorporate qualitative methodologies such as interviews to more deeply investigate the organizational, technological, and environmental factors influencing blockchain adoption.
- This study offers valuable insights into the factors influencing blockchain adoption in manufacturing but it does not address the specific challenges and opportunities of its integration in the Saudi context. Future research should identify key barriers and explore the technical, economic, and scalability aspects of blockchain integration in Saudi manufacturing.

- This study delineates several promising use cases for blockchain technology within the manufacturing sector. Future research should concentrate on the practical development and rigorous implementation of blockchain systems tailored to these specific applications. Taking this step will give manufacturing a tangible edge that goes beyond theoretical potential.
- The study focused on the adoption of blockchain among Saudi manufacturing IT employees. Another direction for future research is to replicate this study to cross-validate the findings and thereby strengthen the validity of the conclusions across different sectors such as energy, finance, telecommunications etc. or groups such as workers, engineers, managers, customers, and retailers using a more structured sampling approach.

In conclusion, this study has contributed both theoretically and practically to the understanding of blockchain adoption in the Saudi manufacturing sector. By identifying the key determinants influencing adoption and aligning them with national priorities such as Vision 2030, the research offers a practical roadmap for implementation. These findings serve as a call to action for policymakers, industry leaders, and researchers to accelerate the integration of blockchain technology, driving innovation, improving transparency, and enhancing operational efficiency in the sector.

APPENDIX

A

APPENDIX

A.1 Appendix A : Ethical approval

UTS UNIVERSITY OF TECHNOLOGY SYDNEY
CRICOS Provider Code 00099F

Neg Risk approval - ETH22-7537

Dear Applicant

Re: ETH22-7537 - "Comprehensive Framework for Blockchain Adoption in Saudi Manufacturing Sector."

You have declared your research as Negligible Risk in accordance with the National Statement on Ethical Conduct in Human Research (Chapter 2.1). This declaration is subject to the following standard conditions:

1. you must notify the UTS Human Research Ethics Committees of any variation to this research that may alter the level or risk associated with it;

2. you must undertake this research in compliance with the National Statement; and

3. you will undertake this research in compliance with the UTS Research Policy or any replacement or amendment thereof.

You have declared that this project **DOES NOT** involve any of the following:

- Establishment of a register or databank for possible use in future research projects
- Collection, transfer and/or banking of human biospecimens(1)
- Any significant alteration to routine care or health service provided to participants
- Interventions and therapies, including clinical and non-clinical trials, and innovations
- Targeted recruitment or analysis of data from any of the participant groups listed in Chapter 4 of the National Statement (or where any of these participants are likely to be significantly over-represented in the group being studies) including:
  - Women who are pregnant and the human fetus
  - Children and young people (under 18 years)
  - People in dependent or unequal relationships
  - People highly dependent on medical care who may be unable to give consent
  - People with a cognitive impairment, an intellectual disability, or a mental illness
  - People who may be involved in illegal activities (including those affected)
  - Aboriginal and Torres Strait Islander Peoples

- Collection, use or disclosure of personal information(2)
- Collection, use or disclosure of health information(3)
- Collection, use or disclosure of sensitive information(3)
- Covert observation, active concealment, or planned deception or participants
- Activity that potentially infringes the privacy or professional reputation of participants, providers or organisations(2)
- Potential for participants to experience discomfort or harm (e.g. physical, psychological, social
- Direct contact or communication with UTS staff/students, patients, consumers or members of the public during recruitment or data collection(2)
- Participants who have a pre-existing relationship with the researcher(2)
- People unable to give free and informed consent due to difficulties in understanding the Information Sheet or Consent Form
- People in other countries

The UTS HRECs consider the following to be of negligible risk:
(1) use of commercial cell lines and/or supply of blood or blood products from Australian Red Cross Lifeblood;
(2) consensus methods (i.e. Delphi) where expert opinion is being canvassed with full disclosure, consent and identification in public use; and
(3) use of existing collections of data or records that contain only non-identifiable data about human beings (i.e. no codes)

Please keep a copy of your ethics application form and approval letter on file to show you have considered the risks associated with your research. You should consider this your official letter of approval.
To access this application, please click here. A copy of your application form has been attached to this email.

If you have any queries about this approval, please do not hesitate to contact your local research office or Research.Ethics@uts.edu.au.

Kind regards,
UTS HREC Ethics Secretariat

C/- Research Office
University of Technology Sydney
Research.Ethics@uts.edu.au | Website
PO Box 123 Broadway NSW 2007
Ref: Ethics 2 -Neg Risk approved (c)

A.2 Questionnaire - English Version

Comprehensive Framework for Blockchain Adoption in the Saudi Manufacturing Sector

Information Sheet

Dear Participant,

My name is Mahasen Abdrabulhassan Alsolmy, and I am a PhD candidate at the University of Technology Sydney. My supervisor is Professor Farookh Hussain.

The purpose of this research/electronic survey is to identify the factors motivating the use of blockchain technology in managing the inventory of raw materials in the manufacturing sector in the Kingdom of Saudi Arabia.

The Saudi government aim to transform the industry sector into a leading industrial powerhouse with the 2030 vision. We believe in the importance of the National Industry Development Program to transform the Kingdom of Saudi Arabia into a leading industrial power and global logistics platform and gain an informed understanding of the advantages and challenges of adopting blockchain technology in raw materials inventory management in manufacturing. By knowing the opinions of managers and/or decision-makers from this study.

If you have any concerns about the research and believe that my supervisor or myself can help you with it, please feel free to contact:
The researcher via email
mahasen.alsolmy@student.uts.edu.au or
The supervisor: Professor Farookh Hussain via email:
farookh.hussain@uts.edu.au

If you would like to speak to someone not associated with the research: You may contact the Research Ethics Officer at Research.ethics@uts.edu.au. Project number ETH22-7537

End of Block: Information Sheet

Consent form

Participation in this study is voluntary. It is entirely up to you whether you decide to participate or not. If you choose to participate, I will invite you to complete an online survey. It will not take more than 7 minutes of your time. You can change your mind anytime and stop completing surveys without consequences.

The data collection process will be strictly confidential, and the identity of the participants will remain anonymous. The data will be used only for this research, and the results will only be limited to academic publications.

Would you like to participate?
- ○ Yes
- ○ No

Skip To: End of Survey If No is selected

End of Block: Consent

A brief explanation of blockchain technology

Blockchain technology is one of the most critical technologies that have emerged recently and has made a great revolution in recent years. The reason for this spread is the many advantages of the blockchain, which contributes to preserving property rights and documenting information. Including information storage and processing.

Also, one of the reasons for the wide spread of the Blockchain is the spread of applications and uses that depend on “Blockchain technology” as a primary technology for its operation. Perhaps the most important use of the Blockchain is Managing the inventory of raw materials in the manufacturing sector.

Raw material inventory management uses blockchain technology to ensure there is enough inventory, from direct to indirect materials, to keep production moving.

Blockchain allows warehouses, manufacturers, suppliers, production sites, distribution centres, and retail partners to connect through a permanent record of every transaction. All records are then stored and made available to everyone within the network.

End of Block: A brief explanation of blockchain technology

Demographic information

Q1 Age
- 18 to 24
- 25 to 34
- 35 to 45
- 46 to 60
- 60+

Q2 Education level
- High school or lower
- Diploma
- Bachelor
- Post-graduate degree

Q3 Working in which industrial city
- Central Industrial Cities (Riyadh, Sudair, Qassim, Al-Kharj, Shaqraa, Al-Zulfi, Dhurna)
- Western Industrial Cities (Jeddah, Makkah, Rabigh, Al-Madina, Taif)
- Eastern Industrial Cities (Dammam, Al-Ahsa)
- Southern Industrial Cities (Al-Baha, Assir, Najran, Jazan)
- Northern Industrial Cities (Ha'il, Tabuk, Ar'ar, Hafr Al-Batin ‹Wa'ad Al-Shamal)

Q4 Current job title
- A chief Information officer CIO
- IT Manager
- IT Administrator
- Computer Engineer
- IT Consultant
- IT Technician
- Other IT Staff

Q5 Work experience years
- <5 years
- 5–9 years
- 10–15 years
- >15 years

Q6 Number of employees in the factory
- Less than 100
- 100–200
- More than 200

Q7 What is your level of knowledge about blockchain?
- Advanced knowledge
- Intermediate knowledge
- Beginner knowledge

End of Block: Demographics

		Strongly disagree	disagree	Somewhat disagree	Neutral	Somewhat agree	agree	Strongly agree
N.	ID	Item						
Tech 1 Technological Factors: Relative Advantage								
8	RAD 1	Blockchain technology speeds up the process of managing the inventory of raw materials.						
		1	2	3	4	5	6	7
9	RAD 2	Blockchain technology will make the process of managing the inventory of raw materials easier						
		1	2	3	4	5	6	7
10	RAD 3	Blockchain will increase the productivity of managing the inventory of raw materials.						
		1	2	3	4	5	6	7
11	RAD 4	Blockchain will increase control of managing the inventory of raw materials.						
		1	2	3	4	5	6	7
12	RAD 5	Blockchain technology effectively checks the inventory of raw materials.						
		1	2	3	4	5	6	7
Tech 2 Technological Factors: Compatibility								
13	CB 1	Blockchain technology is compatible with managing the inventory of raw materials.						
		1	2	3	4	5	6	7
14	CB 2	Blockchain technology fits with checking the stock of raw materials.						
		1	2	3	4	5	6	7
15	CB 3	Blockchain technology is compatible with the factory's goals and values related to managing raw materials inventory.						
		1	2	3	4	5	6	7
Tech 3 Technological Factors: Complexity								
16	CX 1	Blockchain technology is hard to understand.						
		1	2	3	4	5	6	7
17	CX 2	The skills necessary for using blockchain technology are too complicated for our staff.						
		1	2	3	4	5	6	7
18	CX 3	Blockchain technology is difficult to use in raw material inventory management.						
		1	2	3	4	5	6	7
19	CX 4	The tools of blockchain technology are not easy to use.						
		1	2	3	4	5	6	7

End of Block: Technological Factors

		Strongly disagree	disagree	Somewhat disagree	Neutral	Somewhat agree	agree	Strongly agree
N.	ID	Item						
Org 1 Organizational Factors:Top Management Support								
20	TMS 1	Our top management provides sufficient information and courses when applying new technology such as blockchain.						
		1	2	3	4	5	6	7
21	TMS 2	Our top management provides strong leadership when it comes to technology adoption, such as blockchain.						
		1	2	3	4	5	6	7
22	TMS 3	Our top management considers the adoption of blockchain technology in raw material inventory management as strategically important.						
		1	2	3	4	5	6	7
23	TMS 4	Top management supports the implementation of new technologies in the factory.						
		1	2	3	4	5	6	7
Org 2 Organizational Factors: Organization Readiness								
24	RED 1	Our factory is flexible in allocating adequate IT infrastructure resources necessary to adopt blockchain technology in raw material inventory management.						
		1	2	3	4	5	6	7
25	RED 2	Our factory is flexible in allocating adequate financial resources necessary to adopt blockchain technology in raw material inventory management.						
		1	2	3	4	5	6	7
26	RED 3	Our factory understands how blockchain technology can support raw material inventory management.						
		1	2	3	4	5	6	7
27	RED 4	Our factory is flexible in allocating adequate human resources necessary to adopt blockchain technology in raw material inventory management.						
		1	2	3	4	5	6	7

End of Block: Organizational Factors

		Strongly disagree	disagree	Somewhat disagree	Neutral	Somewhat agree	agree	Strongly agree
N.	ID	Item						
Enviro 1	Environmental Factors: Current regulations in manufacturing							
28	CR 1	The regulations and laws in Saudi Arabia protect the use of blockchain.						
		1	2	3	4	5	6	7
29	CR 2	The regulations and laws in Saudi Arabia are sufficient to protect the use of the Blockchain.						
		1	2	3	4	5	6	7
30	CR 3	The regulations and laws in Saudi Arabia support blockchain issues.						
		1	2	3	4	5	6	7
Enviro 2	Environmental Factors: Government Support							
31	GS 1	The Saudi Ministry of Industry offers the facilities to promote blockchain adoption.						
		1	2	3	4	5	6	7
32	GS 2	The Saudi Ministry of Industry is Willing to adopt blockchain.						
		1	2	3	4	5	6	7
33	GS 3	The Saudi Ministry of Industry provides economic incentives to encourage blockchain adoption.						
		1	2	3	4	5	6	7
Behavioral intention (BI)								
34	BI 1	Our factory intends to adopt blockchain technology for managing the inventory actively in the future.						
		1	2	3	4	5	6	7
35	BI 2	Our factory expects to use Blockchain technology for managing the inventory of raw materials in the near future.						
		1	2	3	4	5	6	7
36	BI 3	Our factory is likely to use blockchain technology in managing the inventory of raw materials on a regular basis in the near future.						
		1	2	3	4	5	6	7

End of Block: Environmental Factors and Blockchain Adoption Intent

Q 37 In your opinion, what are the potential applications of blockchain-based manufacturing in the future?

- Quality control and regulatory. (1)
- Managing financial transactions for manufacturing businesses. (7)
- Production task management, such as scheduling. (5)
- Managing the distribution of finished goods. (4)
- Other. (8)

End of Block: Blockchain application

A.3 Questionnaire - Arabic Version

إطار شامل لتبني تقنية البلوك تشين في قطاع التصنيع السعودي

معلومات البحث

عزيزي المشارك ،

اسمي محاسن عبد رب الحسن السلمي ، وأنا طالبة دكتوراه في جامعة التكنولوجيا في سيدني. مشرفي هو البروفيسور فاروق حسين.

الغرض من هذا المسح البحثي / الإلكتروني هو تحديد العوامل المحفزة لاستخدام تقنية البلوك تشين في إدارة مخزون المواد الخام في قطاع التصنيع في المملكة العربية السعودية.

تهدف الحكومة السعودية إلى تحويل قطاع الصناعة إلى قوة صناعية رائدة مع رؤية 2030. نحن نؤمن بأهمية برنامج تطوير الصناعة الوطنية لتحويل المملكة العربية السعودية إلى قوة صناعية رائدة ومنصة لوجستية عالمية واكتساب فهم مستنير لمزايا وتحديات اعتماد تقنية البلوك تشين في إدارة مخزون المواد الخام في التصنيع. من خلال معرفة آراء المديرين و / أو متخذي القرار من هذه الدراسة.

إذا كانت لديك أسئلة أو مخاوف بشأن البحث وتعتقد أن المشرف على البحث أو الباحث يمكنهم مساعدتك في ذلك ، فلا تتردد في الاتصال بـ:
الباحث عبر البريد الإلكتروني
mahasen.alsolmy@student.uts.edu.au أو
المشرف: الأستاذ فاروق حسين عبر البريد الإلكتروني:
farookh.hussain@uts.edu.au

إذا كنت ترغب في التحدث إلى شخص غير مرتبط بالبحث: يمكنك الاتصال بمسؤول أخلاقيات البحث:
Research.ethics@uts.edu.au.
رقم المشروع ETH22-7537

End of Block: Information Sheet

نموذج الموافقة

المشاركة في هذه الدراسة طوعية. الأمر متروك لك تمامًا سواء قررت المشاركة أم لا. إذا اخترت المشاركة ، فسأدعوك لإكمال الإستطلاع عبر الإنترنت. لن يستغرق الأمر أكثر من 7 دقائق من وقتك. يمكنك تغيير رأيك في أي وقت والتوقف عن استكمال الاستبيانات دون عواقب.

ستكون عملية جمع البيانات سرية للغاية ، وستظل هوية المشاركين مجهولة. سيتم إستخدام البيانات لهذا البحث فقط ، وستقتصر النتائج على المنشورات الأكاديمية فقط.

هل ترغب في المشاركة؟

- ○ موافق
- ○ غير موافق

Skip To: End of Survey If No is selected

End of Block: Consent

شرح مختصر لتقنية البلوكشين

تعتبر تقنية البلوك تشين من أهم التقنيات التي ظهرت في الآونة الأخيرة وأحدثت ثورة كبيرة في السنوات الأخيرة، ويرجع سبب هذا الانتشار إلى المزايا العديدة التي تتمتع بها تقنية البلوك تشين، والتي تساهم في حفظ حقوق الملكية وتوثيق المعلومات. بما في ذلك تخزين المعلومات ومعالجتها.

كما أن أحد أسباب انتشار تقنية البلوك تشين على نطاق واسع هو انتشار التطبيقات والاستخدامات التي تعتمد على "تقنية البلوك تشين" كتقنية أساسية لتشغيلها، ولعل أهم استخدامات تقنية البلوك تشين هو إدارة مخزون المواد الخام في قطاع التصنيع.

تستخدم إدارة مخزون المواد الخام تقنية البلوك تشين لضمان وجود مخزون كافٍ، من المواد المباشرة وغير المباشرة، للحفاظ على استمرار الإنتاج.

تسمح تقنية البلوك تشين للمستودعات والمصنعين والموردين ومواقع الإنتاج ومراكز التوزيع وشركاء التجزئة بالاتصال من خلال سجل دائم لكل معاملة، ثم يتم تخزين جميع السجلات وإتاحتها للجميع داخل الشبكة.

End of Block: A brief explanation of blockchain technology

معلومات ديموغرافيه

Q1 ما عمرك ؟
- ١٨ الى ٢٤ سنة
- ٢٥ الى ٣٤ سنة
- ٣٥ الى ٤٥ سنة
- ٤٦ الى ٦٠ سنة
- ٦٠ سنة واعلى

Q2 ماهو المستوى التعليمي ؟
- التعليم الثانوي واقل
- دبلوم
- بكالوريوس
- شهادة عليا (ماجستير - دكتوراه)

Q3 في اي المدن الصناعية السعودية تعمل ؟
- المدينة الصناعية الوسطى
- المدينة الصناعية الغربية
- المدينة الصناعية الشرقية
- المدينة الصناعية الجنوبية
- المدينة الصناعية الشمالية

Q4 ماهي وظيفتك الحالية ؟
- مدير معلومات تنفيذي CIO
- مدير قسم تقنية معلومات
- مسؤول تكنولوجيا المعلومات
- مهندس حاسوب
- مستشار تكنولوجيا المعلومات
- فني تكنولوجيا المعلومات
- موظفو تكنولوجيا المعلومات الآخرون

Q5 ماهي سنوات الخبرة في العمل ؟
- اقل من ٥ سنوات
- من ٥ الى ٩ سنوات
- من ١٠ الى ١٥ سنه
- اكثر من ١٥ سنه

Q6 ماهو عدد الموظفين في المصنع ؟
- أقل من 100
- 100-200
- أكثر من 200

Q7 ما هو مستوى معرفتك بتقنية البلوك تشين؟
- معرفة متقدمة
- معرفة متوسطة
- معرفة مبتدئة

N.	ID	لا أوافق بشدة	لا أوافق	لا أوافق الى حد ما	محايد	أوافق الى حد ما	أوافق	أوافق بشدة
	العناصر							
أول العوامل التكنولوجية هي مزايا تقنية البلوك تشين.								
8	RAD 1	تعمل تقنية البلوكشين على تسريع عملية إدارة مخزون المواد الخام.						
		1	2	3	4	5	6	7
9	RAD 2	تقنية البلوكشين ستسهل عملية إدارة مخزون المواد الخام.						
		1	2	3	4	5	6	7
10	RAD 3	تعمل تقنية البلوكشين على زيادة إنتاجية إدارة مخزون المواد الخام.						
		1	2	3	4	5	6	7
11	RAD 4	ستعمل تقنية البلوكشين على زيادة التحكم في إدارة مخزون المواد الخام.						
		1	2	3	4	5	6	7
12	RAD 5	تقوم تقنية البلوكتشين بفحص مخزون المواد الخام بشكل فعال.						
		1	2	3	4	5	6	7
ثاني العوامل التكنولوجية هي التوافق								
13	CB 1	تتوافق تقنية البلوكتشين مع إدارة مخزون المواد الخام.						
		1	2	3	4	5	6	7
14	CB 2	تتناسب تقنية البلوكتشين مع فحص مخزون المواد الخام.						
		1	2	3	4	5	6	7
15	CB 3	تتوافق تقنية البلوكتشين مع أهداف المصنع وقيمه المتعلقة بإدارة مخزون المواد الخام.						
		1	2	3	4	5	6	7
ثالث العوامل التكنولوجية هي التعقيد								
16	CX 1	تكنولوجيا البلوكتشين صعبة الفهم.						
		1	2	3	4	5	6	7
17	CX 2	المهارات اللازمة لاستخدام تقنية البلوكتشين معقدة للغاية بالنسبة لموظفينا.						
		1	2	3	4	5	6	7
18	CX 3	صعوبة استغلال فوائد تقنية البلوكتشين لإدارة مخزون المواد الخام						
		1	2	3	4	5	6	7
19	CX 4	أدوات تقنية البلوكتشين ليست سهلة الاستخدام						
		1	2	3	4	5	6	7

End of Block: Technological Factors

N.	ID	العناصر	لا أوافق بشدة	لا أوافق	لا أوافق الى حد ما	محايد	أوافق الى حد ما	أوافق	أوافق بشدة
أول العوامل التنظيمية هي دعم الإدارة العليا في المصنع									
20	TMS 1	توفر إدارتنا العليا المعلومات والدورات الكافية عند تطبيق التكنولوجيا الجديدة مثل تقنية البلوكشين.	1	2	3	4	5	6	7
21	TMS 2	توفر إدارتنا العليا قيادة قوية عندما يتعلق الأمر بتبني التكنولوجيا، مثل تقنية البلوكشين	1	2	3	4	5	6	7
22	TMS 3	تعتبر إدارتنا العليا أن اعتماد تقنية البلوكشين في إدارة مخزون المواد الخام أمر ذو أهمية استراتيجية.	1	2	3	4	5	6	7
23	TMS 4	تدعم الإدارة العليا تطبيق التقنيات الجديدة في المصنع.	1	2	3	4	5	6	7
ثاني العوامل التنظيمية هي جاهزية المنظمة									
24	RED 1	يتمتع مصنعنا بالمرونة في تخصيص موارد البنية التحتية الكافية لتكنولوجيا المعلومات اللازمة لاعتماد تقنية البلوكشين في إدارة مخزون المواد الخام.	1	2	3	4	5	6	7
25	RED 2	يتمتع مصنعنا بالمرونة في تخصيص الموارد المالية الكافية اللازمة لاعتماد تقنية البلوكشين في إدارة مخزون المواد الخام.	1	2	3	4	5	6	7
26	RED 3	يدرك مصنعنا كيف يمكن لتقنية البلوكشين أن تدعم إدارة مخزون المواد الخام.	1	2	3	4	5	6	7
27	RED 4	يتمتع مصنعنا بالمرونة في تخصيص الموارد البشرية الكافية اللازمة لاعتماد تقنية البلوكشين في إدارة مخزون المواد الخام.	1	2	3	4	5	6	7

End of Block: Organizational Factors

N.	ID	العناصر	لا أوافق بشدة	لا أوافق	لا أوافق الى حد ما	محايد	أوافق الى حد ما	أوافق	أوافق بشدة
أول العوامل البيئية هي اللوائح الحالية في التصنيع									
28	CR 1	الأنظمة والقوانين في المملكة العربية السعودية تحمي استخدام تقنية البلوكتشين.	1	2	3	4	5	6	7
29	CR 2	اللوائح والقوانين في المملكة العربية السعودية كافية لحماية استخدام تقنية البلوكتشين.	1	2	3	4	5	6	7
30	CR 3	تدعم اللوائح والقوانين في المملكة العربية السعودية قضايا تقنية البلوكتشين.	1	2	3	4	5	6	7
ثاني العوامل البيئية هي الدعم الحكومي									
31	GS 1	وزارة الصناعة السعودية تقدم التسهيلات لتعزيز اعتماد تقنية البلوكتشين.	1	2	3	4	5	6	7
32	GS 2	وزارة الصناعة السعودية مستعدة لاعتماد البلوكتشين.	1	2	3	4	5	6	7
33	GS 3	وزارة الصناعة السعودية تقدم حوافز اقتصادية لتشجيع اعتماد تقنية البلوكتشين.	1	2	3	4	5	6	7
النية السلوكية									
34	BI 1	يعتزم مصنعنا اعتماد تقنية البلوك تشين لإدارة المخزون بشكل نشط في المستقبل	1	2	3	4	5	6	7
35	BI 2	يتوقع مصنعنا استخدام تقنية البلوك تشين لإدارة مخزون المواد الخام في المستقبل القريب	1	2	3	4	5	6	7
36	BI 3	من المرجح أن يستخدم مصنعنا تقنية البلوك تشين في إدارة مخزون المواد الخام بشكل منتظم في المستقبل القريب.	1	2	3	4	5	6	7

End of Block: Environmental Factors and Blockchain Adoption Intent

Q 37 في رأيك ما هي التطبيقات أو الخدمات التي تساعد في استخدام تقنية البلوكشين في قطاع التصنيع السعودي؟

- o مراقبة الجودة والتنظيم.
- o إدارة المعاملات المالية لشركات التصنيع.
- o إدارة مهام الإنتاج، مثل الجدولة.
- o إدارة توزيع السلع النهائية.
- o أخرى.

End of Block: Blockchain application

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