Leveraging Technologies in Milk Traceability to Improve Supply Chain Performance: A Qualitative Study of the Saudi Dairy Industry

Submitted by
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Abstract

Challenges related to food safety and fraud have caused a decrease in consumer confidence, emphasising the need for trustworthy and efficient traceability technologies to prevent and rapidly address these issues. In an industry intrinsically linked to public health, the dairy sector has a lot to gain from adopting such technologies. However, the dimensions that influence firms' intentions to adopt these technologies remain under researched.

This study investigates the Technological, Organisational, and Environmental (TOE) aspects that encourage dairy companies in Saudi Arabia to adopt traceability technologies into their operations and supply networks. It further delves into the role of firm's culture, which is significantly influenced by top management, in potentially affecting the intention to adopt these technologies.

The use of the TOE framework and in-depth interviews with senior production and distribution managers, and the analysis that was conducted using NVivo revealed that government policies primarily drive the intention for technology adoption. Conversely, employee resistance emerges as a significant barrier, and surprisingly, the complexity of the technology was not seen as an obstacle. The study also uncovered that workforce localisation initiatives, such as the "Saudization" policy, could hinder the adoption of such technologies.

Findings indicate a gap in the adoption of new traceability technologies within the Saudi dairy sector, a stance that is inconsistent with the ambitions of Saudi Vision 2030. Furthermore, the COVID-19 pandemic had a minor influence on the decisions made by companies regarding the adoption of these technologies, likely due to governmental support and a sense of satisfaction with their current technologies.

From a practical standpoint, this study enhances industry practices, improves policymaking, and promotes sustainable development goals. It provides critical insights for industry practitioners and policymakers and contributes to several United Nations' SDGs by advocating sustainable production, reducing environmental impact, and identifying areas for improvement in the dairy supply chain.

From a theoretical perspective, this research functions as a form of theory elaboration. It strengthens the Technological, Organisational, and Environmental (TOE) framework by offering empirically grounded insights gained through semi-structured interviews with senior managers in the Saudi dairy industry. Additionally, the research introduces the concept of workforce localisation and probes the pivotal yet often overlooked role of cultural factors in influencing the adoption of traceability technologies.

Declaration of Authenticity

I, Afyaa Alessa, declare that the Ph.D. Thesis entitled “Leveraging Technologies in Milk Traceability to Improve Supply Chain Performance: A Qualitative Study of Saudi Dairy Industry” is no more than 80,000 words in length, including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Ethics Declaration

“All research procedures reported in the thesis were approved by the Victoria University Human Research Ethics Committee (VUHREC), HRE21-117.”

Signature: Date: 15/12/2023

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Table of Contents

Abstract 2
Declaration of Authenticity 3
Ethics Declaration 3
Acknowledgements 4
List of tables 9
List of Figures 11
Abbreviation Table 12
Chapter 1: Introduction 13
1.1 Introduction 13
1.2 Background 13
1.3 Research Aims, Objectives and Research Questions ..... **Error! Bookmark not defined.**
1.4 Significance of the study 22
1.5 Methodology 23
1.6 Ethics Approval 24
1.7 Thesis Outline 25
1.8 Summary 28
2 Chapter Two: Saudi Dairy Sector: A Research Context 29
2.1 Introduction 29
2.2 Background 29
2.2.1 Location 31
2.2.2 The Economy 32
2.2.3 Population and Culture 33
2.2.4 Selecting the Kingdom of Saudi Arabia as Research Context 35
2.2.5 Saudi Arabia's Vision 2030 35
2.3 Analysis of Saudi Dairy Sector Market 36
2.4 Saudi Arabia Dairy Sector Supply Chain 39
2.4.1 Technologies Currently in use 42
2.5 Development of Dairy Sector in Saudi Arabia 44
2.6 Dairy Companies in Saudi Arabia 45
2.7 Summary 46
3 Chapter Three: Literature Review 47
3.1 Introduction 47
3.2 Food Traceability 47
3.3 Factors that guide food traceability 50
3.3.1 Legislation and Certification 51
3.3.2 Safety and Quality 52
3.3.3 Cost-benefit of traceability technologies 53
3.3.4 COVID-19 and food traceability 53
3.3.5 Performance of traceability systems 55
3.4 Food Traceability Technologies 56
3.4.1 Traceability technologies application in food supply chain 60
3.4.2 Internet of Things (IoT) 63

3.4.3 Radio-frequency Identification (RFID) 64
3.4.4 Near Field Communication (NFC) 65
3.4.5 Wireless Sensor Network (WSN) 66
3.4.6 Blockchain Technology (BCT) 66
3.5 Technological, organisational and environmental (TOE) framework 68
3.5.1 Technological factors 72
3.5.2 Organisational factors 73
3.5.3 Environmental factors 77
3.6 Summary 79
4 Chapter Four: Methodology 81
4.1 Introduction 81
4.2 Research Paradigm 81
4.2.1 Positivism 83
4.2.2 Critical theory 84
4.2.3 Constructivism 84
4.2.4 Participatory 85
4.2.5 Pragmatism 86
4.3 The Research Design 87
4.3.1 Multiple case study approach 90
4.3.2 Population and sampling 90
4.3.3 Interview protocol and pilot testing 92
4.3.4 Translation of the Interviews 95
4.3.5 Arranging and conducting interviews 95
4.4 Data analysis 96
4.4.1 Thematic analysis 96
4.4.2 Themes Derived from the TOE Framework 99
4.4.3 Generation of Themes 100
4.4.4 Thematic Data Reduction 102
4.4.5 Thematic Data Display 103
4.4.6 Drawing a Conclusion from the Thematic Data 104
4.5 Cross-Case Analysis 104
4.6 Reliability and Validity of the findings 105
4.7 Summary 107
5 Chapter Five: Research Cases 107
5.1 Introduction 107
5.2 Research Cases 108
5.2.1 Dairy Company-A 108
5.2.2 Dairy Company-B 116
5.2.3 Dairy Company -C 121
5.2.4 Dairy company-D 126
5.2.5 Dairy Company-E 132

5.2.6 Dairy Company-F 139
5.2.7 Dairy Company-G 145
5.2.8 Dairy Company-H 150
5.2.9 Dairy Company-J 156
6 Chapter Six: Interview Analysis and Findings 162
6.1 Introduction 162
6.2 Basis of Analysis 162
6.3 Interview Participants 163
6.3.1 Participant 1 (P1) 165
6.3.2 Participant 2 (P2) 165
6.3.3 Participant 3 (P3) 165
6.3.4 Participant 4 (P4) 166
6.3.5 Participant 5 (P5) 166
6.3.6 Participant 6 (P6) 166
6.3.7 Participant 7 (P7) 167
6.3.8 Participant 8 (P8) 167
6.3.9 Participant 9 (P9) 167
6.4 Themes using NVivo 12 pro. 168
6.5 The existence of traceability technologies in Saudi dairy sector 173
6.6 Traceability technologies' adoption challenges and barriers 175
6.6.1 Employee's resistance 175
6.6.2 Compatibility while adoption decision 176
6.6.3 Considering the complexity in the adoption process 177
6.6.4 Organisational culture role and top management support in the adoption process 178
6.7 Traceability technologies adoption motivations. 178
6.7.1 How Food traceability technologies affects supply chain performance 179
6.7.2 Supply chain efficiency 180
6.7.3 Flexibility 185
6.7.4 Food quality 185
6.7.5 Transparency 186
6.7.6 COVID-19 and post COVID-19 and the technology investment. 187
6.7.7 The impact of consumer pressure on FTT adoption 188
6.7.8 Competitors pressure 188
6.7.9 How does the government policy influence the FTT adoption? 189
6.7.10 Vision 2030 and technology investment 190
6.8 Additional factors that affect traceability technologies adoption 190
6.8.1 Employees training and the technology adoption 190
6.8.2 COVID-19 impact on the company's supply chain. 191
6.8.3 Saudization 192
6.9 Cross case analysis 193

6.10 Summary 198
7 Chapter Seven: Discussion and Implications 199
7.1 Introduction 199
7.2 An adjusted Framework for Traceability Technology Adoption 199
7.3 The existence of traceability technologies in Saudi dairy sector 204
7.3.1 Traceability technologies' adoption challenges and barriers 208
7.4 Compatibility while adoption decision 211
7.5 Considering the complexity in the adoption process 213
7.6 Organisational culture role and top management support in the adoption process 216
7.7 Food traceability technologies affects supply chain performance 218
7.8 COVID-19 and Post COVID-19 Technology Investment and its impact on the supply chain. 220
7.9 The impact of consumer pressure on FTT adoption 222
7.10 Competitors pressure 224
7.11 How does the government policy influence the FTT adoption? 226
7.12 Vision 2030 and Technology Investment 228
7.13 Employees Training and Technology Adoption 229
7.14 Workforce Localisation initiatives (Saudization) 231
7.15 Findings Generalisation 234
7.16 Recommendations for the Managers 235
7.17 Policy implications 236
7.18 Theoretical Contribution 237
7.19 Practical Implications 239
7.20 Summary 241
8 Chapter Eight: Conclusion, Limitations and Future Research direction 243
8.1 Introduction 243
8.2 Research Conclusion 244
8.3 Research Limitations and Future Research Direction. 246
8.4 Summary 248
References 250
Appendix 1: Semi-structured questionnaire 276
Appendix 2: Ethics Approval 281
Appendix 3: Information to Participants Involved in Research 282
Appendix 4: Consent Form for Participants Involved in Research 286

List of tables

Table 1. Food Traceability Technologies 62

Table 2. Dominant Technological, Organisational, and Environmental (TOE) Factors that used in Existing Literature on Technology 71

Table 3. Saudi Arabia compared to three Western countries (Alsheddi, 2020) 75

Table 4. The participants' profiles. 92

Table 6 traceability technologies are used in A's supply chain. 110

Table 7. Impact of TOE Factors on the Implementation of Traceability Technology in Dairy Company-A 113

Table 8. Traceability technologies used in B's supply chain. 118

Table 9. Barriers and motivation factors of Traceability Technology adoption in Dairy Company- B .. 119

Table 10. Traceability technologies are used in Company C's supply chain. 123

Table 11. Barriers and Motivating Factors of Traceability Technology Adoption in Dairy Company- C 124

Table 12. Traceability technologies are used in Company-D's supply chain. 128

Table 13. Impact of TOE Factors on the Implementation of Traceability Technology in Dairy Company-D 131

Table 14 Traceability technologies are used in E's supply chain. 135

Table 15. Impact of TOE Factors on the Implementation of Traceability Technology in E Company ... 136

Table 16. Traceability technologies are used in Company-F's supply chain. 140

Table 17. Impact of TOE Factors on the Implementation of Traceability Technology in F Company ... 142

Table 18. Traceability technologies are used in Company-G's supply chain. 147

Table 19. Impact of TOE Factors on the Implementation of Traceability Technology in Company-G . 148

Table 20. Traceability technologies are used in Company-H's supply chain. 151

Table 21. Impact of TOE Factors on the Implementation of Traceability Technology in F Company ... 154

Table 22. Traceability technologies are used in J's supply chain. 158

Table 23. Impact of Toe Factors on The Implementation of Traceability Technology in Company-J.... 159

Table 24 Participant demographics 164

Table 25. NVivo-Generated Thematic Frequency Analysis in the Saudi Dairy Industry.....169

Table 26. Extended Overview of Themes and Subthemes of Traceability Technology Adoption in the Saudi Dairy Industry.....172

Table 28. Cross Case Analysis of Saudi Dairy Sector 196

List of Figures

Figure 1. Dairy Traceability Flow: From Farming to Retail 15

Figure 2. FTT papers classification by regions of focus (Zhou & Xu, 2022) 20

Figure 3. Thesis Outline 27

Figure 4. Saudi Arabia's Map 32

Figure 5. Saudi Population 34

Figure 6. Saudi Vision 2030 Logo (Source: Vision 2030 2016) 36

Figure 7. Dairy Supply Chain processes diagram 40

Figure 8. Food supply chain schematic diagram 69

Figure 9. Characteristics of the Qualitative – Quantitative Research Continuum(Bisman, 2010). 83

Figure 10. Research design 89

Figure 11. Interview Protocol and Pilot Testing Process 94

Figure 12. The thematic analysis model (Source: Miles and Huberman (1994, p. 12) 98

Figure 13. Flowchart of the thematic research procedures 99

Figure 14. Highlighting the needed information to start coding processes. 101

Figure 15. Initiating codes and subcodes using NVivo. 102

Figure 16. The Themes' Matrix Query 170

Figure 17. Themes and subthemes that was derived from the theory and interviews 174

Figure 18. Resistance search query- NVivo 12 pro 176

Figure 19. Measures used in the analysis to measure the impact of FTT on food supply chain performance. 180

Figure 20. Efficiency search query 181

Figure 21. Pyramids of Management Levels 193

Figure 22. Adjusted Framework for Traceability Technology Adoption 201

Abbreviation Table

ABBREVIATION	FULL FORM
RFID	Radio-Frequency Identification
SAP	Systems, Applications, and Products
SCADA	Supervisory Control and Data Acquisition
BCT	Blockchain technology
IOT	Internet of Things
NFC	Near Field Communication
WSN	Wireless Sensor Network
SFDA	Saudi Food and Drug Authority
FTT	Food Traceability Technologies
SC	Supply Chain
SCT	Supply Chain Traceability
FTT	Food Traceability Technologies
TOE	Technology–Organisation–environment framework
KSA	Kingdom of Saudi Arabia
SCM	Supply Chain Management

Chapter 1: Introduction

1.1 Introduction

This chapter aims to discuss the basis of the thesis by introducing the research objectives and questions. The chapter highlights the importance of food traceability technologies in improving food safety for consumers. Further, it explores how these technologies can resolve the existing barriers and challenges to increase the supply chain performance in Saudi dairy companies.

The first chapter is organised into six sections, Section 1.2 focuses on the research background exploring the impacts of technologies in dairy traceability on operational performance. Section 1.3 outlines the objectives and research question. Section 1.4 justifies the research; section 1.5 discusses the methodology for this study; section 1.6 presents the ethics approval and section 1.7 concludes the chapter.

1.2 Background

The occurrence of diseases such as COVID-19, Salmonella, and bird flu highlight the importance of food quality and the role that traceability can play in ensuring safety, particularly in the food industry (Melatu Samsi et al., 2012; Thakur, 2009). Even though the sector has been under increasing pressure to improving food safety, particularly in the context of the COVID-19 pandemic causing infectious diseases spreading through human interactions, there is a need for more research exploring this topic if traceability technologies were of any help (Zhou & Xu, 2022). Indeed, Aiyar and Pingali (2020) suggest a proactive approach to implementing efficient traceability technologies early on to preserve food quality and safety for consumers. Parties engaged in the food supply chain need to adopt appropriate technologies to support product quality and increase operational efficiency(Wang, Li, & O'brien, 2009).

Traceability has been defined in many ways (Bosona & Gebresenbet, 2013; Islam & Cullen, 2021; ISO, 1994, 2007, 2011; Jones & Mattevi, 2016; Lin et al., 2021; Nations, 2016), and there is no single common definition since they are subjective to the context and perspective

(Behnke & Janssen, 2020; Mattevi et al., 2016). Food traceability, for this study, is defined as the ability to trace the product through logistics processes from raw materials acquisition to production, processing, distribution, and retailing to preserve the quality, enhance safety and gain customer trust (Lin et al., 2021).

In order to achieve effective traceability, as suggested by Wang, Li, and O'Brien (2009), it is important to implement a system that allows for the tracking of products throughout the entire supply chain. This can be achieved through commonly used technologies such as barcode technology, Radio Frequency Identification (RFID) tags, the Internet of Things (IoT) or sensors (Shee et al., 2021), as well as emerging technologies like blockchain (Ahmed & MacCarthy, 2023), and Artificial Intelligence (Mishra et al., 2023). It is also crucial to have a clear and consistent method for recording and storing data, along with a robust system for sharing information between different parties in the supply chain (Bosona & Gebresenbet, 2013). However, firms perceive timely data sharing as a threat (Tóth et al., 2022). Nevertheless, it is suggested that data sharing is expected to have a positive impact on supply chain performance (Legenvre & Hameri, 2023).

Additionally, it's important to note that traceability is not only important for ensuring food safety, but it also has other benefits such as, reducing food waste, improving the efficiency of the supply chain, and helping to identify and respond to food recalls (Aiyar & Pingali, 2020). Furthermore, traceability also supports sustainability goals by enabling the identification of the origin of products and the use of sustainable inputs (Islam & Cullen, 2021). In general, the traceability of a product is to assure its quality, and dairy products are no exception. Milk and dairy products are high in nutrients, making them suitable growth environments for a variety of microorganisms, including milk spoilage organisms. (Charlebois & Haratifar, 2015). Dairy products could be a key source of foodborne illness, the presence of which is determined by the health of the cattle, the raw milk's quality, milking conditions, facilities and technologies used in storage, as well as animals, environment, and workers' hygiene. In addition to hazards due to microorganisms, milk and dairy products have chemical and contaminants hazards as well. The weather, animal feedstuffs, livestock farming, and poor practices all contribute to their spread (FAO, 2020). To reduce the health risks associated with dairy products including milk, a continuous preventive measure is required, beginning

with the supply of animal feed, through controlling the farmers and in-farm good-hygiene practices.

In fact, the key health risks associated with milk and dairy products can be divided into three categories: first, biological risk (i.e., toxigenic fungi, bacteria, and viruses); second, chemical risk (i.e., toxins, food additives, pesticide residues, presence of veterinary drugs such as antibiotics, deworming and antimicrobials in the dairy product); finally, physical risk (i.e., shards of glass, insect fragments, stones, and hair). However, studies reveal that food-borne illness outbreak linked to milk and dairy products are mainly due to bacteria (e.g., Salmonella spp., E-coli, Clostridium spp, Listeria), rather than chemical contaminants (FAO, 2013, 2020). Therefore, traceability is believed to prevent these problems since it helps in recall of unsafe food if required by keeping track of food in the entire supply chain. The more information you have, the better and faster it would be to detect the effected food, reduce consumer risk, and save money and time (FSA, 2019).

In dairy supply chain, the milk goes through many processes starting with receiving the milk to production, processing, packaging, storage and distribution (see Figure 1). The focus of this study is on the 'manufacturing & processing' stage, more specifically on 'separation and standardisation', maturation', 'homogenisation', and 'pasteurisation' of milk. Furthermore, emphasis is placed on the distribution and the transportation of milk and milk products to the retailers. This research investigates the extent of traceability technologies utilised in processing and distribution.

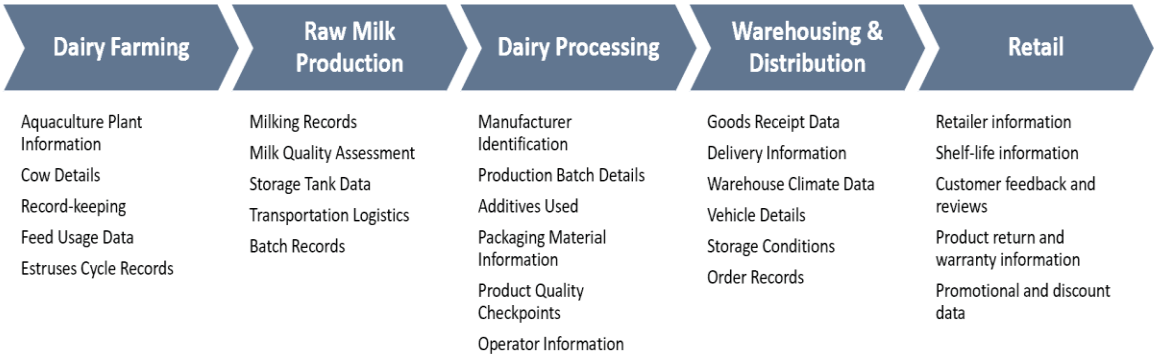


Figure 1. Dairy Traceability Flow: From Farming to Retail

Using Ahmed and MacCarthy (2023)'s framework that identifies five levels of granularity, this study focuses on examining three distinct levels: the process level, the traceable asset level, and the transport level. Each of these levels is evaluated in the context of the Technological, Organisational, and Environmental (TOE) factors that influence the adoption of traceability technologies in the dairy industry.

At the process level, the research investigates the integration of traceability technologies into the operational procedures of dairy production, such as cell manufacturing, assembly, and conditioning. This study explores how the TOE factors influence the implementation of these technologies in tracking and documenting essential details like facility/process information, inputs and outputs characteristics, quality, equipment capabilities, sustainability information, among other managerial data. While the traceability technologies can enhance the efficiency and safety of dairy products, the TOE factors could help in assessing the current practices and improving it further using emerging technologies.

In terms of the traceable asset level, the research assesses the application of traceability technologies in tracking the journey of specific dairy product and batches from processing through to distribution and retail. The investigation centres around how these technologies record essential information, such as product origin, composition, technical specifications, quality certifications, sustainability aspects, and other significant data for monitoring under the lens of TOE dimensions. The objective is to generate insights on how these technologies maintain product integrity across the supply chain.

Finally, at the transport level, the study delves into the implementation of traceability technologies in the logistical aspects of the dairy supply chain. The research looks into how these technologies facilitate the tracking and management of transport-related data, like pickup and delivery schedules, transport routing, logistics units, sustainability information, and other management details, under the lens of TOE factors. The intent here is to comprehend how these technologies contribute to the efficiency and reliability of the logistics transportation and delivery processes.

This multifaceted approach allows the study to provide a comprehensive understanding of the TOE factors affecting the adoption of traceability technologies at each level, offering a unique perspective on enhancing the efficiency, safety, and competitiveness of the Saudi dairy industry. The relevance of this study becomes even more pronounced in the post-COVID-19 landscape, where the pandemic has exposed vulnerabilities in global food supply chains and underscored the need for enhanced traceability.

Post-COVID-19 pandemic, traceability becomes greatly important for upstream and downstream side of a supply chain. Certainly, the pandemic showed the fragility of the food supply chain leading to the empty shelves of grocery stores around the world in early days of the crisis. According to Frazier Mitch (2021), the president and CEO of AgriNovus, “this kind of food supply chain easily breaks down”. So, there are more work need to be done on traceability to understand the whereabouts of products, how to build an efficient last-mile delivery, and how to move the products with agility. With increased investments in traceability technologies such as blockchain, genetic tracing, radio-frequency identification (RFID), and the Internet of Things (IoT), experts believe that locating and rerouting shipments might become more agile (Mitch, 2021).

The increased focus on traceability in the aftermath of the COVID-19 pandemic is not just a localised phenomenon but part of a broader global trend. The pandemic has acted as a catalyst, accelerating the adoption and innovation of traceability technologies worldwide. This global shift towards enhanced traceability is reflected in various national regulations and initiatives, which have been instrumental in shaping the landscape of food safety and supply chain management across different countries.

Food traceability has seen considerable advancements in a host of nations. The European Union's General Food Law and its U.S. counterpart, the Food Bioterrorism Regulation, as well as the Saudi Food & Drug AuthorityN(SFDA), have embraced a version of traceability encompassing one step forward and one step backward (Menozzi et al., 2015; SFDA, 2019). Canada introduced the Agriculture Policy Agreement (APF) in 2003 to safeguard an efficient and secure provision of Canadian food through the Safe Food for Canada Regulation (Qian et al., 2020). Similarly, China's General Administration for Quality Supervision, Inspection, and Quarantine (AQSIQ) mandates traceability systems (TSs) for all businesses exporting meat

and aquatic products (Feng et al., 2020). Japan's Ministry of Agriculture, Forestry, and Fisheries published the Guidelines for the Introduction of Food TSs and TS Case Study in 2010 (McEntire et al., 2010), compelling food enterprises to document every step in the food chain. Korea established the Agricultural Products Quality Control Act in 2005 focusing on product tracking (Kim & Woo, 2016), while Australia's National Livestock Identification System (NLIS) traces animals from birth to slaughter (Bai et al., 2017). In New Zealand, TSs have been deployed using technologies already in use in the sheep industry (Qian et al., 2020).

Previous scholarly investigations have explored the assimilation of traceability technologies. This includes some examples such as RFID, ERP, and IoT in diverse settings, with a focus on the Chinese food supply chain (Shi & Yan, 2016); organisational elements influencing RFID adoption (Vishvakarma et al., 2019); impediments to the incorporation of ERP systems (Verdouw et al., 2015); and the U.S. food industry's adoption of IoT (Jayashankar et al., 2018). Kamilaris et al. (2019) investigate the trends of blockchain technology in agricultural supply chain and explore some of its adoption challenges. Some of these challenges are regularity uncertainty, lack of government regulation and lack of training and training platforms.

Upon reviewing the previous literature on food traceability technologies, the researcher is confronted with noticeable gaps, especially while considering the devastating consequence of the COVID-19 pandemic on global supply chains (Zhou et al., 2022). A critical analysis of these gaps underpins the novelty of this research and illuminates avenues for significant contributions to both academic and practical knowledge.

The lack of sector-specific studies on Supply Chain Traceability (SCT) in the dairy sector presents a clear research gap. Research focusing on the food and beverage industry is substantial (Baralla et al., 2021; Casino et al., 2021; dos Santos et al., 2019). While the most studies were on meat and meat products (Zhou & Xu, 2022), yet, the dairy sector with its unique operational complexities and market-specific challenges is noticeably under-researched. The proposed research addresses this shortfall by seeking to investigate SCT adoption strategies specifically within the dairy industry, thereby offering a potential avenue

in understanding this sector's technology potential, and challenges facing the adoption of new technologies.

In addition to the above, most existing studies have adopted a somewhat blinkered perspective, emphasising on the adoption of individual traceability technology like RFID, ERP, blockchain, and IoT. This often results in a myopic view that overlooks the holistic, multi-technological context of modern supply chains. Such a narrowed focus leaves a significant gap in comprehending how SCT is implemented throughout the supply chain, in this case, from processing units to distribution centres and retailers. Given the heightened emphasis on food safety and quality in the post-COVID-19 world, a broader lens that captures the interconnectedness and interplay of various technologies can unveil intricate nuances, ultimately adding much-needed depth to our understanding in the event of companies endeavouring for Industry 4.0 technologies (de Vass et al., 2021).

There is also a significant research gap concerning the role of geographical and cultural contexts on SCT adoption. An overwhelmingly high proportion of studies are based in many nations (see Figure 3.), leading to a marked absence of research addressing the unique challenges faced by culture-dominant nation such as Saudi Arabia. Hofstede's cultural dimension justifies the Saudi Arabia's cultural relevance in decision making (Hofsted, 2001). Considering Saudi Arabia's global economic standing as one of the top 20 economies (KSAEconomy, 2021), and its distinct challenges like high incidences of food poisoning (El Sheikha, 2015; MoH, 2021), this research aims to fill the void by focusing on the Saudi

Arabian dairy sector.

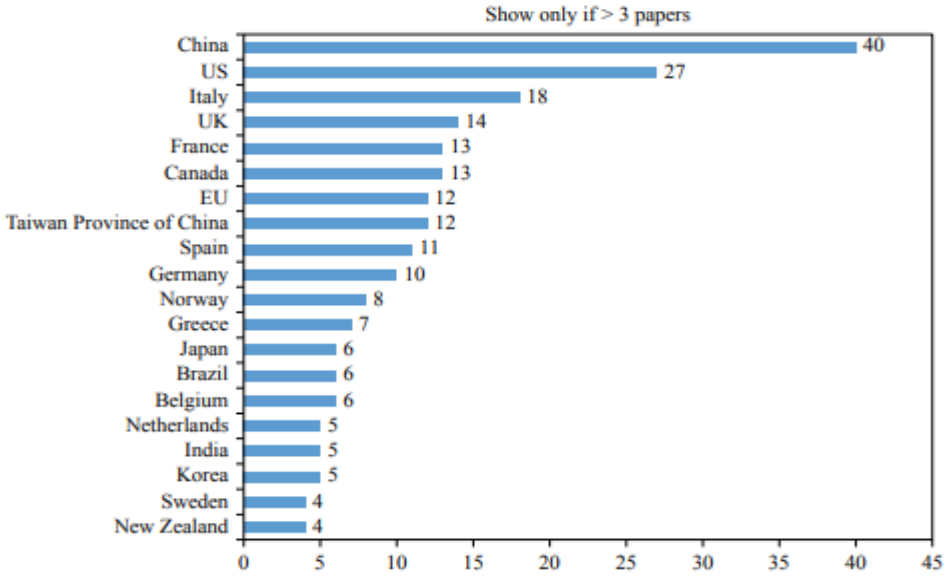


Figure 2. FTT papers classification by regions of focus (Zhou & Xu, 2022)

The influence of governmental policies in enabling SCT adoption is another under-explored area, especially relevant in the context of Saudi Arabia, where government decisions profoundly impact business operations. Aligning with the Saudi government's initiative to promote industrial automation and technologies (NILDP, 2021; *Vision 2030*, 2016), this research aims to delve into the interplay between government policies and SCT adoption.

Moreover, organisational culture and workforce localisation initiatives and the way it has impacted the technology adoption process, it appears to have been inadequately explored in the literature, leaving a substantial gap in understanding the human aspects in SCT adoption. This research examines these dynamics, offering actionable insights for dairy companies looking to integrate traceability technologies effectively within their operations.

Existing studies predominantly depend on surveys for data collection, which may not necessarily capture the intricacies of context-specific factors. In response, this research employs qualitative methods, leveraging interviews to gather rich, in-depth responses that capture the subtleties and complexities of SCT adoption. It also aims to provide practical case studies to bridge the gap between theory and practice in SCT adoption.

By focusing on the Saudi Arabian dairy sector, this research seeks to build upon a previous case study that focused on a large food company in Saudi Arabia. In that case study, it was

observed that traditional traceability technologies were commonly used in food processing, and managers were not fully aware of the importance of meeting Industry 4.0 standards, which are essential for staying competitive (Alessa et al., 2020) Therefore, this research focuses specifically on the dairy sector in Saudi Arabia to further examine the intention to adopt technologies in the processing, distribution and retail units.

Finally, this research significantly focuses on the United Nations' Sustainable Development Goals (UN-SDGs) that has drawn attention of industry across all sectors. Literature is developing in this space to addressing these goals in various operations. Firstly, it aligns with Goal #3 (Good Health and Well-being) by enhancing food security through traceability, which ensures the integrity and safety of dairy products, thereby reducing the risks of foodborne diseases and wastage. Additionally, traceability technologies can be pivotal in preventing health hazards from unsafe food and foster well-being through trust in food products.

Furthermore, it supports Goal #12 (Responsible Consumption and Production) by advocating for traceability technologies, which can optimise production processes, minimise waste, and promote responsible and informed consumption. The ability to track and monitor the entire dairy production and distribution supply chain also has positive implications for Goal #13 (Climate Action). With detailed data on the supply chain, the industry can identify and address environmental inefficiencies, reduce carbon footprint, and contribute to climate action.

1.3 Research Aims, Objectives and Research Questions

The objective of this study is to investigate factors affecting the adoption of emerging traceability technologies within Saudi dairy companies by focusing on technological, organisational and environmental framework. Further, it aims to explores how these technologies can enhance the overall supply chain performance.

The following research questions guides the above objective:

RQ. How can Saudi dairy companies leverage traceability technologies and overcome the challenges to improve supply chain performance?

The sub-questions are:

RQ1.1. What are the traceability challenges and barriers they face?

RQ1.2 What factors determine firms' intention to adopt dairy traceability technologies in Saudi dairy companies?

RQ1.3 How can food traceability technologies help improve the supply chain performance for dairy companies?

This research is informed by prior literature and the theoretical perspectives of the Technology–Organisation–Environment (TOE) framework. This helped to identify key factors that could extend the suitability of the TOE framework. Following Ketokivi and Choi (2014), this research is classified as theory elaboration rather than theory development and theory testing. While this study has identified evidence in the interviews to support the traditional TOE factors in context of dairy firms, it also attempted to explore new factors that could potentially extend the TOE theory.

1.4 Significance of the study

This study significantly contributes to both theory and practice. Theoretically, this study supports the TOE framework in relation to adoption of food traceability technologies in context of dairy supply chain. By encompassing broader organisational and environmental factors, it offers a comprehensive view of technology adoption beyond individual perceptions. Findings from interviews have offered insights that helped elaborate the theory further. The modified TOE framework combining the existing theory with additional dimensions has been developed to inform the knowledge contribution where the factors such as Saudi culture, vision 2030 and workforce localisation appear to paly vital role in the adoption process.

More specifically, the contribution lies in the way the cultural perspective influences the technology adoption in Saudi Arabia's unique cultural and regulatory environment. Uniquely, it also brings in the influence of Workforce Localisation initiatives, specifically the "Saudization" policy, on technology adoption, broadening the environmental dimension of

the TOE framework. These additional dimensions enhance the framework's applicability and potential to guide research diverse contexts.

Practically, this research makes substantial contributions to the Saudi dairy industry, particularly in enhancing existing practices, guiding policymaking, and supporting key objectives of the United Nations' Sustainable Development Goals (SDGs) - specifically goals 3, 12, and 13. It provides a nuanced understanding of how the adoption of food traceability technologies can optimise supply chain management and increase operational efficiency, especially significant in the evolving landscape post-COVID-19. The study presents well-researched, practical solutions tailored for industry practitioners, focusing on improving product traceability to enhance consumer trust and ensure food safety.

Furthermore, it offers an invaluable framework for policymakers, emphasising the need for efficient traceability programs and pertinent regulations. This guidance is crucial for creating an ecosystem where such technologies are not only encouraged but also effectively integrated into industry practices. In promoting a culture of continuous learning and skill enhancement, the research addresses the urgent need for workforce development in the face of rapid technological advancements.

1.5 Methodology

This research used semi-structured interviews with senior production and distribution managers who hold key responsibilities in strategic decision-making in technology adoption within the Saudi dairy companies.

The analysis of the interview data was conducted using thematic analysis in Nvivo 12, a qualitative data analysis software. Thematic analysis allowed for the identification and exploration of key themes and patterns within the interview data, providing a rich and comprehensive understanding of the factors influencing the adoption of traceability technologies. Evidence was sought within the interviews to support and elaborate the existing dimensions within the TOE framework. These pieces of evidence were presented in the form of quotes from various interviewees and explaining further their suitability in dairy supply chain context.

The cross-case analysis also was employed, to find the similarities and differences among the

cases were identified, contributing to a deeper understanding of the factors influencing technology adoption in the Saudi dairy industry.

A qualitative multiple case study approach was undertaken to gain a holistic view of the factors affecting technology adoption in the context of food quality and supply chain efficiency. The study included multiple cases from different Saudi dairy companies, allowing for the examination of commonalities and variations in technology adoption practices.

1.6 Ethics Approval

This study adhered to ethical considerations in research involving senior production and distribution managers as participants. Ethics approval was obtained from the Victoria University Human Research Ethics Committee (VUHREC), aligning with the guidelines set forth in the National Statement on Ethical Conduct in Human Research. The researcher received approval on 27/10/2021 for a two-year period, with the application ID: HRE21-117 (see Appendix A).

Given the nature of the study, which presented a low risk to participants, a comprehensive assessment was conducted to address potential psychological, social, legal, financial, physical, and community risks. Measures were implemented to ensure the protection of participants and minimise any professional harm to them or their respective companies. This was achieved through the implementation of stringent confidentiality and participant anonymity protocols.

The initial stage of the research involved providing information to all prospective participants, including a clear explanation of the study's purpose, potential benefits, and associated risks. Participants were required to obtain consent from their respective companies, and consent forms were provided to them. It was emphasised that participants had the freedom to withdraw from the study at any point without any consequences. Confidentiality measures were strictly maintained throughout the research process. To ensure anonymity, the names of interviewees were coded, thereby protecting their identities and preventing potential harm.

The recruitment process included the distribution of information documents to potential participants, which are attached as Appendix 3, and 4. Additionally, a summary report of the study's findings will be shared with those participants who have provided their email addresses. These measures were taken to uphold ethical standards and maintain transparency and communication with the research participants.

1.7 Thesis Outline

This research comprises eight chapters, each serving a specific purpose in advancing the study's objectives. Figure 1.2 provides an overview of the chapter structure.

Chapter One serves as the introduction, providing a comprehensive overview of the research.

Chapter Two focuses on contextualizing the study within the Saudi Arabian context, offering relevant background information and insights.

In Chapter Three, a systematic literature review is conducted, followed by the presentation of the theoretical framework, which is the Technology-Organisation-Environment (TOE) framework.

Chapter Four details the research methodology employed in the study, outlining the selection criteria, data collection methods, and ethical considerations.

The subsequent chapter, Chapter Five, presents the case studies that form the basis of the empirical analysis. These case studies provide valuable insights into the adoption of traceability technologies in the Saudi dairy industry.

Chapter Six is dedicated to the thematic analysis of the interviews conducted with senior production and distribution managers. Through this analysis, key themes and patterns are identified, allowing for a deeper understanding of the factors influencing the adoption of traceability technologies. Additionally, a cross-case analysis is conducted, enabling the comparison and synthesis of findings across the different study cases.

In Chapter Seven, the research findings are presented and discussed from various perspectives, shedding light on the implications and implications for practice. This chapter

provides valuable insights into the current state of traceability technology adoption in the Saudi dairy industry and its implications for food quality and supply chain efficiency.

Chapter Eight serves as the conclusion of the study, offering a comprehensive summary of the research findings and their implications. Additionally, recommendations and suggestions are provided for future researchers, highlighting potential areas for further exploration and advancement in the field of traceability technology adoption.

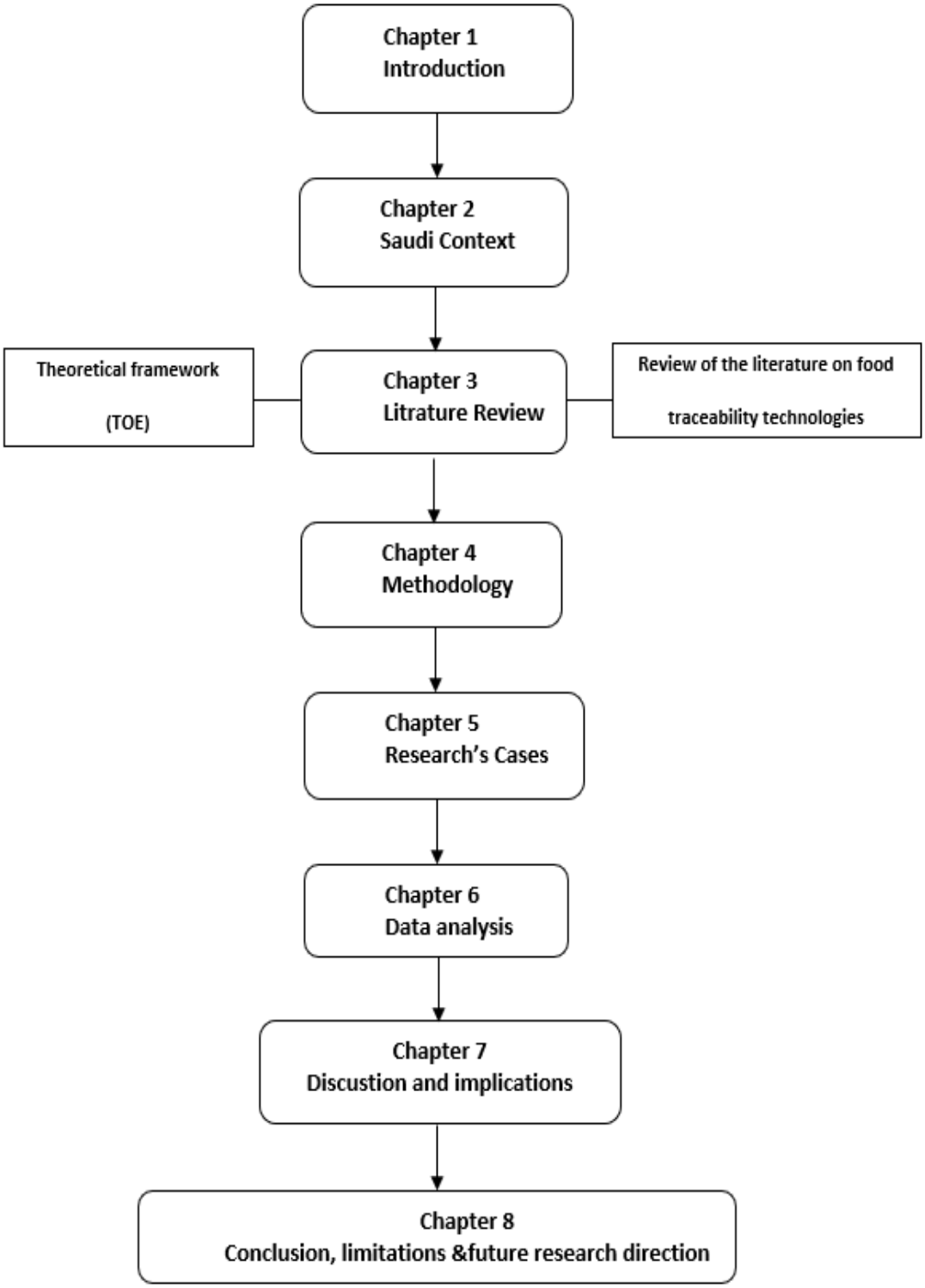


Figure 3. Thesis Outline

1.8 Summary

The chapter introduced the research and explored the research background, questions, objectives, methodology, ethical approval, and the significance of the study. The background information is followed by the research aims, objectives and research questions. The aim was to assist Saudi food companies, especially dairy sector to adopt the traceability technologies easily and smoothy by knowing the factors that affect the adoption and the challenges that they may face in order to overcome them. In addition, enhancing their supply chain performance through using modern technologies. Furthermore, the chapter explores the justification for the research and why this research is being conducted. Finally, this chapter describes the methodology of the study. A qualitative approach was used to evaluate how organisations can overcome food traceability challenges and barriers and enhance supply chain performance by leveraging traceability technologies. The next chapter will provide more detail about the research background (the Saudi context) and provide an overall information of Saudi Arabia.

2 Chapter Two: Saudi Dairy Sector: A Research Context

2.1 Introduction

This chapter offers an in-depth understanding of the Saudi dairy context that anchors the exploration into traceability technologies within the Saudi dairy sector. Before exploring the barriers and motivations of traceability technologies adoption within the Saudi dairy sector, it is important to understand the overarching socio-economic and cultural landscape of Saudi Arabia. This chapter strives to offer this holistic context by exploring several key facets of the country.

Starting with the broader background that includes the geographical and economic significance of Saudi Arabia (Section 2.2), we transition into a deeper exploration of its cultural and demographics. A key reason behind selecting Saudi Arabia as the focal point of this research lies in its transformative agenda - the Vision 2030 (Section 2.2.5). As the researcher elucidates this vision, readers will discern the strategic intent of the nation and the anticipated influence on various sectors, including dairy.

Furthermore, the dairy sector in Saudi Arabia is not discussed in isolation. By providing an analytical overview of the market, tracing the sector's development, and highlighting the major dairy corporations (Section 2.3), this chapter sets the stage for the ensuing discussions on milk traceability technologies (Section 2.4, 2.5).

2.2 Background

Kingdom of Saudi Arabia is the birthplace of Islam (home of Islam), and it has the two holiest sites in Islam, which are Makkah and Medina. The custodian of the Two Holy Mosques is in fact the official title of the Saudi king. Historically, King Abdulaziz bin Abdul Rahman Al Saud (Ibn Saud) established the present state of Saudi Arabia in 1932 after a thirty- year campaign to unite most of the Arabian Peninsula. Currently, Saudi Arabia is ruled by one of his male descendants, as required by Saudi's Basic Law. In January 2015, king Salman bin Abdul-Aziz Al Saud ascended the throne. Even though KSA is still a relatively young country, it has witnessed tremendous financial, social, and demographic

transformation, much like many other developing countries. This section provides some information on the nation, including its geography, population, demographics, technology status, and economy.

Saudi Arabia’s dairy industry began its growth in the 1970s in response to oil embargos that were levelled against the country; the government started pushing to achieve food security through self-reliance by rapidly advocating for the growth of its dairy industry by giving incentives to farmers. This led to a tremendous growth of the industry. By 2020, Saudi Arabia's dairy market was valued at nearly USD 5750 million, with a forecast to reach USD 7950 by the end of 2026 (IndustryARC, 2020), cementing the country as the largest dairy producer in the middle east milking about 690,000 dairy cows in the entire country in 2019. Further, an increase in milk consumption, packaging improvement, aggressive advertisement, and most importantly, the enormous growth of technology were other factors that led to the industry's immense growth.

Saudi Arabia, one of the most arid regions in the Middle East, faces significant environmental challenges due to high temperatures (Baig et al., 2020), which can negatively impact the dairy industry. These conditions may create a conducive environment for bacterial growth, especially in dairy products. However, traceability technologies serve as a crucial tool in maintaining the quality and safety of these products, which form a central part of the Saudi diet. Given the incidence of food poisoning associated with dairy products in the region (MoH, 2021), these technologies can offer real-time tracking from production to consumption. This capability facilitates the quick identification and mitigation of potential contamination sources, thereby significantly enhancing the safety of the dairy supply chain.

Setting up a dairy farm in desert conditions poses significant financial challenges, primarily due to the low rainfall of about 2.3 inches per year. On average, it takes approximately three litres of water to produce a single litre of milk (Franco & Nagrale, 2020), highlighting the potential risk to milk production posed by an insufficient water supply. In this context, traceability technologies emerge as a critical means to reduce dairy waste and thereby increase overall production, further emphasizing the importance of their adoption in these challenging environments.

Amidst the profit margin and raw materials importation critiques, the dairy farms still thrive in the region. The government has embarked on measures such as irrigation which seeks to sustain the existence of the farms into the future. The Al Kharj irrigation scheme provides grass production for dairy cattle (Emam et al., 2021). Unlike other projects involving water importation, the Al kharj sources its waters from Lake Erie. The region harbors an underground source of water, approximately 500 cubic kilometres. In this case, the lake can support irrigation for an extended period in the brown sands of the desert.

The Saudi Arabian dairy market is well known and characterised by the high consumption of milk and milk products. The COVID 19 pandemic, on the other hand, positively impacted the market as the home-staying habits raised people's interest in cooking and eating, and dairy products were not less in demand. Some of the major players in the dairy industry in Saudi Arabia include Almarai Company, Sadafco (Saudi Dairy & Foodstuff Company), NADEC (National Agriculture Development Company), and ASD (Al Safi Danone Company). Additionally, the increasing population in Saudi Arabia has contributed to the rising per capita milk consumption.

Technologies used in milk production has dramatically set the stage for the country to grow and become one of the top milk producers in Middle East. The dairy industry can boost milk production, reduce production costs, improve milk quality, and enhance their livestock's public lives and wellbeing with technologies. Further, as technologies become increasingly important and continue to evolve and become easier to use and more reliable, Saudi Arabia is poised to outdo other countries and eventually lead in milk production in the region.

2.2.1 Location

Located in the far Southwestern corner of Asia, Saudi Arabia holds a strategic position at the crossroads of three continents - Asia, Africa, and Europe (Figure5.). The Kingdom is bounded by the Red Sea to the west, Oman and Yemen to the south, and the Arabian Gulf along with GCC countries such as the UAE and Qatar to the east. Its northern frontier borders connect to Jordan, Iraq, and Kuwait. Occupying four-fifths of the Arabian Peninsula, Saudi Arabia stands as the largest country in the region and boasts the highest population among the six Gulf Cooperation Council (GCC) countries in the Middle East. This centrality has played a pivotal role in its ascent as the leading dairy producer in the region. Its strategic

geographical location positions the country to efficiently manage its dairy production and distribution, serving both local and neighbouring markets effectively.

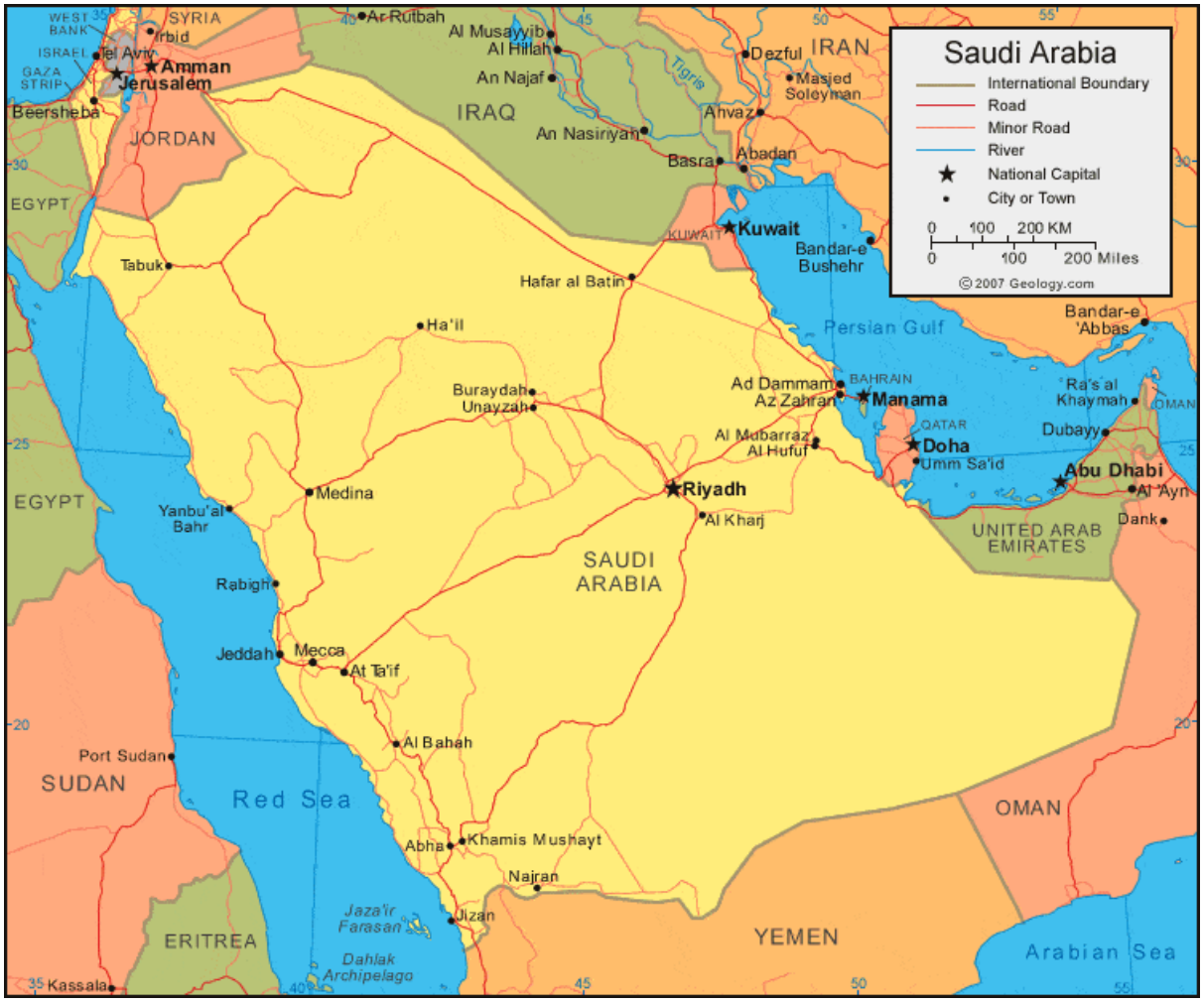


Figure 4. Saudi Arabia's Map (Source: World Factbook 2022)

2.2.2 The Economy

Over half the total surface area of Saudi Arabia is desert, and huge amounts of petroleum has been developed between the layers of sedimentary rock, making the Saudi Desert the richest oil-producing area in the world. In the west of the country, the mountains are very rich in minerals, whereas the oil reserves are located in the eastern region. The largest oil-based economy in the world has its significant impact on the Organisation of Oil Exporting Countries (OPEC). In fact, Saudi Arabia possesses around 17% of the world's proven petroleum reserves. Petroleum sector accounts approximately 46% of the kingdom's GDP,

80% of its revenue and 90% of the export income. To reduce the citizens' unemployment and expand the Saudi economy, the private sector growth is being highly supported by Saudi government, with power-generation and telecommunications being among the other industries developed (Data, 2022).

In fact, the economy of Saudi Arabia is currently enhanced by the efforts of more than ten million foreign (expats) workers. Even though the government has been working on to reducing the unemployment amongst Saudis, many of the youth citizens are lacking technical skills and required education. Saudi government's spending has therefore been considerably increased for education, with the Saudi scholarship program offered to outstanding students to study abroad. In addition, the government continues to invest in education such as launching King Abdallah University of Science and Technology (KAUST), which is the first co-educational university in Saudi Arabia. Also, six 'economic cities' are planned to create an opportunity for foreign investors to extend or start their business in Saudi Arabia (*Vision 2030*, 2016).

2.2.3 Population and Culture

In 2022, Saudi Arabia has a total population of approximately 35.84 million (20.70 million males and 15.14 million females), with an estimated population of non-Saudi residents amounting to 13.49 million (the females are less than half of the number of male expats).

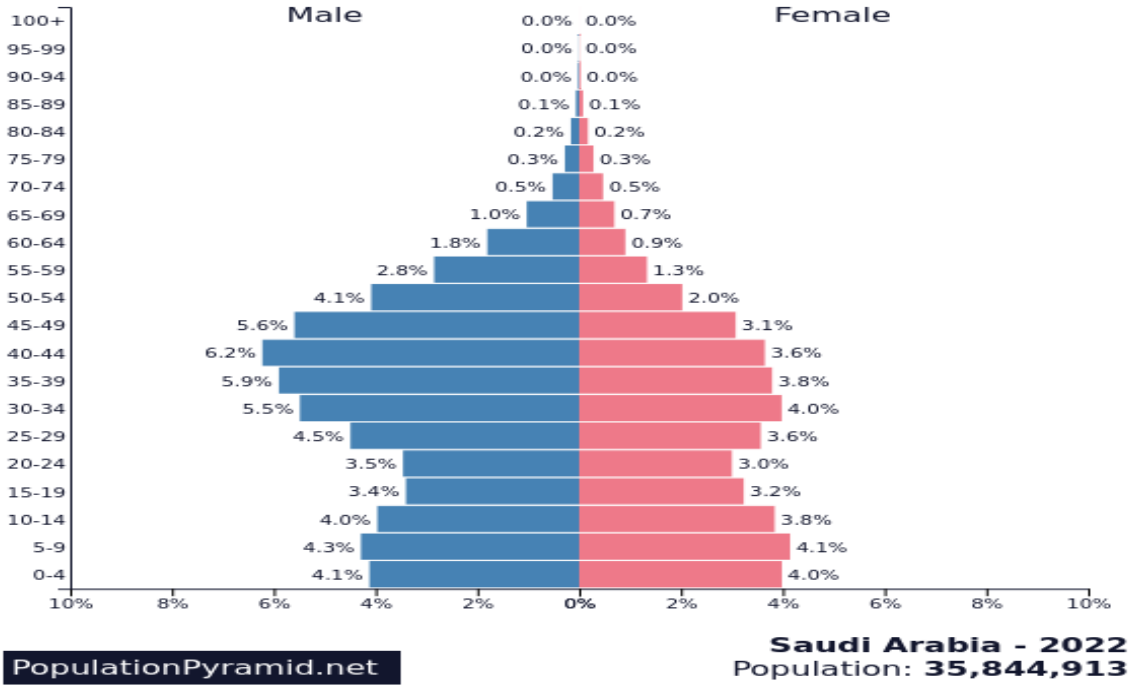


Figure 5. Saudi Population (Source: populationpyramid,2022)

Regarding age structure, the highest percentage of the population of Saudi Arabia are aged 25-54 years (Figure 6).

Saudi culture is mostly shaped by the religion of Islam since it is the centre of the Muslim world. It is also differentiated from other nations by its various ethnic groups. In Saudi Arabia, management decisions, and styles are all influenced by Saudi culture. In organisational context, there are many perspectives of how culture influences technologies and therefore its adoption (Sunny et al., 2019). This research considered cultural factors including the cultural dimensions, such as the uncertainty avoidance, when developing the research model. The implementation of Hofstede's cultural dimension justifies its relevance (Hofsted, 2001). In fact, culture plays a significant role in shaping an individual's behaviour. Therefore, culture can affect an employees' acceptance of traceability technologies as well as managers decision around it. Therefore, the cultural factor is considered to determine its impact on the intention to adopt traceability technologies in Saudi Arabia's dairy supply chain.

2.2.4 Selecting the Kingdom of Saudi Arabia as Research Context

Saudi Arabia entered into its Vision 2030 to diversify the nation's economy, improve public services, technology infrastructure and foster a dynamic society (Vision2030, 2021). But any development process initiated within the nation depends on, and heavily influenced by the Saudi culture (Baker et al., 2007).While Saudi Arabia is still developing, its industries in general need more emerging technologies in view of the Industry 4.0 requirement (de Vass et al., 2021). Dairy sector although is self-sufficient with food processing technologies, yet it has enough room to adopt and execute new and emerging technologies, specifically, track and trace for food products to detect contamination that was highlighted during COVID-19 pandemic. Moreover, Saudi Arabia has positioned itself as a country with the highest rate of population increase in the world. This put pressure on government and private sector to meet the ever increasing demand for food (Zuhur, 2011).

Moreover, the country suffers from high level of food poisoning (El Sheikha, 2015). According to Saudi Ministry of Health, 255 incidences of food poisoning have occurred in one year, and there has been an increase in the number of foodborne illnesses in the country (MoH, 2021), with the majority of those affected being young adults. Food poisoning is an important health issues that needs to be resolved with food tracking and traceability as a viable solution.

2.2.5 Saudi Arabia's Vision 2030

> "*My first objective is for our country to be a pioneering and successful global model of excellence, on all fronts, and I will work with you to achieve that."* [King Salman Bin Abdulaziz, Custodian of the Two Holy Mosques] (Vision2030, 2021, p. 5).

In the above statement, King Salman Bin Abdulaziz started Vision 2030, and this was encouraged by the crown Prince Mohammed bin Salman bin Abdulaziz Al-Saud, a Prime Minister of Saudi Arabia and Chairman of the Council of Economic and Development Affairs, who stated that,

"It is my pleasure to present Saudi Arabia's Vision for the future. It is an ambitious yet achievable blueprint, which expresses our long-term goals and expectations and reflects our country's strengths and capabilities." (*Vision 2030*, 2016, p. 6)

Figure 6. Saudi Vision 2030 Logo (Source: Vision 2030 2016)

Saudi Arabia has launched a long-term strategy, planned to end in 2030, as a plan for the country development. It aims to reduce the country dependency on oil and launching the National Transformation Program(NTP). Vision 2030 has been set to develop the country economically, socially, and nationally (Figure.7).

NIDLP is one of *Vision 2030's* main *Programs* that aims to transform Saudi Arabia into a leading *industrial* power and worldwide *logistics* hub. The Program was started at the beginning of 2019, consistent with the Saudi Arabia's efforts to grow and reach the Economic diversification.

The Program also concentrates on the two pillars of local content and the industry 4.0, given their significance towards allowing some main sectors, such as food sector to reach their pre-set strategic objectives.

2.3 Analysis of Saudi Dairy Sector Market

In 2020, the Saudi Arabia dairy industry generated a sales value of approximately SAR 11,000 million. The value indicated an increase of roughly 8.71% from the previous year.

More so, it stated the continuous increasing trend in dairy product sales. The year 2017 had the lowest sale, which fell by 3.6% compared to 2016 (Mohamad & Asfour, 2020). The cause of the decline in the year was the fall in oil prices. It means that economic changes directly impact dairy product production and sale. The industry is dependent on revenue generated from oil to facilitate the importation of dairy-related raw materials.

Many people in the country depend on dairy products as food and drinks. Import of foodstuff and beverages is expected to grow due to the lack of local agriculture. Dairy product forms a significant part of the Saudi Arabian diet, making them a high preference commodity. It implies that the dairy sector has a ready market of consumers willing to purchase the products. This was evidenced during COVID-19 pandemic when the demand was more rather than a decline (Acosta et al., 2021). Family needed the food and drinks to sustain their new lifestyles. In this case, the adopted online ordering system facilitated the delivery of the products to their homes.

Saudi Arabia exports milk products to the international market due to its exceptional quality and production quantity. The farms have employed outstanding modern technology and maintenance of the cattle, which facilitates quality milk production. The dairy farms employ suitable machineries and process technologies which enable them to produce quality products. For instance, cheese products are in high demand making Saudi Arabia a famous cheese importer. According to UN (2022) Saudi Arabia imported 592 Million- dollar of Cheese, becoming the fourteenth largest importer of cheese in the world. The value of imports rises year after year due to increased demand for the products globally.

The Saudi Arabian government supports daily farming by providing subsidies and incentives. In this case, the cost of production is relatively low, which enables the farmers to export the products to other regions. Another critical factor is the introduction of research and development agencies that promote innovation to meet consumer preferences and tastes. Dairy companies continuously launch new products creating a competitive edge in the market.

In the local dairy industry, a small number of companies and farms create an atmosphere of intense competition. This fierce rivalry has spurred product development and innovation tailored to consumer interests. It has also elevated the standard of quality, gaining

international recognition. Recently, companies have adopted e-commerce business models to easily reach their target consumers and provide delivery services. Factors such as price, product quality, packaging, and brand awareness give these companies a competitive edge. As a result, consumers enjoy a wide range of product options, satisfying diverse needs and preferences.

The development of retail opportunities has led to increased production and innovative products in the region. The Saudi government has given the retail sector significant attention through many economic changes aiming to support the sector and create a suitable environment for the investors (Al-Rajhi, 2020).

The dairy products market in Saudi Arabia is segmented by product types such as dairy desserts, yogurt, cheese, milk, and other product types. The distribution channels include online retails, convenience stores, hypermarkets, supermarkets, and others. The dairy product market in Saudi Arabian was valued at USD 4,807.70 million in 2020. The market was projected to show a Compound Annual Growth Rate (CAGR) of 4.71 % during the predicted period between 2021 and 2026. However, like any other market, the dairy market was significantly impacted by the COVID 19 pandemic.

During the first wave of the pandemic while community and business were in lockdowns, dairy products were in high demand. The pandemic disrupted the supply chains as Saudi Arabia raised trade barriers and closed its borders (Acosta et al., 2021). Interestingly, while at home, there was an increased interest in cooking, thus increasing the demand for some dairy products such as cream, butter, and milk.

The dairy market in Saudi Arabia is characterised by the high consumption of milk and milk products since dairy forms are a crucial component of the Saudi Arabian diet. The state insists on the need for dairy products to meet dietary requirements, which drives the daily market. Moreover, various Saudi Arabian dishes need cheese and milk in their preparation, hence increasing the demand for dairy products in household consumption. Data published in UN (2022) show that Saudi Arabia is the second-largest importer of processed cheese. In compliance with Almarai, a leading Saudi Arabian - based dairy company, Saudi Arabia held

the largest share in 2016 of 68.8% in the GCC processed cheese market, representing an exceptional cheese demand in the country compared to the other countries.

2.4 Saudi Arabia Dairy Sector Supply Chain

The dairy supply chain involves dairy manufacturing/processing units, distribution centres/warehouses, supermarkets, retail stores, and transports for in-store and online operations. Wholesalers receive the products from the manufacturers/processing units and sell them either directly to the market or the retailers. The retailers then sell the products in stores and grocery outlets. Supermarkets and hypermarkets receive products in bulk from manufacturers and stock on the shelves. The consumers can then pick the products from the stands as per their preferences. They sell various products in stores and supermarkets based on the licensing and ability to preserve the products. Different milk products (Figure.7), such as cheese require extra refrigeration to protect them from spoilage. It implies that the stocking and sale of dairy products are relatively high due to expensive equipment.

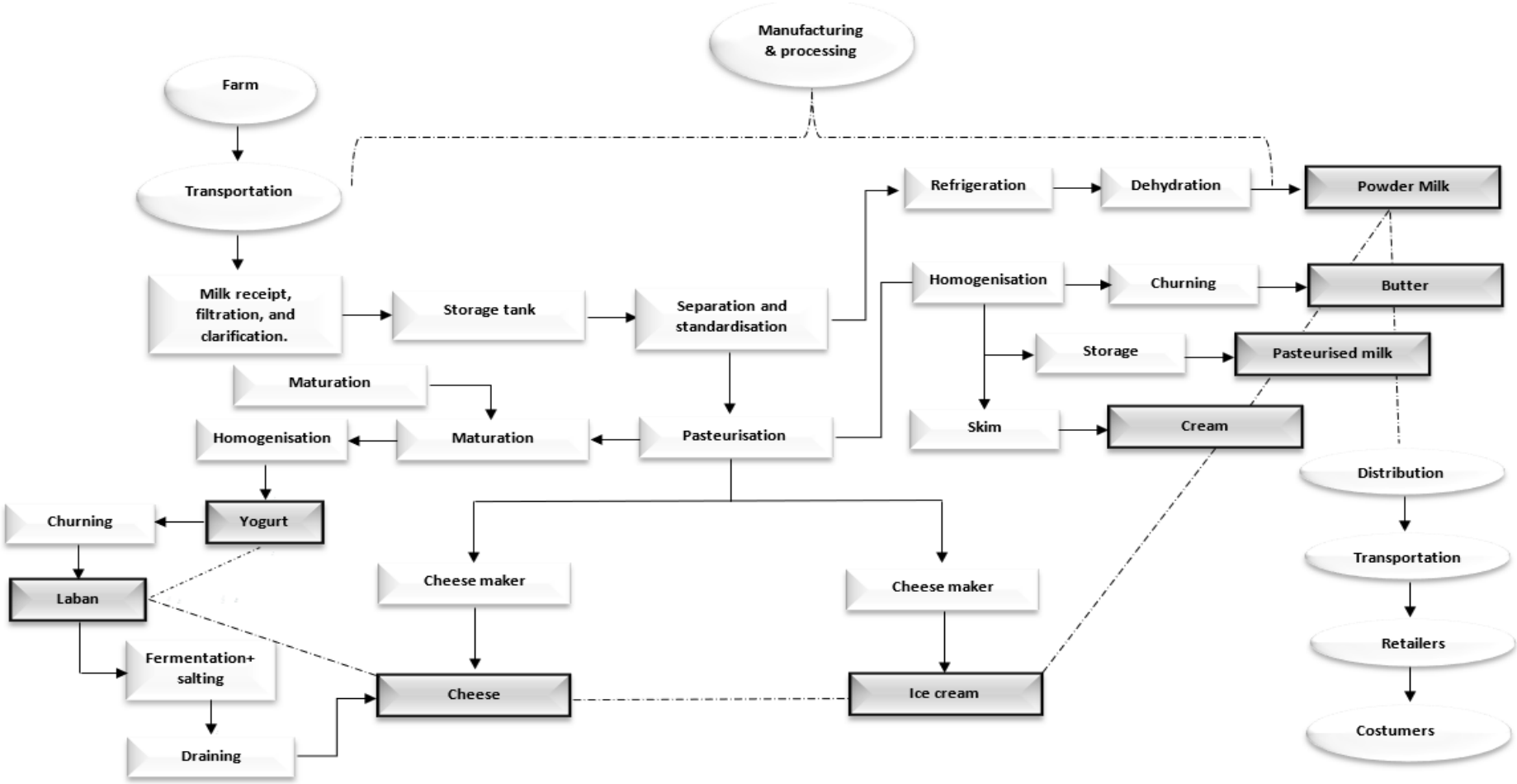


Figure 7. Dairy Supply Chain processes diagram (Created by the researcher)

Saudi Arabia is working on making an outstanding sustainable supply chain by applying advanced planning systems to enhance products' flow, its full supply chain visibility through the technology, development of infrastructure (e.g., transport network) to increase the efficiency of transportation, logistics modelling that adopts tools to improve warehouse size, location, and transportation optimisation in addition to training programs to enhance employees skills in this field (Alsuwailem et al., 2022).

In the dynamic landscape of the Saudi dairy industry, firms are increasingly adopting agile and flexible models to navigate market changes. This shift has become particularly critical in recent years, where the industry has encountered significant challenges due to changes in demand and product distribution. The COVID-19 pandemic exacerbated these challenges, compelling firms to rapidly modify their supply chain models with a heightened focus on food safety and delivery, as noted by Alsuwailem et al. (2022).This adaptation necessitated additional investments in new traceability technology, delivery vans, and refrigerators to meet evolving market needs.

The pandemic has been a pivotal moment for the dairy industry, highlighting the importance of responsive supply chain systems. The urgency to adapt was not just about maintaining operations but also about ensuring consumer trust through improved food safety measures. The investment in traceability technology was not a mere choice but a strategic imperative to track and manage dairy products more efficiently and transparently. This technological shift, while costly, was critical in maintaining market relevance and consumer confidence, especially in a post-pandemic world where consumer priorities have shifted significantly towards health and safety.

Moreover, dairy firms have faced the ongoing challenge of meeting rapidly changing consumer needs. This situation has led to intense competition among firms, pushing them to innovate their dairy products more frequently. Innovation is no longer a luxury but a necessity in this highly competitive environment, where consumer preferences are continuously evolving. The agility of firms in responding to these changes is paramount, not only to stay competitive but also to cater effectively to consumer demands.

The technological advancements, particularly those encompassed in Industry 4.0, have added another layer of complexity (Zhong & Moon, 2023). Firms are now compelled to reassess their existing technologies, especially in the realms of tracking and tracing products along the supply chain. The integration of advanced technologies is essential for efficiency, transparency, and compliance with evolving regulatory standards and consumer expectations. However, this integration is not without its challenges, including the need for upskilling employees and aligning with industry best practices.

2.4.1 Technologies Currently in use

Using technologies is crucial in the dairy industry especially in hot and dry environment where maintaining a perfect temperature through automation is of utmost priority. Overhead misters are used in the open-sided sheds that house the herds of cows to periodically sends out clouds of moisture that wet the cows, consequently keeping them cool at all times. Humongous fans are also used to keep the herds dry while preventing puddles on the ground. Computers are also used to monitor the sheds' humidity and temperature, thereby maintaining optimum temperatures.

Technology has also greatly revolutionised the health monitoring of cows with ground-breaking innovations where collar-attached sensors monitor each cow 24/7 giving the company real-time alerts on cows' health, nutrition, and fertility graphs displayed on a computer (Gehlot et al., 2022). This technology has dramatically increased farm efficiency by diverting attention only to those cows that the system has identified for special attention. This technology has ultimately helped dairy companies reduce labour costs as fewer workers are required to monitor the herds at a given time, reducing stress to the cows while keeping them healthy for more milk production.

Robotic milking and feeding are other technological advancements that have helped Saudi Arabia's dairy industry proliferate. Robotic milking is where an automated milking system is used instead of a person milking the cows. This technology, which is also used to manage the feeding process, has dramatically benefitted Saudi Arabia's dairy farming by significantly reducing labour costs as fewer livestock workers are needed at any given time. Additionally, time saved from milking and feeding cows is used for other activities like improving animal health.

Due to the lack of farming lands, rearing dairy cattle is challenging due to the cows' lack of adequate food supply. The introduction of Liquid Nanoclay (LNC) technology helps growing crops and grass to support Dairy farming. The technology involves mixing sand particles and cray to facilitate water retention. The treatment enables the new soil structure to hold water and promote agriculture. The technology is recommended since Saudi Arabia is water-scarce and lacks good arable lands.

The government provides support for farming by providing a free interest loan to support the agriculture (EKSA, 2022). That leads to enhance the agriculture and farming in Saudi Arabia. In addition, the use of greenhouses and drip irrigation technology had led to an increase in food production and feeds for the cows. Water shortage in the region affects the dairy sector, which calls for innovative measures. However, the introduction of these technologies has led to success in the dairy sector, whereby farmers have adequate feed for the farm animals. They have also focused on purchasing manufactured feed, which consists of appropriate nutrients for the dairy cattle. In this case, they can sustain continuous milk production and meet the market demand.

Better informed strategies and technology have enabled dairy farmers to provide valuable products to consumers. Importation of skilled labour and equipment has enabled the farmers to maintain the dairy cattle healthy and increase production. There is a need to conduct adequate market research and understand the dynamics that affect production and distribution. Unforeseen uncertainties such as the COVID-19 pandemic have led to disruption of farming and caused losses to the farmers. In this case, the firms are adopting a modernized and flexible supply chain model, resulting in sustainability.

The Saudi government is investing heavily in the agricultural sector to facilitate the availability of feeds for the dairy sector. Previously, the firm depended highly on imported feed to manage the cattle. However, the process is costly, and disruptions mean reduced feed for the cattle. Local production of feed under monitored watch will ensure a constant supply of the feed to the dairy farmers. Other development involves searching for permanent sources of water to ensure long-term sustainability. These efforts will aid in eliminating poverty crises and production shortages in the future.

The government is overseeing the construction of dams and water conservation methods to increase the water supply in the region. Desalination plants have made it possible to source water from the sea and conducive to consumption. Further, there is improvement in infrastructure in the area to support farming activities. It involves the construction of roads, irrigation networks, and storage, which enable the dairy farmers to distribute their products. The government is also encouraging scholars and researchers to boost agricultural development. Other notable improvements include establishing training institutions that enable the farmers to learn essential skills.

When it comes to the dairy companies, storage and warehousing, Radio Frequency Identification (RFID) and Global Positioning System (GPS) technologies play pivotal roles. These technologies allow for the real-time monitoring and tracing of dairy products, ensuring their quality and safety are maintained during storage and while in transit.

Temperature-controlled trucks, outfitted with real-time tracking technologies, are commonly used for transportation. These trucks help maintain a constant, safe temperature for dairy products during transit, further contributing to product quality and safety.

At the retail end, QR codes have been deployed to improve product transparency. These codes can be scanned by consumers to access detailed information about the dairy product, further enhancing trust and confidence in the quality and safety of these products.

2.5 Development of Dairy Sector in Saudi Arabia

Growth in GDP(Gross domestic product) is one of the significant growth drivers. Dairy producers in Saudi Arabia, especially milk producers, have always been and continue to be the market leaders in the industry. The producers sell their products locally and within the Gulf region. The increasing population in these regions has contributed to the rising per capita milk consumption. Moreover, the high demand for nutrient-rich foods such as milk and other dairy products has rapidly driven the Saudi Arabian markets to grow. Milk is a rich source of Vitamin B12, potassium, magnesium, calcium, and proteins, all of which play a significant role in muscle growth, cognitive function, facilitating weight loss, and bone health. These factors have further driven the country's sales of milk and other dairy products. Cream obtained from milk has also become another necessity. This is due to cream being an

irreplaceable part of the diet. There has been a recent rise in the importation of cream since its level of consumption has exceeded its production levels.

All these prospects in the success of the dairy sector in Saudi Arabia have significantly been contributed by the stable government. The stability in the government enables a suitable environment for the market. The government also offers new technologies and subsidies, which have played a part in the growth of the dairy sector. The country aims to be self-sustaining and produce all the milk and dairy products needed by the locals without importing. The development of the dairy sector has been very impactful and has resulted in a rise in the economy and reduced the levels of unemployment in the country.

While the Saudi dairy sector has achieved a level of self-sufficiency with its legacy technologies, there remains significant room for improvement, especially in integrating technologies across different locations such as processing units, warehouses, transportation, and retail. These currently localised technologies, while effective in their specific settings, fall short of the cohesive integration that Industry 4.0 promotes. The critical need now is for technologies that not only perform tasks efficiently within a single location but also communicate seamlessly across the supply chain, ensuring a real-time flow of information. This integration is vital for keeping pace with the advancements encouraged by Industry 4.0, which is rapidly defining the future of industrial operations (Zhong & Moon, 2023).

The integration of supply chain processes is essential in achieving efficient tracking, tracing, and visibility of products. This holistic approach ensures that each segment of the supply chain, from production to retail, is interconnected, allowing for real-time data sharing and decision-making (Lopes et al., 2020). In the context of the Saudi dairy industry, the current practice lacks this level of integration. As a result, there are missed opportunities in terms of operational efficiency, risk management, and meeting customer expectations for transparency. Implementing integrated systems would allow for better control over the supply chain, enhancing the quality and safety of dairy products and bolstering consumer trust.

2.6 Dairy Companies in Saudi Arabia

The Saudi Arabian dairy market is highly competitive and has few local companies catering to the country's high demand for milk and milk products. The major player in the dairy

industry in Saudi Arabia include Almarai Company, Sadafco (Saudia Dairy & Foodstuff Company), NADEC (National Agriculture Development Company), and ASD (Al Safi Danone Company). These players in the dairy market are seeking to introduce innovative and new products in the market to accommodate all the interests and needs of the consumers. Additionally, to try and get a competitive advantage, the companies try to compete on different factors and differentiate their offerings. The elements they compete include packaging format, quality, price, marketing activities, flavour, and product offerings.

2.7 Summary

This chapter has shown the research background (the Saudi context) and many important information relating to the kingdom of Saudi Arabia. It creates a fundamental profile of the country, with some information about its background including the location, economy, culture, demography, and population, in addition to the dairy sector important information. The next chapter will review the relevant literature in food traceability adoption, and implementation addition to the supply chain performance.

3 Chapter Three: Literature Review

3.1 Introduction

This chapter offers an in-depth exploration into the very essence of food traceability, providing foundational understanding of the literature established in this area. Section 3.2 undertakes discussion on factors influencing the food traceability, ranging from legislative requirements and certifications to concerns of safety, quality, and the economic feasibility of employing such systems.

Attention is then turned to the tangible impact of traceability systems in Section 3.3, examining their effects on supply chain dynamics and overall firm performance. The technologies propelling the advancements in traceability, including IoT, RFID, NFC, WSN, and Blockchain Technology, are meticulously detailed in Section 3.4. Chapter 3.5 takes a deep dive into the Technological, Organisational, and Environmental (TOE) framework, which breaks down the multifarious factors guiding the adoption of traceability systems.

This literature review aims to furnish readers with a thorough comprehension of the current landscape, laying the groundwork for further discussions and analyses.

3.2 Food Traceability

Food traceability refers to data tracking that follows a physical trail of food products through different stages of its processing and movement (Abad et al., 2009; Smith et al., 2005). Moreover, food traceability is aimed to enhance the safety of food from farm to fork by using digital technologies in order to analyse traceability data (Yu et al., 2020). Unsafe food products, in fact, pose a persistent health risk to consumers. Foodborne illnesses are estimated to cause 600 million cases worldwide each year, with 420,000 deaths (Yu et al., 2020). In the context of the dairy industry, employing traceability technologies mitigate these health risks, aligning with United Nation's Sustainability Development Goal #3 (Good Health and Well-being). Furthermore, efficient traceability technologies can contribute to Goal #12 (Responsible Consumption and Production) by promoting accountability and sustainability in the supply chain. Finally, through minimising waste and optimising resource use, traceability

technologies can also support Goal #13 (Climate Action) by reducing the industry's environmental impact.

The definition of traceability is broad because food is a complex product, and traceability is an instrument used to achieve different objectives. Elise H Golan et al. (2004) suggest three important objectives in using traceability systems: to enhance food safety and quality trackback; to distinguish and sell products with subtle or undetectable quality attributes; and to improve supply chain management, which can translate into higher net revenues for each partner company. The motivations to apply traceability can vary due to different product characteristics and their supply chain positions. For food businesses, meeting the statutory requirements is the most important reason to implement traceability.

The concept of 'traceability' was first defined in the ISO 8402 1994 standard for a quality management and assurance (Zhou et al., 2022). Within this official description, traceability was defined as: "…ability to trace the history, application or location of an entity by means of recorded identifications". In the late 1990s with the spread of mad cow disease in Europe, food industry's quality control gained extraordinary attention. In 1997, the Codex Alimentarius Commission (CAC) identified a definition of food traceability, which explained the range of "tracing" and "tracking" processes. In 2002, the EU general food law proposed a more comprehensive definition, which made a clear description of the traceability goal. Based on the explanations provided by the above organisations, ISO updated the definition of traceability in ISO 9000 and ISO 22005, further widened and developed definition in terms of the traceability goals, so that traceability through the supply chain is not limited to the partial processing connection but also covers all relevant activities and processes.

From the academic research perspective, the definition of 'traceability' generally has two perspectives. Moe(1998) suggested the first one who added high importance to 'accountability', and defined traceability as a tool to show the safety of the product 'responsibility' in each stage of the supply chain (Moe, 1998).Then, Elise H Golan et al. (2004) proposed the other one, which highlighted the purpose of traceability in 'risk' identification and considered it as a record system of the product information to identify any potential risk and crucial control points. Three factors including 'precision', 'breadth', and 'depth' have been used to measure the traceability performance. Precision refers to the

smallest part of product; breadth means the range of information that can be generated; and depth represents the distance at which information can be traced forward or backward. Through the review of traceability definitions mentioned in the previous academic papers, Olsen and Borit (2013) suggested a comprehensive definition by using 'access' to define the action of 'trace' and 'track' and expanded the traceability to 'entire life cycle.' This definition has been recognised and expanded later by many authors (Aung & Chang, 2014; Dabbene et al., 2014; Dandage et al., 2017; Karlsen et al., 2013).

The Codex Alimentarius Commission defines traceability as the ability to trace an entity's history, application or position through recorded identification (Schaarschmidt et al., 2018). Moe (1998) classifies external traceability, which monitors a product batch and its history throughout the entire or part of the harvest chain through transportation, storage, manufacturing, distribution and sales, and internal traceability, that tracks the product internally at every stage, such as the production process.

Amidst a continuing series of food controversies due to outbreaks, such as bird flu, mad cow disease, foot-and-mouth disease, and COVID-19, consumers are increasingly requesting information about the source and ingredients of their food products (Butu et al., 2020; Pigini & Conti, 2017). The design and implementation of complete traceability from farm to fork has become an important task for the food industry to reliably supply top-quality, safe and nutritious products as well as to create consumer confidence (Stefanova & Salampasis, 2019).

Although traceability is very important in food industry, Corallo, Latino, Menegoli, and Pontrandolfo (2020) find that there are only 18 lead papers related to traceability in food industry. Moreover, they stated that papers related to food traceability starting to take on much more prominence in 2016–2017. So, more studies are required to validate the findings and derive trends.

To sum up, the 'traceability' definition can be classified into two types which are the academic and official type. Traceability definitions (the official) created by organisations were mostly formed by the ideas through theoretical conversation, while the academic definitions are broader, specific, and clearer. However, they are the same and aims to monitor the entire supply chain from farm to fork. Additionally, these definitions are changed over

time based on action and content. For instance, traceability definition has been developed to be more accurate since it is named as ‘trace’, then ‘track’, to ‘trace and track’, finally it has been changed to ‘access’, that can be attributed to the update of traceability technologies which makes the information more accessible and transferrable (Islam & Cullen, 2021).

Food traceability has no common definition even though the supply chain implication was clarified by authors (Verbeke et al., 2002). Previous studies often defined traceability from many perspectives: “unit, who, where, when, and how” (Olsen & Borit, 2013). However, those definitions only refer to the behaviour of traceability, instead of defining the goal, or value of traceability. Thus, a clearer definition of FT is needed for further investigation of traceability.

In this study, the author attempts to deliver a definition of FT as “the ability to trace the product through all processes from raw materials acquisition to production, processing, distribution, retailing, consumption and disposal to clarify a product's information in order to improve the quality, enhance safety and gain customer trust”.

3.3 Factors that guide food traceability

The factors that can affect the adoption of traceability in businesses and the level the companies decide to adopt have been a topic of great concern in recent years. Literature has present it in many ways. For example, Banterle and Stranieri (2008) investigated the level of traceability complexity (high, medium, low), whereas Monteiro and Caswell (2009) discussed the traceability dimensions (depth, breadth, and precision). Regarding the traceability level, literature presented different possible factors that affect the firm’s selection of traceability level, for instance, buyer-supplier relationships(Alfaro & Rábade, 2009), and cost and governance (Banterle & Stranieri, 2008). Concerning the traceability technologies, Manos and Manikas (2010) found that traceability could be enhanced by technology updates. Basole and Nowak (2018) used the operations cost and institutional theory to investigate the supply network impact on tracking technology selection and integration. Many theories, for instance, transaction cost theory (Banterle & Stranieri, 2008), institutional theory (Basole & Nowak, 2018), diffusion of innovation theory (Basole and Nowak, 2018), and agency theory

(Monteiro & Caswell, 2009) have been employed to support and underpin the scholars' research founding.

Previous literature focused on the factors that affect the traceability technologies performance at the "organisational level" (Banterle & Stranieri, 2008; Monteiro & Caswell, 2009). However, these research have rarely examined at the supply chain level, where factors directly impact the traceability technologies adoption in the food supply chain (FSC) (Zhou & Xu, 2022). For external factors, Alfaro and Rábade (2009) analyse the relationship of supply chain partners (buyer–supplier) and their impact on traceability adoption. Engelseth et al. (2014) study the supply network integration and its influence on traceability. The current study defines the internal and external factors that may affect traceability adoption, which also suggests that the technology has a positive impact of food traceability. From the perspective of technology, few studies discussed the impact of adoption or management of traceability technologies (Basole and Nowak, 2018). So, this study discusses the factors that affect the traceability technologies adoption in supply chain that was highlighted in a study by Zhou and Xu (2022).

3.3.1 Legislation and Certification

One of the critical factors influencing the adoption of Food Traceability Systems (FTS) is the regulatory landscape. Across the globe, regulatory frameworks such as the EU Food Law 178/2002, the US Bio-terrorism Act, and the US Food Safety Modernization Act (FSMA) have set precedence for traceability in food sectors (Bechini et al., 2008; Charlebois et al., 2014; Qian et al., 2020). Regionally, New Zealand's National Animal Identification and Tracing (NAIT) Act and Japan's Food Traceability Act are instrumental in shaping industrial practices.

Within Saudi Arabia, the Saudi Food and Drug Authority (SFDA) has mandated traceability, converting it from a technological choice to an organisational and legal requirement (SFDA, 2019). This development holds particular relevance for this study as grounded in the Technological, Organisational, and Environmental (TOE) framework. Here, legislation acts as an explicit environmental factor affecting the propensity for dairy firms to adopt food traceability technology (FTS).

Moreover, it is not just the governmental legislation steering the adoption; market-led initiatives also wield influence. Certifications like Good Agricultural Practice UTZ in the coffee and cocoa industries serve as prototypes for what could potentially be implemented in the Saudi dairy industry (Norton et al., 2014). These certifications function not just as a compliance metric but also as a competitive advantage, encouraging both organisational willingness and consumer trust in adopting traceability technologies.

While legislation often serves as an entry ticket for market participation, the interface between regulatory frameworks, consumer behaviour, and market competitiveness requires deeper examination.

3.3.2 Safety and Quality

Safety and quality concerns play a pivotal role in influencing the adoption of traceability technologies within the Saudi dairy industry. This factor is closely linked to the overarching objective of ensuring the integrity and reliability of the dairy supply chain, aligning with the themes of this research on leveraging technologies in milk traceability to enhance supply chain performance within the Saudi dairy sector.

In the dairy industry, as in the broader food sector, the potential for significant disruptions looms large, as exemplified by global crises such as mad cow disease, dioxin contamination, the horse meat scandal, E. coli outbreaks, and the recent COVID-19 pandemic. These critical events have demonstrated the severe repercussions for food safety and quality, shaking consumer confidence and trust in the industry (Aung & Chang, 2014).

To safeguard against such disruptions and fortify the credibility of the Saudi dairy industry, many organisations have implemented Food Traceability Systems (FTSs). FTSs act as a proactive defence mechanism, allowing dairy firms to navigate the challenges posed by potential food safety crises, as previously observed in various international contexts (Opara, 2003). It is important to highlight that the adoption of traceability technologies, consistent with the principles of the Hazard Analysis and Critical Control Point (HACCP) system, empowers dairy enterprises in Saudi Arabia to effectively manage safety hazards (Tian, 2016).

Furthermore, the utilisation of traceability-based time-temperature information management systems holds the potential to minimise food quality deterioration throughout the supply chain (Hassoun et al., 2022). This dimension aligns with the overarching goals of my research, which seeks to delve deep into technological aspects impacting the dairy industry's supply chain performance, and how traceability technologies can act as a transformative tool to mitigate quality loss.

3.3.3 Cost-benefit of traceability technologies

Adoption of food traceability technologies may cause an increase in costs and offers less benefits in the short term (Banterle & Stranieri, 2008). Therefore, a pre-assessment of cost-benefit analysis is paramount prior to any adoption decision (S Andrew Starbird & Vincent Amanor-Boadu, 2006). In terms of case studies, Saltini and Akkerman (2012) have examined the extra benefits and comprehensive income generated from traceability information, while Chen et al. (2019) have looked into the additional costs of adopting traceability technologies in agro-product enterprises. The cost-benefit analysis was built to evaluate the economic usefulness of traceability technologies (Fritz & Schiefer, 2009). On the other hand, Gunawan et al. (2019) analysed perceived costs of traceability system implementation. It allows enterprises to consider their ability to adopt a traceability technology in a rational way, or the timing of the technology adoption. Aiello et al. (2015) investigate the perceived internal and external benefits. Additionally, a comprehensive cost-benefit analysis framework has been done to compare the cost of traceability and value creation in food supply chain (Chryssochoidis et al., 2009). Researchers usually employ survey and case study methods to assess the cost-benefit analysis, and then, they use more in-depth methods, such as cross-case comparison (Gunawan et al., 2019), break-even pricing (Chen et al., 2019), a single case study (Chryssochoidis et al., 2009), and so on. However, literature in this context has hardly mentioned the theoretical lens that underpin the research.

3.3.4 COVID-19 and food traceability

In recent years, transmissible diseases have caused major challenges, particularly since the start of the COVID-19 pandemic at the beginning of 2020 (Aburumman, 2020; Aday & Aday, 2020). As of late 2019, COVID-19 was first discovered in Wuhan, China. The World Health

Organisation (WHO) called it “a new coronavirus illness” because it spread fast worldwide. Certainly, COVID-19 pandemic caused a global economic crisis which led to an economic recession that the world has not faced since the World War II. As countries depend more on essential food products (Koppenberg et al., 2021), supply chain disruptions during COVID-19 paused this with an aim to prevent the virus transmission. A balanced diet provides the body with nutrition in order to increase immunity against diseases. Healthy diet contains micronutrients (Heck et al., 2020), that can be provided by balancing the consumption of plant and animal-based diets (Galanakis et al., 2022). However, consumers were very much keen to know the sources of the food products they are eating and how much it was free from any virus contamination during COVID-19. Therefore, food traceability was a major concern in a sense that what extent the food products and its ingredients could be traced to its immediate source of supply.

Before COVID-19, developing countries already suffered from unstable and weak food supply chain. For example, Nordhagen et al. (2021) estimate that for every three persons, one experiences malnutrition, and one-ninth people suffers from starvation. These results are particularly from Africa and Asia (Ahmed et al., 2020; Kumar et al., 2020). The food supply chain disruptions and shortages of food directly affect the health and well-being of 1:3 of the worlds’ population. This was further highlighted during COVID-19.

To facilitate the control of the coronavirus, authorities across the world limited face-to-face contact and applied social distancing (Benedek et al., 2022; Guo et al., 2021; Laborde et al., 2021). Such restrictions negatively affected food supply chain in both midstream and downstream segments, causing a huge disruption (Khan et al., 2022). A middleman plays a significant role in food distribution, especially in highly populated countries in Asia, whereby they put efforts to minimise the operational costs of logistics activities (Bassett et al., 2022; Erlina & Elbaar, 2021). To prevent the transmission of COVID-19, marketplaces were closed (Khan et al., 2022) where wholesale markets, cold storage services, and fruit and vegetable market suffered from labour shortages and unable to handle food deliveries in timely manner. The food supply chain disruption was caused due to restrictions on movement of goods as the borders were closed (Rejeb et al., 2020). This affected both food loss and waste along the upstream and downstream of the supply chain (Bhattacharya et al., 2021).

In the previous two years, the impact of COVID-19 on food supply chain has been investigated significantly; however, the importance of food supply chain traceability during and post COVID-19 needs more work (Zhou & Xu, 2022).

In the previous two years, the impact of COVID-19 on food supply chain has been investigated significantly; however, the importance of food supply chain traceability during and post COVID-19 needs more work (Zhou & Xu, 2022). More insights through traceability can bring more actions to improving the performance before any bad happens to the supply chain.

3.3.5 Performance of traceability systems

The performance evaluation is required to validate whether the traceability technologies can trace and track the products in an effective way. Four factors such as breadth, depth, precision, and speed have been commonly used to evaluate traceability technologies performance (Gunawan et al., 2019). Additionally, 'granularity', which was assessed by size of batch and scale was used to characterize the precision of the product traceability (Karlsen et al., 2013). Also, traceability track record and traceability time have been used to assess the system's capability to generate and manage traceable data (Dzwolak, 2016).Approaches such as "simulated recall methods" (Donnelly et al., 2012; Forås et al., 2015) and "factorial and cluster analyses" (Banterle & Stranieri, 2008) are used to evaluate a technology performance.

3.3.5.1 Food traceability impacts on supply chain performance

The research on food supply chain traceability emerged during 2001-2008, and the discussion was centred around the impact of traceability technologies on companies' operational performance and supply chain network relationship. The adoption of traceability technology not only solves the challenge of food quality control but also brings many benefits to focal enterprises and the entire supply chain. Literature shows that traceability technologies can cause transaction modes change (Vo et al., 2016), along with financial incentives (Stranieri et al., 2016). Also, the use of traceability technology improves supply chain's resource integration in the companies (Engelseth et al., 2014). Mol and Oosterveer (2015) indicated that traceability could enhance the structure of the supply chain and urge people to pay more attention to companies' social responsibility and sustainable development goals (SDGs) (Garcia-Torres et al., 2019), not limit themselves to just financial benefits. In addition, Epelbaum and Martinez (2014) and Engelseth et al. (2014) assumed that traceability could

contribute to technological diffusion and innovation for operations management. Literature exploring this topic reveals that the theory of transaction cost economics (Banterle & Stranieri, 2008; Vo et al., 2016), and resource-based view (Engelseth et al., 2014; Epelbaum & Martinez, 2014), are the most adopted theories by scholars.

3.3.5.2 Food Traceability Impacts on Firm Performance

Academic literature has explored food traceability and its impact on performance (Kumar et al., 2017; Song & Morgan, 2019), the findings, however, are mixed. Some studies show that food traceability leads to increased firm performance (Epelbaum & Martinez, 2014; Kumar et al., 2017; Song & Morgan, 2019), while others demonstrate a little effect (Hosseini et al., 2012; Wilson et al., 2008). Moreover, some reveal a U-shaped relationship (Dabbene & Gay, 2011; S Andrew Starbird & Vincent Amanor-Boadu, 2006) and others indicate no direct relationship (Beheregarai et al., 2014; Ralston et al., 2015). In addition, the results also vary when considering the respective impact of food traceability on upstream and downstream movement. The literature highlights that food traceability enhances the performance both directly (Jraisat et al., 2013) and indirectly (Chavez et al., 2015). Later, Kumar et al. (2017) revealed that food traceability technologies contributed to performance directly. Meanwhile, Flynn et al. (2016) showed an indirect relationship and Hosseini et al. (2012) reported a negative relationship.

3.4 Food Traceability Technologies

Due to food safety crises, coupled with pressure from consumers, food companies are increasingly implementing track and trace system to ensure product quality and safety while making supply chain transparent (Guldiken et al., 2021; Zhang et al., 2020).

Technologies that are commonly used in food traceability include bar codes, Radio Frequency Identification Tags (e.g., *RFID* tags), *Wireless Sensor Networks* (*WSN*), QR code, Near Field Communication (NFC) and blockchain technology to capture and secure data. These technologies are often utilised for product identification, quality and safety, ensuring genetic analysis, environmental monitoring including temperature (Violino et al., 2019) and transparency and security in food supply chain (Feng et al., 2020). Some of them are discussed in detail in the following Section 3.4.1.

The benefits of food traceability technologies are significant and wide-ranging. These technologies have the potential to improve cost, quality, speed, dependability, risk reduction, sustainability, and flexibility (Kshetri, 2018), while also offering additional functionalities such as reliability, traceability, and authenticity of information, along with smart contractual relationships in an environment of mistrust, impacting food safety in supply chains (Kshetri, 2018). Furthermore, food traceability technologies contribute to achieving several Sustainable Development Goals (SDGs), which were adopted by the United Nations in 2015 (UNSP, 2015). These goals aim to eradicate poverty, protect the environment, and promote peace and prosperity for all by 2030, recognising that development must take into account social, economic, and environmental sustainability.

This research aims to contribute to achieving several SDGs, including Goal #3 (Good Health and Well-being), Goal #12 (Responsible Consumption and Production), and Goal #13 (Climate Action). Food traceability can help reduce food waste, improve food safety, and ensure equitable distribution, thereby improving global food security. It can also promote sustainable production, reduce environmental impact, and identify areas for improvement in the supply chain, contributing to responsible consumption and production. Additionally, food traceability can help reduce the carbon footprint of food production, promote sustainable land use, and reduce deforestation.

In fact, this study can contribute to achieving Goal #3 Good Health and Well-being by reducing foodborne illnesses and outbreaks. By tracking the food supply chain, the source of contamination can be quickly identified, and affected products can be isolated, reducing the risk of widespread illness. Furthermore, food traceability can help ensure the safety and quality of food products, which can help prevent illnesses and promote overall health. Finally, food traceability can support efforts to promote healthy and sustainable diets by providing consumers with information about the origin and production methods of their food, empowering them to make more informed choices.

Concerning Goal #12, which aims at Responsible Consumption and Production, this study goes beyond mere operational tracking. It serves as a mechanism for sustainability by aligning with Target 12.3 to halve food waste and reduce losses along supply chains. Implementing traceability technologies isn't just a logistical decision; it's an environmental

imperative. The pinpoint accuracy afforded by these systems allows producers to mitigate waste at each juncture of the supply chain, making significant strides toward this target. The ability to identify, and thus eliminate, areas of inefficiency translate into real-world reductions in waste, aligning perfectly with the global aspiration to cut food waste in half.

Furthermore, with regard to Target 12.8, which advocates for ensuring that people everywhere have the relevant information and awareness for sustainable development and lifestyles, traceability serves as an educational tool. It grants consumers unprecedented access to information about the origins and production methods of their food, thereby encouraging conscious consumption patterns. Empowered by knowledge, consumers can become active participants in sustainable development, effectively driving demand for responsible practices up the supply chain.

Shifting to Goal #13, Climate Action, this research aligns synergistically with Target 13.1, which calls for increased resilience and adaptive capacity to climate-related hazards. The implementation of traceability technologies can create a supply chain that is both robust and adaptable. By knowing the specifics of where each product is in the supply chain, companies can adapt more dynamically to climate-induced disruptions, such as extreme weather events affecting transportation or production. This proactive approach stands in line with global initiatives to create systems that can adapt and withstand the climate challenges ahead.

Moreover, in the context of Target 13.2, which emphasises the integration of climate change measures into national policies and planning, traceability technologies serve a dual purpose. They're not just operational tools; they're instruments for environmental governance. By streamlining the supply chain, we inherently decrease wasteful practices and, consequently, harmful emissions. This efficiency is an actionable step in the incorporation of climate-sensitive policies into the business ecosystem. However, achieving these environmental governance goals through technology adoption is not without its challenges.

As we transition into a deeper analysis, it's important to recognise that the implementation of traceability technologies is influenced by a trifecta of challenges, that is, technological, organisational, and environmental, collectively identified by the TOE framework, which will

be further discussed in Section 3.5. (Gangwar et al., 2015; Low et al., 2011; Shee Himanshu et al.).

The first challenge is related to technological aspects of food traceability (FT) technologies. Understanding the functionalities and benefits of emerging technologies supports the adoption decision. Technologies are known for issues related to complex structure and compatibility issues. Compatibility issues include technical aspects of an organisation as well as customisation of existing applications to cloud systems. Ideally, organisations should be able to move their application or data without compatibility issues when adopting FT (Marston et al., 2011). Complexity challenges relate to the integration of new technologies with existing systems, which requires a level of expertise that may not be readily available within the organisation (Ali et al., 2021; Hasan, 2007).

The second challenge is related to organisational aspects of FT adoption. Top management needs to contemplate and analyse possible changes in organisational culture, process and work relationships when considering FT adoption (Elson & Howell, 2009). Support from top management is also the main challenge in new technology adoption because of financial investment, willingness to understand its business benefits and implementation within the organisation (Alshamaila et al., 2013; Wang et al., 2010). Furthermore, FT adoption involves specialized human resources, i.e., people with knowledge and skill to implement the technologies (e.g., employees with computer skills, IT specialists)(Gangwar et al., 2015). However, support for training and skills development for employees can be effectively implemented to make the best out of the new technologies. Trained employees, supported by organisational resources, can understand the usefulness of FT technologies and find easier way to incorporate modern technologies.

The third challenge pertains to the environmental factors that influence the competitiveness of FT technologies. External environmental forces such as government regulations, consumer demands for transparency, and market competition significantly impact the decision to adopt FT technologies. The COVID-19 pandemic has intensified these factors, emphasising the need for resilient and transparent supply chains (Nordhagen et al., 2021). Regulatory mandates related to health and safety have become more stringent, further nudging organisations toward adopting traceability systems. The pandemic has also heightened

consumer awareness and expectations for greater transparency in food sourcing, as disruptions in the supply chain have led to increased scrutiny. Moreover, the competitive landscape has evolved, with companies that successfully integrated FT technologies during the pandemic setting new industry benchmarks. This has exerted additional pressure on organisations to either adapt or risk obsolescence. Managers need to have a deep understanding of these environmental elements, exacerbated by the pandemic, to strategise effectively for FT technology adoption. Not comprehending the market dynamics and external pressures can lead to poor adoption strategies, potentially affecting the organisation's competitiveness and consumer trust (Matzembacher et al., 2018).

3.4.1 Traceability technologies application in food supply chain

Several methods have been used for supply chain traceability ranging from traditional approaches such as papers records to complex and advanced technologies (Wang & Li, 2006). While there have been several of modern techniques discussed to implement traceability in supply chain, the traditional traceability method such as manual paper records is still highly preferred for food supply chain in developing and less developed countries (Bello et al., 2005). For example, Berman and Swani (2010) said that most of Chinese farmers were not even interested in the idea of having to record on papers the wholesalers who want to buy their products, not to mention their participation in a complicated computer-based systems. However, Roth et al. (2008) reported that traceability technologies have already been implemented in the Chinese seafood industry even though it is not yet used to its full potential.

Wognum et al. (2011) state that there are only some technologies that are developed in particular for traceability because firms often look to adopt the existing integrated system than higher level technologies such as ERP to avoid high cost. Product identification technologies, such as, barcodes and RFID (Radio - Frequency Identification) are the most popular technologies of traceability. RFID-based traceability systems have been investigated deeply in academic research with many papers looked into several food products such as beef, cheese, egg, wine, and seafood (Alfian et al., 2020; Papetti et al., 2012; Parreño-Marchante et al., 2014). It is also used by many international top supermarket chains such as

TESCO and Walmart. Big supermarkets such as Woolworths, Coles, IGA and Aldi in Australia use barcodes for quick scanning of items in shelves and checkout counters.

QR code is defined as an upgrade of the linear barcode since it supports better data storing and coding while it is environment-friendly (N Sivakami, 2018). QR codes have advantage over RFID and traditional barcodes in that it can be decoded by different devices such as smartphones as there are a wide range of QR decoding applications available as an alternative to the reader equipment. However, QR and traditional barcodes can detect and scan items one by one to access the information. In contrary, RFID's invisible wireless reading mode provides automatically decoded information without human direct intervention.

In context of food traceability, where many technologies are available, each one has its own set of advantages and challenges. However, the focus of this literature review was deliberately narrowed down to some key technologies—IoT, RFID, NFC, WSN, and Blockchain—due to their frequent mention and utilisation in the food supply chain literature and real-life applications. These technologies are at the forefront of innovation in food traceability, offering a combination of robustness, scalability, and real-time data capture capabilities that are critical for modern supply chain management. Furthermore, they have demonstrated their potential in enhancing transparency, safety, and efficiency of products flowing from farm to table, thus making the case highly relevant for in-depth investigation. While many food companies prefer to adapt their existing integrated systems to mitigate costs (Wognum et al., 2011), these technologies were chosen for their unique ability to transcend traditional limitations and offer transformative possibilities. It is important to note that the food industry is at a juncture where simply adapting existing systems may not suffice in meeting the increasingly stringent demands for food safety and traceability. Therefore, a thorough understanding of the traceability technologies (Table 1) for food sector is paramount.

Table 1. Food Traceability Technologies

Technologies	Purpose	Example	Features & Observations
Near Field Communication (NFC)	Identification	(Pigini & Conti, 2017)	• No line-of-sight needed. • Enhanced data capacity compared to barcodes. • Supports wireless data transitions
Bar code	Identification	(Žurbi & Gregor-Svetec, 2023)	• Cost-effective alternative to RFID • Quick and consistent readings • Needs direct visibility for scanning
Radio Frequency Identification (RFID)	Identification	(Shi & Yan, 2016)	• No direct visibility required. • Extended read ranges with high precision • Offers increased data retention capabilities. • Efficient, but at a higher cost
Blockchain	Data Integration	(Saurabh & Dey, 2021)	• Decentralised data structure • Reduces potential for data tampering
Internet of Things (IoT)	Data Integration	(de Vass et al., 2021)	• Networked device connectivity • Enables automated data collection and smart controls
Wireless Sensor Network (WSN)	Data Integration	(Wang & Li, 2013)	• Facilitates "One-up one-down" traceability. • Requires specific data formatting like EDIFACT or XML

3.4.2 Internet of Things (IoT)

The Internet of Things (IoTs) have been identified as catalyst for technological advancement, especially within the supply chain industry (de Vass et al., 2018). IoT facilitates interaction with intelligent objects, with environment, or with other computer devices. These objects, initially associated with RFID technology, have now expanded to include a vast array of embedded technologies (e.g., micro-chips) within physical entities, culminating in far-reaching and eclectic diffusion capabilities (de Vass et al., 2020).

The integrated framework of IoT is composed of six fundamental elements: norms for identifying things, mechanisms for sensing, communication technologies for object connectivity, hardware and software, IoT services, and semantics (Al-Fuqaha et al., 2015). These services span four main categories - identity-related services, collaborative-aware services, ubiquitous services, and information aggregation services - each with distinct implications for supply chain processes. Indeed, IoT applications cover all phases of the food supply chain, from agricultural production to packaged food monitoring, thereby promising for real-time supply chain monitoring and swift responses to dynamic changes (Atzori et al., 2010).

As an increasing number of objects start to carry barcodes, RFID tags and sensors, the IoT is expected to play an even more significant role in the logistics industry (Evdokimov et al., 2010). By producing geospatial data, these technologies enable accurate, real-time traceability of physical objects throughout the supply chain process. de Vass et al. (2018) claim that investments in IoT could potentially boost both supply chain performance and organisational performance.

However, the current literature does not adequately delve into the critical role of IoT within the contemporary supply chain context. Specifically, the studies in context of dairy industry lacks a comprehensive, qualitative investigation of tracing and tracking of the dairy products.

de Vass et al. (2018) made a laudable attempt in a qualitative study, identifying IoT's critical role in Supply Chain Integration (SCI) and supply chain performance. Their findings suggest

that IoT extends beyond mere internal logistics integration, impacting cost, quality, delivery, and flexibility of the entire supply chain, and subsequently enhancing sustainable performance across financial, social, and environmental outcomes.

Despite these promising assertions, it's crucial to approach this evidence critically. For example, findings of de Vass et al. (2018) are limited to the specific context of Australian retail supply chains. Therefore, there exists a clear knowledge gap surrounding IoT applications in different industries, geographic regions, and cultural contexts. de Vass et al. (2018) also pointed out a need for an in-depth exploration of the drivers, constraints, and enablers of IoT adoption. This omission is significant, as Ali et al. (2023) highlighted the role of organisational inertia and high perceived costs as potential barriers to adopting such technology.

Kiritsis (2011) and Lianguang (2014) discussed the potential of IoT to track and trace entities throughout the supply chain, a capability particularly pertinent to industries like dairy. Yet, this aspect was explored by De Vass et al. (2018) from a unilateral focal retailer's perspective, leaving a gap in understanding how this potential unfolds among other supply chain entities, such as distributors and transporters.

3.4.3 Radio-frequency Identification (RFID)

RFID technology consists of identification tags that store information captured through radio waves by remote readers. Such tags can be passive and operate only in the action area of the user, or it can be active with an integrated battery, maintaining full-time communication regardless of the location (Kumari et al., 2015). This tool can be linked to several food categories and food supply chains, demonstrating its versatility. For example, animals can be traced individually from birth to distribution; fresh fish can be traced from the fishing vessel to the port (Abad et al., 2009). Mainetti et al. (2013) even suggest a traceability system of plants using radio frequency technologies. Yet, RFID is not frequently cited in the individual identification of final products/items due to its high cost. Instead, barcodes are considered more economical as retailers use them frequently and customers can easily read them through radio-frequency (RF) guns (Feng et al., 2013). Moreover, devas et al. (2018) state that RFID is not yet popular for individual items, although it is economical for cases or pallets of

product. By connecting an RFID reader to the Internet terminal, users can recognise, track and control tag-attached objects globally, automatically and, if necessary, in real time, as RFID is also considered as having a sensor mechanism similar to IoT (Jia et al., 2012). In fact, RFID is considered as the most predominant technology for sensing and communication protocols in the context of technological traceability systems (Corallo, Latino, Menegoli, & Pontrandolfo, 2020)

3.4.4 Near Field Communication (NFC)

In the dynamic context of supply chain management, Near Field Communication (NFC) is increasingly gaining attention for its potential to transform food traceability systems. As Pigini and Conti (2017) claim, NFC technology serves as a conduit for short-range communication between electronic devices, thereby facilitating an intricate yet easily accessible information network spanning from producers to consumers. This advancement is particularly relevant given the increasing societal demand for transparency and accountability in food sourcing and quality assurance.

Beyond its capacity for enhancing transparency, NFC technology also fulfills contemporary industry prerequisites for wireless, passive, low-cost, and portable detection systems(El Matbouly et al., 2022). These attributes make it an attractive choice for organisations looking to upgrade their supply chain capabilities. Nonetheless, existing literature has yet to provide a substantive comparative analysis between NFC and other extant traceability technologies such as Radio-Frequency Identification (RFID) and Quick Response (QR) codes. Such a gap in literature raises questions about the specific benefits and drawbacks of NFC, which could otherwise provide valuable insights for organisations deliberating on which technology to adopt for optimal traceability.

Furthermore, NFC technology's applications contribute significantly to food safety and quality control (Pigini & Conti, 2017). Despite these promising avenues, comprehensive studies exploring the multifaceted challenges of implementing NFC—such as the costs, scalability, and integration complexities—are notably absent from the current academic literature. This gap restricts a nuanced understanding that would be instrumental for stakeholders when making decisions related to technology adoption in various food sectors.

Thus, while NFC holds considerable promise for revolutionising food traceability and contributing to enhanced food safety mechanisms, there remains a pressing need for further research. Investigative efforts should focus on comparative analyses to discern NFC's unique strengths and limitations in comparison to other traceability technologies. Furthermore, empirical studies should be conducted to examine the organisational, technological, and environmental variables that could influence the effective implementation of NFC-based traceability systems across diverse food industry sectors. By addressing these gaps, future research can offer a more comprehensive framework to guide the adoption and optimisation of NFC technologies in the realm of food traceability.

3.4.5 Wireless Sensor Network (WSN)

The WSN is a group of linked sensor nodes used to track the weather (Ruiz-Garcia et al., 2009). Temperature, relative humidity and levels of volatile compounds, among other environmental data, can be sensed by the sensors. Each node in the WSN consists of a microcontroller and an antenna for communication with other nodes (Xiao et al., 2017). The WSN records the real-time temperature and humidity in cold chains that store and distribute temperature-sensitive foods, such as vegetables, fresh fruits, meats and other perishables (Kim et al., 2015). WSN technology shows promise for use in the food supply chain; however, it needs to be further developed to meet more complex and stringent security requirements.

3.4.6 Blockchain Technology (BCT)

Blockchain technology (BCT) operates as a distributed and decentralized system composed of time-stamped blocks linked via cryptographic hash (Andoni et al., 2019; Feng et al., 2020; Galvez et al., 2018; Ølnes et al., 2017). Renowned for addressing fundamental problems related to trust, security, information transparency, and tampering prevention, BCT offers a promising approach to enhance trust mechanisms and resolve confidentiality and security issues within supply chains.

More conventional, centralized traceability systems, where data centres are primarily centralized, are frequently susceptible to issues such as a single point of failure and potential data tampering (Demestichas et al., 2020; Feng et al., 2020; Liu et al., 2022; Tanwar et al.,

2022). This is where BCT's strength lies - it is a data structure designed to support distributed digital ledgers, offering a secure repository for data within chained blocks (Zarpelão et al., 2021). While BCT is most widely used in the financial sector, its potential as a transformative driver is gradually being recognised by other industries as well (Caro et al., 2018). The advent of international standards like ISO 22739:2020 and ISO 23257:2022 is testament to the growing efforts to facilitate BCT applications.

The benefits of BCT extend to providing a reliable stream of traceability information among supply chain participants, presenting a significant advantage (Compagnucci et al., 2022; Varavallo et al., 2022). Nevertheless, the knowledge regarding the creation of a conceptual framework for BCT application and implementation, particularly in complex agri-food supply chains (AFSCs), is limited (Feng et al., 2020; Zhang et al., 2022).

Given the growing significance of real-time monitoring systems in food supply chain logistics, BCT application in AFSCs is increasingly essential (Surasak et al., 2019). It enables the creation of a transparent, immutable, and reliable system, which in turn fosters real-time decision-making. In the context of digital food traceability systems, Internet of Things (IoT) tools such as radio frequency identification (RFID) are already being utilised, while BCT is emerging as a potentially efficacious solution (Demestichas et al., 2020; Feng et al., 2020; Surasak et al., 2019).

The incorporation of BCT into traceability systems is still in its early stage, with no well-established and cost-effective commercial applications developed to date (Compagnucci et al., 2022; Loke & Ann, 2020; Mirabelli & Solina, 2020; Zhai et al., 2022). Consequently, a more profound knowledge base, including a thorough understanding of data structure requirements and supply chain design for effective BCT application in AFSCs, is needed (Tsolakis et al., 2021). Additionally, the potential impacts of BCT-based traceability systems in FSCs remain inadequately understood (Compagnucci et al., 2022).

Due to its immutability, blockchain-based traceability systems prevent any single party in the supply chain from altering the information, hence offering enhanced security, transparency, and efficiency. Consequently, they are increasingly being seen as a potent solution for tracing product data from the farm to the consumer (Feng et al., 2020).

3.5 Technological, organisational and environmental (TOE) framework

Research has applied many theories that underpin the adoption research. The commonly used are Technology Acceptance Model (TAM), Theory of Reasoned Action (TRA), Technology-Organisation-environment (TOE) framework and Innovation Diffusion Theory (IDT). The last two frameworks are used to explain technology adoption from the perspective of organisational use (Gangwar et al., 2015; Gharaibeh et al., 2020; Kalaitzi et al., 2019). IDT takes technological and organisational factors into account, however it does not include environmental factors, such as competitor pressure or government policy (Gharaibeh et al., 2020; Kalaitzi et al., 2019). Instead, this study employs the TOE framework founded by Tornatzky et al. (1990) to explore the adoption of new technologies based on three main factors such as technological, organisational and environmental factors (Gangwar et al., 2015). It is adopted for exploring factors affecting traceability technologies in the food supply chain. It is a comprehensive approach that widely used in technology adoption literature more than other adoption frameworks, e.g., the IDT and the TRA (Awa et al., 2016).

Transitioning to the practical implications of these theoretical underpinnings, there's a discernible challenge faced by developing countries, Saudi organisations included, in technology adoption. Factors such as technological intricacies and hurdles in implementation amplify these challenges. However, policy initiatives like Saudi Vision 2030 signal a transformative push, emphasising the nation's ambition to emerge as a food sector powerhouse driven by technology and automation (Vision2030, 2021). This is further underlined by the heightened consumer demand during the COVID-19 pandemic for transparency in food products' origin and handling. Consequently, this study's focus sharpens on the Saudi food industry's segments: processing, distribution, and retailing, as illustrated in Figure8.

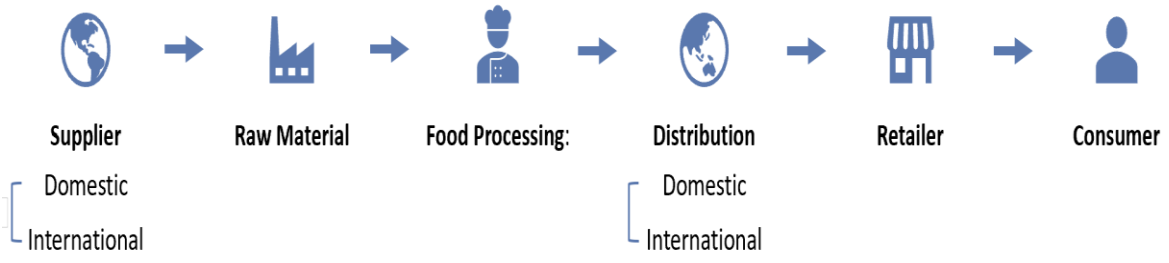


Figure 8. Food supply chain schematic diagram

Recently, the exploration of technology adoption has burgeoned, drawing researchers towards understanding the intricate interplay of technological, organisational, and environmental factors. The TOE (Technology-Organisation-Environment) framework serves as a pivotal framework through which these dynamics are analysed.

In traceability technologies context, blockchain technology was a focal point of digital transformation for researchers such as Orji et al. (2020) and Gökalp et al. (2022). Both studies converge on specific technological factors like the relative advantage and complexity, but nuances emerge. Gökalp et al. (2022) emphasise standardisation and scalability, suggesting a maturing technology, while Orji et al. (2020) prioritise the availability of tools, hinting at practical implementation challenges.

Another riveting technological arena is artificial intelligence (AI) and robotics, meticulously dissected by Nam et al. (2021). Beyond the evident technological merits, their exploration delves into the nuanced balance organisations need to strike, especially concerning external and internal IT expertise. This finding resonates with Siew et al. (2020) who underscored the indispensable role of IT employee competency.

While technological attributes form the bedrock of adoption, organisational factors are equally, if not more, instrumental. A consistent theme, be it in Gökalp et al. (2022) or Gangwar et al. (2014), is the unwavering role of top management support. However, studies like Low et al. (2011) on cloud computing highlight additional dimensions, emphasising the organisation's readiness and the broader scope of business operations.

The environmental context, however, brings many external variables that play a crucial role in the adoption of new technologies. Regulatory aspects, as highlighted by Nam et al. (2021) and Gökalp et al. (2022) either facilitate or hinder the technology adoption, depending on their alignment with the technology's objectives and capabilities. In parallel, consumer pressure for transparency, investigated by Liu et al. (2019) and Lusk et al. (2018), support organisations to revisit and possibly upgrade their traditional supply chain traceability technologies. Additionally, the COVID-19 has added another layer of complexity,

magnifying the need for more robust and transparent systems, as indicated by Rizou et al. (2020).

Drawing upon the existing literature, the importance of the TOE framework in elucidating technology adoption becomes clear. Numerous factors frequently surface as central themes in prior research. Given the consistent focus on these factors in the TOE literature, the subsequent sections will outline the main TOE factors derived from past studies (Table 2).

The literature outlined in Table 2 shows the dominant factors influencing the adoption of various advanced technologies within the context of the TOE framework. The studies reviewed span a range of technologies, from Industry 4.0 to blockchain and cloud computing, and highlight key technological factors like compatibility and complexity. Organisational factors such as top management support and environmental factors like competitive pressure are consistently noted as influential.

Table 2. Dominant Technological, Organisational, and Environmental (TOE) Factors that used in Existing Literature on Technology

Sl.No	Authors	Study Focus	Technological Factors	Organisational Factors	Environmental Factors
1	(Zhong & Moon, 2023)	Industry 4.0 Technology:	compatibility, cost	Top management support, employee capability	Competitive pressure
2	(Gökalp et al., 2022)	Blockchain technology	Complexity, relative advantage compatibility, trust standardisation, and scalability.	Organisations' IT resources, top management support, organisation size, financial resources	Competitive pressure, trading partner pressure, government policy and regulations, inter-organisational trust
3	(Nam et al., 2021)	Artificial intelligence and robotics	External IT expertise, relative advantage, complexity, internal IT expertise.	Market position, financial justification, resistance by employees	Customer readiness, customer expectation, competition, legal issues
4	(Orji et al., 2020)	Blockchain technology	,Infrastructural facility, complexity, availability of specific blockchain tools perceived benefits, privacy, compatibility, security	Presence of training facilities, top management support, firm size, capability of human resources, perceived costs, organisational culture	Government policies, competitive pressure, institutional-based trust, market turbulence, stakeholder pressure
5	(Siew et al., 2020)	Computer-assisted audit tools and techniques (CAATTs)	n/a	Firm size, top management commitment, employee IT competency	Complexity of clients' accounting information systems, perceived level of support of professional accounting bodies
6	(Clohessy & Acton, 2019)	Blockchain technology	n/a	Top management support, organisational readiness, organisation size	n/a.
7	(Zadeh et al., 2018)	Cloud computing	Compatibility, relative advantage, complexity, ease of use, trialability, technology integration	Firm size	Competitive intensity, regulatory support
8	(Verma & Bhattacharyya, 2017)	Big data analytics	Complexity, compatibility, IT assets.	Top management support, organisation data environment, perceived costs	External pressure, industry type
9	(Awa et al., 2016)	Enterprise resource planning (ERP) software	Technical know-how, perceived compatibility, perceived value, security, technology (ICT) infrastructure	Organisation-demographic composition, size, scope of business operations, subjective norms	Competitive pressure, external support, trading partners' readiness

3.5.1 Technological factors

The technological context focuses on internal and external technology that is beneficial for companies. The technological features such as relative advantage, compatibility, and complexity are critical in new technologies adoption decision (Gangwar et al., 2015).

3.5.1.1 Relative advantage

Additional advantages of new technologies over the legacy systems play a crucial role in the adoption of technology within an organisation. Rogers (2010) describes relative advantage as the extent to which a technological factor is regarded as offering superior benefits to organisations. Recent studies by Luomala et al. (2015) demonstrate that food tracing systems using technologies have improved operations and efficiency in the organisation. The frequent familiarity with each step helps identify problem sources and keeps the staff and executive faculty updated on the performance and production processes. It also improves the supply chain, increases inventory accuracy and aids in meeting consumer needs. Furthermore, food traceability technologies enable end-to-end traceability operations (Kshetri, 2018), which can trace the origin of products from farms to consumers. The traceability information of farming origins, lot numbers, quarantine date, factory and processing details, transportation information, storage data (i.e., storage temperature, humidity, gas, time, operator) and shelf-life can be recorded at each step of the production process (Badia-Melis et al., 2015; Thakur & Donnelly, 2010). As a result, adoption of food traceability technologies can build trust among stakeholders, which enables inspection of the records of the whole supply chain. Moreover, supply chain participants can track them more comprehensively than ever before. Companies can use the information to provide legal proof of the traceability management of food products and prove the authenticity of products.

Adoption of food traceability technology can significantly contribute to effective sustainability and transparency of traceability management (Chang et al., 2019; Galvez et al., 2018; Hong et al., 2018). Some food traceability technologies offers users the ability to access and improve documents from anywhere in the world, provided they have computer access and an Internet (Jain & Bhardwaj, 2010). Users do not need to own a computer for cloud computing services. Shared resources is another advantage for companies offered by

cloud systems, which enables employees to access resources in the cloud from any location, saving businesses time and money (Jain & Bhardwaj, 2010; Shee et al., 2018). With the relative advantage of emerging technologies, it is likely that the technologies will be adopted into the organisation.

3.5.1.2 Compatibility

Rogers (2010) defines compatibility as the extent to which an innovation aligns with the values, previous experiences, and requirements of prospective adopters. Later, Calisir et al. (2009) define it as the degree to which technology is considered compatible with the current values, past experiences and requirements of potential users. Perceived compatibility considers whether an organisation and its employees' current values, behavioural habits, and experiences are reconcilable with emerging technologies and/or innovation (Calisir et al., 2009; Chen et al., 2019; Gangwar et al., 2015; Peng et al., 2012).

It has been suggested that the more compliant a foreign technology is with the current technology, the greater the trust in mastering the new technology and the more positive the attitude that can be obtained (Gangwar et al., 2015; Kai-ming Au & Enderwick, 2000).

3.5.1.3 Complexity

The perceived level of difficulty in learning and using a system is known as "complexity" (Gangwar et al., 2015; Sonnenwald et al., 2001). The more complicated the technology, the less likely its successful application. When a type of technology is considered complex for a company to adopt, upper management decides whether to ignore it or to adopt it later. Thus, the complexity of food traceability technologies has a negative relationship with its adoption (Shi & Yan, 2016). Generally, it is quite similar to ease of use. However, numerous studies treat it as different and independent factor (Chau & Hu, 2001; Parveen & Sulaiman, 2008).

3.5.2 Organisational factors

The organisational context refers to the firm's structure, as well as the resources and intra-firm communications (Lian, 2015). In this research, organisational culture, top management support and training and education included as organisational variables. Indeed, organisational construct is the main factor in this study because it has a significant effect on

the relationship between the technology adoption intention and the other two factors (Technological and environmental). Organisational culture is the main factor that has an important role since cultural and social norms have a strong impact on technology adoption in the Arab world. Thus, technology adoption is not only difficult but also risky for organisations there (AlBar & Hoque, 2019; Aldraehim, 2013). Saudi Arabia's culture is tightly bound by Islamic belief and norms, which is supported by the government of Saudi Arabia (Alqahtani et al., 2018). As a consequence, in order to improve technological adoption in Saudi Arabia, it is important to better understand the cultural factors to investigate the reason behind the slow process of technology adoption (Alqahtani et al., 2018). There has been very little studies that explored technology adoption in Saudi Arabia from various perspectives (Alqahtani et al., 2018). Some studies have explored environmental and behavioural factors while others investigated the logistics, legislation, and technology infrastructure (AlGhamdi et al., 2011; Alqahtani & Wamba, 2012; Eid, 2011). However, very little has concentrated on understanding and identifying the cultural factors related to technology adoption in the form of traceability. As a result, focusing on organisational culture and its effect on technology adoption in Saudi Arabia is both important and timely.

3.5.2.1 Effect of organisational culture

Culture wields a significant impact on technology adoption, specifically in developing countries such as those with Arab histories (Ameen & Willis, 2015). Nadi (2012) states that individuals carry cultural biases, beliefs and values that affect their perceptions of what new technologies may offer and its acceptance decision. Moreover, the results of Al-Ghaith (2015) suggest that attitude and subjective norms significantly affect the intention of adopters. The incompatibility of any technology with cultural practices, values and traditions is considered as one of the main factors in rejecting new technologies adoption (Akman & Turhan, 2016; Hill et al., 1994).

In Saudi Arabia, organisational culture is heavily influenced by national culture (Alsheddi et al., 2019), since more than 70% of top management are Saudis (Abueish, 2020). So, their national culture might influence their decisions and behaviours (Hofsted, 2001). Hence, that shapes the organisational culture. In fact, national culture influences organisational culture through the style of leadership, managerial decision-making, the practices of human resource

management, and managerial functions (e.g. motivation, communication, organisational design, employees' expectations, and reward systems) (Khan & Law, 2018). Moreover, Hofstede (1980) model shows the effects of a national's culture on the values of the society members, and how these values relate to behaviour or decisions such as adoption intension (Syed & Malik, 2014).

Hofstede's dimensions suggested two opposite types of cultures: First, it is based on weak uncertainty avoidance, individualistic, and low long-term orientation; and the second, which is strong uncertainty avoidance, collectivistic, and high long-term orientation (Hofstede, 1991). According to Hofstede's model, the culture of Saudi Arabian is high on uncertainty avoidance, masculinity, power distance, and collectivism. In contrast, the Western countries are low in uncertainty avoidance, power distance, and masculinity and high in individualism (Table3). Hence, Saudi Arabian culture is very different from occident culture, despite the advancement in the technological innovations in the country (Alsheddi, 2020; Minkov & Hofstede, 2010).

Table 3. Saudi Arabia compared to three Western countries (Alsheddi, 2020)

	KSA	USA	UK	Australia
Power Distance	95	40	35	36
Individualism	25	91	89	90
Masculinity	60	62	66	61
Uncertainty Avoidance	80	46	35	51
Long-term Orientation	35	26	51	21
Indulgence	52	68	69	71

3.5.2.2 Effect of top management support

Relevant literature emphasises the role of top management in technology adoption and execution. Gangwar et al. (2015) highlighted the significant influence of top management in

driving technological change within organisations. Salwani et al. (2009) argue that the perceptions and awareness of top management about the usefulness of technology create substantial value for companies. This value is manifested through a long-term vision, enhancement of resources, and fostering an ideal organisational environment, which includes higher evaluation of employee self-efficacy and support in overcoming obstacles and employee resistance (Jang, 2010; Ramdani et al., 2009; Teo et al., 2009; Wang et al., 2010). Additionally, the impact of top management support is often intertwined with organisational culture, as indicated by Lee et al. (2016). In the context of Saudi Arabia, the citizens hold 71.53% of key managerial positions due to Saudization, a policy encouraging the employment of Saudis to reduce unemployment (Abueish, 2020).

Shee et al. (2018) further elucidate the multifaceted role of top management in technology adoption. For instance, findings that top management support positively influences supply chain integration and performance underscore the necessity of management commitment in adopting new technologies. However, they also reveal that the influence of top management varies across different aspects of organisational functioning. For instance, while top management intervention significantly moderates the relationship between supplier and internal integration with supply chain performance, it does not have a similar effect on customer integration. This differential impact suggests a nuanced role of top management in technology adoption, particularly in areas where direct management influence might be less pronounced.

In integrating these findings, this research aims to explore how top management support within Saudi organisations, shaped by the unique cultural and strategic landscape of Saudisation, influences the adoption of technology. The study particularly focuses on the mechanisms through which top management support facilitates or hinders technology adoption, considering the diverse roles that management plays in resource allocation, strategic decision-making, and cultural influence within an organisation.

3.5.2.3 Effect of training and education

Training is defined as how a firm teaches its workers to use a tool in terms of quantity and quality (Schillewaert et al., 2005). Since food traceability technologies can be a complex, employees need to be trained and educated before implementing these tools. It decreases

employee stress levels and anxiety about the technology, increases motivation and provides improved understanding about the technological benefits for employee tasks. In addition, training reduces ambiguity and assists employees in understanding successful use in future (Gangwar et al., 2015), which improves overall ease of use and usefulness.

3.5.3 Environmental factors

In the context of technology adoption, the environmental context plays a significant role, encompassing a variety of external factors that may influence organisational decisions. This spectrum of factors includes but is not limited to, market dynamics, competitive pressures, customer readiness, and broader socio-economic elements such as the impact of COVID-19.

Differing from one firm to another, the decision to embrace new technologies is often driven by the unique developmental needs and strategic objectives of each enterprise. Environmental influences, ranging from competitive forces to regulatory mandates, play a substantial role in this decision-making process. Hsu et al. (2014) and Ifinedo (2011) have emphasised how pressures from business partners, competitors, and regulatory bodies shape technological choices.

The urgency of ensuring food supply chain safety, particularly in the context of farm-to-fork traceability, was brought to the forefront by Rizou et al. (2020). This concern is further amplified by increasing consumer demand for information about the traceability of food products, spurred by concerns over food quality, safety, and environmental considerations, as illustrated in the studies by Gao and Schroeder (2009), Liu et al. (2019), Lusk et al. (2018), and Wongprawmas and Canavari (2017).

The ability of organisations to maintain competitiveness is intrinsically linked to their adoption of new technologies, which in turn is influenced by competitive pressures and support from trading partners. Gangwar et al. (2015) noted the interdependence between competitive pressure, regulatory support, and the adoption of new technologies. This perspective is further supported by Bhattacharya & Wamba (2018), Jian et al. (2016), and Matias & Hernandez (2019), who identified competitive advantage, regulatory support, and competitive pressure as key determinants in the adoption of new technology. This body of

literature collectively underscores the multifaceted and dynamic nature of technology adoption within the context of organisational and environmental factors.

COVID-19 has been a transformative force, altering business landscapes on a global scale. Its impact transcends traditional market dynamics, introducing new challenges and accelerating digital shifts in unprecedented ways (Alsuwailem et al., 2022). By exploring the ramifications of this pandemic, essential insights will be gained into how businesses adapt to sudden, large-scale disruptions and the pivotal role technology plays in these adaptations.

In addition, consumer pressure, particularly in areas concerning food safety and traceability, has increasingly become a primary catalyst in shaping business strategies. In today's market, consumer preferences are not only rapidly evolving (Liu et al., 2019), but also exerting a profound influence on organisational decision-making processes. Delving into this dynamic offers an understanding of how consumer-driven demands can spur technological innovation and adoption, especially in sectors where transparency and safety are paramount.

Moreover, government policy is a critical factor, acting both as an enabler and a regulatory framework within which businesses operate (Orji et al., 2020). Policies can dictate the pace and nature of technological adoption, either by encouraging innovation through incentives or by imposing restrictions that necessitate adaptation. Understanding the interplay between policy and technology adoption sheds light on how regulatory environments shape and sometimes even redefine technological trajectories.

3.5.3.1 COVID-19 pandemic

The COVID-19 pandemic had disastrous results. Companies would not have expected and prepared for a situation like that (Reid et al., 2020). Rizou et al. (2020) argue that food supply chain safety was the first urgent problem under consideration, requiring safety measures for the entire food supply chain (from farm to fork). In fact, advanced and more appropriate digital traceability technologies are largely argued in case of an emerging public health crisis (Hahn, 2020). Traceability technologies such as blockchain, artificial intelligence (AI), and sensor technology (e.g., Internet of Things (IoT), would allow direct tracing from farm to fork. By combining advanced traceability technologies with new analytical and smart

technologies such as remote or virtual inspections, data streams could help minimise the time required to respond to foodborne outbreaks (Galanakis et al., 2021).

3.5.3.2 Consumer pressure

Consumers demand for information about traceability of food products has increased significantly in the last decade due to issues related to food quality and safety, and environmental protection (Gao & Schroeder, 2009; Liu et al., 2019; Lusk et al., 2018; Wongprawmas & Canavari, 2017). They increasingly request information about the source and ingredients of their food products due to the COVID-19 pandemic (Marchant-Forde, 2020). Hence, food industry is facing challenges of tracking and tracing the food products through production, processing and distribution (Liu et al., 2019).

Adopting suitable food traceability technologies can provide reliable and continuous information flow in supply chains, identify root causes of problems and recall high-risk products from the market (Liu et al., 2019). Therefore, food traceability systems can reduce consumer information asymmetry and food safety risks (Dandage et al., 2017; Shaosheng Jin & Lin Zhou, 2014; Wu et al., 2016).

3.5.3.3 Government policy

On 15 July 2017, the Strategic Management Committee in Saudi Arabia, approved the delivery plan for the National Industrial Development and Logistics Program (NIDLP) (NILDP, 2021). The program is mandated to transform the Kingdom of Saudi Arabia into a leading industrial powerhouse and a global logistics hub in promising growth sectors, including the food sector, focusing on automation and transformation toward Industry 4.0 (Taboada & Shee, 2020), which is consistent with Saudi Vision 2030, and emphasises adopting new technologies, requiring massive investments in technology to ensure its success (Alshuaibi, 2017). Hence, Saudi companies have been pressured to adopt and implement new technologies to meet government requirements.

3.6 Summary

This chapter has highlighted a review and discussion of related literature. It investigated the context of food traceability and its technologies in appropriate depth by highlighting the

crucial factors influencing the adoption of such technologies. It investigated the most critical technological, organisational, and environmental factors that influence the adoption of traceability technologies in Saudi Arabia's dairy sector. The next chapter will explain the research methodology that was adopted for data collection, data analysis and methodology justification.

4 Chapter Four: Methodology

4.1 Introduction

Chapter 3 undertook the literature review. Technological, organisational, and environmental factors were explored for their impact on the adoption of traceability technologies in dairy sector in Saudi Arabia. This chapter will discuss in detail the most important points relating to methodology. In addition, this chapter is intended to discuss the research approaches. It begins with an introduction to the methodology (Section 4.1), setting the stage for a deeper understanding of the research process.

The research paradigms discussed (Section 4.2) range from positivism to pragmatism, providing a framework for the study's philosophical underpinnings. The research design (Section 4.3) is elaborated through a multi-case study approach, detailing population, sampling, and interview processes.

Data analysis (Section 4.4) follows, with a thematic exploration grounded in the TOE framework, and Section 4.5 enhances this with cross-case analysis. The chapter ensures the rigor of the findings through reliability and validity discussions (Section 4.6) and concludes with a summary (Section 4.7).

4.2 Research Paradigm

This study is grounded in the post-positivist paradigm, which is anchored by foundational beliefs. Within post-positivism, these beliefs concern our understanding of reality, termed as ontology, and our conception of knowledge, referred to as epistemology.

Ontology in research addresses our understanding of the nature of reality. In the realm of post-positivism, there's an acceptance of an objective, external reality, but it also holds that our comprehension of this reality is inevitably filtered through our own subjective experiences and interpretations. In the context of this study on the adoption of traceability technologies by Saudi dairy firms, the ontological stance can be elucidated as follows: The traceability technologies themselves, with their features like data accuracy, food quality, customer satisfaction and supply chain visibility, are considered objective entities that exist

independently in the dairy supply chains. However, their value, implications, and impact are not universally fixed; instead, they're shaped by the unique organisational, environmental and technological contexts within the dairy firm. This suggests that while the technologies are real and tangible, their significance and role within different dairy firms are subject to interpretation and vary based on numerous factors (Crotty & J, 1998; Gruber, 1993).

Epistemology, on the other hand, delves into the creation and dissemination of knowledge. It questions what qualifies as knowledge and how such knowledge is acquired and understood. The post-positivist perspective acknowledges the value of empirical, objective knowledge but also accepts that our understanding is often coloured by our subjective experiences and biases. Applying this to the current study: The traceability technologies can be empirically evaluated for their technical merits, and such evaluations can produce objective, quantifiable data. Yet, when the study seeks to understand the influence of organisational, technological and environmental factors on technology adoption, it enters the realm of subjective knowledge. These insights, often derived from interviews and interactions with industry stakeholders, are influenced by personal beliefs, experiences, and values. They provide a richer, more nuanced understanding that complements the objective data, offering a holistic view of the research topic (Bryman, 2016; Jonassen, 1991).

This research, grounded in the post-positivist paradigm, navigates the continuum between objective reality and subjective interpretation. It recognises the tangible existence of traceability technologies but also values the TOE context that shape their adoption and implementation within the Saudi dairy industry.

The research paradigms that frequently used are constructivism, post-positivism, transformative and pragmatism (Creswell, 2014). The discussion below (Figure 9) is briefly explained six of the commonly used research paradigms, namely: post-positivism, positivism, critical theory, constructivism, participatory, and pragmatism.

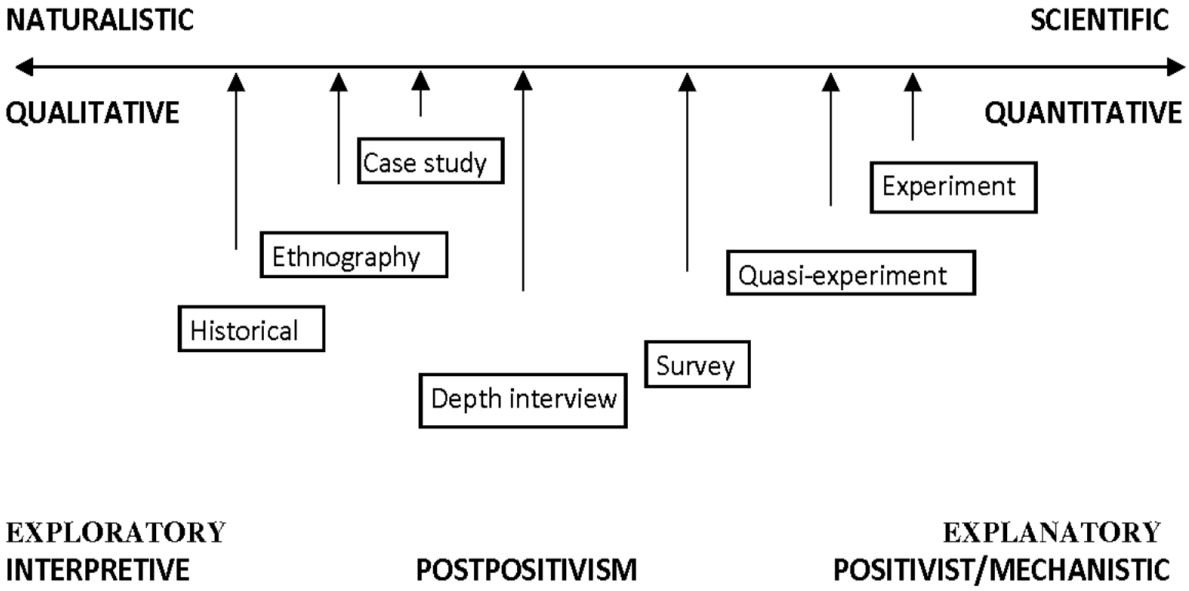


Figure 9. Characteristics of the Qualitative – Quantitative Research Continuum(Bisman, 2010).

4.2.1 Positivism

Positivism, rooted in the tenets of naïve realism, is a philosophical stance that asserts the existence of a singular, unchanging reality that can be directly apprehended through human sensory experience. In this context, reality is not a construct subject to individual interpretation but is ontologically static, consistent, and objective.

This deterministic viewpoint contends that events and phenomena, both in the natural world and within human interactions, adhere to specific causal patterns. By thoroughly understanding these patterns, it becomes feasible to predict outcomes with a high degree of accuracy. Within this paradigm, human beings are perceived as rational entities. Their understanding and interpretation of reality are distinct from their personal consciousness. As such, behaviours and actions are shaped predominantly by direct experiences, observations, and external inputs, leading to largely predictable outcomes.

Epistemologically, positivism mandates a clear dichotomy between the researcher and the subject of investigation. Such a distinction ensures that research findings are not tainted by personal biases or subjective interpretations. It underscores the importance of objectivity in the pursuit of knowledge. Methodologically, given that reality is perceived as precise and quantifiable, empirical approaches, particularly quantitative methodologies, are favoured.

Such methodologies allow for the systematic testing of hypotheses and derivation of findings that can be consistently replicated. This approach aligns with the positivist belief in the importance of repeatability and the pursuit of unbiased, objective knowledge (Lincoln & Guba, 1985).

4.2.2 Critical theory

Critical theory is a multifaceted framework encompassing various paradigms, ranging from participatory inquiry and materialism to feminism and neo-Marxism (Denzin & Lincoln, 1998). While (Denzin & Lincoln, 1998) classify it as a broad paradigmatic category, Creswell (2009) considers it more specifically as a qualitative theoretical perspective.

At its core, critical theory acknowledges the existence of a singular reality. However, this reality is not fixed or inert; it's deeply influenced by historical factors. Specifically, elements like political ideologies, economic systems, ethnic dynamics, gender norms, and broader social forces play a foundational role in shaping this reality. Over time, these historically-rooted influences evolve into established structures that are perceived by society as both "real" and "natural", even if they originated from specific historical or ideological contexts (Lincoln & Guba, 1985).

Epistemologically, critical theory stands in contrast to both positivism and post-positivist dualism. It posits that the researcher's own values and perspectives inevitably intertwine with the research subject, culminating in conclusions that are both value-informed and subjective. This understanding paves the way for a methodological approach that is both dialogical and dialectical in nature. Leveraging a diverse toolkit of both qualitative and quantitative research methods, critical theory seeks to elucidate the ways in which these historical structures continue to impact and mould human behaviour (Onwuegbuzie et al., 2009).

4.2.3 Constructivism

At the heart of constructivism lies the philosophical stance of relativism, challenging the notion of an immutable, objective truth. Instead, constructivism posits that reality is a fluid construct, inherently subjective, and contingent upon individual perceptions and interpretations of the external world. From an ontological perspective, this framework

diverges significantly from positivism by suggesting that there are multiple, contextually crafted realities rather than a single, universal one. These realities, far from being innate or static, are actively constructed and are deeply influenced by social interactions and personal experiences. Hence, one's understanding and perception of their environment play a pivotal role in shaping these constructed realities (Anderson, 1986; Creswell, 2009; Creswell, 2014; Lincoln & Guba, 1985).

Epistemologically, constructivism emphasises the interplay between the researcher and the subject under investigation, resonating with the tenets of critical theory. Knowledge, in this paradigm, isn't merely discovered but is co-constructed through the dynamic interaction between the researcher and participants. As research unfolds, this knowledge evolves, reflecting the participants' evolving perceptions and understandings of the phenomena being studied (Anderson, 1986; Creswell, 2009; Lincoln & Guba, 1985).

Methodologically, constructivism predominantly harnesses qualitative approaches, employing both hermeneutical and dialectical techniques. The dialectical method fosters a rich dialogue between the researcher and participant, eliciting diverse interpretations of reality. Subsequent hermeneutical analysis aids in interpreting these shared realities, guiding researchers toward a more refined, synthesised understanding. While some constructivists occasionally incorporate descriptive statistics as an additional lens to view a phenomenon, the more orthodox adherents tend to be wary of quantitative measures, given the paradigm's emphasis on subjective, contextual truths (Onwuegbuzie et al., 2009).

4.2.4 Participatory

Originating from the insights of Heron and Reason (1997), the participatory paradigm emerges as a critique and extension of constructivism. While constructivism has offered profound insights into knowledge construction, Heron and Reason contend that it sometimes falls short in addressing experiential knowledge, which is characterised by "knowing through acquaintance, encounter, and felt involvement in the presence of what is there" (Heron & Reason, 1997, p. 277). Heron's critique, that if our understanding of reality is limited to "internal mental constructs, no basis can be offered for supposing that the other persons under investigation exist" Heron (1996, p. 10), further sharpens this contention.

Ontologically, the participatory paradigm navigates the intricate balance between subjective and objective realities. It suggests that "what can be known is a subjectively articulated world that is objective concerning how the knower shapes it" (Heron & Reason, 1997). This understanding foregrounds the interconnectedness and mutual awareness of beings, emphasizing that true knowledge is intertwined with recognizing and engaging with others' existence and perspectives.

From an epistemological perspective, the participatory paradigm introduces a multifaceted framework of knowing. It encompasses knowledge that's framed propositionally through theories and statements, that which is derived from direct experiences, and that which is communicated through various aesthetic mediums, along with the proficiency associated with skills or the ability to execute tasks. Each of these dimensions of knowledge is rooted in critical subjectivity, underscoring the importance of context, perspective, and personal engagement (Onwuegbuzie et al., 2009).

In terms of methodology, participatory research, based on "cooperative inquiry, both between co-researchers and informants who participate in all elements of research decision-making," emphasizes deep collaboration throughout the research process (Heron & Reason, 1997). The language and discourse used in this paradigm are chosen for their resonance with shared experiential backgrounds to foster mutual understanding and enriched collaboration.

4.2.5 Pragmatism

Unlike constructivism, positivism, and post-positivism, pragmatism introduces a refreshingly different approach that places paramount importance on research implications and tangible outcomes. At its core, pragmatism prompts researchers to concentrate on the practical implications of their inquiries, rather than getting entangled in rigid philosophical discourses (Johnson & Onwuegbuzie, 2004). Biesta (2010) notably posits that pragmatism should be viewed less as a standalone philosophical doctrine and more as an adaptable toolkit for problem-solving.

Rooted in pragmatism is the belief that philosophy should be directed toward addressing concrete problems rather than mere ideation or the construction of abstract theoretical frameworks. Such an actionable orientation has led some scholars to label pragmatism as an

"anti-philosophy" (Johnson & Onwuegbuzie, 2004). Creswell (2014, p. 39) further elucidates that “Pragmatism is not committed to any one system of philosophy and reality”.

Ontologically, pragmatism adopts a flexible stance, emphasizing the pursuit of real-world issues. It acknowledges the existence of multifaceted "existential" realities (Yvonne Feilzer, 2010, p. 8) , which could encompass objective, subjective, or hybrid dimensions. The essence of pragmatism is captured in the maxim that "things are what they are perceived to be", indicating that every encounter, regardless of its knowledge-bearing capacity, holds intrinsic value. This stance facilitates empirical explorations, unhindered by the conventional dichotomies that often delineate positivist/post-positivist from constructivist methodologies. (p. 13).

From an epistemological point of view, pragmatism affirms that knowledge is grounded in the reality we encounter in the world we inhabit, and, in the world, we have created (Onwuegbuzie et al., 2009). Methodologically, pragmatism's inherent flexibility urges researchers to transcend procedural rigidity, directing focus instead on the subject matter, comprehension mechanisms, and real-world relevance (Creswell, 2014).

Pragmatism posits that the traditional division between qualitative and quantitative research methodologies is not imperative(Onwuegbuzie et al., 2009). Such a belief allows researchers to move away from traditional dualisms (quantitative/qualitative) and employ pluralistic approaches to knowledge creation, allowing free and informed movement between qualitative and quantitative methods, techniques, and procedures to best serve the researchers' needs and goals (Creswell, 2014). Given its recognition of multiple layers of reality—encompassing objective, subjective, and hybrid dimensions—pragmatism serves as a robust philosophical foundation for mixed-methods research (Biesta, 2010; Creswell, 2014; Johnson & Onwuegbuzie, 2004; Onwuegbuzie et al., 2009) .

4.3 The Research Design

In this study, a qualitative research design was chosen as the most appropriate approach to deeply understand the complexities surrounding the adoption of traceability technologies in Saudi dairy companies. The emphasis on uncovering the factors effecting the adoption within

the dairy sector is rooted in the qualitative nature of the research, which places priority on context-specific understanding (Creswell, 2014; Denzin & Lincoln, 1998).

Embracing the multi-case study approach, the research captures detailed insights from various contexts (Merriam & Tisdell, 2015; Yin, 2014). Given the complex and diverse nature of supply chain management within the dairy industry, such an approach is not only appropriate but also encouraged, as evidenced by previous studies (Childerhouse & Towill, 2011; Wamba, 2012).

Central to the study is the research question: "How can Saudi dairy companies leverage traceability technologies and overcome their challenges to improve the supply chain performance?" To address this, the qualitative approach, supported by Gammelgaard and Flint (2012), is employed, enabling a deeper understanding of underlying dynamics and offering the flexibility to explore varied facets of the phenomenon.

Comprehensive data collection methods have been chosen, combining both primary (interviews) and secondary sources (literature review and company websites). Interviews, as expounded upon by Creswell (2014), offer first-hand insights into the experiences and perceptions of industry managers. The importance of member checking, highlighted by Birt et al. (2016), has been observed to ensure the credibility of collected data, addressing potential challenges identified by Marshall & Rossman (2014).

Reiterating the value of case studies in supply chain research (Childerhouse & Towill, 2011), this study focuses on understanding the nuances specific to Saudi dairy companies. Ensuring the findings' relevancy and accuracy, the research adheres to principles of confirmability as highlighted by Moon et al. (2016). Additionally, the concept of transferability, as described by Mesec and Lamovec (1998), is maintained to ensure the study’s broader relevance.

Finally, the research emphasises data saturation. Informed by the guidelines of few authors (Fusch & Ness, 2015; Morse, 2015), data collection continued until no new patterns or themes emerged. Probing questions, member checking, and supplementary data from company websites, as recommended by Hennink et al. (2017), were instrumental in reaching this saturation point, ensuring a thorough and comprehensive understanding of the research topic. Figure 10 below outlines the research flow in a schematic diagram.

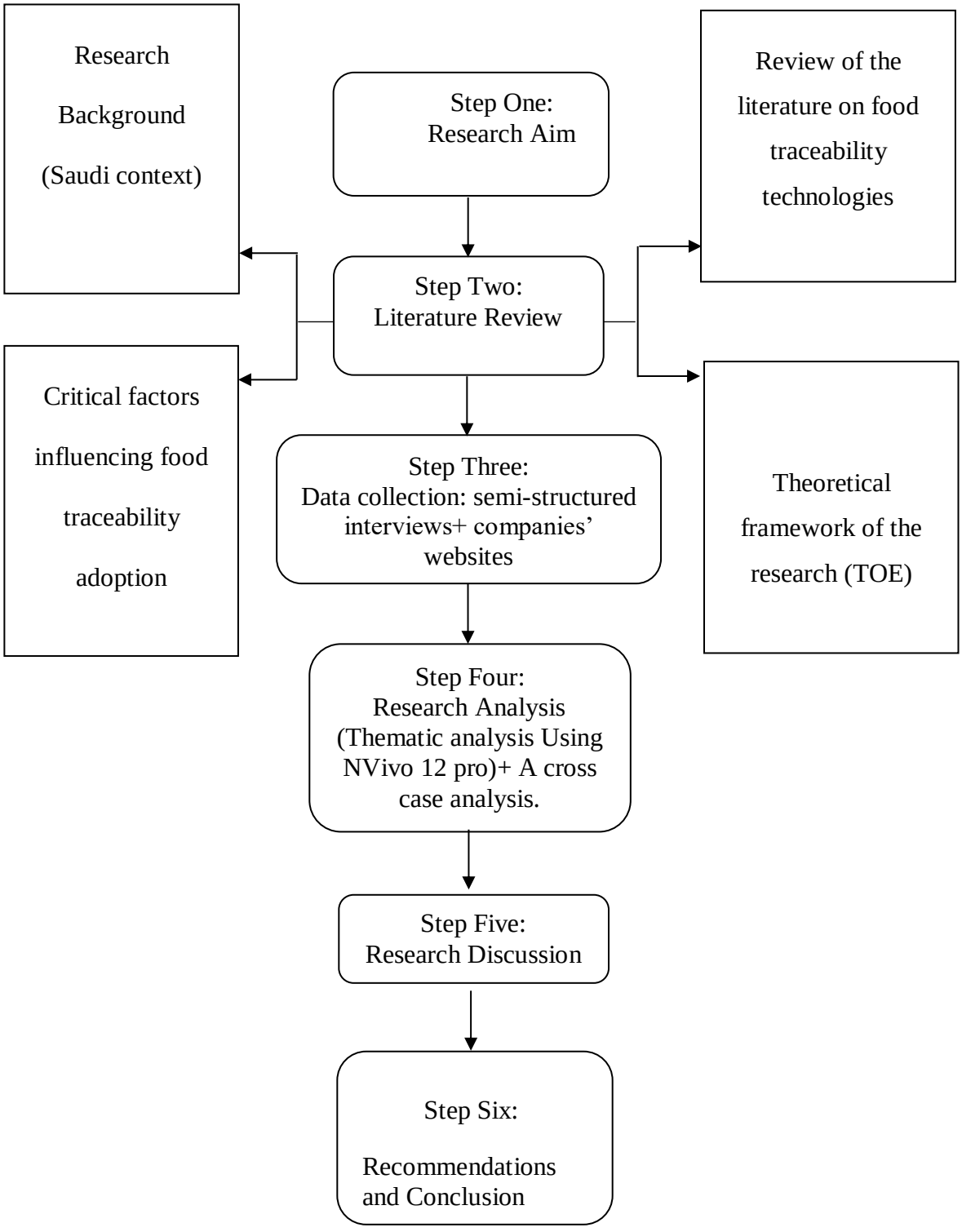


Figure 10. Research design

4.3.1 Multiple case study approach

In this research, a multiple case study approach is adopted, where each of the nine selected dairy companies in Saudi Arabia is treated as a distinct case. This allows for a meticulous exploration of the nuances within each company concerning the adoption of traceability technologies, guided by the Technology-Organisation-Environment (TOE) framework.

Using a variety of data collection methods, such as semi-structured interviews, literature reviews, and evaluations of company websites, a comprehensive understanding of traceability technology adoption in each individual Saudi dairy firm is sought. This approach offers a deep dive into each company's unique context while offering the flexibility to draw comparisons across the firms.

The emphasis on semi-structured interviews with participants from each dairy company ensures that the insights gathered are both detailed and relevant to the specific circumstances of each case. The strength of the multiple case study design lies in its ability to provide in-depth, individualised insights while also facilitating a broader comparative analysis. By integrating multiple data collection techniques, the research achieves a richer understanding of the topic and bolsters the reliability and validity of the findings (further details on the Reliability and Validity of the Thematic Analysis are elaborated in section 4.4.5).

4.3.2 Population and sampling

As of the year 2020, data obtained from the head of the National Committee for Fresh Dairy Producers at the Council of Saudi Chambers revealed the presence of 12 national dairy companies operating within Saudi Arabia. Remarkably, four of these companies commanded a substantial 89% market share within the dairy industry (Asharq, 2021). This data served as a foundational reference point for identifying the population of interest for this research.

To facilitate access to key participants within these dairy companies, the researcher-initiated contact with Saleh al-Towayan, the Head of the National Committee for Dairy Producers at the Council of Saudi Chambers. Mr. Al-Towayan generously provided the researcher with

valuable information about the dairy companies under consideration. Furthermore, he supplied contact information for some of the potential interviewees, facilitating the data collection process.

The data collection process involved reaching out to potential participants through various means, including email, WhatsApp, LinkedIn, and phone calls. All 12 dairy companies were formally invited to participate voluntarily in this research to ensuring a comprehensive representation of the industry.

Ultimately, nine senior production and distribution managers from nine different companies ranging from small to large agreed to participate. These individuals, who hold significant decision-making authority, are crucial for understanding the adoption of traceability technologies across the sector. Notably, the participating companies include the four largest firms, which together command nearly 95% of the market share. While the researcher tried to contact the remaining three companies through multiple means, there was no response.

The three companies not included in the study are considerably smaller and have minimal impact on market dynamics. Preliminary data from similar interviewed small companies revealed the same information, e.g., all these firms predominantly rely on traditional methods such as Excel sheets and manual reporting for product tracking. Since the interviewed small companies share similar supply chain practices and technologies, including the remaining companies would likely yield redundant information. Given this scenario, the study has reached data saturation, suggesting that additional interviews would not provide new or significant insights. Therefore, focusing on the nine participating companies ensures a comprehensive understanding of the supply chain and technological adoption strategies within the Saudi dairy industry.

Lastly, it is important to note that all nine interviewees held managerial positions and played integral roles in making strategic decisions within their respective organisations (Table 4). The participants' additional demographic details, including their backgrounds and positions within the industry, are comprehensively discussed in Chapter 6 (Findings).

Table 4. The participants' profiles.

Code	Work Exp.	Job role	Firm size	First adopted FTT
A	32	Head of quality	Large	2002
B	14	Supply chain manager	Large	2011
C	21	Senior director of manufacturing	Large	2010
D	19	Head of Production	Large	2013
E	26	Supply chain manager	Medium	2019
F	21	The CEO	Medium	Not yet- adopting
G	+20	Supply chain manager	Medium	2014
H	17	Plant manager	Small	Not yet
J	18	Manufacturing Manager	Small	Not yet

4.3.3 Interview protocol and pilot testing

This study used semi-structured interviews to help obtain deep insights into the main themes. A list of pre-prepared questions (interview questionnaire) was used as a guide of the semi-structured interview process, with additional flexibility to ask questions linked to the interview context (Kallio et al., 2016). In fact, Semi-structured interviews allow flexibility for the interviewee's spontaneous speech and narratives, while also providing structure to obtain the interviewee's insights in a systematic way (Denzin & Lincoln, 1998; Yin, 2009).

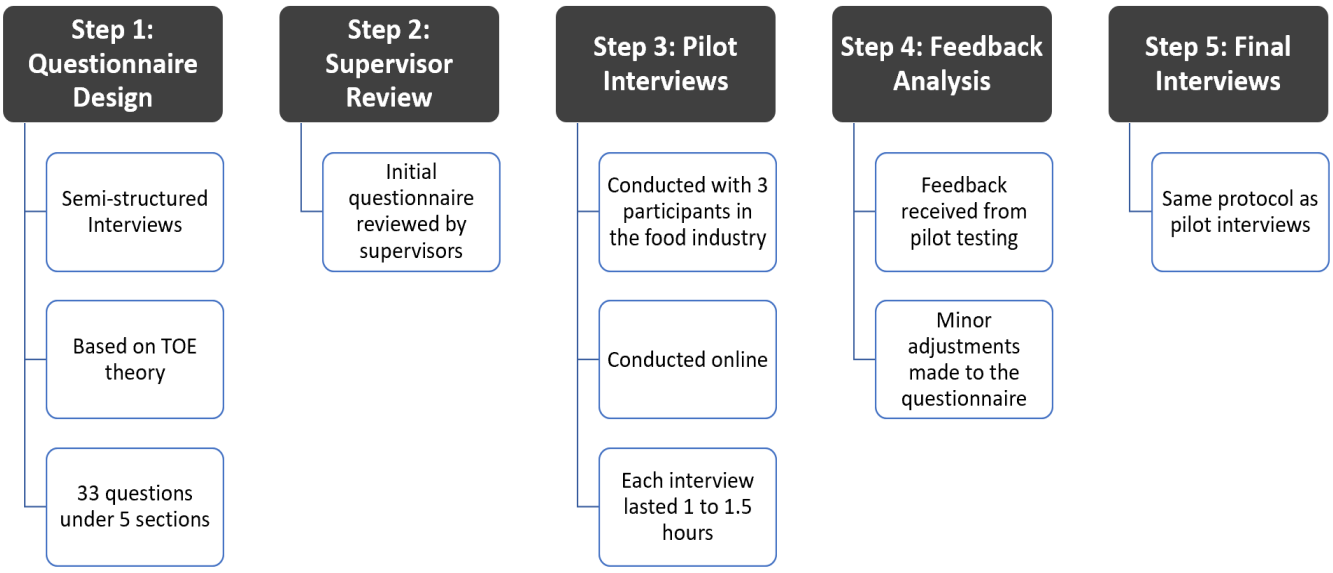
Adopting open-ended questions allowed the respondent to engage in an open way within the framework, to provide the interviewer with new facts and concepts throughout the interview time. It enables the researcher to ask "how" "why" questions, to investigate and explore information that had not been expected.

The interview questions were designed based on the TOE theory which was used as a research framework underpinning this research. The open-ended questions were aimed to investigate the factors that affect the adoption of food traceability technologies (the motivations, barriers, and challenges). The interview questionnaire (see Appendix H) had 33 questions under 5 sections which focused on general information about the respondents and traceability technologies adoption in diary supply chain.

Section 1 focused on information about the representative company and the respondents' background. Section 2 was asking about the technological factors that affected the company's adoption decision. Following this, participants were asked to reflect on the traceability technologies employed in their supply chain. Simultaneously explored was their future traceability technologies adoption plans. Then participants were asked to reflect on how traceability technologies adoption in processing, distribution, and retail affected their operational efficiency, and in turn, how these technologies influence the performance of the supply chain. Traceability technologies enabled supply chain performance outputs was discussed in terms of operational efficiency, quality, transparency, and flexibility. In section 3 the questions concerning the organisational factors such as top management support, training, employee's resistance was asked. In this section the participants were asked about the organisational culture if it support the adoption or not? In addition to that, participants were asked about the top management support followed by what they think are the barriers to traceability technologies adoption. In section four, the environmental factors were explored. The researcher asked broadly about COVID-19 and its effect on the adoption and how it affected the consumer demands. In addition, consumer pressure, and government policy including Vision 2030 were discussed. Finally, the researcher asked whether the participants had anything important to add during the interview.

The languages of the questions were carefully examined to lower "social desirability bias" which may make the participants answer the questions in a way that will be seen favourably by others (Nederhof, 1985). The interview questionnaire draft was initially reviewed by the supervisors. Then a meeting was held to discuss and evaluate the questionnaire appropriateness, where its length, scope and word expressions were assessed. The modified interview questionnaire was further examined through pilot interviews ahead of the target participants.

Pilot interviews were conducted online with three employees in the food industry to verify the relevance of the questions, and its reliability and validity. With the intention to reduce bias during the pilot interviews, commenting on responses and clarification "unless otherwise asked" was highly avoided. The participants were not interrupted unless the answers were



very long or far deviating from the question. The same approach was used for the final interviews. The pilot interviews took between 1 hour or one and half hours. Later, feedback on the questionnaire clarity and other suggestions were provided by the respondents in pilot testing. Minor improvements to the interview questionnaire were done. Specifically, changes were made to enhance the clarity of the questions, ensuring that respondents could understand and respond to them without ambiguity. Adjustments were also made to the wording of some questions to minimise potential bias in the responses. These modifications were carefully integrated to maintain the integrity of the questionnaire while improving its reliability and validity. The feedback was employed to modify and improve the final questions (Figure 11). Finally, the interview questionnaire used in this research is attached as Appendix 1.

Figure 11. Interview Protocol and Pilot Testing Process

4.3.4 Translation of the Interviews

The last step involved was translating the interview questions from English to Arabic. Since some interviewees were native Arabic speakers from Saudi Arabia, it was important for them to fully understand the questions to make the most of the interviews.

First, the researcher, a native Arabic speaker, translated the questions from English to Arabic. This served as the initial translation. Then, an accredited translator (NAATI) carefully reviewed the translated questions to ensure accuracy and correctness. The accredited translator officially confirmed that the translation was accurate and reliable.

4.3.5 Arranging and conducting interviews

All the 12 dairy companies were requested to participate in the interviews, and they were approached via e-mail to participate voluntarily for the study. In most cases, these participants volunteered the interview. Negotiation with the CEOs, HR managers and Directors was required when organisational permission was necessary, but the choice was mainly left to the participants who are the managers of the company (Bryman, 2016; Denzin & Lincoln, 1998; Yin, 2009). Once the researcher received a signed consent form (Appendix 4), the formal information to participant document was sent to them (Appendix 3).

The participant information document includes the research aim, purpose of the interview, interview duration, research contributions and privacy guarantee. It is generally agreed that to obtain a higher possibility of acceptance from potential participants, one should keep the time and resource requirements to the minimum. Consequently, the interviews were limited to approximately an hour and a half and only a single participant was invited from each company. The interviews were online, and the time was scheduled at the participants' convenience. Also, the participants were given the choice of participation and withdrawal at any time, and they were informed that their withdrawal will not jeopardise them in any way (Corbin & Strauss, 2014). The researcher ensures the privacy and confidentiality of the participants. The interviews were recorded using an audio app on the researcher's smart phone and then uploaded to a safe drive. The recorded interviews enabled the researcher to verify the reliability of the interview's information. However, the researcher had an alternative plan that an extensive note was taken in case a participant was not comfortable

about being recorded. The first question was centred around their organisational role to make the interviewees comfortable, develop the relationship, and start the discussion. The researcher avoided the leading questions to allow the interview a free discussion (Denzin & Lincoln, 1998).

4.4 Data analysis

In the context of data analysis for this research, a dual-layered methodological approach was undertaken to ensure both breadth and depth of understanding. Initially, thematic analysis was employed to provide a panoramic perspective on the collected data. This analytical technique, rooted in the principles of qualitative research, facilitated the identification, analysis, and reporting of overarching patterns or themes that spanned across the data set. By discerning these general themes, the researcher was able to grasp the broader narratives and tendencies evident in the responses.

Following this holistic thematic exploration, a more granular and focused analytical strategy was embarked upon, in the form of a cross-case analysis. In this phase, each company under study was treated as an individual case. By adopting this case-centric approach, the research was able to delve deeper into the idiosyncrasies and unique dynamics inherent to each firm. This meticulous case-by-case examination ensured that while broader patterns were identified in the thematic analysis phase, the subtleties and nuances specific to each company were not overshadowed but rather brought to the fore, providing a multi-dimensional understanding of the research topic.

By synergising the general insights from thematic analysis with the detailed findings from the cross-case analysis, the research strikes a balance between capturing overarching trends and appreciating company-specific intricacies. This comprehensive analytical strategy enriches the research outcomes, offering robust and layered insights into the adoption of traceability technologies by dairy firms.

4.4.1 Thematic analysis

For the investigation of technological adoption determinants among dairy firms in Saudi Arabia, a methodical and layered approach to data analysis is vital. Yin (2014) outlines that

data analysis entails the classification, exploration, and articulation of findings tailored to the core objectives of the study . Within the landscape of qualitative research, various analytical techniques are available. This thesis leverages thematic analysis, a technique that, along with content analysis, is a cornerstone in qualitative investigations (Vaismoradi et al., 2016). As Braun and Clarke (2006, p. 6) aptly describe, thematic analysis is geared towards "identifying, analysing, and reporting patterns (themes) within data, thereby offering a rich and comprehensive portrayal of the dataset." This method proved instrumental in capturing the essence of data related to the factors influencing technological decisions among Saudi dairy firms. Through it, salient contexts and features embedded in the data were harnessed during the coding phase, culminating in the extraction of pertinent themes.

In analysing the factors influencing the adoption of technology within Saudi Arabian dairy firms and their impact on the supply chain performance, a multi-faceted approach to data analysis was imperative. This research adopted a combination of thematic analysis and cross-case analysis to ensure a comprehensive and accurate exploration. Utilising the capabilities of the N-Vivo 12 Pro software, thematic analysis was meticulously executed. Interviews from various dairy firms formed the root of the data. Based on quotes and the researcher's interpretations of interview transcripts, dot points are derived, and these were arranged thematically to draw out themes from the findings. These themes were created using a deep and critical understanding of the interviews. The analysis was conducted with the help of a theoretical framework (TOE) and the Literature Review, so that the themes can be framed. Thematic analysis "is a form of pattern recognition within the data, where emerging themes become the categories for analysis" (Fereday & Muir-Cochrane, 2006, p. 4).

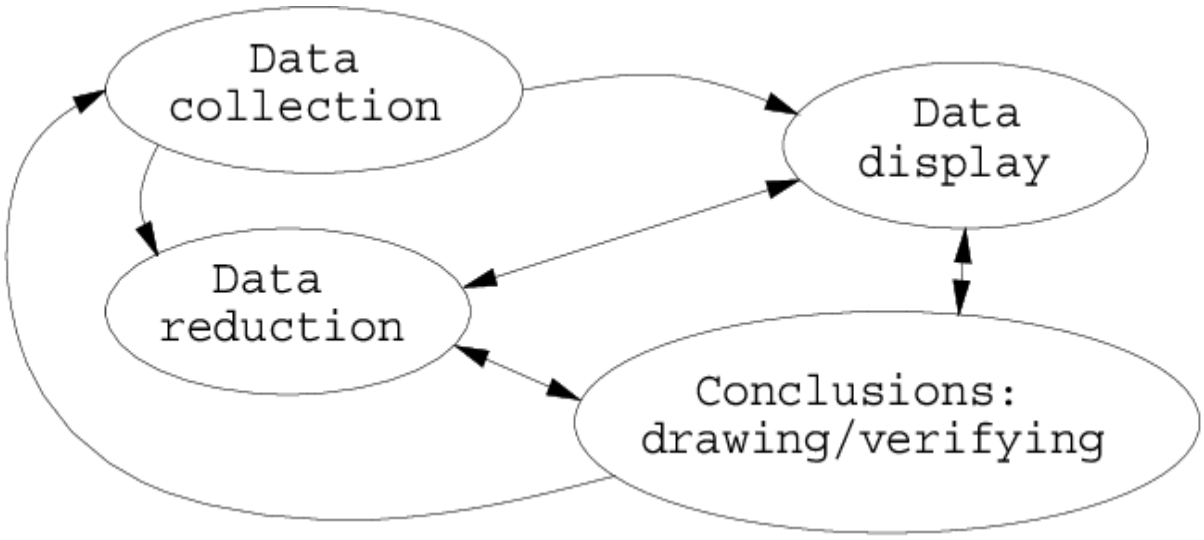


Figure 12. The thematic analysis model (Source: Miles and Huberman (1994, p. 12)

In this study, the researcher follows the thematic analysis model that suggests a few-step process (Figure 12) which includes data reduction, data display, and drawing a conclusion (Alhojailan, 2012).

For more explanation, figure 13 illustrates the structured process of thematic analysis employed in this study. Beginning with the established themes from the TOE framework, the research progresses systematically. The initial step involves developing interview questions that are directly informed by these pre-existing themes. Subsequent data collection is then carried out with these themes in mind, ensuring focused and relevant data gathering.

Once the data is collected, the analysis phase commences with the generation of themes. This step is iterative, allowing new themes to emerge from the interviews while also maintaining the integrity of the established TOE themes. The process of reducing the themes involves filtering and condensing the data to retain only the most significant and relevant information. The synthesis of themes follows, wherein the reduced themes are integrated to form a cohesive understanding of the data.

The analysis culminates in the drawing of conclusions from these synthesised themes, which are then re-immersed into the conceptual framework. This immersion allows for the existing TOE framework to be elaborated upon, with the research findings providing evidence to support both the initial and any new emergent themes. The use of quotes from the interviews serves to validate the themes and ground the theoretical discussion in empirical evidence.

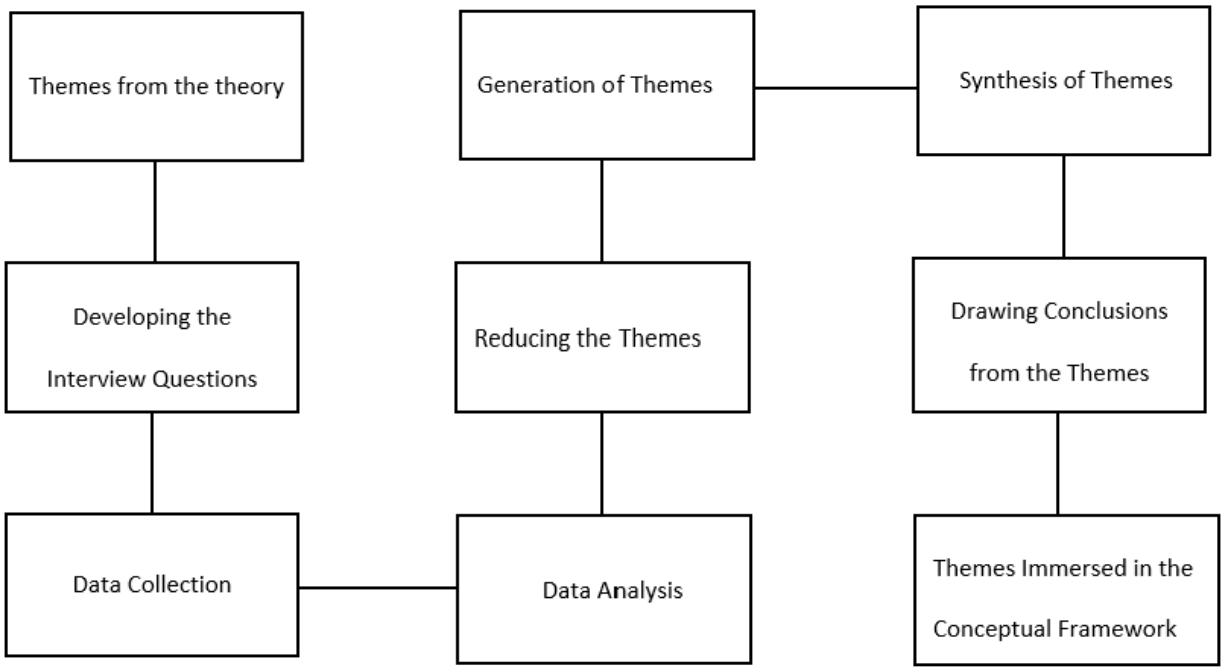


Figure 13. Flowchart of the thematic research procedures

4.4.2 Themes Derived from the TOE Framework

Using existing literature as secondary data is a pivotal part of thematic analysis, as it aids in the establishment of initial themes, which subsequently inform the construction of research instruments (Crawford, 2008). In the present study, these literature-derived themes laid the foundation for developing the interview questions. Upon gathering primary data through interviews, it further assisted in pinpointing the core research themes, as illustrated in Figure 13.

The application of thematic analysis in this research proved beneficial, broadening the study's purview and enabling the exploration of descriptive datasets. As part of the analysis, the researcher amassed a vast amount of data, aiming to encompass a comprehensive spectrum of the topic at hand. Several themes, in line with the study's objectives, were identified. Examples of such overarching themes include Future Challenges, Government Policy, Organisational Culture, Technology Advantages, Employees Resistance, and COVID-19. These thematic constructs were instrumental in steering the research towards fulfilling its

objectives. Moreover, using thematic analysis, the raw data was transformed into meaningful, comparative insights, fostering an enriched discussion (Clarke et al., 2015).

Echoing the aforementioned, numerous themes were extrapolated from the Literature Review, synchronising with the research's aims and objectives. These themes were intricately linked to the central research question, facilitating its comprehensive addressal. Following data acquisition, transcripts were meticulously prepared, paving the way for an intensive coding process (Bazeley and Jackson, 2013).

4.4.3 Generation of Themes

Following the completion of the interviews, the researcher proceeded to the critical phase of thematic analysis, which is the generation of themes. This involved integrating insights from the primary data with the foundational themes previously established from the TOE framework (Figure15).

- Data Import and Familiarisation: All interview transcripts were systematically imported into NVivo. The researcher meticulously perused the data within the software, annotating preliminary patterns or insights were evident (Figure 14).
- Coding Process: Using NVivo's robust coding functionalities, segments of the primary data were methodically coded. This entailed segmenting the data and assigning labels to denote what each fragment represents contextually.
- Theme Identification: Potential themes were discerned employing NVivo's querying capabilities. This step congregated the coded data by mutual ideas or conceptual similarities.
- Theme Refinement: A thorough review and refinement process was undertaken within NVivo. Certain themes were amalgamated, some were bifurcated, while others, lacking substantive support, were omitted.
- Theme Definition: Post refinement, each theme was precisely defined within the context of the research. The researcher delineated the essence of each theme and its role in answering the research inquiries.
- Integration with Initial Themes: Leveraging NVivo's comparison tools, the themes emerging from the interview data were seamlessly integrated with the initial themes

rooted in the TOE framework. This ensured a comprehensive theme set rooted both in literature and empirical data.

- Visualization: NVivo's advanced visualization instruments, such as matrices and hierarchical charts, provided insights into theme interrelations, their prevalence among respondents, and their overarching relevance to the research.

Throughout this analytical journey, NVivo served as an invaluable ally, enhancing the precision, depth, and systematic approach to theme generation. The suite of tools offered by the software enriched the thematic analysis and deepened the researcher's comprehension of the primary data.

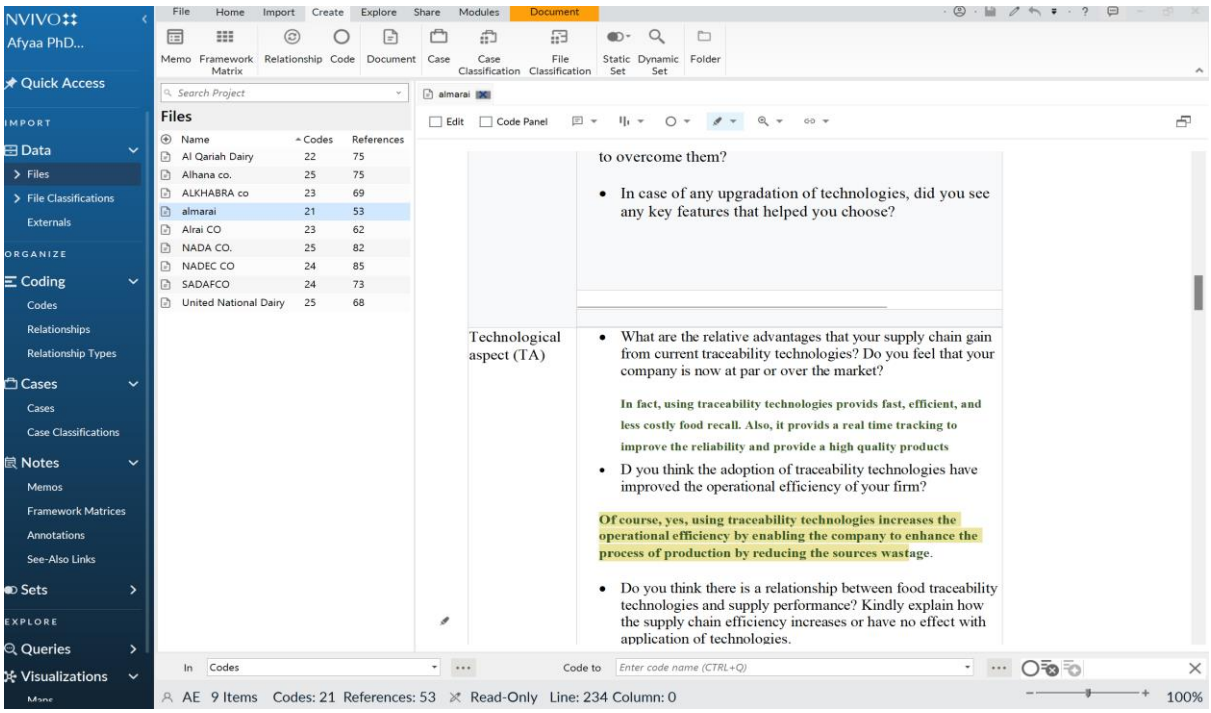


Figure 14. Highlighting the needed information to start coding processes.

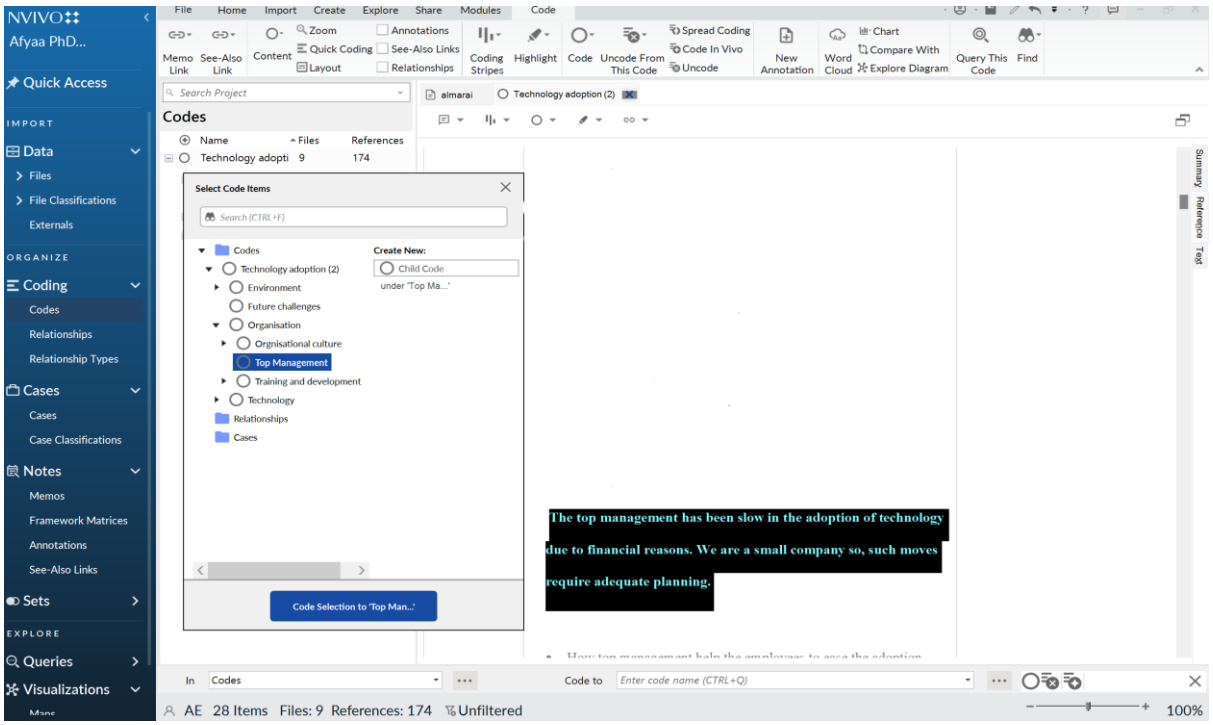


Figure 15. Initiating codes and subcodes using NVivo.

4.4.4 Thematic Data Reduction

Data reduction is an instrumental stage in the thematic analysis process that ensures the distilled essence of data brought to the fore. This stage is underpinned by the objective of refining and prioritising the myriad of themes that have emerged, ensuring they are not only consistent with the primary data but are also resonant with the research objectives (Flick, 2015).

After accumulating a vast array of themes from the interviews, the process of refining began. Utilising NVivo, the raw interview data were organised, coded, and examined to identify overlaps, redundancies, and gaps. Tools such as charts, tables, and data visualisation in NVivo were pivotal in detecting patterns, relationships, and the frequency of themes.

During this intense analytic phase, overlapping themes were merged to capture their collective essence, while others that didn't sufficiently contribute to the research objectives were pruned. This discerning process also led to the discovery of relevant sub-themes, which provided additional granularity to the primary themes. The challenge was to retain the

integrity and richness of the participants' voices while streamlining the themes to be more manageable and focused.

The culmination of this reduction stage was a set of refined themes that were both comprehensive and poignant. These themes, backed by NVivo's analytical capabilities, ensured a rigorous and nuanced understanding of the research topic, allowing for deeper insights and a clearer path to answer the research questions. This meticulous approach ensured that the final themes were robust, relevant, and ready for further exploration in subsequent stages of the research (Flick, 2015).

4.4.5 Thematic Data Display

In the data display phase of thematic analysis, a systematic presentation of the amassed data is vital to ensure clarity and coherence. Leveraging NVivo, the researcher laid out the data in an organised matrix (see Table 4), along with narratives, tables, and direct quotes. This visual approach made it easier to see the main themes and the stories connected to them. These varied representations facilitated a comprehensive visualisation of the themes and their associated narratives, aiding in the synthesis of insights.

As delineated by Alhojailan (2012), following the display of data is the culmination of the thematic analysis process: drawing conclusions. At this juncture, the focus shifts to discerning the intricate interconnections among the factors and the data. This stage is pivotal for crafting conceptual meanings and affirming the reliability of the data.

Moreover, thematic analysis seeks to clarify the relationships between data sets derived from diverse sources or groups. This holistic approach ensures a comprehensive understanding, fostering connections that might otherwise remain obscured.

It's noteworthy that the themes arising from the thematic analysis are emergent in nature. They are borne out of the primary data, and their evolution is organic. Presetting themes would diminish the authenticity of the analysis, potentially leading to skewed insights. By allowing themes to surface naturally from the primary data, the analysis maintains its integrity and ensures that the findings are both genuine and pertinent to the research questions.

4.4.6 Drawing a Conclusion from the Thematic Data

Concluding the thematic analysis means bringing together the main themes, understanding their relationships, and explaining what they mean in the context of the study. This isn't just about summarising, but about giving a deeper understanding based on the data.

For this research, after carefully examining and exploring the data, conclusions were drawn. These conclusions were based on insights from both the interviews and the existing literature on the topic. By comparing the research findings with existing knowledge, a clearer picture of technology adoption in Saudi Arabian dairy firms emerged.

Using the thematic analysis model helped provide a clear and organised way to interpret the data. This ensured that the conclusions were well-founded and based on solid evidence. By breaking down the complex data into clear themes, the main goals of the research were achieved.

To make sure these conclusions were accurate, they were constantly checked against the data that was analysed. This step helped refine the conclusions and made sure they were in line with the main goals of the research. Through this detailed process, the study provided important information about technology adoption in dairy firms.

4.5 Cross-Case Analysis

Cross-case analysis is a research method that facilitates the comparison of commonalities and differences in the events, activities, and processes that are the units of analyses in case studies. This method is widely advocated as a powerful mechanism to enhance the robustness and generalizability of qualitative findings, especially in studies that adopt a multi-case approach (Stake, 2006; Yin, 2009).

In the context of the present study, which uses a multi-case design, the cross-case analysis was deemed instrumental. Multi-case study research, by its nature, offers a unique advantage: the opportunity to analyse data within each specific context and across different contexts (Baxter & Jack, 2008). Cross-case analysis allows the researcher to delve deep into the complexities of each individual case, and subsequently, compare them to discern patterns,

themes, and insights that might not emerge from a singular case. The main objective behind employing cross-case analysis in this study was twofold:

- Enhancing Depth of Analysis: As each case in a multi-case study brings its unique nuances, challenges, and contexts, cross-case analysis ensures that the depth of information is not compromised. This method enables the exploration of individual cases in detail and subsequently synthesizes information for a comprehensive understanding.
- Ensuring Robustness of Findings: Cross-case analysis provides a platform for the iterative comparison of findings from each case. By comparing and contrasting the outcomes, patterns, and themes from each case, it acts as a validation tool. The patterns that consistently emerge across different cases strengthen the validity and reliability of the findings.

The use of software tools can be advantageous in handling, organising, and analysing vast amounts of qualitative data drawn from multiple cases. The cross-case analysis, in tandem with the thematic analysis, ensured that the study's conclusions were both detailed and robust, providing a holistic view of technology adoption in Saudi Arabian dairy firms.

4.6 Reliability and Validity of the findings

Ensuring the reliability and validity of findings is crucial to substantiate the contributions of this research to the field of technology adoption within the Saudi dairy industry. This study employed comprehensive methodological rigour to achieve these goals by drawing on the established academic references (Simpson et al., 2021; Yin, 2018).

The validity of the study was supported through data triangulation, ensuring robust data collection from multiple sources. Information was gathered from semi-structured interviews and supplemented by reviews of companies websites (Leonard-Barton, 1990). This approach not only corroborated the findings but also enhanced the depth and credibility of the data.

Purposive and theoretical sampling techniques were utilised to select twelve national Saudi dairy companies representing the entire population within the dairy industry. Nine senior production and distribution managers from these companies were interviewed based on their

critical roles in decision-making processes relevant to the adoption of traceability technologies. This sampling strategy aligns with case study methodology recommendations (Eisenhardt, 1989) and ensures that the study captures comprehensive insights from key industry players.

To enhance reliability, the coding process was rigorously designed and implemented using NVivo software. The initial coding was performed by the researcher, followed by a review and verification by supervisors, ensuring consistency and accuracy in data interpretation (Duriau et al., 2007). Discrepancies in coding were discussed and resolved through consensus, referring back to the literature to address intercoder reliability issues effectively (Huberman & Miles, 1994).

Construct validity was meticulously addressed by developing an interview questionnaire informed by the TOE framework and a comprehensive literature review. Pilot testing played a critical role, providing initial feedback that led to significant refinements in the questionnaire, ensuring the questions were relevant and clear. These adjustments enhanced the questionnaire's alignment with the study's objectives and its theoretical foundation.

Confidentiality of the data from participating firms was strictly maintained, reinforcing the study's ethical integrity and further supporting the validity and reliability of the findings.

The study's internal validity, or credibility, was underpinned by the plausibility of data and the trustworthiness of participant responses, corroborated by a thorough review of literature and secondary data from company's website. External validity, or transferability, was addressed by detailed analysis within each interview context, allowing the findings to be applicable to similar regulatory and industrial environments both within and outside Saudi Arabia.

Through these methodological measures, the study ensures that the findings are both reliable and valid, offering confident insights into the landscape of technology adoption in Saudi Arabian dairy firms. This rigorous approach provides a firm foundation for the study's contributions to understanding technology adoption dynamics in the region.

4.7 Summary

This chapter has outlined the approaches and methods employed in this research. The methodological options and justifications for the choices taken were presented. The objectives of the study and the research question demanded a comprehensive understanding and a detailed analysis, which the qualitative approach could address. The quality was discussed. The next chapter will highlight the research cases and provide in depth information about each case.

5 Chapter Five: Research Cases

5.1 Introduction

The previous chapters have provided an in-depth discussion of the research methodology. In this chapter, the researcher shifts her focus towards the cases themselves. The dairy industry in Saudi Arabia has undergone significant changes in recent years due to increasing demand for dairy products and changes in consumer preferences. As such, it is important to examine the different strategies and practices adopted by various companies in this industry.

This chapter will provide a detailed analysis of nine dairy companies operating in Saudi Arabia. Each case will be presented individually, highlighting the unique characteristics and challenges faced by the company. Furthermore, the SWOT analysis will be used as a tool to examine the internal and external factors affecting each company's performance. The use of SWOT analysis will help identify the strengths, weaknesses, opportunities, and threats of each company and provide insights into their competitive position.

The aim of this chapter is to provide a comprehensive understanding of the dairy industry in Saudi Arabia through an analysis of different companies. By examining the strategies and practices adopted by these companies, the researcher hopes to gain insights into the factors contributing to their success or failure. Furthermore, the use of SWOT analysis will help identify areas where improvements can be made to enhance each company's performance. This chapter is essential in providing a foundation for the subsequent chapters, where the findings of the research will be presented and discussed.

5.2 Research Cases

5.2.1 Dairy Company-A

5.2.1.1 Summary of the company

Dairy company-A is a leading company based in Saudi Arabia that is known for its high-quality milk, yogurt, cheese, and other dairy products. According to the company's website, it has a vertically integrated business model, meaning it is involved in every stage of the production process, from milk collection and processing to distribution and retail (A, 2021).

Dairy company-A has a network of dairy farms, milk processing plants, distribution centres, and retail outlets throughout the region. In addition, the company has a strong focus on sustainability and has invested in innovative technologies and practices to reduce its environmental impact (A, 2021).

5.2.1.2 Diary Company-A Supply Chain

Dairy Company-A supply chain begins with the collection of raw milk from its own dairy farms. This milk is then transported to processing plants, where it is cleaned, pasteurised, and processed into various dairy products. These products are then transported to distribution centres, where they are stored and distributed to retail outlets throughout the region. The

retail outlets include supermarkets, convenience stores, and other outlets that sell the products to consumers (Participant 1, personal communication, July 2021).

Throughout its supply chain, Dairy Company-A uses traceability technology to track and trace the movement of its products. This technology is used to monitor the quality of raw milk, to ensure that the dairy products are produced safely and consistently, and to provide transparency to consumers about the origins of the products they purchase (Pant et al., 2015).

Overall, the Dairy Company-A supply chain is complex, involving multiple stages, but the use of traceability technology helps the company to manage and optimise this process to ensure the production and delivery of high-quality, safe, and sustainable products to its customers (Saurabh & Dey, 2021).

5.2.1.3 Traceability technologies

Dairy Company-A has a fully integrated traceability system that spans the entire supply chain, from farm to finished product. The company uses a variety of technologies to track and trace its products, including SAP's ERP (Enterprise Resource Planning), Brorlly, RFID (Radio Frequency Identification), and geographical positioning systems (GPS) (A, 2022). In its milk processing operations, Dairy Company-A uses SAP-ERP to track and trace its products and ingredients. The company also uses a patch management system called "Brorlly" in its Ingredient Processing (IP) and Control (C) facility, which is responsible for handling sensitive ingredients. This system is linked to the SAP-ERP system and helps the company to track the movement of every ingredient within the facility, including where it came from, where it was used, and in what quantity.

The company also uses RFID technology to track and locate its products, particularly in distribution. The company has over a thousand reefers (i.e., refrigerated trailer) that are equipped with GPS to track their location and sensors to monitor humidity and temperature. In retail, customers can scan a code to trace the product back to the farm.

Overall, Dairy Company-A traceability technologies practices are focused on ensuring the quality and safety of its products, while also improving efficiency and meeting regulatory requirements. The company's fully integrated traceability system helps it to track and trace its products at every stage of the supply chain and provide transparency and accountability to its customers (Zhao et al., 2021)

Table 5 traceability technologies are used in A's supply chain.

Unit	Traceability Technologies Used	Usage
Processing	SAP, Brorlly software, Human intervention	SAP is used to track and trace products and ingredients, while Brorlly is used in IP and C facilities to track sensitive ingredients. Human intervention is also utilised.
Distribution	RFID, GPS, SAP, Sensors	RFID and GPS are used to track and locate products during distribution, while SAP is used for product tracking and traceability. Sensors are used to monitor humidity and temperature.
Retail	RFID	RFID is used to trace products back to the farm in retail settings.

5.2.1.4 *Drivers of traceability technology adoption in Dairy Company-A*

The Dairy Company-A has several key drivers that influenced its decision to adopt traceability technologies. One of the main drivers was the need to meet regulatory compliance requirements, such as those set forth by the Food Safety System Certification 22000 (FSSC 22000) and the Saudi Food and Drug Authority (SFDA). These regulations stipulate that food companies must maintain strict standards for food safety and quality and having a robust traceability system in place is an important aspect of meeting these requirements (SFDA, 2019).

Another driver for the company was the desire to gain maximum benefits from the technology. The company conducted meetings with managers from different departments such as IT, Quality, and Finance to gather their opinions and consider their points of view before making any adoption decisions (A, 2022).

The company also highlighted the relative advantages that its supply chain has gained from the current traceability technologies. They emphasised their commitment to excellence in food safety and quality, and how the use of traceability technology has allowed them to maintain the highest standards that fulfil statutory, regulatory, and customer requirements(A, 2022). They also mentioned that by using traceability technologies they can provide safe and superior food and beverage products that enrich consumers' lives every day indicating that

without the traceability technologies this couldn't happen. Furthermore, Dairy Company-A being the biggest and best dairy company in the middle east, they are all over the market.

Finally, the company stated that the adoption of traceability technologies has improved the operational efficiency of the firm. By using traceability technologies, they can enhance the process of production by reducing waste and therefore increasing efficiency. They also mentioned that the traceability technologies have helped them to comply with the regulations set forth by the ministry of transport and logistics, this could include tracking the movement of goods, storage and handling of products as well as ensuring compliance with safety and security regulations (Participant 1, personal communication, July 2021).

5.2.1.5 Barriers to technology adoption in A

In the context of traceability technology adoption in Dairy Company-A company, there are several barriers that can hinder or prevent the adoption of these technologies. These barriers can be categorized into cultural, organisational, technical, regulatory, and awareness-related challenges. While there may be several drivers that encourage technology adoption in Almarai, it is important to address these barriers to ensure the successful adoption of traceability technology.

One of the cultural barriers to technology adoption in Dairy Compnay-A is the strong influence of Saudi culture within the company, with over 50% of top management members being Saudi native. This presents challenges in terms of the adoption of new technologies, as employees resistant to change and may prefer traditional methods of doing things (Participant 1, personal communication, July 2021).

Another organisational barrier to technology adoption is employee resistance. Change can be difficult for employees, and the adoption of new technologies can be especially challenging. Dairy Company-A faces resistance from employees who are hesitant to learn new systems or who are worried about their job security(Participant 1, personal communication, July 2021). This is a significant barrier to technology adoption, as the support and engagement of employees are critical to the success of any new technology implementation. The employees' resistance can be related to the lack of awareness and education about the benefits and capabilities of traceability technology. Many people may be unaware of the benefits and capabilities of traceability technology, and this lack of awareness can create barriers to

adoption. A need to educate and raise awareness among employees, customers, and other stakeholders about the benefits of traceability technology in order to encourage adoption.

Technical challenges are also a significant barrier to technology adoption, one of these challenges is compatibility with existing systems or the need for additional training (A, 2022). The adoption of traceability technology is complex and require significant investments in infrastructure and training. Hence, Dairy Company-A faces technical issues or challenges as it seeks to implement these technologies, which slow or disrupt the adoption process.

Regulatory hurdles are another challenge that Dairy Company-A faces. One particular regulation that the company identified as burdensome was mandated by the Saudi Food and Drug Authority (SFDA). The SFDA requires companies to integrate their vehicles' GPS tracking systems with the SFDA's own system. A company viewed this requirement as an unnecessary expenditure of resources, both in terms of time and financial investment. Such views provide a critical perspective on the interplay between regulatory requirements and technology adoption, and signal the need for more streamlined, cost-effective regulatory processes to facilitate the effective implementation of traceability systems.

In conclusion, while there may be several drivers that encourage the adoption of traceability technology, there are also several barriers that may hinder or prevent the adoption of these technologies. These barriers include cultural, organisational, technical, regulatory, and awareness-related challenges. Overcoming these barriers will require careful planning and a strategic approach to ensure the successful adoption of traceability technology in this company (A, 2022).

Table 6. Impact of TOE Factors on the Implementation of Traceability Technology in Dairy Company-A

Factors	Motivations	Barriers
Technological Factors	The need to meet regulatory compliance requirements	Resistance to change due to Saudi culture
	The desire to gain maximum benefits from the technology	
	The commitment to excellence in food safety and quality	
	The need to improve operational efficiency of the firm	
Organisational Factors	Support from managers in different departments	Lack of expertise or knowledge in using traceability technology
	Availability of resources such as funding and IT infrastructure	
	The company's commitment to sustainability	
Environmental Factors	Environmental concerns such as reducing waste, FSSC 22000, SFDA requirements. Improved customer satisfaction	Government pressure such as linking GPS with SFDA system.
Economic Factors	Cost savings from increased efficiency and reduced waste	

5.2.1.6 SWOT Analysis for Dairy Company-A

5.2.1.6.1 Strengths

- Vertically integrated business model, which allows the company to control every stage of the production process from milk collection and processing to distribution and retail.
- Strong focus on sustainability and investment in innovative technologies and practices to reduce environmental impact.
- Fully integrated traceability system that spans the entire supply chain, from farm to finished product, which helps to manage and optimise the process to ensure the production and delivery of high-quality, safe, and sustainable products to customers.
- Wide network of dairy farms, milk processing plants, distribution centres, and retail outlets throughout the region.
- High quality and safe products that meet regulatory requirements.

5.2.1.6.2 Weaknesses

- Dependence on the dairy industry, which can be impacted by changes in consumer preferences, economic downturns, and other external factors.
- High competition in the dairy industry from both local and international brands.
- Complex supply chain with multiple stages, which can increase operational costs and lead to potential quality and safety issues.

5.2.1.6.3 Opportunities

- Growing demand for dairy products in the region, especially among younger consumers.
- Increasing focus on healthy and sustainable food products, which aligns with the company's core values and strengths.
- Potential for expansion into new markets, outside the region.
- Use of traceability technology as a competitive advantage in the market.

5.2.1.6.4 Threats

- Economic and political instability in the region, which can impact consumer demand and supply chain operations.
- Regulatory changes that could impact the dairy industry, such as changes to import/export policies or food safety regulations.
- Increasing competition from both local and international dairy companies.
- Consumer trends shifting towards plant-based alternatives to dairy products.

Overall, the Dairy Company-A has several strengths, including its vertically integrated business model, strong focus on sustainability, and fully integrated traceability system. However, the company also faces several challenges, such as competition in the dairy industry, complex supply chain, and potential regulatory changes. There are also opportunities for growth and expansion, such as increasing demand for dairy products and potential for new market entry.

5.2.1.7 Conclusion

In conclusion, Dairy Company-A, the largest dairy company in the Middle East, has a complex supply chain that spans from its dairy farms to retail outlets, and uses traceability technology to track and trace its products at every stage. The company has adopted a fully integrated traceability system that includes the use of technologies such as SAP, Brorlly, RFID, and GPS to ensure the safety and quality of its products, improve efficiency, and meet regulatory requirements. However, there are also several barriers to technology adoption, including cultural, organisational, technical, regulatory, and awareness-related challenges that need to be addressed to ensure the successful adoption of traceability technology. Overall, Dairy Company-A's adoption of traceability technology has allowed the company to maintain its commitment to excellence in food safety and quality while also providing transparency and accountability to its customers.

5.2.2 Dairy Company-B

5.2.2.1 Summary of the Company

Dairy Company-B is a leading producer of dairy products in the Middle East, with a focus on high-quality, safe, and nutritious products. The company was founded in Riyadh, Saudi Arabia in 2007 and has since grown to become a major player in the region's dairy industry. Dairy Company-B is known for its commitment to innovation, quality, and sustainability, and has implemented a range of traceability technologies to ensure the safety and quality of its products (GFM, 2022).

Dairy Company-B is a vertically integrated dairy company, with operations covering the entire value chain from milk production to retail. The company operates a network of modern dairy farms, as well as a state-of-the-art processing and distribution facility. In addition to its core dairy business, B also operates a retail division, with a range of dairy products sold through its own outlets and through third-party retailers (B, 2022).

5.2.2.2 Company-B Supply Chain

Dairy Company-B's supply chain is a critical element of its business, as it enables the company to efficiently and effectively produce, process, and distribute its products. The company's supply chain includes the following key components:

Company-B operates a network of modern dairy farms, where it produces high-quality milk using advanced technologies and practices. The company's farms are located throughout Saudi Arabia and are designed to maximise efficiency and minimise environmental impact (B, 2022).

Company-B's state-of-the-art processing and distribution facility is located in Riyadh, Saudi Arabia. Here, the company processes raw milk into a range of dairy products, including milk, yogurt, cheese, and other items. The facility is equipped with advanced equipment and technologies to ensure the safety and quality of the products.

In addition to its core dairy business, Company-B also operates a retail division, with a range of dairy products sold through its own outlets and through third-party retailers. The company's retail operations are an important part of its supply chain, as they allow Company-B to bring its products directly to consumers.

Company-B has implemented a range of traceability technologies throughout its supply chain, including RFID tags, SCADA System, and Oracle. These technologies enable the company to track and trace its products from farm to retail, providing transparency and ensuring the safety and quality of its products.

5.2.2.3 Drivers of Traceability Technology Adoption in Dairy Company-B

Company-B has recognised the value of these technologies and has implemented a range of traceability systems in its operations (Participant 2, personal communication, June 2021). Since Company-B is committed to producing high-quality, safe products, Company-B has implemented traceability technologies to help achieve this goal. These technologies allow the company to track the origin and movement of products, as well as monitor the temperature and humidity of products during transportation. In addition, Company-B operates in a heavily regulated industry and must comply with a range of rules and standards related to food safety and quality. Traceability technologies help the company meet these requirements and demonstrate compliance to regulators and customers. Also, Company-B traces their products because they value their customers and are committed to meeting their needs and expectations. By implementing traceability technologies, the company provides customers with detailed information about the origin and movement of its products, which can enhance their satisfaction and loyalty.

5.2.2.4 Company-B Traceability Technologies Practice

Company-B's supply chain traceability practices are in compliance with both ISO requirements and those set forth by the Saudi Food and Drugs Authority (SFDA). The company utilises a variety of technologies to ensure accurate tracking and monitoring of products throughout the supply chain.

In the production and processing stages, Company-B employs a SCADA system to automatically record all steps in the process. Additionally, some information is recorded manually, such as filling quantity, packaging sizes, production dates, and distribution regions. This information is then entered into the Oracle system as patches.

For distribution, the company utilises the Oracle system. Previously, the company used Axapta, but found it incompatible with other technologies and thus switched to Oracle. It is

also in the process of implementing a new system that utilises barcode scanning to track the quantity of milk pallets distributed to stores.

In retail, the specific traceability technology used may vary depending on the market. However, the largest markets currently employ the Oracle system. Dairy Company-B is also considering further automation and converting their factories into smart factories in order to ensure that data is recorded automatically and available 24/7 to responsible employees (B, 2022).

To ensure the safety of products during transportation, the company equips their trucks with temperature sensors that automatically record and transmit temperature data to the system. Overall, it uses various traceability technologies and their ongoing efforts to improve and update these systems demonstrate a commitment to accurate and efficient tracking of their products throughout the supply chain.

Table 7. Traceability technologies used in B's supply chain.

Unit	Traceability Technologies
Processing	SCADA system, Manual recording of filling quantity, packaging sizes, production dates, and distribution regions, Oracle system for data entry
Distribution	Oracle system, Barcode scanning (planned), SCADA
Retail	Oracle system (in some markets), Barcodes
Transportation	Temperature sensors in trucks in addition to GPS.

5.2.2.5 Barriers of Technology Adoption in Dairy Company-B

Despite numerous benefits of traceability technologies, there are also challenges and barriers to their adoption in the dairy industry. The adoption of traceability technology faced certain challenges. One significant issue was compatibility. Past experiences had compatibility issues while integrating the new technology with existing systems. However, these compatibility issues have now been addressed, clearing a major hurdle in the path of adoption.

Another barrier encountered was the resistance from some employees. This is often typical in organisations where employees have easy going with existing systems and processes. Such resistance can stem from fear of change, lack of understanding, extra training requirement, or perceived threats to job security or roles.

Despite these challenges, the interviewed manager remained optimistic. The belief was that these barriers could be overcome with time and through a targeted approach to change management. This would involve employee training, open communication, and involving employees in the adoption process to help them understand the benefits of the new technology (Participant 2, personal communication, June 2021).

Factors	Barriers	Motivations
Technological	compatibility of traceability technologies	Compliance with regulations
		Food safety and quality
Organisational	Resistance to change by employees	
Environmental	---	Customer satisfaction

Table 8. Barriers and motivation factors of Traceability Technology adoption in Dairy Company- B

5.2.2.6 SWOT analysis for B Dairy Company

5.2.2.6.1 Strengths

1. Vertically integrated supply chain from milk production to retail.
2. Commitment to innovation, quality, and sustainability.
3. Implementation of traceability technologies to ensure the safety and quality of its products.
4. Utilisation of advanced equipment and technologies to ensure the safety and quality of products.
5. Strong presence in the Middle Eastern dairy market.

5.2.2.6.2 Weaknesses

1. Heavy reliance on the Middle Eastern dairy market.

2. High costs associated with implementing and maintaining traceability technologies.
3. Dependence on dairy farming, which can be impacted by weather and other environmental factors.
4. Limited product portfolio compared to competitors.
5. Limited retail presence in some Middle Eastern countries.

5.2.2.6.3 Opportunities

1. Diversification of product portfolio to include non-dairy products.
2. Expansion into new geographic markets.
3. Growing demand for healthy and nutritious food products.
4. Increasing consumer interest in sustainable and traceable food products.
5. Introduction of new traceability technologies to enhance supply chain efficiency.

5.2.2.6.4 Threats

1. Intense competition in the Middle Eastern dairy market.
2. Fluctuations in milk prices and supply.
3. Stringent regulations and compliance requirements.
4. Political instability and economic uncertainty in the region.

Generally, Dairy Company-B has a strong position in the Middle Eastern dairy market, with a vertically integrated supply chain and a commitment to innovation and quality. However, the company faces challenges such as high costs associated with implementing traceability technologies, dependence on dairy farming, and limited product portfolio. To capitalize on opportunities such as expanding into new geographic markets and introducing new traceability technologies, Company-B may need to diversify its product portfolio, improve supply chain efficiency, and navigate complex regulations and compliance requirements.

5.2.2.7 Conclusion

Overall, Dairy Company-B has successfully implemented a range of traceability technologies to improve the quality and safety of its products. These technologies have provided numerous

benefits to the company, including improved food safety and quality, better compliance with regulations, and enhanced customer satisfaction. However, there are also challenges and barriers to the adoption of traceability technologies, including cost, complexity, and resistance to change. Despite these challenges, Company-B has demonstrated that it is possible to overcome these barriers and achieve significant benefits from the adoption of these technologies.

5.2.3 Dairy Company -C

5.2.3.1 Summary of the Company

This Company is a leading dairy and juice company in Saudi Arabia. The company was founded in 1980 with a mission to provide high-quality dairy products to the local market. It has a strong presence in the dairy and juice industry in Saudi Arabia(C, 2022).

In addition to its dairy operations, it also has a partnership with Dairy Company-C , the largest dairy company in the Middle East, to process and distribute milk products. Company-C's dairy products are distributed through a network of retail stores and distributors, and the company also has a strong presence in the online market.

5.2.3.2 Dairy Company-C Supply Chain

Company-C's dairy supply chain consists of several stages, including raw material sourcing, processing, packaging, distribution, and retail. The company has a partnership with A company, the largest dairy company in the Middle East, to process and distribute milk products (C, 2022).

In the raw material sourcing stage, the company sources milk from their local farms. The milk is collected and transported to their processing facilities, where it is pasteurised and treated to ensure food safety and quality (Participant 3, personal communication, March 2021)

After processing, the dairy products are packaged and labelled according to Company-C's quality standards and food safety regulations. The packaged products are then distributed to Company-C's retail stores and distributors, as well as online retailers.

Company-C has a strong presence in the retail sector, with a network of retail stores and distributors across Saudi Arabia. The company also has a strong presence in the online

market, with a website and mobile app that allow customers to order products and track their delivery (Participant 3, personal communication, March 2021)

Overall, Company-C's dairy supply chain is designed to ensure the safety and quality of its products, as well as to provide transparency and convenience for customers. The company has implemented traceability technologies, such as RFID tags and GPS tracking, to improve the efficiency and visibility of its supply chain.

5.2.3.3 Drivers of Traceability Technology Adoption in Dairy Company-C.

There are several drivers that have led to the adoption of traceability technologies in Company-C's operations. These include government pressure and policies. Since the Saudi government has implemented a number of regulations and standards related to food safety and traceability, which have encouraged Company-C to adopt traceability technologies to comply with these regulations. In addition, Company-C sees traceability technologies as a way to differentiate itself from competitors and gain a competitive advantage in the market since they describe the competition in the Saudi dairy market as a war.

5.2.3.4 Company-C Traceability Technologies Practice

Company-C has implemented supply chain traceability technologies in order to comply with government requirements (Participant 3, personal communication, March 2021). These technologies allow the government to monitor and control the logistics activities of Company-C by connecting them to the government system (SFDA) and Ministry of Transport and Logistic Services. This allows for monitoring of the products, including temperature, time, and location of trailers.

In addition to government monitoring, Company-C also uses SCADA systems provided by Siemens in their production and processing units. This allows for easy connection to machines and access for service providers to solve any issues or update the system (Participant 3, personal communication, March 2021).

After production, the products go to Company-C's cold warehouse for quality checks before being transported via trailers to a warehouse. All of these processes are connected to Company-C's internal system as well as the Saudi SFDA system. The products then go to a depot, which serves as a collection point in the city. Finally, the products are distributed to retail points.

To trace the products during distribution, Company-C uses GPS systems to track the trailer number, location, speed, distance, and temperature. This allows for efficient and accurate tracking of products, ensuring they reach their intended destinations (Participant 3, personal communication, March 2021).

Overall, Company-C's use of supply chain traceability technologies not only meets government requirements but also improves the overall efficiency and accuracy of their logistics operations.

Table 9. Traceability technologies are used in Company C's supply chain.

Unit	**Traceability Technologies**	**Purpose**
Processing	SCADA system provided by Siemens	Connects machines and allows for service provider access to solve issues or update the system.
Distribution	SCADA system & GPS systems	Allows for efficient and accurate tracking of products during distribution, ensuring they reach their intended destinations.
Retail	Barcode scanning	Used for product locating and tracking at retail points.

5.2.3.5 Barriers to Technology Adoption in Dairy Company-C

Despite the benefits of traceability technologies, there have been some barriers to their adoption. These include cost since implementing traceability technologies is costly, Company-C has had to invest in new equipment and systems, as well as training for employees, which has resulted in additional expenses. Moreover, there have been some technical challenges in implementing traceability technologies, including issues with data integration and compatibility with existing systems. Company-C has been working with technology providers to overcome these challenges.

TOE Factors	Barriers to Adoption	Drivers of Adoption
Technological	Issues with data integration and compatibility with existing systems Technology cost	
Organisational	-------	Competitive advantage
Environmental	-------	Government pressure and policies

Table 10. Barriers and Motivating Factors of Traceability Technology Adoption in Dairy Company- C

5.2.3.6 SWOT Analysis for Dairy Company-C

5.2.3.6.1 Strengths

1. Market share: Dairy Company-C has a strong presence in the dairy and juice industry in Saudi Arabia with a high market share, which gives it a competitive advantage over its rivals.
2. Quality standards: The company is committed to providing high-quality dairy products and has implemented quality control measures throughout its supply chain. Dairy Company-C is known in Saudi Arabia of its high products' quality and good price.
3. Strong distribution network: Company-C has a strong distribution network of retail stores and distributors, as well as an online presence, which helps the company reach a wider customer base.
4. The Company's ownership of the entire supply chain, including local farms that supply milk, provides them with greater control and visibility over their supply chain, reducing the risk of supply chain disruptions.

5. Dark factory: Company-C company is the first dairy company who is implementing a dark factory. Company-C's investment in a dark factory gives them a competitive advantage by allowing them to automate their production processes and increase efficiency.

5.2.3.6.2 Weaknesses

1. Dependence on their local farms: Company-C sources its milk from local farms, which could lead to supply chain disruptions if there are any issues with the farms or the milk supply.
2. Cost of traceability technologies: Implementing traceability technologies is costly, which has resulted in additional expenses for the company.
3. Rising marketing expenses and financial charges, which could affect profitability.
4. The need to continuously innovate and introduce new products to stay competitive in the market.

5.2.3.6.3 Opportunities

1. Diversification: Company-C could into other related industries, such as plant-based dairy alternatives.
2. Online market: The company could focus on expanding its online presence to reach a wider customer base and increase sales.
3. International expansion: The company could explore opportunities for international expansion into other Middle Eastern or Asian markets.

5.2.3.6.4 Threats

1. Competition: The dairy industry in Saudi Arabia is highly competitive, with several established players competing for market share. New entrants could also pose a threat to Company-C's market position.
2. Regulatory changes: Changes in government regulations and standards related to food safety and traceability could require the company to invest in new technologies or processes, which could be costly.

3. External factors: External factors such as changes in weather, natural disasters, or political instability could disrupt the company's supply chain and operations.

5.2.3.7 Conclusion

In summary, Company-C has a fully integrated traceability system that is connected to the government system and allows for the tracking and tracing of its products from the manufacturing stage through to distribution and retail. The company uses a variety of technologies, including SCADA systems and GPS tracking, to ensure the quality and safety of its products and to meet regulatory requirements. These technologies are an important aspect of Company-C's supply chain strategy, and the company is committed to continuously improving and updating its traceability systems in order to maintain its competitive edge and provide the best possible products and services to its customers. In addition, Company-C's strengths include its market share, quality standards, and strong distribution network, while its weaknesses include its dependence on local farms and the cost of implementing traceability technologies. The company has opportunities for diversification, expanding its online presence, and international expansion, but faces threats from competition, regulatory changes, and external factors.

5.2.4 Dairy company-D

5.2.4.1 Summary of the Company

Company-D is a large leading dairy company in Saudi Arabia, with a strong presence in in the Gulf Cooperation Council (GCC) market. The company is well-known for its long-life milk products and is also the market leader in the tomato paste and ice cream markets in Saudi Arabia. In addition to these products, Company-D also produces snacks, fruit drinks, laban, breakfast cream, cheese, butter, powdered milk, ketchup, and fortified children's milk. With annual net sales exceeding SAR 1.5 billion and more than 500 sales routes serving over 35,000 customers through 24 depots, D has a strong distribution network and a focus on producing high-quality food products for the GCC and selected export markets in the Middle East and North Africa (D, 2022).

Company-D has three ISO 22000:2005 accredited factories in Jeddah and Dammam and employs modern technologies to run the business efficiently. The company is required by the Saudi government to use food traceability technologies, and as such has implemented the

Siemens SCADA system in its production and processing units. This system allows Company-D to link its systems to machines and enables access to a service provider for any difficulties or upgrades. After quality inspections, products are transported to a cold warehouse and then loaded onto a trailer for distribution. GPS devices are used to trace the items and determine the trailer number, position, speed, distance, and temperature.

5.2.4.2 Dairy Company-D Supply Chain

Company-D maintains full ownership of its entire dairy supply chain, which begins right at the farm where the raw materials are produced, ensuring the quality right from the source.

The raw materials are transported to the company's factories. Here, using sophisticated technologies, the company converts these raw materials into a range of dairy products. The SCADA system provides a robust solution for trace and track the products and their operations by controlling, monitoring, and analysing industrial processes, thereby ensuring the efficiency and effectiveness of the production.

Once the dairy products are produced, they are moved to a temperature-regulated warehouse using warehouse temperature Monitoring System for thorough quality inspections. These checks are designed to guarantee that only products of the highest quality reach consumers.

Following the quality inspection, the dairy products are loaded onto trailers for distribution. Each of these trailers is equipped with GPS devices that continuously monitor their location, speed, distance covered, and importantly, the temperature within. This meticulous tracking ensures that the dairy products remain fresh and are efficiently delivered to the customers.

Company-D 's well-designed supply chain, that stretches from the farm to the consumers, guarantees the production and distribution of high-quality dairy products. The use of traceability technologies, such as the SCADA system and GPS tracking, plays a crucial role in maintaining the efficiency, safety, and integrity of their supply chain across the GCC and selected export markets in the Middle East and North Africa (Participant 4, personal communication, June 2021).

5.2.4.3 Drivers of traceability technology adoption in Dairy Company-D

One of the main drivers of traceability technology adoption at D is the requirement by the Saudi government to connect all logistical activities to the SFDA and Ministry of Transport

and Logistic Services. This allows the government to manage products and monitor temperature, time, and trailer position. In addition, the company has faced competition from other dairy companies and therefore, the adoption of traceability technologies has helped Company-D to stay competitive and meet market requirements. Additionally, Company-D has recognised the importance of efficiency and productivity in the dairy industry and has adopted traceability technologies in order to improve these areas. Overall, the adoption of traceability technologies at Company-D has been driven by a combination of external factors such as government requirements and market competition, as well as internal factors such as a focus on efficiency and productivity (Participant 4, personal communication, June 2021).

Table 11. Traceability technologies are used in Company-D's supply chain.

Unit	Traceability Technology	Purpose
Processing	SCADA system	Monitors and controls industrial processes in real-time, providing operators with detailed data and insights into production processes.
Retail	SAP (ERP) system	Manages and automates various business processes, such as accounting, procurement, and inventory management. Tracks and manages product information, such as production dates, lot numbers, and expiration dates, providing a centralized database that can be accessed and analysed by authorized users.
Distribution	SAP (ERP) system with GPS and sensors integration	Integrates with GPS and sensors to provide real-time visibility into the location and condition of products throughout the distribution process, ensuring that products are delivered to the correct locations in a timely and efficient manner, and that they are in good condition upon arrival.

5.2.4.4 Barriers of technology adoption in Dairy Company-D

Company-D faced some challenges and barriers in the adoption of traceability technologies. One of the main barriers was employee resistance. According to the company's senior production and distribution managers, some employees were resistant to the adoption of traceability technologies due to a lack of knowledge, skills, and understanding of how they

were used. This led to a negative impact on the efficiency and productivity of the company. To overcome this barrier, Company-D provided education and training opportunities to its employees, which helped to improve their knowledge and understanding of traceability technologies.

Moreover, while Company-D is a large company with substantial revenue, the discussion with the participant shed light on an intriguing aspect: the high cost of implementing traceability technologies is indeed a significant barrier. The participant highlighted that for any new technology adoption, cost becomes a mainstay hurdle.

The company was required to invest a hefty amount into acquiring and setting up the necessary hardware and software. Additionally, a considerable portion of their budget had to be allocated for staff training to ensure efficient utilisation of these new technologies.

These expenditures posed a challenge for Company-D as the resources could have potentially been allocated to other operational areas. However, the participant underscored the company's long-term vision, justifying this initial expenditure. They firmly believed that the long-term advantages of traceability technologies, such as enhanced efficiency and productivity, would be worth the upfront costs.

The participant's emphasis on cost as a barrier to new technology adoption overall sheds light on a crucial aspect of the business decision-making process. While investing in new technology can bring numerous benefits, it also presents significant challenges, especially for large companies with diverse operational demands. It also underscores the importance of strategic planning and risk assessment in such investment decisions (Participant 4, personal communication, June 2021).

Lastly, Company-D faced some challenges in integrating traceability technologies into its existing systems and processes. The company had to make some changes to its existing systems and processes to accommodate the new technologies, which required time and resources. The company had to ensure that the traceability technologies were compatible with its existing systems and processes, which was a challenge in itself. Despite these challenges, Company-D was able to successfully integrate traceability technologies into its systems and processes and is now reaping the benefits of increased efficiency and productivity.

Table 12. Impact of TOE Factors on the Implementation of Traceability Technology in Dairy Company-D

TOE Factors	Drivers of Traceability Technology Adoption	Barriers of Traceability Technology Adoption
Technological	Improving efficiency and productivity in the dairy industry	High cost of implementing traceability technologies
Organisational	Staying competitive and meeting market requirements	Resistance from employees
Environmental	Government requirements to connect all logistical activities to SFDA and Ministry of Transport and Logistic Services	Integration of traceability technologies into existing systems and processes

5.2.4.5 SWOT analysis for D Dairy Company

5.2.4.5.1 Strengths

1. Strong presence in the Saudi Arabia and GCC market
2. Market leader in the ice cream markets in Saudi Arabia
3. ISO 22000:2005 accredited factories using modern technologies.
4. Strong distribution network with over 500 sales routes serving over 35,000 customers through 24 depots.

5.2.4.5.2 Weaknesses

1. Heavy dependence on the Saudi Arabia's market.
2. Vulnerability to fluctuating dairy prices.

5.2.4.5.3 Opportunities

1. Expansion into new markets in the Middle East and Africa
2. Diversification of product portfolio
3. Growth in demand for dairy products in the region

5.2.4.5.4 Threats

1. Intense competition from other large dairy companies.
2. Volatile dairy prices affecting profitability.
3. Political and economic instability in the region.

Overall, Dairy Company-D has established itself as a prominent player in the dairy industry in the GCC region. While the company has a strong focus on quality and traceability, it needs to expand into new markets to reduce its dependence on the Saudi Arabian market. Additionally, it needs to address the threat of intense competition and fluctuating dairy prices, which could impact its profitability. Despite these challenges, Company-D has the potential to grow and capitalize on the increasing demand for dairy products in the region.

5.2.4.6 Conclusion

In conclusion, Company-D is a leading dairy company in the GCC milk market and has a strong focus on food traceability and quality control. The company has adopted a range of traceability technologies, including SCADA systems, temperature monitoring sensors and GPS devices, in order to meet the requirements of the Saudi government and ensure the safety and quality of their products. While Company-D has faced some challenges in terms of employee resistance to new technology, they have overcome this through education and training opportunities. As the market and regulatory requirements evolve, Dairy Company-D will continue to update their technologies in order to maintain their position as a leader in the industry.

5.2.5 Dairy Company-E

5.2.5.1 The Company's Summary

Dairy Company-E is a medium company based in Al-Ahsa, Saudi Arabia that was established in 1968. It serves the local market and exports its products, including dairy, juice, and ice cream, to all GCC countries. The company has 500 employees at its location and generates $80.53 million in sales. Company-E is accredited with ISO 22000 and HACCP, and it is in the process of becoming accredited with The British Retail Consortium (BRC). To meet these accreditations, traceability is a key requirement (Company E, 2022).

5.2.5.2 Dairy Company-E supply chain

Company-E's supply chain starts with the procurement of raw materials from local and international suppliers. However, they own the entire dairy supply chain. The dairy supply chain starts with raw material from their own farms. These materials are then stored in the company's warehouses, where they are managed using the StorePro system. This system stores information about each material, including its batch number, production date, expiry date, manufacturing details, and supplier information. This information is accessed by the production team, who add manufacturing and processing data, including machine usage, employee names, and temperature information. When the finished product is ready, a shelf-life document is prepared and automatically sent to the finished goods warehouse.

Before being dispatched for distribution, the finished product is checked by the warehouse supervisor using a paper checklist that verifies the truck's hygiene, temperature, and overall condition. The product is then loaded onto the truck and dispatched using the RoutePro system, which stores traceability information and is electronically communicated to the distribution channel (salesperson or truck driver). The truck is equipped with a GPS system called SariSafe, which records temperature, location, route, and time every 5 minutes.

In the retail sector, Company-E has its own branches across Saudi Arabia. The company uses the RoutePro system in its retail operations to store product information and traceability data (Participant 5, personal communication, Feb 2022).

5.2.5.3 Drivers of traceability technology adoption in Dairy Company-E

One of the main drivers of traceability technology adoption at Company-E is the need to meet local and international standards. E is accredited with ISO 22000 and HACCP and is in the process of becoming accredited with The British Retail Consortium (BRC) standard. In order to meet these standards, traceability is a key requirement. As a result, Ehas implemented traceability technologies in order to comply with these regulations.

Another driver of traceability technology adoption at E is the need to improve efficiency and reduce errors within the supply chain. By using StorePro and RoutePro, E is able to automate and streamline many of its processes, which helps to save time and reduce the risk of human error.

In addition to these internal drivers, external factors such as government pressure and policies also play a crucial role in Al Rai's adoption of traceability technologies. The Saudi government has implemented various regulations and policies related to food safety and traceability, and Ehas implemented these technologies in order to meet these regulatory requirements.

Overall, the combination of internal efficiency goals and external regulatory pressures has led to the adoption of traceability technologies at E Food Industries. These technologies have helped the company to meet various standards and improve the efficiency of its supply chain operations (Participant 5, personal communication, Feb 2022).

5.2.5.4 Company-E Traceability Technologies Practice

Company-E has implemented traceability technologies in all stages of its dairy supply chain, from processing and distribution to retail. The company uses StorePro and RoutePro systems to store and track information about materials, production processes, and finished products. This allows them to meet local and international standards for traceability and ensure the quality and safety of their products.

In terms of adoption, Company-E began using traceability technologies in 2019, replacing manual documentation with electronic systems. The company reports that the main barrier to adoption was employee resistance, as it requires them to record information at each step of the process. However, the company is planning to overcome this barrier by looking for automation technologies in the future.

In terms of relative advantages, Company-E believes that the traceability technologies they are using have helped them to stay competitive in the Saudi dairy market. They also report that the technologies have allowed them to meet the requirements of accreditations such as ISO 22000 and HACCP, which have helped to improve the overall quality and safety of their products.

Overall, Company-E's traceability technology practice appears to be well-implemented and effective in meeting the needs of the company and its customers. By continuously seeking out new and improved technologies, the company is positioning itself to stay ahead of the curve in terms of traceability and quality management (Company E, 2022; Participant E, 2022).

Table 13 Traceability technologies are used in E's supply chain.

Unit	Technology Used	purpose
Procurement	StorePro	StorePro is a system used to manage raw materials in Al Rai's warehouses. It stores information about each material, including its batch number, production date, expiry date, manufacturing details, and supplier information. This information is accessed by the production team to add manufacturing and processing data.
Processing	StorePro	StorePro is used in the processing stage to store information about the materials used and production data, including machine usage, employee names, and temperature information.
Distribution	StorePro, RoutePro, GPS	StorePro and RoutePro are used to store traceability information about finished products and to track their movement through the supply chain. GPS technology, specifically the SariSafe system, is used to record temperature, location, route, and time every 5 minutes during product transportation.
Retail	RoutePro	RoutePro is used in E's retail operations to store product information and traceability data.

5.2.5.5 Barriers of technology adoption in Dairy Company-E.

There are several barriers that Company-E has encountered in the adoption of traceability technologies. One major barrier is the resistance of employees to change. Many employees are hesitant to adopt new technologies and prefer to stick to traditional methods that they are familiar with. This resistance can lead to delays in the adoption process and can also cause errors and inefficiencies in the supply chain (Participant 5, personal communication, Feb 2022)

Another barrier is the cost of implementing and maintaining new technologies. The initial investment in purchasing and installing new traceability technologies are significant, and there are ongoing costs associated with maintaining and updating the systems. This is a challenge for Company-E, especially given the competitive nature of the dairy industry in Saudi Arabia.

Finally, there are also regulatory barriers that Company-E. The company ensures that its traceability technologies are compliant with local and international regulations and standards. This is a complex and time-consuming process, especially given the constantly evolving nature of these regulations (Participant 5, personal communication, Feb 2022).

Table 14. Impact of TOE Factors on the Implementation of Traceability Technology in E Company

Factors	Drivers	Barriers
Technological	Need to meet local and international standards, improve efficiency and reduce errors	Employee resistance to change, Cost of implementing and maintaining new technologies
Organisational	External regulatory pressures, Government policies related to food safety and traceability	Regulatory compliance requirements
Environmental	Competitive market, Food safety and traceability regulations	Constantly evolving regulations and standards

5.2.5.6 SWOT Analysis for E Dairy Company

5.2.5.6.1 Strengths

1. Accreditation: Company-E is accredited with ISO 22000 and HACCP.
2. Traceability: Company-E has implemented traceability technologies in most stages of its dairy supply chain, from processing and distribution to retail, to ensure the quality and safety of their products.
3. Efficiency: By using StorePro and RoutePro systems, Company-E has been able to partly automate and streamline many of its processes, saving time and reducing the risk of human error.
4. Strong Local Presence: Company-E has its own branches across Saudi Arabia, allowing it to have a strong local presence and establish itself as a leading player in the market.

5.2.5.6.2 Weaknesses

1. Resistance to Change: The resistance of employees to change can lead to delays in the adoption process and can also cause errors and inefficiencies in the supply chain.
2. Cost: The cost of implementing and maintaining new technologies can be a barrier to adoption and may put a strain on the company's finances.

5.2.5.6.3 Opportunities

1. Expansion: Company-E has the opportunity to expand its market beyond Saudi Arabia and cater to a larger customer base.
2. Diversification: Company-E can explore new products and diversify its product portfolio to cater to different segments of the market.
3. Sustainability: Company-E can focus on sustainability and incorporate eco-friendly practices in its supply chain, which can appeal to environmentally conscious consumers.

5.2.5.6.4 Threats

1. Competition: Company-E, being a medium-sized player, confronts intense competition in the marketplace from other rivals. This high level of competition can significantly influence Company-E's market standing and profit margins. It's crucial to note that in the Saudi market, four of large companies claim possession of 60% of the market share, making it an even more challenging environment for E.
2. External Factors: The impact of external factors such as economic downturns, government policies, and natural disasters can negatively impact Company-E's operations.
3. Pricing Struggles: The intense market competition significantly affects the pricing dynamics. Large dairy companies, given their vast resources and high production volume, possess the capability to slash their prices. This, in turn, gives them an upper hand in attracting cost-conscious consumers. On the contrary, Company-E, being a medium-sized player, grapples with financial constraints and limited production scale. This makes it challenging for them to match the price cuts of larger competitors while also ensuring their survival and profitability in the competitive marketplace. Consequently, the company struggles with price adjustment strategies to stay competitive.

Overall, Company-E appears to be a well-established company that has implemented traceability technologies in all stages of its dairy supply chain to ensure the quality and safety of its products. While there are some challenges such as employee resistance to change and cost of implementing new technologies, Company-E has the opportunity to expand its market, diversify its product portfolio, and focus on sustainability to stay ahead of the competition.

5.2.5.7 Conclusion

Company-E has implemented traceability technologies in their processing, distribution, and retail units in order to meet local and international standards and ensure the quality and safety of their dairy products. These technologies include StorePro and RoutePro, which allow the company to track and record information about the materials they receive from suppliers, the manufacturing and processing of products, and their distribution to customers. Company-E

has faced some challenges in the adoption of these technologies, including the time and effort required for employees to manually record information and the need for automation in the future. However, the benefits of these technologies, including the ability to stay competitive in the market and meet consumers' demand for provenance information, outweigh the challenges. In conclusion, traceability technologies play a crucial role in ensuring the quality and safety of food products, and Company-E has successfully implemented and benefited from these technologies in their supply chain.

5.2.6 Dairy Company-F

5.2.6.1 Summary of the company

This is a medium dairy company based in Al Qassim, Saudi Arabia, that was established in 1975. The company owns and operates the entire supply chain for its products, including the farms and cows that provide the raw materials. Company-F currently produces fresh milk, Laban, and yogurt, and is also working on adding butter and cream to its product line. The company has a team of around 200 employees and has traditionally relied on traditional technologies (F, 2022).

5.2.6.2 Company-F supply chain

Company-F's supply chain includes several stages, starting with production, where raw milk is collected from the farms and processed into various dairy products. After that, the finished products are transported to warehouses or distribution centres in the distribution stage. Here, they may be stored until they are ready to be shipped to retailers or customers. In the retail stage, the products are sold to end consumers through outlets such as grocery stores or online marketplaces. Finally, in the consumption stage, the products are purchased and consumed by end consumers. Company-F does not use any traceability technologies currently (Participant 6, personal communication, Jan 2022).

5.2.6.3 Company-F traceability technologies practice

Company-F currently does not use traceability technologies but is in the process of implementing a new system called Qoyood. This system will allow employees to enter traceability information and make it visible to all users. The adoption of traceability technologies can help to improve the efficiency and transparency of the supply chain and ensure the safety and quality of the products. It may also be helpful in building trust with

customers by providing them with information about the origin and quality of the products

Unit	Traceability Technologies (Current)	Traceability Technologies (Future)	Explanation
Processing	None	Qoyood	Qoyood is a new system that Fis implementing to track and trace the movement of products and ensure their safety and quality.
Distribution	None	Qoyood, GPS, Temperature Monitor	In addition to Qoyood, GPS and temperature monitoring technologies will be used to track the location and condition of the products during transit.
Retail	None	Qoyood	Qoyood will be used in the retail stage to provide customers with information about the origin and quality of the products they are consuming.

they are consuming (Participant 6, personal communication, Jan 2022).

Table 15. Traceability technologies are used in Company-F's supply chain.

5.2.6.4 Drivers of traceability technology adoption in Dairy Company-F

The main drivers for the adoption of traceability technologies at Fare regulatory requirements, competition, and food safety. These factors are the most reasons motivating the company to implement traceability technologies in order to comply with government regulations, keep up with industry standards and competitors, and ensure the safety and quality of its products. It is important for the company to carefully consider the potential benefits and costs of traceability technologies and how they align with the company's goals and values in order to make a well-informed decision about adoption.

5.2.6.5 Barriers of technology adoption in F DAIRY

There are several barriers to the adoption of traceability technologies at F dairy. One major barrier is cost. Implementing new technologies is expensive, and the company consider

whether the benefits of adoption outweigh the costs. Another barrier is employee resistance. The CEO of F company complained about the employee's resistance while he does not consider the complexity while adoption. It is important for F to consider the complexity of the technologies they are adopting and how it may impact their employees since he said that they don't consider complexity when adopting! And if the technologies are too complex or difficult to use, it can lead to frustration and reduced productivity. It may be more effective to consider technologies that are user-friendly and easy to learn, as this can help to reduce employee resistance and increase the likelihood of successful adoption. It is also important for the company to help employees understand and adapt to the new technologies. This can help to minimise any potential resistance and ensure a smoother transition. Overall, to overcome these barriers, the company may need to help employees understand and adapt to the new technologies. Additionally, the company needs to communicate the benefits of the technologies to employees and explain how they will improve efficiency and quality. It may also be helpful to involve employees in the decision-making process and gather their feedback and input.

TOE Factors	**Barriers to Adoption**	**Drivers of Adoption**
Technological	Cost of implementation	Regulatory requirements (e.g. compliance with government regulations)
	---	Competition
Organisational	Employee resistance	Food safety
	Lack of employee training and support	

Environmental	Lack of infrastructure support	

Table 16. Impact of TOE Factors on the Implementation of Traceability Technology in F Company

5.2.6.6 SWOT Analysis for Dairy Company-F

5.2.6.6.1 Strengths

- Company-F owns and operates its entire supply chain, giving it control over the quality and safety of its products.
- The company has a long history and experience in the dairy industry.
- Company-F is working on expanding its product line to include butter and cream.
- The adoption of traceability technologies will help to improve the efficiency and transparency of the supply chain.

5.2.6.6.2 Weaknesses

- Dairy Company-F currently relies on traditional methods and may not be keeping up with industry standards and competitors.
- The company currently does not use traceability technologies, which can impact its ability to ensure the safety and quality of its products.
- Employee resistance to the adoption of new technologies may hinder the company's ability to implement and benefit from traceability technologies.

5.2.6.6.3 Opportunities

- The expansion of the product line can help Company-F to increase its market share and revenue.
- The adoption of traceability technologies can help Company-F to build trust with customers and enhance its reputation for safety and quality.
- Company-F can leverage new technology to improve the efficiency of its supply chain and reduce costs.

5.2.6.6.4 Threats

- Regulatory requirements may become more stringent, making it necessary for Company-F to adopt traceability technologies.
- Competition in the dairy industry may increase, making it necessary for Company-F to adopt new technologies to remain competitive.

- Food safety concerns can negatively impact the reputation and sales of Company-F if the company is unable to ensure the safety and quality of its products.

Overall, Company-F Company has the opportunity to improve its supply chain efficiency and build trust with customers through the adoption of traceability technologies. However, the company must carefully consider the costs and potential barriers to adoption, including employee resistance, and ensure that the technologies align with its goals and values. Company-F also has the opportunity to expand its product line and increase its market share but must be aware of the threats posed by regulatory requirements, competition, and food safety concerns.

5.2.6.7 Conclusion

In conclusion, Company-F is in the process of implementing a new traceability system, Qoyood, in order to meet regulatory requirements, keep up with industry standards and competitors, and ensure food safety. However, the company has faced barriers to adoption, including employee resistance and the high cost of implementing new technologies. It is important for the company to carefully consider the benefits and costs of traceability technologies, as well as how they align with the company's goals and values, in order to make a well-informed decision about adoption. To overcome employee resistance, it may be necessary to provide training and support to help employees understand and adapt to the new technologies.

5.2.7 Dairy Company-G

5.2.7.1 Summary of the Company

Company-G company is a leading dairy company in the Middle East region, with a focus on milk processing, distribution, and retail. Established in the early 1990s, Company-G has grown significantly over the years, expanding its operations to cover multiple countries in the region (G, 2022).

Company-G's milk processing plants are equipped with state-of-the-art technology and follow strict quality control measures to ensure the production of high-quality dairy products. The company's distribution network is efficient and reliable, with a strong focus on customer service and satisfaction. In addition to its own retail outlets, Company-G's products are also available in major supermarkets and convenience stores across the region (G, 2022).

5.2.7.2 Company-G dairy supply chain

Company-G's supply chain is centred around its milk processing, distribution, and retail operations. The company sources raw milk from their local farms and processes it at its state-of-the-art facilities. The processed milk is then packaged and distributed to Company-G's retail stores and other outlets throughout the region (Participant 7, personal communication, Jan 2022).

In the distribution phase, Company-G uses a combination of refrigerated trucks and reefers to transport the milk from its processing plants to the retail stores. The company also uses a variety of technologies, including the SAP system and the Van Sale Software, to manage and track inventory in the reefers and ensure that the milk is delivered fresh to the stores, in addition, Barcode in retail to track products and enable traceability.

Company-G's retail stores are located in convenient locations throughout the region and offer a wide range of dairy products, including milk, cheese, yogurt, and other items. The stores are designed to provide a convenient and enjoyable shopping experience for customers, with a focus on quality, value, and customer service.

Overall, Company-G's supply chain is designed to ensure that its dairy products are of the highest quality and are delivered fresh and on time to its customers. The company's use of traceability technologies and its focus on customer satisfaction are key to its success in the competitive dairy industry (Participant 7, personal communication, Jan 2022).

5.2.7.3 Drivers of traceability technology adoption in G co

Company-G has implemented traceability technologies throughout its supply chain to ensure that raw materials and finished products meet high quality and safety standards. This is important as consumers increasingly demand information about the origin of the products they purchase. By providing detailed information about the journey of its products, Company-G builds trust and loyalty among its customers (Participant 7, personal communication, Jan 2022).

In addition to meeting consumer demand, Company-G has also adopted traceability technologies to comply with government regulations and industry standards. The adoption of traceability technologies is primarily driven by the Saudi government's policies and the requirements of the Saudi Food and Drug Authority. These policies and regulations aim to improve the quality and safety of food products, and traceability technologies are instrumental in meeting these requirements. By adopting these technologies, Company-G can demonstrate compliance with relevant regulations and ensure that its products meet the highest standards for quality and safety.

For instance, the company has implemented these technologies to comply with food safety regulations. Moreover, the SFDA has established traceability requirements for dairy products, which Company-G has met through the use of traceability technologies. This allows Company-G to provide the SFDA with essential information about its products, ensuring that they are safe and of the highest quality.

In conclusion, the adoption of traceability technologies at Company-G is driven by the need to meet consumer demand, comply with government regulations and industry standards, and ensure the highest standards for quality and safety. By using these technologies, Company-G can build trust and loyalty among its customers and demonstrate its commitment to producing safe and high-quality products.

5.2.7.4 Company-G's traceability technologies practice

Table 17. Traceability technologies are used in Company-G's supply chain.

Unit	Traceability Technologies
Processing	SAP system
Distribution	SAP system, Van Sale Software, GPS, sensors for weather monitoring in reefers.
Retail	Barcode

5.2.7.5 Barriers to technology adoption in Dairy Company-G

Despite the many benefits of traceability technologies, there are also some barriers to their adoption in Company-G. One of the main barriers is the cost associated with implementing and maintaining these technologies. Another barrier is employee resistance, as some employees may be hesitant to adopt new technologies or may lack the necessary skills to use them effectively. There are also some technical challenges and the need for extensive training, which hinder the adoption of traceability technologies.

Table 18. Impact of TOE Factors on the Implementation of Traceability Technology in Company-G

TOE Factors	Barriers to Adoption	Motivations for Adoption
Technological	Cost of implementation and maintenance	Compliance with government regulations and industry standards, commitment to quality and safety
Organisational	Employee resistance and lack of necessary skills	Increasing demand from consumers for information about product provenance
Environmental	----	Government policies and requirements, need to ensure highest standards for quality and safety

5.2.7.6 SWOT analysis for Dairy Company-G

5.2.7.6.1 Strengths

1. High-quality dairy products: Dairy Company-G is known for its high-quality dairy products produced at state-of-the-art facilities with strict quality control measures.
2. Efficient distribution network: The company has a reliable and efficient distribution network with a focus on customer service and satisfaction.
3. Strong supply chain: Dairy Company-G has a strong supply chain that sources raw milk from its local farms, processes it at its facilities, and distributes it to retail stores and other outlets throughout the region.

5.2.7.6.2 Weaknesses

1. Limited geographical reach: While Dairy Company-G has expanded its operations to cover most of the Saudi region. Yet, it is still limited in its geographical reach.
2. Limited product portfolio: Although Dairy Company-G offers a wide range of dairy products, its product portfolio is still limited compared to most of its competitors.

5.2.7.6.3 Opportunities

1. Growing demand for dairy products: The demand for dairy products is expected to increase in Saudi Arabia due to population growth and rising incomes.
2. Expansion into new markets: Dairy Company-G could expand its operations into new markets in the Middle East region to increase its customer base and revenue.

3. Diversification of product portfolio: Dairy Company-G could diversify its product portfolio by introducing new dairy products or expanding into other food and beverage categories.

5.2.7.6.4 Threats

1. Intense competition: The dairy industry in Saudi Arabia is highly competitive, with many players competing for market share.
2. Government regulations: The government regulations in the region could pose a threat to Dairy Company-G if it fails to comply with them or if the regulations change.

Overall, Dairy Company-G has a strong foundation with high-quality dairy products, efficient distribution, and a strong supply chain. However, it will need to navigate the challenges of a competitive market, comply with government regulations, and mitigate risks associated with its supply chain to sustain its growth in the future.

5.2.7.7 Conclusion

In conclusion, Company-G is a leading dairy company in the Middle East region, with a focus on milk processing, distribution, and retail. The company has implemented a number of traceability technologies, including the SAP system, the Van Sale Software, GPS, and sensors, to ensure the quality and safety of its products. While these technologies offer many benefits, there are also some barriers to their adoption, such as cost and employee resistance. Despite these challenges, Company-G has successfully implemented traceability technologies, and they have become an integral part of the company's operations.

Overall, traceability technologies are becoming increasingly important in the food industry, as they help to ensure the quality and safety of products and build consumer trust. Company-G's experience with traceability technologies demonstrates the potential benefits of these technologies, as well as the challenges that companies may face when implementing them. By carefully considering the costs and benefits, and addressing any potential barriers, companies in the food industry can effectively adopt traceability technologies to improve their operations and better serve their customers.

5.2.8 Dairy Company-H

5.2.8.1 Summary of the company

Dairy Company-H is small Saudi Arabian dairy company that was founded in 1983. It is known for its high quality, internationally competitive products, which include over 40 different dairy products. Company-H operates an integrated farm in the Al-Qassim region, approximately 250 kilometres north of Riyadh. The farm employs a diverse team, including veterinarians, engineers, nutritionists, food technologists, quality controllers, lab technicians, skilled sales and marketing staff, and laborers. The company's head office is located in Riyadh and is responsible for managing the company and providing logistical support to the various divisions (Company H, 2022).

Since its inception, Company-H has focused on milk production using Holstein-Friesian cows. The initial foundation stock was imported from Germany, and the company has continued to use top bulls from the United States to improve the genetic capabilities of its herd for milk production. As a small dairy company, His involved in all aspects of the dairy production process, including production, processing, distribution, and sales. While it does currently use some technologies in milking and processing, it does not have any traceability systems in place, relying instead on manual documentation. However, the company is in the process of implementing a new tracking technology provided by BazyTrack, which will allow for the automatic GPS tracking and temperature sensors of its vehicles and warehous and connect directly with the Saudi Food and Drug Authority system (Participant 8, personal communication, Feb 2022).

5.2.8.2 Dairy Company-H Supply chain

Dairy Company-H has a vertically integrated supply chain, meaning that the company is responsible for every step of the process from farm to finished product. This includes the production of milk at the company's integrated farm in Al-Qassim region, the processing of the milk into various dairy products, and the distribution and sales of these products (Participant 8, personal communication, Feb 2022).

In terms of technology, Company-H currently uses some technologies in the milking and processing stages of its supply chain. However, the company has not yet adopted automated traceability systems, and currently traces its products manually using spreadsheets in

Microsoft Excel. The company is currently working on a strategy to upgrade its technologies, including the adoption of automated traceability software, in order to improve efficiency and meet regulatory requirements.

Overall, Company-H's supply chain is focused on producing high quality dairy products that meet international standards, while also being responsive to the needs of its customers and the changing market conditions. The company is committed to continuously improving its processes and technologies in order to maintain its competitive edge and provide the best possible products and services to its customers (Company H, 2022; Participant H, 2022).

Table 19. Traceability technologies are used in Company-H's supply chain.

Supply Chain Unit	Current Technology Used	Planned Upgrades
Processing Unit	Some technologies in milking and processing stages but no traceability technology	Adoption of automated traceability software
Distribution Unit	Manual traceability using spreadsheets	Implementation of GPS and temperature monitoring systems
Retail Unit	No automated traceability systems in place	Adoption of automated traceability software

5.2.8.3 Drivers of traceability technology adoption in Dairy Company-H

There are a couple of factors that drive the adoption of traceability technology in H company, which are:

The presence of stringent government requirements is a key driver for Dairy Company H's adoption of traceability technology. Regulatory organisations such as the Saudi Food and Drug Authority (SFDA) and the Ministry of Transport and Logistic Services necessitate the incorporation of this technology. As a result, to comply with these mandatory regulations and avoid potential penalties, Dairy Company-H finds itself compelled to implement an automated GPS system and live sensors, which are directly linked to the systems managed by SFDA and the Ministry. This regulatory adherence is not merely an option but an operational requirement for the company, prompting a strong motivation towards the adoption of the specified technologies.

Staying competitive in the market is the second key driver for Company H's adoption of traceability technology. The Saudi dairy industry is fiercely competitive, with survival relying heavily on keeping pace with market trends and evolving consumer preferences. The ability to track and trace products across the supply chain not only satisfies consumers'

demand for transparency but also gives Company-H an edge against rivals. It's a critical measure for Company-H to remain a viable competitor amidst the larger, more resource-laden dairy firms. If they fail to keep up with this vital market trend, the risk of being pushed out of the market is imminent. Thus, the adoption of traceability technology serves as a crucial lifeline for Company-H to retain its market position and ensure its longevity in the industry.

5.2.8.4 Traceability technologies practice in Dairy Company-H

Currently, Company-H does not have any traceability technologies in place for tracking and tracing its products within the supply chain. Instead, the company relies on manual tracking methods using spreadsheets in Microsoft Excel.

However, the company is in the process of implementing a new traceability technology provided by BazyTrack Co. for tracking its vehicles automatically. This technology is connected directly to the Saudi Food and Drug Authority (SFDA) system and is required by law for all companies operating in Saudi Arabia.

In the future, Company-H plans to adopt a more advanced traceability technology that can connect with production data, provide detailed analysis and align with the ISA-95 global model for integrating businesses and control systems. This technology will help the company to improve the efficiency and effectiveness of its traceability processes, while also meeting the regulatory requirements of the government and the needs of its customers.

Overall, traceability technologies are an important aspect of Company-H supply chain strategy, and the company is committed to adopting and implementing these technologies in order to improve the quality and safety of its products, as well as the efficiency and effectiveness of its operations.

5.2.8.5 Barriers of technology adoption in Dairy Company-H.

There are several barriers that may impact the adoption of traceability technologies in Company-H. One of the main barriers is the lack of adequate financial resources to invest in these technologies. Implementing new technologies is very costly and require significant upfront investments in software, hardware, and training while Company-H is a small company.

Another barrier is the complexity of the technology itself. Adopting a new traceability system require significant changes to the company's processes and systems, which Company-H considers it as time-consuming and challenging to implement. Company-H reported, if the technology is not compatible with the company's existing systems and processes, it will be difficult to integrate and will require additional investments in customisations or new systems.

Organisational factors, the lack of support from management and the resistance from employees to embrace change, also was obvious and reported as well in Company-H and that impact the adoption of new technologies.

Finally, external factors, such as regulatory requirements, impact the adoption of traceability technologies. since government and industry standards require the use of certain technologies, companies may be forced to adopt these technologies in order to remain compliant.

Table 20. Impact of TOE Factors on the Implementation of Traceability Technology in F Company

TOE Factors	Drivers of Adoption	Barriers to Adoption
Technological Factors	----------	Complexity of technology
	----------	Compatibility with existing systems and processes
	----------	Lack of financial resources
Organisational Factors	Enhanced quality and safety	Resistance to change
Environmental Factors	Stay in the market, Regulatory requirements	

5.2.8.6 SWOT analysis for Dairy Company-H

5.2.8.6.1 Strengths

- Vertically integrated supply chain allows for complete control over the production and quality of its dairy products.
- Company-H longevity within the marketplace: Despite the presence of fierce competition, they have managed to sustain their operations for an extended period, much longer than many of their competitors.

5.2.8.6.2 Weaknesses

- Limited use of technology in milking and processing, resulting in manual tracking and documentation of products.
- Lack of automated traceability systems, which can impact the efficiency and effectiveness of the supply chain.
  Lack of management support.

5.2.8.6.3 Opportunities

- The desire for dairy products in Saudi Arabia is on the rise, and there are only a few dairy companies to fulfill this increasing demand. This means that a high number of customers are depending on a limited number of suppliers for their dairy needs.
- Company-H can improve their supply chain efficiency using traceability technologies. With the high demand for dairy products in Saudi Arabia, ensuring a smooth and efficient supply chain is key to meeting customer demands and reducing operational costs. By implementing or enhancing traceability technology, Company-H could streamline their operations, improve product tracking, and enhance overall supply chain performance. This could lead to cost savings and an increase in profitability in the long term.

5.2.8.6.4 Threats

- Intense competition from other dairy companies in the market.
- Regulatory changes or requirements that may be costly or difficult to implement, such as new traceability regulations .

Overall, Company-H, a long-standing company in the Saudi dairy market, has shown its resilience over time, outlasting many rivals. Their main strength is their self-reliant supply chain, allowing total control over dairy production and product quality.

On the other hand, they face some difficulties, such as limited tech-use in milking and processing and lack of automated systems for product tracking. These issues can lead to difficulties in product tracking and weaken the supply chain's effectiveness.

Despite these challenges, Company-H has promising opportunities for growth. The growing demand for dairy in Saudi Arabia and limited competitors means there's a good chance for the company to expand its market share. If the company invests in modern tracking technologies, it could significantly improve supply chain efficiency, making operations smoother and product tracking more effective. This could help meet customer needs and reduce costs, which could increase profits.

Still, there are threats to consider. The fierce competition from other dairy companies is a constant hurdle. Also, adapting to new regulations, especially those related to product tracking, could be costly and challenging.

5.2.8.7 Conclusion

In conclusion, Dairy Company-H is a leading Saudi Arabian dairy company that is known for its high quality, limited products. While it has already adopted some technologies in its supply chain, it has not yet implemented traceability systems for tracking and tracing its products. However, the company is in the process of implementing a new traceability technology provided by Bazy Track for tracking its vehicles automatically and connecting with the SFDA system. In the future, Company-H plans to adopt more advanced traceability technology to improve efficiency and meet regulatory requirements. There are several barriers that may impact the adoption of traceability technologies, including financial constraints, resistance to change, and external factors such as regulatory requirements and consumer demand. However, Company-H committed to improving its traceability system and adopting modern technologies in order to meet the needs of its customers and maintain its competitive edge in the market.

5.2.9 Dairy Company-J

5.2.9.1 Summary of the company

Since its establishment in 2002 in Saudi Arabia, Company-J has devoted itself to producing high-quality dairy products utilising organic ingredients and time-saving methods. The company's supply chain is comprehensive, beginning at their private farms, transitioning to the milk processing phase, and culminating in the creation of a diverse selection of dairy items, such as milk, yogurt, and cheese. Regrettably, their product line is not extensively recognised in the region yet.

Continual improvement is at the core of Company-J's approach, especially regarding their supply chain management. In line with this, they are planning to implement traceability technologies to comply with the government requirements in addition to enhance the tracking of their products, ensuring improved safety and quality standards (J, 2022).

5.2.9.2 Dairy Company-J Supply chain

One of the key strengths of Company-J's supply chain is that it owns the entire process, from farm to finished product. This means that the company has full control over the quality and safety of its products and can ensure that it meets the highest standards of excellence (Participant 9, personal communication, Sep 2021).

In terms of technology, Company-J does use new technologies in the processing and other stages of its supply chain. However, the company does not yet have any traceability technologies in place for tracking and tracing its products within the supply chain. Instead, it relies on manual tracking methods using spreadsheets in Microsoft Excel.

Despite this, Company-J is committed to improving its supply chain and adopting modern technologies. The company is currently in the process of implementing a new traceability technology for tracking its vehicles automatically, which is connected to the Saudi Food and Drug Authority (SFDA) system. In the future, Company-J plans to adopt a more advanced traceability technology to improve the efficiency and effectiveness of its traceability processes, while also meeting the regulatory requirements of the government and the needs of its customers (J, 2022).

Overall, Company-J is a small company that is working hard to provide its customers with high quality, natural dairy products. While it is still using manual practices for traceability at this time, the company is committed to improving its supply chain and adopting modern technologies in order to meet the needs of its customers and remain competitive in the market.

5.2.9.3 Traceability technologies practice in Company- J.

Company-J currently does not have any traceability technologies for tracking and tracing its products within the supply chain. The company uses manual tracking methods with spreadsheets in Microsoft Excel, but this method is labour-intensive and is not as effective as more advanced traceability technologies. Company-J is implementing a new traceability technology for tracking its vehicles that is required by law and connected to the Saudi Food and Drug Authority (SFDA) system. In the future, Company-J plans to adopt a more advanced traceability technology to improve the efficiency and effectiveness of its traceability processes. This technology will likely be an automated traceability software that

connects with production data, has a visual trace graph, provides detailed data and analysis, and aligns with the global standards. Company-J is committed to adopting and implementing traceability technologies to improve the quality and safety of its products and the efficiency of its operations (Participant 9, personal communication, Sep 2021).

Table 21. Traceability technologies are used in J's supply chain.

Supply Chain Unit	**Current Traceability Technology**	**Future Traceability Technology**
Processing Unit	Currently, Company-J relies on manual tracking methods with spreadsheets in Microsoft Excel to monitor their supply chain.	Company-J has confirmed that they are fulfilling the government requirements. They have already begun implementing live GPS tracking and temperature monitoring systems. According to SFDA, J must comply with by the beginning of 2023. Company-J is installing live GPS tracking on their vehicles. Temperature monitoring systems are installed in their delivery vehicles and warehouses. With this technology, the company can keep a real-time check on the temperature at which their dairy products are being stored and moved. This is crucial as it helps keep the products fresh and of high quality by reducing the chances of spoilage or damage due to incorrect temperatures.
Distribution Unit		
Retail Unit		

5.2.9.4 Barriers of technology adoption in Dairy Company-J.

One of the main barriers to the adoption of traceability technologies is cost. Implementing new technologies is costly for them as a small firm and require significant upfront investments in software, hardware, and training. This isa significant challenge since they do not have the financial resources to invest in new technologies.

5.2.9.5 Drivers of technology adoption in Dairy Company-J.

There is a single driver that can influence the adoption of traceability technologies in a company like Company-J. which is regulatory requirements. In the case of Company-J, the company is required to implement a traceability technology for tracking its vehicles that is connected to the Saudi Food and Drug Authority (SFDA) system. This means that the company has no choice but to adopt this technology in order to comply with regulatory requirements.

Table 22. Impact of Toe Factors on The Implementation of Traceability Technology in Company-J

Technology Adoption Factors	***Drivers***	***Barriers***
Technological factors	-------	Cost of implementation
Organisational factors	--------	lack of expertise
Environmental factors	Regulatory requirements, desire for competitive advantage	Limited resources

5.2.9.6 SWOT analysis for Dairy Company-J

5.2.9.6.1 Strengths

- Company-J owns the entire supply chain from farm to finished product, giving the company full control over the quality and safety of its products.
- The company is committed to producing organic dairy products using natural ingredients and traditional methods.

5.2.9.6.2 Weaknesses

- Company-J currently does not have any traceability technologies in place for tracking and tracing its products within the supply chain, relying instead on manual tracking methods with spreadsheets in Microsoft Excel.
- As a small company, J does not have the financial resources to invest in new technologies, which could be a barrier to the adoption of traceability technologies.

5.2.9.6.3 Opportunities

- Company-J could improve the efficiency and effectiveness of its traceability processes by adopting modern traceability technologies.
- By investing in social responsibility, the company could set itself apart from its competitors, potentially leading to an increase in its market share.
- There is a growing demand for organic dairy products, which presents an opportunity for Company-J to expand its customer base.

5.2.9.6.4 Threats

- Company-J operates in a highly competitive market, with many players in the industry.
- The company's lack of traceability technologies could put it at a disadvantage compared to competitors who are using more advanced technologies.
- government increasing policies could impact the company's operations and profitability.

Overall, Company-J. needs to address its weaknesses and capitalise on its strengths and opportunities to remain competitive in the market. Adopting modern traceability technologies

could help the company to enhance its efficiency and effectiveness, which may lead to an increase in market share and customer satisfaction.

5.2.9.7 Conclusion

In conclusion, Company-J is a small dairy company based in Saudi Arabia that is known for its commitment to producing organic dairy products using traditional methods. The company's supply chain includes the production of milk on its own farms, the processing of the milk into various dairy products, and the distribution and sale of these products.

Currently, Company-J does not have any traceability technologies in place for tracking and tracing its products within the supply chain. However, the company is in the process of implementing a new traceability technology for tracking its vehicles automatically, which is required by law and connected to the Saudi Food and Drug Authority (SFDA) system. In the future, Company-J plans to adopt a more advanced traceability technology to improve the efficiency and effectiveness of its traceability processes.

There are several drivers that can influence the adoption of traceability technologies in Company-J but the most important one is the regulatory requirements. In other hand, there are some barriers to the adoption of traceability technologies, such as cost of these technologies.

6 Chapter Six: Interview Analysis and Findings

6.1 Introduction

This chapter is essential in producing the thematic analysis of interviews conducted with key managers from Saudi dairy firms. While the semi-structured interview questions were initially designed around the Technological, Organisational, and Environmental (TOE) framework, the flexible nature of the interviews allowed for the emergence of new themes that extend beyond this predefined schema. Consequently, the analysis adopts a hybrid approach partially deductive in applying the TOE framework, yet also inductive in accommodating newly emerged themes.

By merging insights from both the TOE framework and the real-world experiences captured in our interviews, this chapter aims to offer a comprehensive understanding of the factors that affecting the adoption of traceability technologies in the Saudi dairy industry. Through this, the researcher seeks not only to identify challenges and barriers but also to explore the complex interplay of factors that either impede or facilitate technology adoption, thereby providing actionable insights for enhancing supply chain performance.

6.2 Basis of Analysis

In the analysis section of the study, the well-established Technology-Organisation-Environment (TOE) framework was employed as the guiding principle. This involved referring to specific themes and sub-themes within the TOE framework while coding the interview transcripts. The study aimed to elaborate on the TOE framework specifically within the context of the Saudi dairy industry, using evidence gathered from interviewees. It's important to note that this approach was about elaboration rather than developing or testing the TOE framework itself. Additionally, the analysis explored new themes that were mentioned by the interviewees, providing new insights beyond the existing framework.

6.3 Interview Participants

The study involved nine managers who hold responsibility for making strategic decisions related to technology adoption. Each of the participants provided detailed information, including demographic factors such as age, gender, nationality, level of education, experience, and position. All participants were male and fell within the age range of 37 to 52 years, with most falling within their forties and an average of 20 years of experience. Of the nine participants, six were Saudi citizens, while the remaining three were of British, Indian, and Syrian nationalities, respectively. All participants held a bachelor's degree or higher and demonstrated a high level of openness and willingness to provide the researcher with the required information. Refer Table 5.1 for a detailed overview of each participant's demographic profile.

The sample included nine companies of Saudi dairy sector. The majority (four) of them are large companies (>500 employees, as classified in Nitaqat), and three were sized medium (>50 & <499), the rest (two) were sized small (>10 & <49). The participants have worked for their company for a minimum of 7 years to a maximum of twenty-six years. Table 24 shows the profiles of each participant. The participants' identity is decoded for anonymity and coded as p1 to P9.

Table 23 Participant demographics

CODE	AGE	GENDER	CITIZINSHIP STATUS	JOB ROLE	EXPERIENCE	FIRM SIZE	LOCATION	FIRST FOOD TRACEABILITY TECHNOLOGIES (FTT) ADOPTED
P1	52	MALE	NON- CITIZEN	HEAD OF QUALITY	32	LARGE	RIYADH	2002
P2	37	MALE	CITIZEN	SUPPLY CHAIN MANAGER	14	LARGE	ALAHSA	2011
P3	46	MALE	CITIZEN	SENIOR DIRECTOR OF MANUFACTURING	21	LARGE	RIYADH	2010
P4	45	MALE	CITIZEN	HEAD OF PRODUCTION	19	LARGE	JEDDAH	2013
P5	50	MALE	NON-CITIZEN	SUPPLY CHAIN MANAGER	26	MEDIUM	ALAHSA	2019
P6	46	MALE	CITIZEN	THE CEO	21	MEDIUM	ALQASSIM	NOT YET-ADOPTING
P7	47	MALE	NON-CITIZEN	SUPPLY CHAIN MANAGER	20	MEDIUM	ALAHSA	2014
P8	43	MALE	NON-CITIZEN	PLANT MANAGER	17	SMALL	ALQASSIM	NOT YET-ADOPTING
P9	41	MALE	CITIZEN	MANUFACTURING MANAGER	18	SMALL	JEDDAH	NOT YET-ADOPTING

6.3.1 Participant 1 (P1)

P1 is head of quality at a large size company. He is 52-year-old from United Kingdom. With his extensive experience (32 years of experience), **P1** shows a good understanding of traceability technologies and their importance. **P1** was very confident that his company is the best not just in traceability but in general and he emphasised on their products' quality. He was satisfied with their current technologies. However, the only thing **P1** was complaining about is the Government Policy.

He said the government system does not need to connect with his traceability systems in Warehouses, depots and transportation. He thinks that is very costly since it costs millions of Riyals while it's the company's responsibility not the government.

6.3.2 Participant 2 (P2)

P2 is 37-year-old with 14 years of experience. **P2** is a Saudi supply chain manager at a large dairy company. Currently, he is pursuing a master's degree while working full time job. **P2** was the first one accepted my interview request, then he arranged the interview immediately. **P2** considered his company as one of the best while he said that "it needs some improvement". **P2** is very optimistic regarding the company's future, and he highly appreciated the government support (not financially). **P2** supports the technology and automation, and he thinks technology helps increase the efficiency of the products and the performance in general . He said that they are *"planning to implement a smart factory".* Although **P2** understands the importance of traceability for the firm, he emphasised that the consumers are unaware of the traceability.

6.3.3 Participant 3 (P3)

Participant **P3** is 47-year-old Saudi senior director of manufacturing. With his 21 years of experience, **P3** emphasised on the importance of traceability and the technology adoption in general. When the researcher asked him about COVID-19 effects on their supply chain, **P3** laughed and said positive affect. He attributes that to the government support that time. **P3**

revealed that the company is starting a *"dark factory"* soon. **P3** also mentioned that they support technology because the think that when you adopt the right technology the return will always be higher than the cost *"Technologies give us lot of advantages and save money".* **P3** said, *"all the biggest four companies are using the same traceability technologies and he added we must keep updated to stay in the market".*

6.3.4 Participant 4 (P4)

P4 is 45-year-old Saudi head of production at large size company. **P4** got his master's degree in management of business administration, and he has 19 years of experience at the same field. **P4** said traceability technologies currently in use are fine, but he thinks it is better to implement blockchain to beat the competition. **P4** emphasised on the importance of traceability, and he claimed that his company supported the technology. **P4** indicated that Saudi dairy market was very competitive, and his company was one of the biggest four.

6.3.5 Participant 5 (P5)

Participant **P5** is 50-year-old Indian Supply chain manager at medium size company. **P5** has a post graduate degree in computer science in addition to 26 years of experience. **P5** considered himself very involved in strategic decision making. He seems very excited for technology *adoption "in future, we will look for automation technology to safe us a lot of time effort and cost and to reduce errors."* He claimed that using traceability technologies will help them meet the international standards, then they can export and increase their market share. However, he revealed that they don't have any plan for future adoption yet.

6.3.6 Participant 6 (P6)

Participant 6 is the CEO; he started at the bottom and climbed the company ladder to become the CEO. He is 46-year-old with 21 years of experience in the same field and company. **P6** was very excited to talk about the strategy they are creating. Since he recently promoted, he is full of ideas. His main concern was employee's resistance that he is facing. He said, *"they're resisting every change that we make".* He added, "*the managers are not supportive as well".*

6.3.7 Participant 7 (P7)

P7 is supply chain manager at medium size company. He is 48-year-old Syrian with more than 20 years of experience. He said he supported technology adoption "*if needed";* he added *"We consider how the new technology can help us to meet our goals and then we evaluate whether the technology is the best for our company. Also, the return on investment is the most crucial thing to look at*". **P7** thinks the adoption decision is not easy *"adopting new technology requires serious time dedication and a lot of effort from the development team."* He thinks the employee's resistance is normal and it *"happens everywhere"*. When the researcher asked about the employees and management nationalities to analyse the cultural factor, **P7** thinks that question is inappropriate and kind of Racist. In general, he was very helpful, supportive, and honest with his answers.

6.3.8 Participant 8 (P8)

P8 is 39-year-old with has 17 years of experience. **P8** is Saudi plant manager at a small size company. As the rest of participants, **P8** mentioned many benefits of traceability adoption . However, he said *"but they're costly and we afraid that may not pay-off for years or ever".* **P8** added *"the company culture and I support the technology adoption after appropriate analysis."* **P8** said that they are lagging behind the competition and they're working on the development.

6.3.9 Participant 9 (P9)

P9 is 43-year-old with 18 years of experience. **P9** is Saudi manufacturing manager at a small size company. As **P8**, and **P9** said the company does not have any traceability technology and their products are traced manually using traditional ways. He claimed that they're doing their best to stay in the market. **P9** said they heard about SFDA new traceability requirements, but they didn't receive the official letter yet. He thinks they started with the large and medium companies then they will apply it for the small companies. **P9** said the technology cost is one of the main obstacles. **P9** was very busy while answering the researcher questions.

6.4 Themes using NVivo 12 pro.

In section 4.6, it was previously stated that the researcher implemented six phases following the coding process. Firstly, the researcher acquainted herself with the data by reading and identifying the significant information. Subsequently, the initial codes were generated, followed by the identification and creation of nodes while searching for themes. The themes and subthemes were reviewed before the final report was produced. The entire process was facilitated using NVivo 12 pro software.

After identification and creation of themes and subthemes, NVivo queries were executed to undertake a thorough investigation. Table 25 encapsulates the prevalence of specific themes derived from qualitative interviews with industry participants, labelled P1 through P9. The frequencies, expressed as percentages, reflect the extent to which each theme was referenced by participants, offering insights into areas such as technology adoption, environmental considerations, competitive pressures, and the impact of COVID-19. This data, organised through NVivo's analytic capabilities, provides a quantitative look at qualitative data, aiding in understanding the focal concerns and priorities within the industry's current discourse.

Table 24. NVivo-Generated Thematic Frequency Analysis in the Saudi Dairy Industry

	P2	P9	P5	P3	P4	P6	P8	P7	P1
Technology adoption	21.06%	12.06%	10.96%	13.67%	9.1%	7.97%	7.19%	8.39%	9.6%
Environment	29.53%	13.32%	12.68%	16.85%	8.99%	2.73%	4.65%	4.98%	6.26%
Competitors	4.25%	20.4%	15.01%	27.2%	3.4%	4.82%	8.22%	5.67%	11.05%
Consumer pressure	62.59%	4.07%	9.63%	3.33%	16.3%	0%	0%	4.07%	0%
Consumer Awareness	62.59%	4.07%	9.63%	3.33%	16.3%	0%	0%	4.07%	0%
Government Support	24.04%	11.86%	16.67%	10.26%	8.97%	11.54%	8.01%	4.49%	4.17%
Mandatory SFDA	17.49%	4.96%	12.29%	23.4%	28.84%	5.91%	0%	0%	7.09%
Vision 2030	50%	0%	0%	23.08%	0%	21.37%	0%	0%	5.56%
Future challenges	12.96%	14.2%	5.86%	13.27%	7.41%	27.47%	6.17%	3.4%	9.26%
Organisation	10.33%	13.09%	8.01%	20.84%	14.87%	7.39%	14.16%	4.81%	6.5%
Organisational culture	0%	0%	11.11%	64.05%	11.11%	0%	13.73%	0%	0%
Saudization-OC	10.99%	10.64%	17.38%	10.28%	12.77%	7.8%	11.35%	5.32%	13.48%
Top Management support	16.25%	19.11%	9.29%	14.11%	7.5%	9.11%	13.39%	0.71%	10.54%
Training and development	18.29%	7.62%	4%	10.86%	20.57%	6.1%	15.43%	9.52%	7.62%
Technology factors	22.07%	10.71%	11.72%	12.29%	8.07%	7.93%	6.25%	10.57%	10.4%
Compatibility	16.26%	21.54%	10.16%	0%	9.35%	3.66%	26.02%	8.54%	4.47%
Complexity	9.12%	20.85%	14.33%	9.12%	11.73%	14.66%	15.31%	4.89%	0%
Employees' resistance	14.94%	20.12%	17.84%	19.09%	7.88%	5.19%	7.88%	7.05%	0%
Future technology	23.62%	20.09%	7.95%	9.05%	8.39%	16.56%	5.52%	6.62%	2.21%
Technology advantages	32.28%	2.11%	13.18%	14.76%	10.41%	5.67%	4.61%	3.69%	13.31%
Supply Chain performance	9.33%	18.48%	23.43%	5.71%	7.62%	12.57%	8.95%	6.48%	7.43%
The existence of traceability technologies	20.51%	5.9%	9.2%	10.32%	6.59%	6.96%	3.92%	18.46%	18.15%
Traceability technologies adoption motivations	33.8%	7.18%	16.2%	17.13%	3.94%	5.09%	8.33%	3.7%	4.63%
COVID-19	21.73%	8.25%	14.08%	10.26%	9.96%	12.37%	5.23%	2.31%	15.79%

Both Table25 and Figure 16 visualise the occurrence of specific themes based on coding from the interviews data within the Saudi dairy industry. The bar chart graphically represents the data from the table, with each segment of the bars corresponding to the percentage or count of references for each theme as coded in NVivo. Both serve to highlight the relative emphasis different companies in the study place on various factors such as 'Technology Adoption', 'Government Policy', 'COVID-19', and so on. The bar chart provides a visual comparison, while the table offers numerical details.

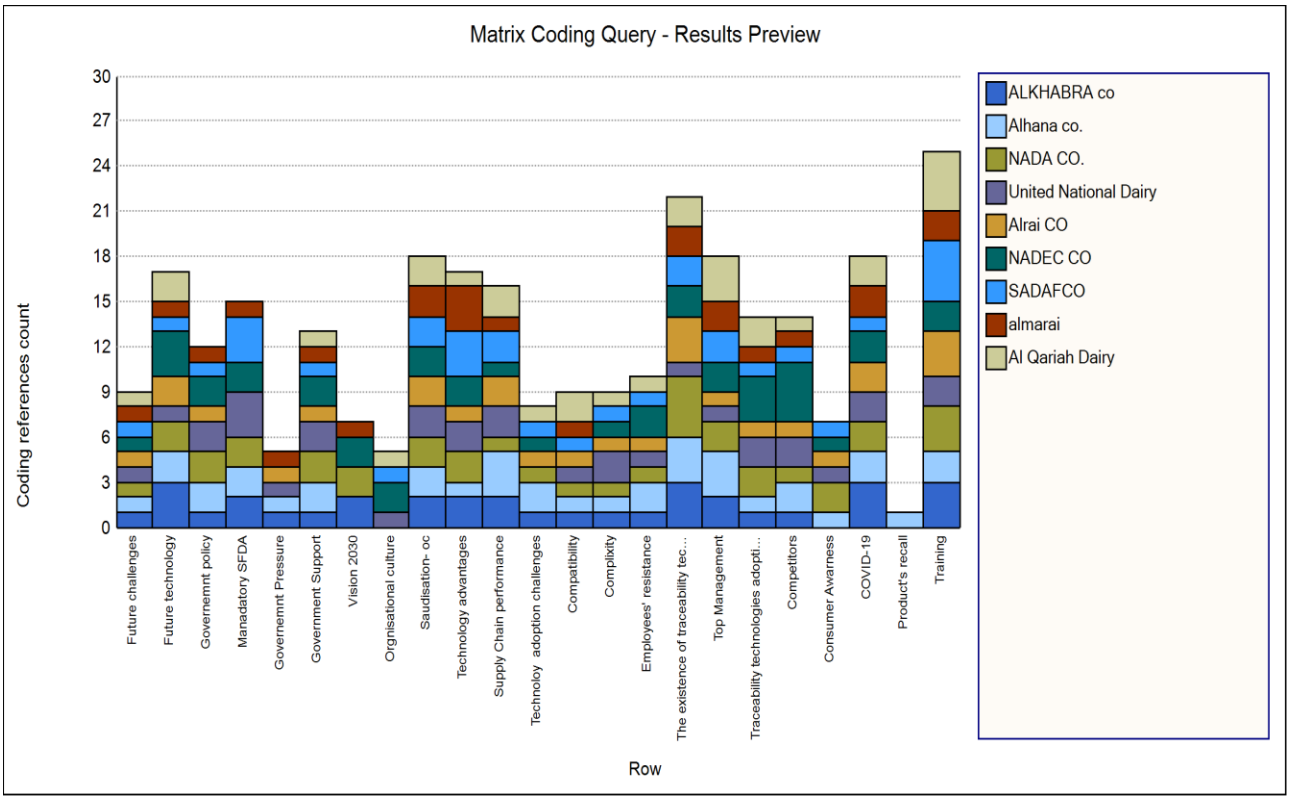


Figure 16. The Themes' Matrix Query

Table 26 serves as an analytical framework, detailing the main themes and subthemes pertinent to the adoption of traceability technology within the Saudi Dairy Industry. It presents a structured overview of the TOE factors influencing technology adoption, ranging from internal organisational dynamics to external market pressures. Each main theme is meticulously broken down into its constituent subthemes, painting a comprehensive picture of the various elements at play. This framework not only guides the analysis of qualitative data but also shapes the discussion of results, ensuring a thorough examination of each aspect of traceability technology adoption in the industry.

Table 25. Extended Overview of Themes and Subthemes of Traceability Technology Adoption in the Saudi Dairy Industry

TOE factors	Main Theme	Subtheme 1	Subtheme 2	Subtheme 3	Subtheme 4
Technology	Existence of Traceability Technologies in Saudi Dairy Sector (P1,P2,P3,P4,P5,P8).				
Technology and organisation	Traceability Technologies' Adoption Challenges and Barriers (P1,P2,P6,P3,P8,P9).	Employee's Resistance (P2,P6,P3)	Compatibility Considerations (P2,P4,P6,P7)	Complexity in the Adoption Process (P6,P1,P7,P2,P3)	
Organisation	Role of Organisational Culture and Top Management Support in the Adoption Process (P2,P3,P6).	Role of Organisational Culture(P2,P6)	Role of Top Management Support (P3,P2,P6)		
Technology and organisation	Impact of Food Traceability Technologies on Supply Chain Performance(P1,P2,P3,P4,P5,P6,P7,P8,P9)	Efficiency: Cost, Profit, Time, Effort (P1,P2,P3,P5,P7,P8)	Flexibility (P5)	Food Quality (P1,P2,P5)	Transparency, Information Availability, and Accuracy(P7)
Environment	Impact of COVID-19 and post-COVID-19 Period on Technology Investment(P1,P2,P3,P5,P7,P8)				
Environment	Impact of Consumer Pressure on Food Traceability Technology (FTT) Adoption. (P1,P2,P3,P9)	Consumer Awareness (P2)			
Environment	Influence of Competitor Pressure (P1,P2,P3,P4,P5,P6,P7,P8,P8)				
Environment, technology	Role of Government Policy in Influencing FTT Adoption(P1,P2,P3,P4,P7,P8)	Vision 2030 Initiative (P1,P2,P3)	Technology Investment (P1,P4,P8,P7)		
Organisation	Importance of Employee Training in Technology Adoption(P1,P2,P4)				
Environment	Workforce localisation initiative (Saudization) (P1,P2P6,P9)				

6.5 The existence of traceability technologies in Saudi dairy sector

In the theme of traceability technologies in the Saudi dairy sector, it was found that several different technologies are being used by different companies in the industry. For example, SAP is being used to trace products through the processing and distribution by companies A, C, and G. SCADA systems are being used in the processing units of large companies B and C. In the distribution of dairy products, 50% of the companies interviewed reported using real-time monitoring of temperature and humidity in cold chain, warehouses, and reefers, with the remainder in the process of adopting these technologies to avoid penalties. RFID technology is being used in the warehouses of large companies A and B, while GPS is being used by all companies to track vehicles and connect to the Saudi Food and Drug Authority (SFDA) and Ministry of Transport and Logistics systems. Traditional methods such as excel sheets and manual reports are still being used by companies F, H, and J. Finally, barcoding is widely used in large companies in the retail sector, while small and medium companies are not using any traceability technologies

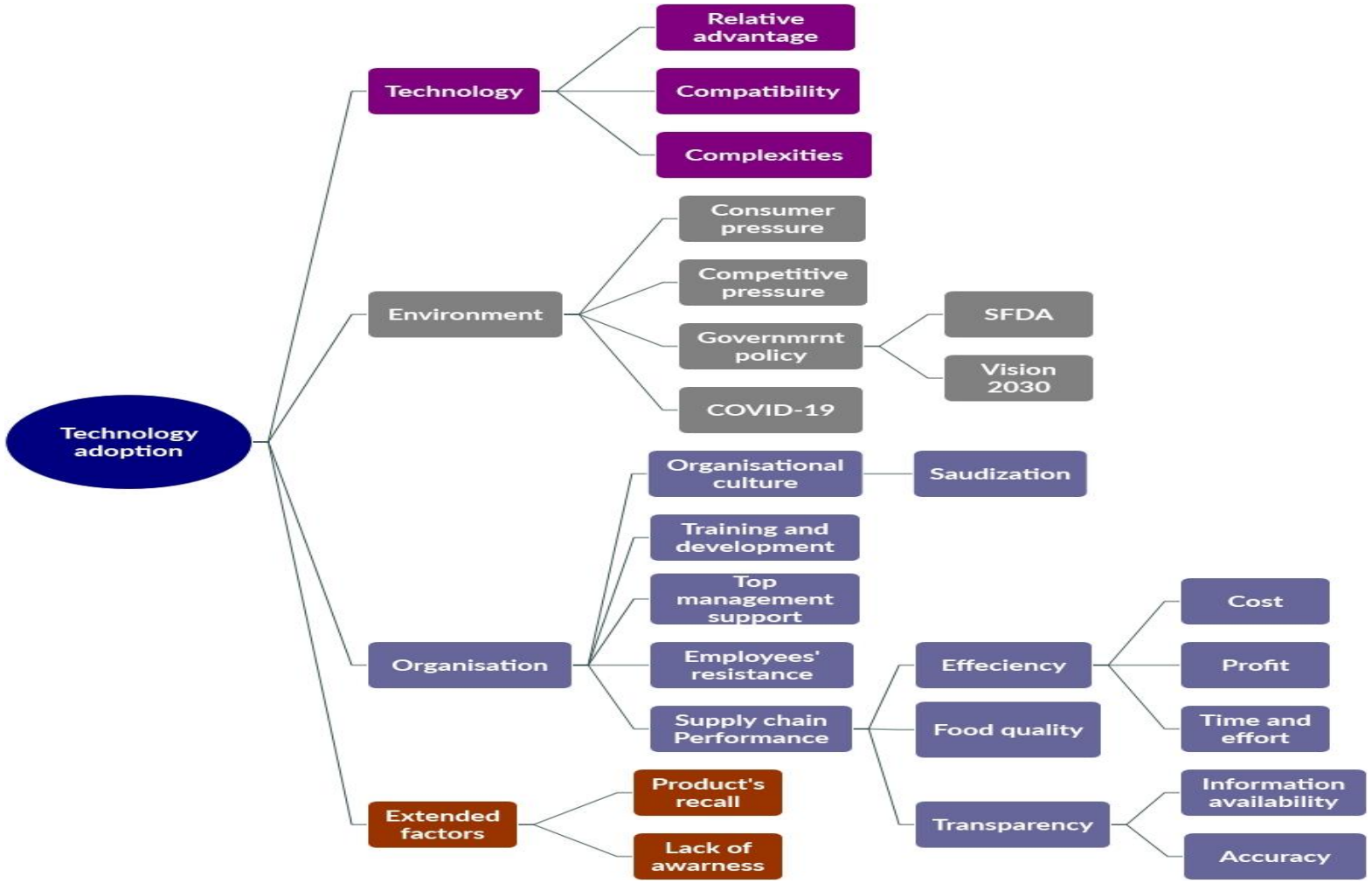


Figure 17. Themes and subthemes that was derived from the theory and interviews

6.6 Traceability technologies' adoption challenges and barriers

During the interviews, several challenges and barriers were mentioned by the participants as obstacles to the adoption of traceability technologies. Cost was identified as a major barrier by participants P6, P8, and P9. P8 stated that *"the adoption of modern technologies is expensive, and the cost of training is high as well."* P6 added that *"the decision to adopt is not easy; we need to ensure that the benefits of the technology outweigh the cost."*

Eight out of the nine participants indicated that employee resistance to technology adoption was a significant barrier they faced. P2 said, *"our employees constantly resist new technologies, probably because they are afraid of losing their jobs."* P6, a CEO, said *"we are struggling because our employees, including managers, always resist new decisions, regulations, or technologies. We need new people.*" However, P3 had a different perspective and said *"our employees are very adaptable; they quickly adopt new technologies. They are young and, as you know, the younger generation uses technologies on a daily basis such as smartphones, computers, and smart devices.*

6.6.1 Employee's resistance

Several participants mentioned employee resistance as a significant barrier to the adoption of traceability technologies. 8 out of 9 participants reported that employee resistance was a primary challenge they faced in implementing these technologies. P2 stated that *"The employees keep resisting new technologies, I think they're afraid that technology may take their jobs"*. P6, a CEO, mentioned that *"our employees, including the managers, always resist new decisions, regulations or technologies, the company needs new blood"*, implying that hiring new employees may be a solution to this issue. On the other hand, participant P3 emphasised that *"our employees are very flexible; they quickly adapt to new technology. They are young and, as you know, the new generation uses technology on a daily basis. They have smartphones, computers, smart devices...etc"*. This suggests that the age and familiarity with technology of employees may impact their resistance to its adoption in the workplace. Overall, employee resistance to the

adoption of traceability technologies appears to be a common challenge faced by companies in the dairy industry.

Figure 18. Resistance search query- NVivo 12 pro

6.6.2 Compatibility while adoption decision

The theme of compatibility while adoption decision highlights the importance of considering whether a traceability technology is compatible with other technologies and the organisational culture, strategy, and values. All participants emphasised the significance of compatibility in the adoption process. Some participants shared their experiences of facing problems with incompatible technologies and systems, stressing the need to learn from past mistakes. P2 stated, "*We've learned from past experience. We had two incompatible traceability technologies, one in production and the other in distribution, and it cost us a lot. So, we've learned a valuable lesson*

from that." P4 also agreed, "*Compatibility is considered to save time, cost, and effort*." Compatibility is crucial in ensuring a smooth adoption process and minimising potential challenges and difficulties.

The participants also mentioned that compatibility with the current systems and processes is important to ensure a smooth transition and integration. P5 stated "*We need to make sure that the new technology is compatible with our current systems and processes. If it's not compatible, it will cause problems and difficulties for us*." P6 added "*We need to ensure that the new technology is compatible with our company culture and values. If it's not a good fit, it will be difficult to get employee buy-in and adoption."* In addition, the participants stressed the importance of considering compatibility with industry standards and regulations. P7 stated "*We need to ensure that the new technology meets industry standards and regulations. If it does not, it can cause problems for us in terms of compliance and reputation.*" Overall, the participants emphasised the importance of compatibility in the adoption decision process to avoid difficulties and ensure a successful implementation.

6.6.3 Considering the complexity in the adoption process

The theme of complexity highlights the participants' views on the role of complexity in the adoption decision process. 7 out of 9 participants revealed that they do not consider complexity to be a significant factor and believe that adequate training programs can overcome any complexity. P6 stated, *"It's not important at all and we don't consider it. We provide workshops and seminars, and if someone keeps resisting or is not willing to use the technology, then we have to replace them with a new employee who has the required ability and flexibility."* On the other hand, P1 and P7 emphasised the importance of considering complexity in the adoption decision. P7 stated, *"It's very important, we do consider the complexity while making the adoption decision. We ensure that the technology is easy to use so that our staff can easily adapt and get the maximum benefit from it."* The participants' views on the importance of complexity in the adoption process varied, with some participants prioritizing the need for easy-to-use

technology to facilitate adoption and maximise benefits, while others believed that training programs were sufficient to overcome any complexity.

6.6.4 Organisational culture role and top management support in the adoption process

Organisational culture and top management support were identified as important factors influencing the adoption decisions of traceability technologies in the dairy industry. Over 50% of the top-level management in the companies interviewed were Saudi, while the middle level management was mostly composed of foreigners. All participants reported that top management was supportive of the adoption of new technologies.

P3 stated,

> *"We have a unique collaborative culture where we expect employees to be agile and make decisions quickly. If the adoption of a new technology is needed, top management is very supportive. They support everything that enhances the company performance."*

P2 confirmed that,

> *"The technology adoption is highly supported. The top management welcomes suggestions for new technologies from inside or outside the company, provided the benefits are clearly explained. They will then conduct further investigation before making a decision to adopt it."*

The influence of Saudi culture on organisational culture and top management support was also noted. As most of the top management in the companies were Saudi, the culture and values of the country played a significant role in the adoption decisions.

6.7 Traceability technologies adoption motivations.

Depends on the participants responses there are several factors that may motivate the companies to adopt traceability technologies. These factors are included but are not limited to supply chain performance, COVID-19, consumer pressure, competitors' pressure, Government policy, and Vision 2030.

6.7.1 How Food traceability technologies affects supply chain performance

All nine participants were positive about the outcomes of traceability technologies and its effect on performance. The critical performance outcomes can be grouped under the efficiency, food quality, transparency, and flexibility. Food quality and cost saving was addressed by all the participants as they consider it as the main benefit that they can obtain from using traceability technologies. **P1** revealed that "*Using FTT allowed the company to target the product that affected with a food safety problem and minimise any potential health risk***."**

The efficiency was mentioned broadly. The participants agreed that using FTT help a lot in reducing cost, time, effort, and product recall, while still producing food with high quality. 5 of the participants mentioned the customer satisfaction and 3 of them mentioned that FTT reduce customers' complaints "Figure19".

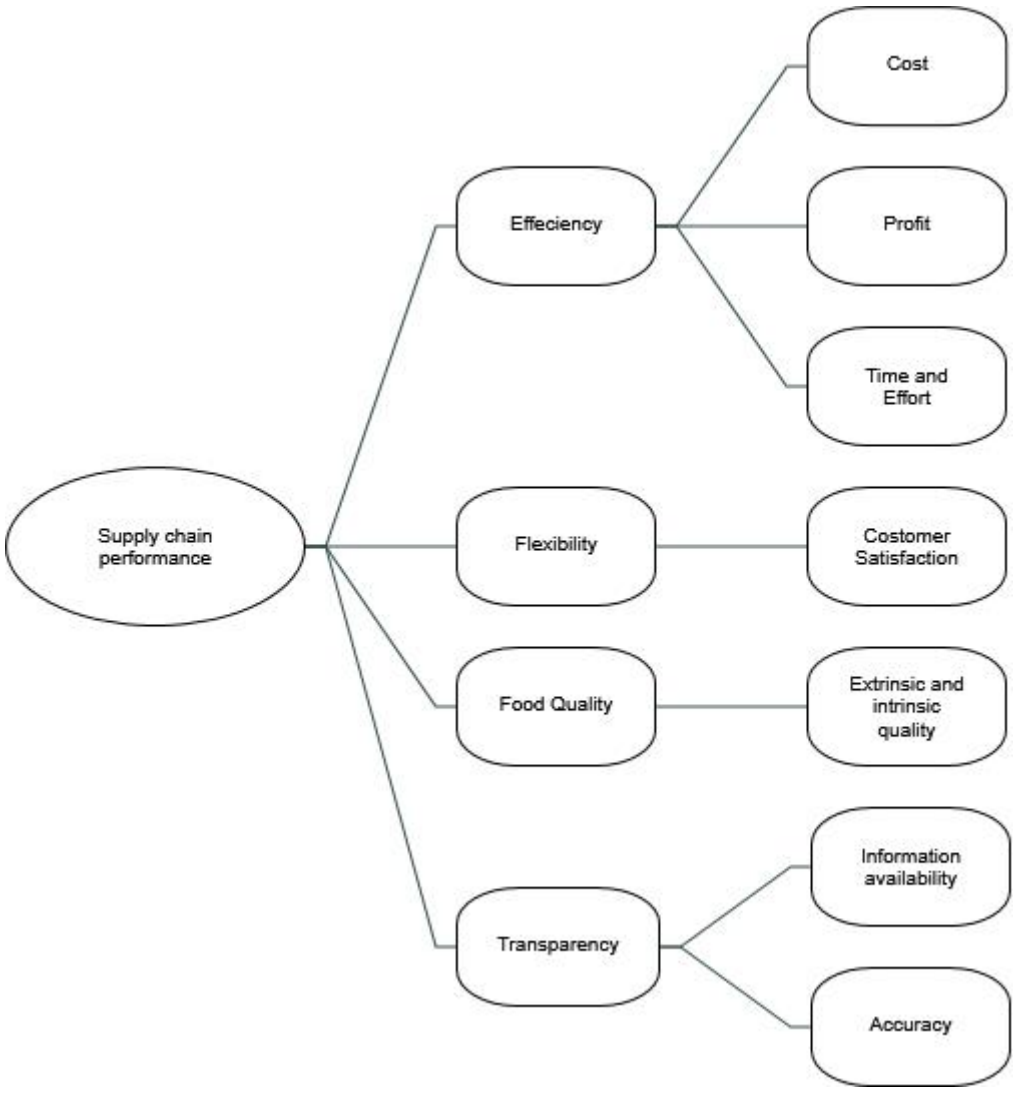


Figure 19. Measures used in the analysis to measure the impact of FTT on food supply chain performance.

6.7.2 Supply chain efficiency

Supply chain efficiency (Figure 20) concentrates on the internal supply chain processes. It is a company's ability to deliver products that meet customer's expectations with least raw materials, labour, and cost wastage. Most of managers interviewed revealed that using traceability technologies has a significant positive impact on the operational efficiency.

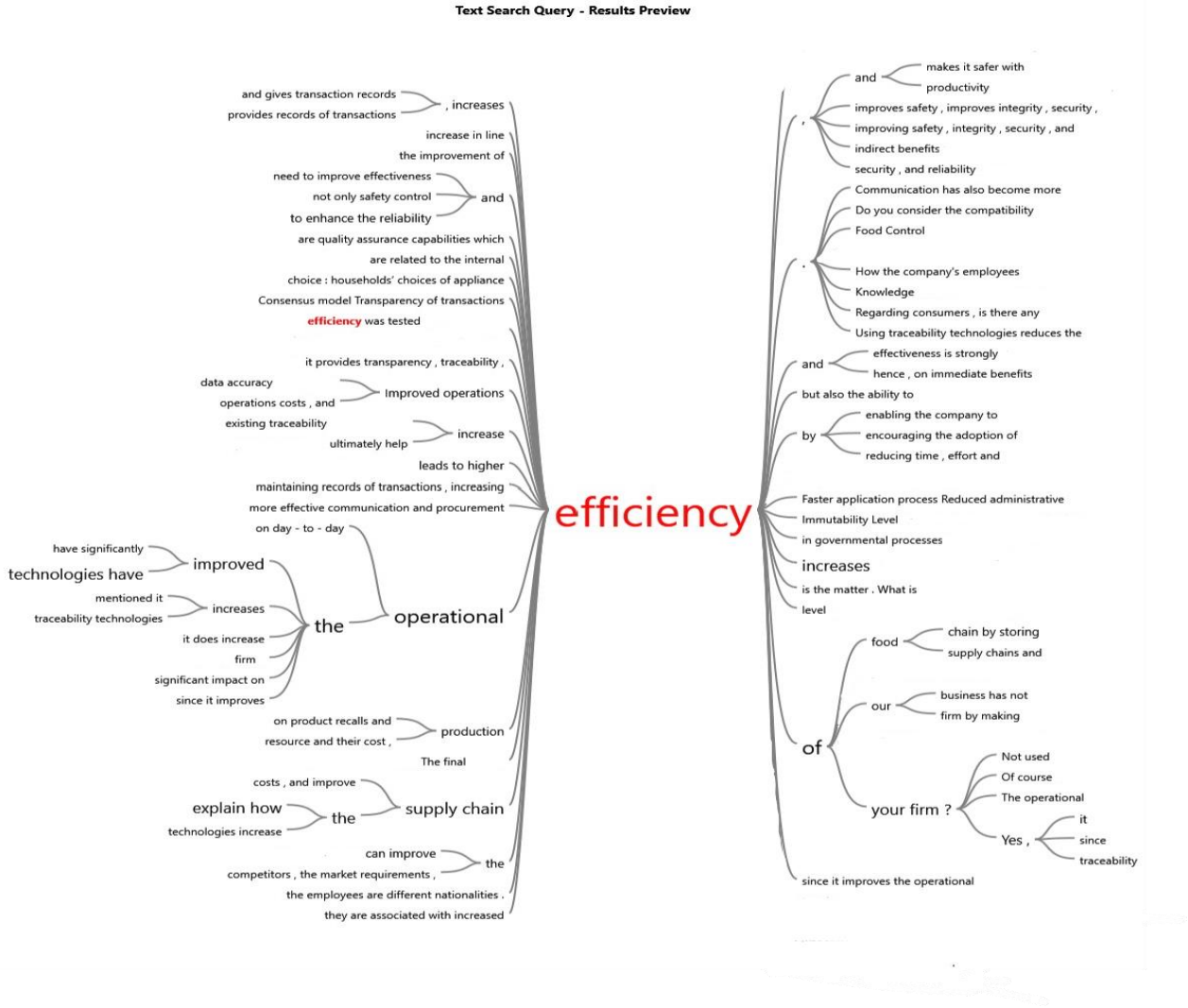


Figure 20. Efficiency search query

According to the managers, traceability technologies have a positive impact on operational efficiency by reducing waste and effort, while still producing high-quality and safe products. As one manager, P2, stated,

> *"Using traceability technologies reduces the waste in time and effort, while still producing high-quality and safe products. It cost the company a bit at the beginning. However, the return is too high and worth it."*

Traceability technology is also seen as important in the event of a food recall, as it allows for quick and efficient removal of unsafe products, protecting consumer safety and reducing recall costs. P1 manager noted that,

> *"It's really important to use traceability technology for food recall because it helps us move quickly, work more efficiently, and save money. With the right traceability technology, we can quickly remove any unsafe products to keep people safe and avoid unnecessary recalls."*

Another manager added that traceability technology *"reduces time and recall costs."* While some of the managers have not yet implemented traceability technologies, they theorised that they would improve supply chain performance. P8 stated that *"The operational efficiency of our business has not improved since we use the manual traceability. However, the traceability technologies would increase the quality and decrease the time and effort for sure."* P6 also commented,

> *"If you want my opinion based on what I've seen, I think we should wait until we start using traceability technologies. Theoretically, these technologies can help improve how our supply chain works by making it easier to manage inventory and keep our costs down, which is good news for our customers".*

Overall, the managers interviewed in this study highlighted the importance of traceability technologies in improving supply chain efficiency and performance.

6.7.2.1 Cost

cost was frequently discussed among the participants in this study, particularly in relation to the benefits of traceability technologies. These technologies were seen as a way to reduce costs by eliminating food waste and recall expenses. P3 stated that *"Traceability systems can help us save money, make better products, and keep our customers happy. So, they play a big role in improving our overall business performance"* P1 agreed, saying "Using traceability technologies is crucial for fast, efficient, and cost-effective food recall."

While some participants recognised the benefits of traceability technologies, they also mentioned that the cost of these technologies was a factor in their adoption decision. P7 stated that *"The technology cost, SFDA requirements, competitors, and the company strategy and goals, are the main factors"* in their decision-making process. He also noted, "*I think top management does not see technology as a way to gain an advantage over competitors. Instead, they view it as an expense they want to minimise*." P8 added that "*Many top managers think that the latest traceability technologies are too expensive and not worth the cost right now."* This suggests that cost is an important consideration for companies when deciding whether to implement traceability technologies.

Despite the initial cost of implementing traceability technologies, several participants in this study emphasised the long-term cost savings that these technologies can provide. For example, P3 noted that traceability systems *"significantly improve our business performances in terms of cost saving, product quality, and customer satisfaction."* P1 also mentioned that using traceability technologies is *"crucial for fast, efficient, and cost-effective food recall."* By reducing the amount of food waste and recall expenses, traceability technologies can ultimately result in cost savings for the company.

However, it is clear that the cost of these technologies is a factor that must be considered during the adoption decision. P7 stated that *"The technology cost, SFDA requirements, competitors, and the company strategy and goals"* are all factors in this decision-making process. P8 suggested that most of the top management members find the latest traceability technologies too expensive and very costly at this stage. This suggests that companies must weigh the potential benefits of traceability technologies against the initial cost of implementation in order to determine whether it is a worthwhile investment.

6.7.2.2 Profit

Three of the participants in this study reported that traceability technologies have increased or would increase their profits indirectly. They stated that the use of traceability technologies would

lead to improved product quality, resulting in increased customer satisfaction and, in turn, increased sales and profits.

For example, P5, who works at a company that recently implemented traceability technology, said *"If we get accredited and follow international standards (which we can't do without traceability), we'll be more attractive to export markets."* That means we'll be able to sell more products. P2 added that traceability can increase market share, which is a major factor in business profitability, stating *"I can say the traceability system will increase the food quality then the complaint will be decreased. Thus, the market share will be increase consequently."*

P1 linked the use of traceability technologies to customer satisfaction, suggesting that satisfying customers leads to profit. He said, *"Providing the customers with high quality products and all their food information will help us to gain their trust and loyalty which will lead to enhance our market share."*

Overall, the participants in this study emphasized the importance of traceability technologies in improving product quality and customer satisfaction, which can ultimately lead to increased profits.

6.7.2.3 Time and Effort

The theme of time and effort emerged from the interviews with several participants, who emphasised the benefits of traceability technologies in saving time and reducing effort. G stated that "*It reduces the waste in time, effort, and materials,*" while P4 and P2 both mentioned *"saving time and efforts"* as a key advantage of traceability technologies. These participants emphasised the importance of these technologies in streamlining processes and reducing the amount of time and effort required to complete tasks. By reducing waste and increasing efficiency, traceability technologies can help companies save time and effort, allowing them to focus on other important tasks and priorities. Overall, the use of traceability technologies is seen as an effective way to improve productivity and efficiency within the supply chain.

6.7.3 Flexibility

The theme of flexibility in supply chains refers to the ability of a company to adapt and alter its operations in response to unexpected changes or situations. In this study, traceability technologies were identified as a way to enhance flexibility by providing real-time tracking and information exchange.

P5, one of the participants in the study, stated that the COVID-19 pandemic highlighted the need for traceability technologies in order to increase accuracy and supply chain flexibility. They said, *"If we had used the latest traceability technologies during the COVID-19 pandemic, our data would have been more accurate, and our supply chain would be flexible to cope with the new situation."*

Another participant emphasised the importance of increased investment in traceability technologies in order to increase flexibility in the supply chain. They said, *"COVID-19 makes us realise that more investment in traceability technologies is highly required to increase the accuracy and supply chain flexibility."*

Overall, the theme of flexibility highlights the value of traceability technologies in enabling companies to adapt and respond to changing circumstances in an effective manner.

6.7.4 Food quality

Food quality emerged as a significant factor for the participants in this study, with all of them mentioning the importance of food traceability in increasing the quality of the products they produce.

P6 emphasized the potential of traceability technologies to boost the quality of products and increase consumer engagement, stating *"The quality would be boosted, and therefore more likely to engage with consumers."* P5 also highlighted the role of traceability technologies in maintaining the quality of their products and gaining consumer trust, saying "*Using these*

technologies guarantee the quality of our products and that's very important to gain consumer trust."

P2 also emphasised the impact of traceability technologies on product quality, stating *"They help us to Increase the products quality."* Overall, the participants in this study emphasised the importance of traceability technologies in ensuring the quality of food products and maintaining consumer trust.

6.7.5 Transparency

Supply chain transparency refers to the ability of companies to have complete knowledge and understanding of what is happening at each stage of their supply chain and to disclose this information both internally and externally. This is seen as important for building trust with customers and demonstrating honesty and transparency in business practices.

In this study, only one manager, P7, commented on the importance of supply chain transparency. He stated,

> *"Using traceability is the best way to make our supply chain transparent. This builds trust between our company and customers because it shows that we're honest about how we do things. When we're honest, people are more likely to trust us."*

The importance of supply chain transparency was emphasised by one manager in this study as a key factor in building trust with customers and ensuring honesty and transparency in business practices. The use of traceability technologies can help to enhance supply chain transparency by providing a complete record of the journey of a product from its raw materials to its final destination.

6.7.5.1 Information availability

One participant, P9, noted the benefits of traceability for employees, stating that *"Traceability will make it easy for the employees to obtain any products information through supply chain stages whenever they need it."* This increased access to information can facilitate decision-making and improve overall efficiency within the supply chain. The use of traceability

technologies can greatly enhance information availability, providing stakeholders with the necessary data and insights to make informed decisions and drive supply chain performance.

6.7.5.2 Accuracy

In this study, the topic of information accuracy was not frequently mentioned by the participants. However, one interviewee, P5, did mention the importance of accuracy in relation to food traceability. P5 stated that "*Food traceability enhances the supply chain performance by providing more accurate data."* This suggests that accurate data is crucial for the effective functioning and performance of the supply chain.

6.7.6 COVID-19 and post COVID-19 and the technology investment.

In this study, seven large and medium companies reported that the COVID-19 pandemic did not change their investment in technologies, as they already supported the adoption of new technologies. One manager, P1, stated,

> *"In fact, we use the latest technologies before covid-19, and it didn't pressure us to adopt more technologies. We always deliver the best quality and the highest food safety. But I can say COVID-19 might encouraged us to provide more information to the consumers and that require more complex traceability systems."*

Another manager, P2, added that *"With or without COVID-19 we always believe that we need to invest in technology. Our culture supports technologies, and we know how important they are."*

However, two other managers indicated that the COVID-19 pandemic had changed their thinking and made them realize that more investment in technologies was necessary. P5 noted that,

> *"COVID-19 made us think about upgrading our technologies, not just the traceability technologies but all the technologies that we use. It showed us the importance of using the latest technologies that don't require humans' intervention and we can control from anywhere."*

In short, the managers in this study emphasized the importance of technology investment in the food industry, with some noting that the COVID-19 pandemic had highlighted the need for more advanced technologies, particularly those that minimise the need for human intervention.

6.7.7 The impact of consumer pressure on FTT adoption

Several participants in this study indicated that consumer pressure plays a role in their decision to adopt traceability technologies. Consumers are increasingly demanding more information about the food they consume, including its production, origin, and safety. As a result, companies feel pressure to provide this information and implement more sophisticated traceability systems. One participant, P1, stated that *"Consumers encourage us to provide more information to them and that require more sophisticated traceability systems."* Another participant, P3, agreed, saying *"Consumers have increased their focus on food safety due to COVID-19 pandemic and that put us under pressure to provide them with the product's information so they can trust us."*

However, four of the participants reported that there is no pressure from consumers to adopt traceability technologies. These reasons can be grouped into two categories: consumer awareness and high-quality products. P9 and P2 claimed that their products are of high quality and therefore do not face any pressure from consumers. P9 stated *"There is no pressure at all. The consumers are happy with our products, and we are known for the quality of our products."* On the other hand, P2 and P5 believed that consumers are unaware of traceability technologies and therefore do not put pressure on the company to adopt them. P2 stated, *"In my opinion, the consumer does not understand what traceability is."*

6.7.8 Competitors pressure

All of the participants in this study mentioned their competitors during their interviews and were aware of their competitors' actions. Some described the dairy market competition as "a war" and were concerned about their place in the market. Other participants noted that they were running behind their competitors without elaborating further. For example, P9 stated "*They (the competitors) use traceability technologies, and they do progress over our business since they started their*

business before we do..."

Six out of nine participants mentioned that the pressure from competitors is one of the factors that motivates them to upgrade or adopt new technologies. P3 commented that "*The government regulation, market needs, competitors, and production are the main factors that affect their adoption decision,"* while P2 stated that *"I can say government policies, competitors, cost, and production efficiency" are important considerations in their decision-making process.*

In short, it is clear that competitors play a significant role in the adoption of new technologies and in the motivation of these participants to improve their businesses.

6.7.9 How does the government policy influence the FTT adoption?

The theme of government policy influencing traceability technology (FTT) adoption was consistently noted by all participants in this study. The Saudi Food and Drug Authority (SFDA) is the government agency responsible for regulating and monitoring foods and drugs and has recently implemented a policy requiring food companies to invest in traceability technologies such as sensors and GPS for their warehouses and logistics systems. These technologies must be directly connected to the SFDA's system, and failure to comply with this policy may result in penalties. participant, p6, stated.

> *"We're adopting a new traceability system because SFDA has a new regulation that requires an investment in traceability technologies. They start with transportation and, as far as I know, they will gradually require full traceability."*

This suggests that the SFDA is implementing the policy gradually, starting with transportation and eventually expanding to full traceability.

6.7.10 Vision 2030 and technology investment

Vision 2030 and technology investment emerged in this thematic analysis as a result of the Saudi government's efforts to transform the country into an industrial powerhouse in the food sector through automation and technology transformation. According to the nine participants interviewed in this study, there has been an increase in government regulations requiring more investment in technology, which they attribute to the launch of Saudi Vision 2030.

P2 stated that "I'm working in the industry for 14 years, I've noticed that SFDA in the last 5 years has been pressuring the companies gradually, I think they're trying to help the companies to invest in technology step by step." P1 confirmed this, saying *"The new requirements of acquiring traceability technologies are part of 2030 vision."*

In general, it appears that the Saudi government's efforts to transform the food industry through Vision 2030 have led to an increased focus on technology investment in order to meet new regulations and improve efficiency.

6.8 Additional factors that affect traceability technologies adoption

The participant mentioned some factors that have no impact on the adoption of traceability technologies neither supply chain performance e.g., Training, Saudization, and covid-19 impact on the supply chain. These factors remain unclassified and needed to be investigated deeply.

6.8.1 Employees training and the technology adoption

In this study, all of the participants reported that they provide training programs to ensure the successful adoption of technology by their employees. Some participants, such as P1, P3, and P4, reported providing technology-specific training, with P1 noting that *"Different technologies have different skills requirements."* Other participants mentioned providing employees with seminars and workshops to ease the adoption process. P2 stated that,

"We ease the adoption process through providing training and workshops. For example, when we decided to adopt SCADA, we held workshops for the employees to explain the changes that will happen and the potential benefits to ease the adoption. After adoption, we held workshops and seminars to train the employees, we took a few employees from each department and when they learned they came back and taught their colleagues."

Overall, it is clear that the participants in this study place a strong emphasis on providing their employees with the necessary training to ensure the successful adoption of new technologies. By providing specific training and workshops, the participants aim to not only teach employees the skills required for new technologies, but also to ease the adoption process and ensure a smooth transition for all employees.

6.8.2 COVID-19 impact on the company's supply chain.

The COVID-19 pandemic has had a significant impact on companies worldwide, with many experiencing challenges in their supply chain operations. In this study, all participants reported that their supply chain was not negatively affected by the pandemic. They attributed this to government support. One participant stated that they received *"big support from the government to keep things going smoothly"* which included providing healthcare and daily PCR testing for employees. As participant 3 *stated "No, we didn't face any challenges at all. We received a big support from government to keep things going smoothly. They provide our employees with healthcare by providing daily PCR, doctors in site to check the employee's health and provide urgent help if needed".*

Another participant reported that the lockdown actually increased demand for their dairy products and thus, enhanced their production. As P6 stated,

"Not at all, the government made it easy to get past this situation by providing us with doctors and COVID-19 tests. In addition, the lockdown enhanced the demand for dairy products. Since people cook meals at home and many Saudi dishes need dairy products, our sales had increased at that time, therefore, the production increased in return."

It is clear that the participants in this study felt that government support played a crucial role in helping their supply chain remain unaffected by the pandemic. They mentioned the provision of healthcare and testing for employees, as well as the quarantine of infected employees, helped them to continue with the supply chain operations. Additionally, the quarantine has led to an increase in the demand for dairy products as people cook meals at home and many Saudi dishes need dairy products. These findings demonstrate the importance of government support in mitigating supply chain disruptions caused by the pandemic. It also shows that the Saudi dairy sector has been able to adapt to the challenges posed by COVID-19pandemic.

6.8.3 Saudization

The theme of Saudization, as revealed in this study, highlights the prevalence of Saudi national managers at the senior level of the companies involved. This trend is significant as it suggests that the top management of these companies is largely composed of individuals with a Saudi cultural background, which is likely to have an impact on the organisation's culture as a whole. This cultural influence may also play a role in the adoption process of new initiatives within the company, as the values and practices of the Saudi national managers may shape the decision-making process.

The managers interviewed in this study discussed the Saudization and its impact on their companies. One manager, P7, stated that *"We have a high percentage of Saudi national managers at the senior level, which definitely influences the culture of our organisation."* Another manager, P6, commented that *"Our top management is largely composed of Saudis."*

The theme of Saudization also highlights the efforts of these companies to increase the number of Saudi employees, particularly at the lower levels. As one manager, P9, explained, *"We are trying to increase the number of Saudi employees in our company, especially at the lower levels. We want to promote Saudization as much as possible."* This effort to increase Saudi representation within the organisation may be driven by a desire to align with the culture and values of the top management, as well as the government requirements.

Overall, the theme of Saudization reveals the significant presence of Saudi national managers at the senior level of these companies and the potential impact this has on the Organisation's culture and adoption process.

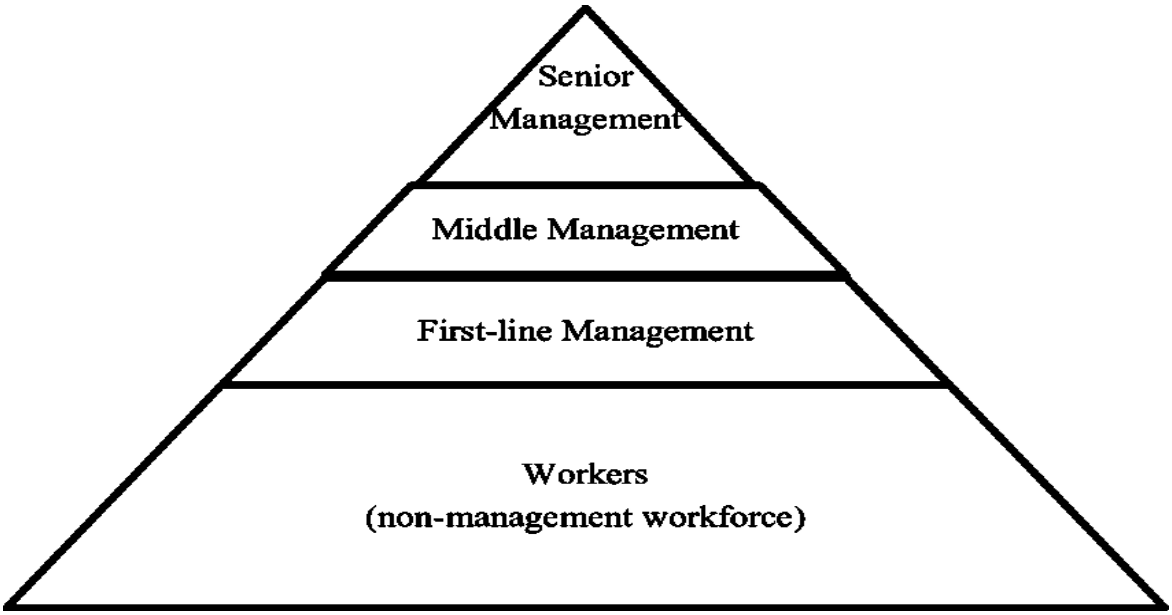


Figure 21. *Pyramids of Management Levels*

6.9 Cross case analysis

In this study, a cross-case analysis was adopted to understand the various dimensions of technology adoption within the Saudi dairy industry. According to Barratt et al. (2011), cross case analysis can be performed in three primary ways: firstly, by comparing two cases for similarities and differences; secondly, by selecting constructs informed by existing literature and seeking evidence that addresses these constructs; and thirdly, by segmenting the data according to its source and validating evidence from one source with another. This study analysis leans toward the second approach, focusing on constructs derived from the Technological, Organisational, and Environmental (TOE) framework.

Taking a flexible stance during interviews, the researcher has allowed for in-depth discussions to gain additional insights that extend beyond the scope of the TOE framework. In aligning with the concept of 'theory elaboration,' as described by Ketokivi and Choi (2014), this study seeks to

contribute to the existing literature by offering a contextualised exploration of the TOE framework's applicability to the Saudi dairy industry. Emphasis is placed more on theoretical elaboration than on theory generation or testing (table 28).

	Themes	Theoretical Codes	Codes	A	B	C	D	E	F	G	H	J	TOE Classification
1	***The existence of technologies in Saudi dairy sector***												
			Traceability Technologies existence	x	x	x	x	x		x			Technology
2	***Traceability technologies' adoption Challenges and barriers***												
		Employee's resistance		x		x	x	x	x	x	x	x	Organisation
		Compatibility		x	x	x	x	x	x	x	x	x	Technology
		Complexity		x	x	x	x	x	x		x		Technology
			High Saudization Level	x		x			x	x	x	x	Organisation
			Adoption cost						x		x	x	Economy
3	***Traceability technologies' adoption motivations.***												
3.1	***Supply Chain Performance***												
			Efficiency	x	x								Organisation
			Less costly food recall	x									Economy, Organisation
			Long-term cost savings										Economy, Organisation
			Increase Profit			x		x					Economy , Organisation
			Reduce Time and Effort		x		x						Organisation
			Flexibility					x					Organisation
			Food quality		x			x	x				Organisation
			Supply chain Transparency							x			Organisation

4	***COVID-19***												
4.1	***COVID-19 Impact on traceability technologies adoption decision***												
		COVID-19 has no Impact		x	x								Environment
		COVID-19 has a positive Impact						x		x			Environment
5	***Consumer***												
		Consumer pressure plays a role in the adoption decision			x		x		x	x	x		Environment
			Consumers are unaware of the traceability		x			x					Environment
7	***Competitors pressure***												
		Motivate their adoption decision			x	x	x		x	x	x		Environment
8	**government pressure**												
			SFDA	x	x	x	x	x	x	x	x	x	Environment
		Vision 2030		x	x	x						x	Politics
9	***Employees***												
		Employees Training		x	x	x	x	x	x	x	x	x	Organisation
			Employees resistance	x	x		x	x	x	x	x	x	Organisation

Table 26. Cross Case Analysis of Saudi Dairy Sector

Table 28. presents an exhaustive cross-case analysis, illustrating various themes and codes corresponding to the adoption of traceability technologies in the Saudi dairy sector.

The initial theme unveils the prevalence of traceability technologies in the sector, capturing diverse aspects of their existence, relevance, and adoption.

Subsequently, the analysis unearths challenges obstructing the successful incorporation of these technologies. Factors like employee resistance, compatibility issues, complexities, high levels of Saudization, and adoption costs are underlined in this segment.

Thereafter, the study delves into the motivating factors encouraging firms to adopt traceability technologies. Within the realm of supply chain performance, codes related to efficiency, cost-effective food recalls, long-term savings, profit increase, time and effort reduction, flexibility, food quality enhancement, and supply chain transparency are considered.

Next, the impact of the COVID-19 pandemic on the decision to adopt these technologies is scrutinized, assessing whether the pandemic has wielded any influence over the adoption decision.

Consumer pressure and its significant role in pushing organisations towards adopting traceability technologies form the next theme. Here, the table represents the extent of influence exerted by consumers and their awareness about traceability.

Competitor pressure also surfaces as an influential factor in the decision-making process related to the adoption of traceability technologies.

In addition, government pressure, particularly from the Saudi Food and Drug Authority (SFDA) and the Vision 2030 initiative, is also recognised as a key determinant in the decision to implement these technologies.

Finally, the role of employees in the technology adoption process is examined, considering aspects like employee training and potential resistance to technology adoption.

In essence, the table provides an intricate cross-case analysis, painting a comprehensive picture of the diverse factors influencing the adoption of traceability technologies within the Saudi dairy sector.

6.10 Summary

This chapter presented the findings of a thematic analysis and cross case analysis of nine dairy companies in the Saudi dairy sector. The objective of this study was to understand the technological, organisational, and environmental factors that motivate Saudi dairy firms' intentions to adopt traceability technologies in their internal operations as well as in distribution network.

The thematic analysis identified several themes, including the importance of traceability technologies in ensuring food safety, the role of government policies in promoting adoption, and the challenges faced by companies during adoption, including employee resistance and financial constraints.

The cross-case analysis was used to gain in-depth insights into the individual experiences of each of the nine companies. The analysis revealed that traditional methods such as excel and manual reports are still in use in small and medium firms, despite the managers' awareness of the importance of acquiring new traceability technologies. Additionally, the government's pressure and policies were identified as the main factor that enhances the intention of technology adoption in the Saudi dairy sector.

7 Chapter Seven: Discussion and Implications

7.1 Introduction

The purpose of this discussion chapter is to provide an in-depth analysis of the research results and to explore their implications for theory and practice. In particular, this chapter aims to address the following questions: What are the key findings of the study and how do they contribute to our understanding of the adoption of food traceability technologies in the Saudi dairy sector? How do these findings compare to those of previous research in this area? And what are the practical implications of these findings for Organisations seeking to adopt food traceability technologies in the Saudi context?

To address these questions, the chapter is structured as follows. First, the adjusted framework guiding the study is presented. This is followed by a detailed listing of the research propositions. The main findings of the study are then explored and discussed at length. Subsequent to this, a comparison is made with prior research concerning the adoption of food traceability technologies in various contexts. The chapter concludes by examining the practical implications of these findings and suggesting avenues for future research. Overall, the chapter aims to offer valuable insights into the adoption of food traceability technologies in the Saudi dairy sector, contributing to a more comprehensive understanding of how to successfully implement these technologies in this particular setting.

7.2 An adjusted Framework for Traceability Technology Adoption

The adoption and successful implementation of traceability technologies within industries is a complex process, shaped by a confluence of technological, organisational, and environmental factors. The Technology-Organisation-Environment (TOE) framework has previously used to understand this multifaceted process. However, through this research focused on the Saudi dairy industry, the TOE framework needed to be adjusted to encapsulate crucial factors that generated specifically for this study after the analysis.

This study sought to identify and understand the specific factors influencing the adoption of traceability technologies within the Saudi dairy sector, aiming to provide a more nuanced perspective. The research unveiled key influencing factors such as the unique labour policy of Workforce Localisation (Saudization), the strategic national plan 'Vision 2030,' and the significant impact of the global COVID-19 pandemic on technology investment. In addition, it underscored the importance of compatibility considerations and complexities in the adoption process, as well as the notable resistance to technology adoption among employees.

Building on these additional findings, this section presents an adjusted TOE framework, moving beyond its usual scope. This adjusted framework incorporates these newly identified factors, providing a more comprehensive tool to understand technology adoption processes not only within the Saudi dairy industry, but potentially across various industries and geographical contexts. By doing so, it contributes to the broader literature on TOE factors that affect technology adoption.

The process of technology adoption is intrinsically linked to the dynamics of the environment in which it operates, in addition to the technological and organisational characteristics, as underlined by the TOE framework.

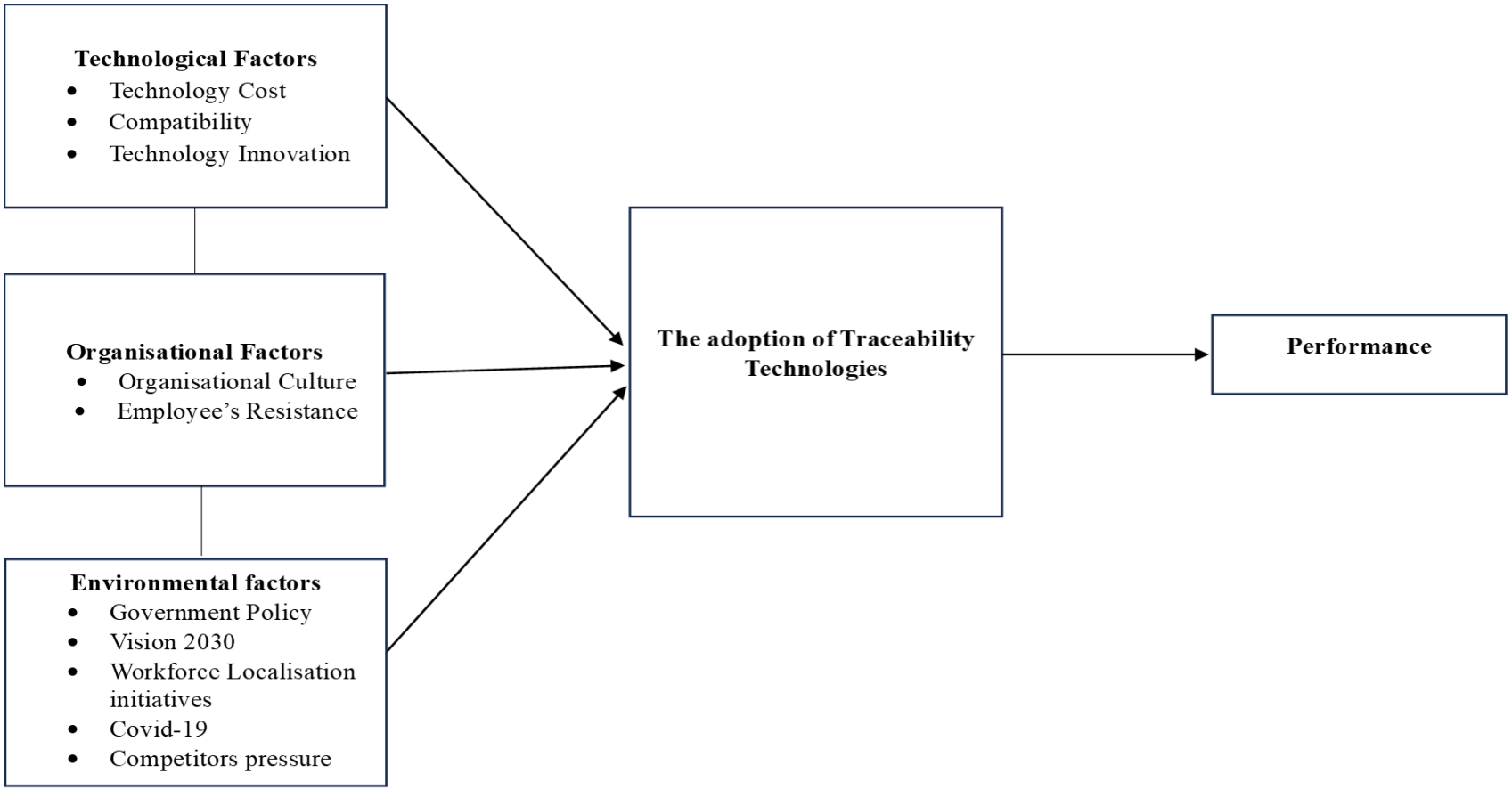


Figure 22. Adjusted Framework for Traceability Technology Adoption

This research originally relies on a well-known theoretical model—the Technology-Organisation-Environment (TOE) framework—which commonly incorporates some factors. As the study progressed, it became apparent that the Saudi dairy industry presented unique aspects that were not accounted for in the traditional TOE framework. Consequently, the framework was adapted and extended to include previously unexplored factors unique to this industry, such as workforce localisation initiatives that falls under Environmental factor. This modification not only tailors the TOE framework to the specific conditions and challenges observed in the Saudi dairy industry but also contributes a novel extension to the existing TOE framework by introducing new, previously unconsidered factors.

After an intensive series of interviews and in-depth analysis of the research data, this study found that some of the common TOE factors did not hold as much significance as previously thought. For instance, complexity, which refers to the perceived difficulty of understanding and using a new technology, was less of a concern for the participants. This finding suggests that the participating organisations were more inclined to focus on the cost of the technology and its relative advantages rather than its ease of use. This led to an adjustment in the framework to include technology cost as a new factor, taking precedence over complexity.

The focus on cost was particularly notable among Small and Medium Enterprises (SMEs) (i,e., H, and J), who viewed the technology cost as a significant barrier to adopting new technology. Larger companies (i.e.,A,B,and C), on the other hand, showed more interest in technology innovation, valuing the potential competitive advantage that innovative technologies could provide. Despite these variations, compatibility remained a well-recognised factor, indicating that how all businesses, regardless of their size, face challenges when it comes to new technology integration into their existing processes and systems.

After considering top management support as a crucial factor, the research led to a re-evaluation of its importance, because the interviews were primarily conducted with top management individuals, who are likely to view themselves as supportive. For a more objective assessment of top management support, input from different levels of the organisation would be necessary.

Interestingly, competitor pressure emerged as a new factor in the environmental context. The interviews revealed a high level of awareness and concern about competitors' progress, with participants describing the market as a battlefield where losing their place was a major fear. This competitive awareness underscores the importance of maintaining an up-to-date understanding of market trends and technologies to ensure a strong market position.

Despite the findings indicating that the pandemic has not had an impact on the adoption of traceability technologies, the decision to retain COVID-19 as a factor in the study's framework is informed by its significant societal and global influence . The pandemic has heightened consumer awareness and concerns about the safety and sourcing of food products, including dairy. This concern, while not translating into immediate changes within the industry's traceability practices as per the managerial perspectives, is a critical societal shift that cannot be overlooked. It suggests an underlying potential for influence on consumer behaviour and, consequently, on industry operations in the longer term. The inclusion of COVID-19 in the framework acknowledges this broader impact and recognises the importance of consumer sentiment in shaping industry priorities, which may lead to a greater emphasis on traceability in the future, as firms respond to evolving market demands.

In contrast, Vision 2030 and government policies were identified as significant drivers for traceability technology adoption. These national policies emphasise the country's commitment to technological advancement and the digital transformation of various sectors, including the dairy industry.

In another hand, organisational factors as expected remains as critical in influencing technology adoption decisions. This study found that the organisational culture, shaped largely by Saudi nationals in leadership positions, significantly influences all other factors. A high presence of Saudi nationals in management roles could shape the organisational culture to reflect Saudi Arabian societal values and traditions, following Hofstede's (2001) theory on the influence of national culture on organisational culture and management practices.

Saudi Arabia’s culture is characterised by high uncertainty avoidance, masculinity, power distance, and collectivism. This cultural context may explain some of the challenges in technology adoption faced by Saudi dairy companies. For example, the high uncertainty avoidance may result in resistance to new technologies, and the high-power distance may lead to an overemphasis on managerial directives, potentially overlooking the complexity of technologies and leading to employee resistance.

In fact, one of the most significant contributions of this study is the identification of workforce localisation, in this study known as 'Saudization,' as a novel factor influencing technology adoption. While this factor was identified through research focused on the Saudi Arabian dairy industry's traceability technology adoption, its significance likely extends beyond this specific context. Workforce localisation could potentially influence technology adoption in other sectors within Saudi Arabia or in other countries with similar workforce localisation policies.

The introduction of workforce localisation as a new factor in the TOE framework could serve as a starting point for future research. The current academic landscape reveals a noticeable gap in recognising it as a significant influence on technology adoption.

7.3 The existence of traceability technologies in Saudi dairy sector

The study participants exhibited a comprehensive understanding of traceability technologies and recognised the pivotal role they play in enhancing supply chain efficiency and improving food quality. This perspective aligns with existing literature, which underscores the substantial benefits of well-developed traceability systems (Cui et al., 2019; Dandage et al., 2017; Zhu, 2017). Specifically, Zhu (2017) asserted that an adeptly implemented traceability system could significantly bolster supply chain performance, serving as a profitable investment for the food industry. Complementing this, Cui et al. (2019) identified that, in serial supply chains, traceability invariably leads to improved product quality and increased profits for all firms, establishing a mutually beneficial situation.

The Saudi dairy sector uses some traceability technologies to safeguard the quality and safety of dairy products. These technologies enable consistent monitoring of crucial parameters such as

humidity, temperature, and the movement of dairy products across the supply chain. Any deviations or potential issues are quickly identified, enabling instant corrective measures (Pant et al., 2015).

According to the research findings, the adoption of traceability technologies in the Saudi dairy sector varies considerably. For example, large-scale companies like A, B, and C employ SAP and SCADA systems for their processing and distribution units. SCADA systems provide real-time monitoring and control of production processes, while SAP software offers comprehensive supply chain, inventory, and product tracking capabilities. Their combined use in the dairy industry can lead to improved efficiency, product quality, and compliance with industry standards. This finding aligns with Wognum et al. (2011), who suggested that many companies leverage pre-existing integrated enterprise information systems, like SAP, to avoid redundant costs.

The research findings divulged that approximately half of the companies interviewed actively employ real-time monitoring technologies for temperature and humidity within their warehouses, cold chain, and reefers. Interestingly, the remaining half indicated serious contemplation towards adopting these technologies, primarily driven by the aim to avoid potential penalties.

These real-time monitoring technologies represent critical elements of the Internet of Things (IoT) ecosystem. They play a significant role in facilitating data collection and transmission, thereby enabling constant monitoring and control measures (Palattella et al., 2016; Shee, 2022).

This viewpoint is supported further by de Vass et al. (2021) and Shee (2022), which sheds light on the practical implementations of IoT technologies in supply chain management. Examples include the application of IoT engine monitoring technology for tracking vehicle emissions and idle time and the deployment of sensor networks in cold-chain logistics for tracing temperature-sensitive products. These practical implementations emphasise the substantial role these technologies play in collecting and transmitting data, which leads to superior monitoring and control.

Further supporting this perspective, the findings by Dweekat Abdallah (2017) emphasise the capability of IoT to amplify supply chain performance management (SCPM). Based on their case study, they demonstrated that the utilisation of IoT can provide real-time data collection, augment data efficiency, and enable real-time communication within the supply chain. This capability demonstrates a promising pathway towards optimizing supply chain operations and making them more responsive, efficient, and resilient.

Therefore, the integration of IoT technologies, including real-time monitoring systems, into supply chain operations appears to be an escalating trend amongst the studied companies. This shift can potentially revolutionise supply chain management, emphasising the importance of these technologies in driving operational efficiency, improving product quality, and reducing risks in the supply chain.

This investigation accentuates the significant role of governmental regulations and policies in adopting traceability technologies within the Saudi dairy sector. This emphasis echoes the findings of Sherer et al. (2016), who demonstrated the compelling impact of institutional mechanisms, such as governmental policies and industry norms, on the adoption of pivotal technologies.

However, it's important to note that the influence of these regulatory mechanisms may fluctuate across different nations and regions. For example, a study in Taiwan by Tu (2018) revealed that while regulatory factors were essential, other factors like pressure from supply chain partners could have a more dominant role. This variation might stem from cultural disparities between countries like Saudi Arabia and Taiwan.

Further enhancing this viewpoint, the findings of Raj et al. (2020) identify barriers that could impede the adoption of such technologies. Their research suggests that enhancements in standards and government regulations could foster the assimilation of Industry 4.0 technologies in developing nations like Saudi Arabia. Simultaneously, they underline the necessity for a robust technological infrastructure to boost the incorporation of these technologies in developed nations.

Moreover, this study highlights the paramount influence of government regulations and policies on the adoption of traceability technologies in the Saudi dairy sector, consistent with previous literature. However, it is worth noting that regulatory impact may vary across different countries and regions. For instance, a study conducted in Taiwan by Tu (2018) found that while regulatory factors were vital, other factors such as supply chain partner pressure, played a more significant role. This contrast might be due to cultural differences between Saudi Arabia and Taiwan.

Interestingly, despite the competitive nature of Saudi Arabia's dairy sector and the government's emphasis on technology and automation, the study uncovered that some companies still employ traditional methods such as Excel spreadsheets and manual reports. This is surprising, especially when larger companies e.g., company A within the sector have already embraced advanced traceability technologies like IoT tracking sensors and RFID systems.

Most companies have adopted real-time GPS technology for vehicle tracking and regulatory compliance, aligning with the requirements set forth by the Saudi Food and Drug Authority (SFDA) and Ministry of Transport and Logistics. For inventory management, RFID technology is prevalent among large dairy companies, providing automated and real-time identification and tracking, increasing inventory accuracy, enhancing supply chain visibility, and reduce the inventory loss (Chen et al., 2021).

On the other hand, it has been observed that medium-sized dairy firms tend to persist with traditional barcode systems, corroborating the findings from N Sivakami (2018) study. Although Radio Frequency Identification (RFID) brings substantial benefits surpassing traditional barcodes, the adoption rates are inconsistent across the sector. This discrepancy can be attributed to cost concerns and the absence of essential technical expertise (Temidayo et al., 2020).

The Saudi dairy industry's landscape of traceability technologies is varied and evolving, shaped by factors such as governmental regulations, technological advancements, company size, and cultural contexts. Understanding this landscape and its influencing factors can help shape future policy decisions and business strategies, promoting the effective use and further adoption of traceability technologies in this sector.

Proposition 1 (P1): Traceability technologies adoption and its integration have no significant presence within the Saudi dairy industry, neither they meet advanced standards of Industry 4.0 and the objective of Vision 2030.

Rationale: The research findings reveal a varied landscape in the implementation of traceability technologies within the Saudi dairy sector. Although larger companies such as company A and B have started incorporating advanced systems like SAP and SCADA, enhancing certain aspects of supply chain efficiency and product quality, the industry as a whole still demonstrates a significant gap in fully embracing the ideals of Industry 4.0. Many medium-sized and smaller firms predominantly rely on more traditional methods, such as manual tracking and basic barcode systems. This mixed scenario of technology adoption points to a sector that is in the early stages of a more comprehensive technological transformation. The proposition thus reflects this uneven progression, highlighting the need for further development and integration of advanced traceability technologies across the sector to achieve the modernization and efficiency envisaged by Vision 2030.

7.3.1 Traceability technologies' adoption challenges and barriers

The adoption of traceability technologies presents several significant challenges and barriers that must be carefully navigated, most notably the constraints imposed by costs and employee resistance. The results of the current research converge with the findings of a study conducted by Shaikh et al. (2021), suggesting that the significant impediments to technology adoption prominently include the high cost of technology. This study unravelling a multiplicity of considerable challenges and obstacles that must be judiciously addressed when integrating traceability technologies into existing systems. Among the hurdles encountered, two factors stand out: the financial constraints and the resistance from employees.

In this research, participants F, H, and J emphasised the considerable financial implications associated with the acquisition and implementation of these advanced technologies. However, the financial obligations do not merely cease with the initial hefty investments. There is a continuation of recurring expenses that companies have to endure, such as those related to the

maintenance of these systems, the upskilling of the workforce to operate the new technologies, and training to ensure that employees can efficiently and effectively use these systems.

This apprehension concerning the fiscal challenges, as voiced by the participants, reflects the practical difficulties experienced by a multitude of small to medium-sized dairy firms operating within Saudi Arabia. For these firms, limited resources and budget constraints may significantly impede their capacity to invest in advanced traceability technologies. That consistent with Corallo, Latino, Menegoli, and Striani (2020) who found that small-sized companies expressed concerns regarding the adoption costs associated with implementing a traceability system. Understanding and addressing the cost barriers is an intricate process necessitating Organisations to perform comprehensive cost-benefit analyses. Indeed, it is essential to assess the cost-benefit ratio when considering the adoption of a traceability system (Corallo, Latino, Menegoli, & Striani, 2020). Some agrifood companies may find safety issues and product recalls to be strong motivating factors, perceiving the benefits to outweigh the costs(Fritz & Schiefer, 2009). However, for small and medium-sized enterprises (SMEs), the financial investment required for implementation can pose a significant burden.

In another hand, resistance from employees emerges as another substantial barrier to the adoption of traceability technologies (Jang et al., 2023). Employee resistance can emanate from a variety of reasons, from fear of unemployment due to technological takeover, to a simple lack of familiarity with the systems. Several strategies can be employed to overcome this resistance, most of which involve proactive change management approaches addressing employee concerns while promoting a culture of acceptance and adaptability. Also, highlighting the potential enhancement of job roles, increased efficiency, and opportunities for skill development foster a positive attitude towards the adoption.

Indeed, employee resistance to traceability technologies as a significant barrier to the adoption is deeply rooted in the broader discourse on resistance to organisational change. This discourse is both multifaceted and complex, touching upon diverse aspects from individual personalities to organisational culture and power dynamics.

The foundational element of this resistance is the human inclination towards the familiar and the known, as underscored by Sven (2016) People inherently resist innovation because it introduces the unfamiliar and unknown. This natural tendency is a common thread that runs through much of the literature discussing resistance to change.

Further, certain individuals are predisposed to resist change more than others due to their personality traits and dispositions (Nov & Ye, 2009; Oreg, 2003). This resistance can also be driven by a variety of deeply ingrained factors such as values, motives, emotions, cognitive structures, and cultural norms (Danışman, 2010; Howard & Mozejko, 2015; Oreg, 2003). These variables intricately interplay and can result in individuals becoming hesitant or outright hostile towards proposed changes within their Organisation.

Overcoming this resistance necessitates an understanding of these factors and the implementation of appropriate strategies. Organisations can employ work-psychological measures like increasing task autonomy, providing feedback (Battistelli et al., 2013), or adopting broader organisational development initiatives for sense-making, providing an appropriate training programs. Other recommendations which is a humanistic approaches like adopting the concept of spirituality (Lawton, 2017).

Understanding employee resistance to traceability technologies requires a deep dive into these diverse factors. Recognizing resistance as a valuable source of feedback and a reflection of the complex dynamics at play can aid in creating a more effective strategy for implementing change. The challenge lies not just in overcoming resistance but in leveraging it to improve the overall change process.

Cost and employee resistance, while being formidable barriers to traceability technology adoption in the Saudi dairy sector, can be navigated through strategic planning and effective change management. The financial constraints faced by dairy companies necessitate careful cost-benefit analyses to ascertain the feasibility of investments. Meanwhile, employee resistance can be addressed through clear communication, comprehensive training, and a participatory approach

in decision-making. Furthermore, the creation of a learning environment and a culture of acceptance can facilitate the successful adoption of traceability technologies.

While the challenges seem daunting, it is crucial to understand these barriers not as insurmountable obstacles, but as areas for potential growth and development. In the realm of cost, Organisations can explore various approaches to optimize resource allocation, such as phased implementation or seeking collaborative partnerships with technology providers. On the employee resistance front, a carefully crafted change management strategy encompassing communication, education, and involvement can significantly improve acceptance of the new technologies. Furthermore, cultivating a culture that is open to technological innovation and change can further ease the adoption process.

Proposition 2 (P2): The cost of technology adoption and employee resistance have a negative impact on the adoption of traceability technologies in the Saudi dairy industry.

Rationale: This proposition is derived from the research findings indicating that financial constraints and employee resistance are significant impediments to the implementation of traceability technologies within the Saudi dairy sector. The financial aspect primarily involves the costs associated with acquiring, implementing, and maintaining these advanced technologies, which can be particularly challenging for small and medium-sized enterprises. Employee resistance, often rooted in apprehension about new technologies and potential job security concerns, further complicates the adoption process. Addressing these two primary barriers is essential for the successful integration of traceability technologies, which are key to improving supply chain efficiency and meeting industry standards.

7.4 Technological Compatibility in adoption decision

Compatibility with other technologies emerged as a crucial factor, as participants shared their experiences of facing problems with incompatible technologies and systems. This highlights the importance of considering interoperability and integration when adopting traceability technologies. Incompatibilities can lead to inefficiencies, increased costs, and disruptions in the

supply chain. Therefore, Organisations must assess the compatibility of new technologies with existing ones to ensure a seamless integration process.

Compatibility in the full traceability systems requires a strategic collaboration amongst various actors within a supply chain, and that can only be voluntary by nature (Bosona & Gebresenbet, 2013). This voluntary approach triggers a diverse range of responses from these actors towards the installation and operation of traceability systems (Stranieri et al., 2016). The existing widespread voluntary adoption of traceability further complicates the establishment of a centralized system, as many actors have developed their unique methods and systems of tracking and tracing (Elise Golan et al., 2004).

Luckily the scenarios described above, where various actors in a supply chain employ different systems are not applied to the Saudi Arabian dairy industry where the companies own and manage their entire supply chains in return, the compatibility would be much easier.

The alignment of traceability technologies with the Organisation's culture, strategy, and values was also identified as a key aspect of compatibility. Organisations need to ensure that the adopted technologies are a good fit with their cultural norms and values (Sunny et al., 2019). This is crucial for obtaining employee buy-in and fostering a positive reception to the technology. Failure to consider compatibility with organisational culture and values may result in resistance from employees, hampering the successful adoption and implementation of traceability technologies.

Additionally, compatibility with current systems and processes was emphasized by participants. Organisations need to assess whether the new traceability technology is compatible with their existing infrastructure. Incompatibilities can lead to disruptions in operations, increased costs associated with modifying or replacing current systems, and delays in the adoption process. Therefore, careful evaluation of compatibility with current systems and processes is vital to ensure a smooth transition and integration of traceability technologies.

Furthermore, participants stressed the importance of compatibility with industry standards and regulations. Compliance with these standards is crucial for Organisations to meet legal

requirements and maintain a positive reputation within the industry. Non-compliance can result in legal consequences, reputational damage, and loss of customer trust. Therefore, Organisations need to ensure that the adopted traceability technologies align with industry standards and regulations. Therefore, a proposition P3 is proposed as follows:

Proposition 3 (P3): Compatibility plays a critical role in influencing the decision to adopt traceability technologies in the Saudi dairy industry .

Rationale: This proposition is based on the findings that highlight the multifaceted role of compatibility in the decision-making process for traceability technology adoption within the Saudi dairy sector. The study reveals that organisations place significant emphasis on ensuring that new traceability technologies are interoperable with existing systems and processes. This focus on compatibility extends beyond mere technical integration to include alignment with organisational culture and values, crucial for facilitating employee acceptance and smooth implementation. Additionally, compliance with industry standards and regulations is also a key aspect of this compatibility, underscoring its importance in maintaining legal and market standing. Therefore, this proposition reflects the sector's collective approach to technology adoption, where compatibility is not an afterthought but a fundamental criterion guiding the selection and integration of traceability technologies, aligning with the broader objectives of operational efficiency and regulatory compliance.

7.5 Considering the complexity in the adoption process

The findings reveal a disconnection between the perspectives of the majority of participants from Saudi dairy companies and the existing literature about the adoption complexity of new technologies. The participants did not consider complexity as a significant factor in their decision to adopt technology. They believe that appropriate training programs can overcome any complexity-related challenges. However, this perspective, while interesting, begs a more profound exploration in the context of Saudi Arabian culture and its implications for technology adoption.

Interestingly, existing literature suggests a different scenario. According to Wong et al. (2020), complexity is a significant barrier to technology adoption. Clohessy and Acton (2019) also report a perceived complexity of technology that deters organisations from adopting it. These findings starkly contrast with the attitudes prevalent among the participants of this study who seem to downplay the role of complexity in technology adoption.

This discrepancy can be attributed to cultural underpinnings of high-power distance and hierarchical structure embedded in Saudi Arabian culture as per Hofstede's framework(Alsheddi, 2020). The managerial participants' disregard for complexity could be a manifestation of their perceived superiority and decision-making power. That means, in the established hierarchical structure, managers might believe that their directives are absolute and that employees should adapt to technology implementation, irrespective of its complexity.

However, such a viewpoint could have potential ramifications. While managers have the power to implement new technologies, ignoring their complexity can negatively affect employee morale, productivity, and eventually, the success of adoption. Complexity can instigate resistance- which already happens- and frustration among employees, leading to diminished efficiency if they struggle to grasp and utilise complex technologies effectively. Thus, it is essential for managers to balance their authority with a practical consideration of technology complexity.

The nuances of technology adoption extend beyond just managerial decision-making; it calls for active employee engagement and support. Attempting to impose the use of complex technologies without considering employee apprehensions or providing sufficient training can stimulate resistance and impede the overall adoption process. Therefore, it is crucial for managers to cultivate a work environment that encourages open communication, addresses employee concerns, and equips employees with the necessary resources and training to tackle complexities associated with new technologies.

Traditional gender roles and expectations in Saudi Arabian society may also contribute to the prevailing attitudes towards complexity and technology adoption. The majority of the

participants in this study were men, who, as per societal norms, are typically associated with positions of power and decision-making authority. This cultural context might influence their perspectives on the importance of complexity in technology adoption, warranting further exploration and analysis.

Ignoring complexity in technology adoption decisions may lead to challenges such as resistance, errors, and delays, affecting the effectiveness and success of the adoption process. While training programs may help alleviate some of these issues, a comprehensive approach that takes into account employees' technological literacy, capabilities, and cultural context should be considered. Therefore, a proposition P4 is proposed as follows:

Proposition 4 (P4): The complexity of traceability technology adoption is commonly underestimated and consequently not considered as a significant barrier in the decision-making process in the Saudi dairy industry.

Rationale: This proposition is based on the study's finding that participants from Saudi dairy companies largely dismiss the complexity of new technologies as a concern in their adoption decisions. Contrary to the views in existing literature which identify complexity as a notable barrier (e.g., Wong et al., 2020; Clohessy & Acton, 2019), the participants in this research believe that complexities can be readily overcome, primarily through appropriate training programs. This perspective could be a reflection of the high-power distance and hierarchical culture prevalent in Saudi Arabian organisations, where managerial decisions may overshadow practical considerations of technology usage at the employee level. The neglect of complexity in decision-making processes suggests a potential oversight of the challenges and resistance that employees might face in adapting to new technologies. This scenario highlights a need for a more comprehensive approach in the adoption process, one that considers the practical implications of technology complexity and actively involves employees to ensure successful integration and utilisation of new technologies.

7.6 Organisational culture role and top management support in the adoption process

The role of organisational culture and top management support in the adoption process is a critical theme that emerged from this study, particularly in the context of the adoption of traceability technologies in the Saudi Arabian dairy industry. The current research has taken into account the viewpoints of top-level management, who have highlighted their supportive nature and the positive influence of the organisational culture on technology adoption decisions.

In these companies, the presence of Saudi top-level management, which accounts for over half the companies interviewed, is demonstrative of the influence of Saudi culture and values on decisions about technology adoption. The culture, with its emphasis on collaboration, agility, and quick decision-making, forms the bedrock of organisational culture within these companies and nurtures an environment conducive to the adoption of new technologies.

Despite the encouraging narratives regarding the role of organisational culture and top management support in the adoption process, it is crucial to critically evaluate these assertions. Top management reportedly shows high involvement in decision-making processes, which underscores their commitment to adopting new technologies. However, there is still a need to understand the depth and continuity of this support through the implementation phase. The management's level of commitment in terms of resource allocation and their perseverance in backing the process, even in the face of challenges or roadblocks, are critical aspects that warrant further exploration (Alsheddi et al., 2019; Hofsted, 2001). It is not just about initial approval, but the continuous support and strategic guidance that are important factors influencing the successful integration of new technologies into the Organisation's operations.

Furthermore, the diverse composition of the middle-level management, primarily consisting of expatriates, introduces the potential for a dynamic interplay of different cultural perspectives within the organisations. The resulting diversity can exert its own influence on the decisions related to the adoption of traceability technologies (Khan & Law, 2018).

Moreover, the study also highlights some conflicts within the organisational culture that impede the process of technology adoption. These stem from the fear of change, resistance to new technologies, and lack of technological readiness among employees, who are the eventual end-users of these technologies. Exploring these conflicts and their resolution is integral to a comprehensive understanding of the role of culture and management support in the technology adoption process (Ameen & Willis, 2015).

A more rounded view of the influence of organisational culture and top management support on technology adoption requires considering the larger strategic alignment and long-term goals of the Organisations. The role of top management extends beyond initial support to the development of a robust technology adoption strategy, effective resource allocation, and continuous monitoring of outcomes (Al-Ghaith, 2015; Nadi, 2012).

Another significant consideration is the potential bias due to the composition of the interviewed participants, which were all from the top management level. Future research should therefore strive to include a broader spectrum of employees, as their experiences, attitudes, and concerns can significantly impact the successful implementation and utilisation of traceability technologies. By incorporating these diverse perspectives, we can capture a broader range of experiences and create a more comprehensive picture of the complexities involved in the process of technology adoption in the Saudi Arabian dairy industry (Akman & Turhan, 2016; Hill et al., 1994). Therefore, a proposition P5 is proposed as follows:

Proposition 5 (P5): The adoption of traceability technologies in the Saudi dairy industry is significantly influenced by the organisational culture, which is shaped predominantly by the Saudi cultural values of the top management.

Rationale: This proposition stems from the finding that more than 75% of top management in the Saudi dairy industry are Saudis, thereby embedding strong Saudi cultural values within the organisational culture. The top management's cultural background not only influences their supportive stance towards technology adoption but also affects the overall organisational approach to embracing technological change. This cultural dynamic plays a crucial role in how

technology adoption is perceived and implemented within these organisations. It suggests that understanding the nuances of Saudi culture and its integration within the organisational context is essential to comprehend the adoption process of traceability technologies in the Saudi dairy industry fully. The proposition underscores the importance of considering cultural factors and management influence when examining technology adoption in culturally distinct environments.

7.7 Food traceability technologies affect supply chain performance

Traceability technologies and their impact on supply chain performance in the dairy industry is crucial, as affirmed by the literature and the findings of this study. Past research and the opinions of the study participants align significantly, pointing out that the implementation of traceability technologies brings manifold benefits to the companies and the entire supply chain.

Previous literature, from 2001-2008, elucidated how traceability technologies affect operational performance and supply chain network relationships (Engelseth et al., 2014; Stranieri et al., 2016; Vo et al., 2016). Scholars noted that the use of traceability technologies could contribute to changes in transaction modes, provide financial incentives, improve resource integration within the supply chain, and stimulate attention towards social responsibility and Sustainable Development Goals (SDGs) (Garcia-Torres et al., 2019).These technologies also have the potential to spur technological diffusion and innovation for operations management (Engelseth et al., 2014; Epelbaum & Martinez, 2014).

In tandem with these research findings, participants in the current study echoed positive sentiments concerning the impact of traceability technologies on supply chain performance. They identified critical performance outcomes such as increased efficiency, enhanced food quality, augmented transparency/visibility, and improved flexibility.

The efficiency improvements highlighted by participants align with literature insights into cost reductions and improvements in resource integration brought by traceability technologies (Banterle & Stranieri, 2008; Vo et al., 2016). By reducing product recalls, minimising health risks, and enhancing productivity, these technologies demonstrate their positive impacts on operational efficiency.

Similarly, the benefits of traceability technologies for food quality, as cited by participants, mirror the literature's emphasis on how such technologies solve food quality control challenges (Engelseth et al., 2014). By ensuring product safety and bolstering consumer trust, the adoption of traceability technologies evidently enhances the quality and safety profile of dairy products.

Participants' views on supply chain transparency align with the literature, which suggested traceability could enhance the structure of the supply chain and heighten attention towards companies' social responsibility (Garcia-Torres et al., 2019; Mol & Oosterveer, 2015). Traceability technologies enhance visibility and accountability throughout the supply chain, fostering a greater level of trust with consumers.

The notion of improved flexibility due to traceability technologies has also been echoed in previous research, primarily through the theory of transaction cost economics (Banterle & Stranieri, 2008; Vo et al., 2016). By allowing companies to adapt to unexpected changes effectively, such technologies demonstrate their value in creating agile and resilient supply chains.

While participants have expressed positive views on traceability technologies, the study also identified areas for further examination and potential limitations. As suggested by the literature, the implementation of traceability technologies could present challenges, including initial setup costs, potential disruptions during implementation, data privacy and security concerns, interoperability issues, and training needs (Engelseth et al., 2014; Epelbaum & Martinez, 2014). An in-depth understanding of these potential trade-offs and a comprehensive evaluation of the implications, including costs, return on investment, and long-term cost savings, are crucial for any firm considering the adoption of traceability technologies. Therefore, a proposition P6 is proposed as follows:

Proposition 6 (P6): The implementation of traceability technologies in the Saudi dairy industry has positive influence on supply chain performance, notably enhancing efficiency, food quality, transparency, and flexibility.

Rationale: This proposition is based on the findings from the current study, which indicate a positive impact of traceability technologies on the supply chain performance in the Saudi dairy industry. Participants from the industry have noted several key improvements as a result of implementing these technologies. These include increased operational efficiency, which encompasses cost reductions and productivity enhancements; enhanced food quality, particularly in terms of safety and reliability; augmented transparency throughout the supply chain, leading to improved accountability and consumer trust; and greater flexibility, allowing companies to adapt more effectively to changes and disruptions. These benefits reflect the direct experiences and observations of industry participants in this study, highlighting the substantial role that traceability technologies play in advancing the performance of the dairy supply chain in Saudi Arabia.

7.8 COVID-19 and Post COVID-19 Technology Investment and its impact on the supply chain.

The literature underlines the significant disruptions brought about by the COVID-19 pandemic, highlighting a distinct emphasis on food supply chain safety and the requisite investment in digital traceability technologies (Hahn, 2020; Reid et al., 2020; Rizou et al., 2020). Advanced technologies such as blockchain, AI, and IoT, combined with smart analytical tools, can aid in swift and effective response to foodborne outbreaks, a crucial requirement in public health emergencies like a pandemic (Galanakis et al., 2021).

Contrary to the broader global trend depicted in the literature, the findings from our interviews with Saudi dairy company managers suggest that most companies had already embraced modern food technologies prior to the pandemic. As per Manager A and B, the pandemic did not alter their technology investment trends, but rather reinforced the need for complex traceability systems and enhanced information provision to consumers.

However, there were also managers who found the pandemic a catalyst for a deeper realisation of the need for technology, primarily for those minimising human intervention and enabling remote

control. Manager E's statement corroborates the literature's emphasis on the urgency of tech-investment brought in by the pandemic.

Interestingly, all participants in this study reported a positive or neutral impact of the pandemic on their supply chains, a marked deviation from the global trend of significant supply chain disruptions, such as those experienced by the Australian supply chain (Louie et al., 2022). This divergence can be attributed to the robust government support provided in Saudi Arabia.

The government's aid extended to healthcare provisions, regular testing for employees, and financial support that enabled these companies to manage the extra expenses brought about by the pandemic. By providing these resources, the government effectively alleviated the health crisis at the workforce level, ensuring smooth supply chain operations, and prevented a rise in food prices, a common repercussion of supply chain disruptions seen in other regions.

In addition, the quarantine measures brought about an unexpected outcome. These measures led to an increased demand for dairy products, as people confined to their homes cooked more, many Saudi dishes requiring dairy products. This upturn in demand inadvertently boosted the dairy industry's performance, further cushioning the potential impact of the pandemic on their operations. Therefore, a proposition P7 is proposed as follows:

Proposition 7 (P7): The COVID-19 pandemic had no impact on the adoption of traceability technologies in the Saudi dairy industry.

Rationale: This proposition acknowledges the unique position of the Saudi dairy industry in the context of technological adoption. The study indicates that while the industry is making steady strides in integrating traceability technologies, it has not reached the pace required to be fully aligned with the rapid advancements characterising Industry 4.0. The COVID-19 pandemic, contrary to expectations and global trends, did not substantially expedite this process. Interviews with industry leaders suggest that the adoption of these technologies continued at a measured pace, reflective of a long-term strategic approach rather than a rapid response to the pandemic. This gradual progression, while indicative of a commitment to modernisation, also highlights the gap between the current state of technology adoption in the Saudi dairy industry and the more

advanced stages of Industry 4.0 adoption seen globally. This discrepancy underscores the need for a more accelerated approach to technology adoption to fully harness the benefits of Industry 4.0 and maintain competitiveness in the rapidly evolving global dairy market.

7.9 The impact of consumer pressure on FTT adoption

The findings from this study align with the literature on the impact of consumer pressure on the adoption of food traceability technologies (FTT) in the Saudi dairy industry. The participants' responses provide further support for the notion that consumer pressure is a significant driver for companies to adopt traceability systems.

Several participants acknowledged the influence of consumer pressure on their decision to adopt traceability technologies. They highlighted the increasing demands from consumers for more information about the food they consume, including details about its production, origin, and safety. Participant 1 emphasised that consumers actively encourage companies to provide more information, which necessitates the implementation of sophisticated traceability systems. This finding is consistent with the literature, which suggests that consumers are increasingly seeking transparency and accountability from food industry stakeholders (Gao & Schroeder, 2009; Liu et al., 2018; Wongprawmas & Canavari, 2017).

Furthermore, the participants recognised the heightened focus on food safety brought about by the COVID-19 pandemic. Participant C specifically mentioned that consumers' increased concerns over food safety during the pandemic have placed additional pressure on companies to provide comprehensive product information. This aligns with the literature, which states that the COVID-19 pandemic has further fuelled consumers' demands for traceability information (Marchant-Forde, 2020).

However, it is worth noting that some participants in the study reported no pressure from consumers to adopt traceability technologies. Two main reasons were cited for this lack of pressure: consumer awareness and high-quality products. Participants J and B attributed the absence of pressure to the perception that their products are of high quality, and therefore, consumer satisfaction and trust are already established. Participant J explicitly stated that

consumers are content with their products and recognise their reputation for quality. On the other hand, participants B and E suggested that consumers may be unaware of the concept of traceability and its significance. Participant B expressed the opinion that consumers lack understanding of traceability technologies. These findings are consistent with the literature, which highlights variations in consumer awareness and knowledge regarding traceability systems (Shaosheng Jin & Lin Zhou, 2014).

In summary, while the majority of participants in the study acknowledged the influence of consumer pressure on the adoption of traceability technologies, a few participants reported no such pressure. This discrepancy can be attributed to differences in consumer awareness and perceptions of product quality. Nonetheless, the overall findings support the literature's assertion that consumer pressure is a significant environmental factor driving the adoption of food traceability technologies in the Saudi dairy industry. The increasing demands for information, particularly regarding food safety, and the evolving consumer expectations necessitate the adoption of traceability systems to enhance transparency, consumer trust, and overall food safety practices within the industry. Therefore, a proposition P8 is proposed as follows:

Proposition 8 (P8): Consumer pressure has a slightly less positive impact on the adoption of Food Traceability Technologies (FTT) in the Saudi dairy industry, driven by demands for more information about food safety and production.

Rationale: This proposition demonstrate that consumer pressure plays a considerable role in motivating Saudi dairy companies to implement traceability technologies. Participants from the industry (e.g., P1) have acknowledged the growing consumer demand for detailed information about the food they consume, including its safety, production, and origin. This demand has led companies to consider more sophisticated traceability systems to meet these consumer expectations. However, the study also reveals variations in the intensity of this pressure. Some participants reported a lack of consumer pressure, attributing this to either the high perceived quality (P2, P6) of their products, which already fosters consumer trust, or to a general lack of consumer awareness about the concept and benefits of traceability (P2). This variation indicates that while consumer pressure is a notable driver for FTT adoption in the Saudi dairy industry, its

impact is not uniform across all companies and depends on specific consumer segments and their levels of awareness and trust in the product quality.

7.10 Competitors pressure

The findings of this research indicate that competitors play a significant role in the adoption of new technologies and the motivation of companies within the Saudi dairy industry to improve their businesses. All participants in the study acknowledged the actions of their competitors and expressed concern about their position in the market. This aligns with the existing literature, which underscores the influence of competitor pressure on technology adoption decisions across various industries.

Competitor pressure has been recognised as a crucial factor driving technology adoption in previous studies. For instance, the research conducted by Kamble et al. (2021) emphasizes that competitor pressure is one of the most influential factors for the adoption of blockchain technology. Their findings suggest that when companies observe their competitors adopting new technologies, it creates a sense of urgency and motivates them to follow suit (Kamble et al., 2021). In the context of the Saudi dairy industry, the participants' awareness of their competitors' utilisation of traceability technologies and their concern about falling behind align with the notion that competitor pressure acts as a driving force for technology adoption.

Similarly, Ezzaouia and Bulchand-Gidumal (2020) found that external factors, including competitive pressure, had a strong effect on the adoption of information technology (IT). Their research highlights that companies are more likely to adopt new technologies when they perceive their competitors to be doing so. Competitor pressure creates a fear of losing market share or falling behind in terms of technological advancements, thereby motivating companies to embrace new technologies (Ezzaouia & Bulchand-Gidumal, 2020). The participants in the current study echo this sentiment by mentioning that competitor pressure serves as one of the factors influencing their decision to adopt or upgrade traceability technologies.

Furthermore, the study conducted by Ali Abbasi et al. (2022) sheds light on the impact of perceived competitor pressure on social media marketing adoption. Abbasi's research emphasises

that companies are more inclined to adopt new technologies when they perceive that their competitors are doing so too. The participants' recognition of their competitors' use of traceability technologies and their desire to catch up with them align with the concept of perceived competitor pressure influencing technology adoption decisions (Ali Abbasi et al., 2022)

In short, the findings of this research align with the existing literature, highlighting the significant role of competitor pressure in driving the adoption of food traceability technologies within the Saudi dairy industry. The participants' awareness of their competitors' actions and their concern about staying competitive in the market reflect the importance of competitors in motivating companies to adopt and upgrade their technologies. The literature further supports these findings by emphasising the influence of competitor pressure on technology adoption decisions across various industries. By recognising the advancements made by competitors, companies within the Saudi dairy industry are motivated to embrace traceability technologies to maintain their competitiveness and market position. Therefore, a proposition P9 is proposed as follows:

Proposition 9 (P9): Competitor pressure has a strong positive impact on the adoption of food traceability technologies in the Saudi dairy industry, driven by companies' needs to stay competitive and maintain their market position.

Rationale: This proposition stems from the study's findings that competitor actions and advancements play a critical role in influencing technology adoption decisions within the Saudi dairy industry. Participants in the study unanimously acknowledged the impact of their competitors' technological strides, particularly in the area of traceability technologies, on their own strategic decisions. This awareness of competitors' advancements creates a sense of urgency and a need to keep pace, thereby motivating companies to adopt or upgrade their traceability systems. The desire to not fall behind in the market and to maintain or enhance their competitive edge is a key driver for these companies to embrace new technologies. This scenario mirrors similar findings in other industries, where competitor pressure is recognised as a pivotal factor in prompting businesses to adopt new technologies to stay relevant and competitive. The

proposition highlights that in the Saudi dairy industry, keeping abreast of competitors' technological advancements is not just a matter of staying current but is crucial for sustaining market presence and competitive advantage.

7.11 How does the government policy influence the FTT adoption?

The complex relationship between government policy and the adoption of traceability technologies has been a focal point in previous literature. Research by De Castro et al. (2020) and Lee et al. (2011) highlights the significant role of government regulations in encouraging organisational adoption of innovative technologies, including those in the realm of traceability. This is echoed in the current study, where government policy was found to be a major driving force behind the adoption of traceability technologies in Saudi dairy companies.

Regulatory frameworks are not just facilitators but crucial motivators in this context. They shape organisational behaviour and decision-making, as evidenced by the alignment of Saudi dairy companies with these policies. Lee et al. (2018) further underscore that the effectiveness of these regulations' hinges on factors like enforcement, clarity of guidelines, and support provided to organisations.

This study specifically found that the Saudi Food and Drug Authority (SFDA) plays a pivotal role in implementing policies that mandate the adoption of traceability technologies (SFDA, 2019). This aligns with the broader objectives of the National Industrial Development and Logistics Program (NIDLP) and Saudi Vision 2030, which aim to establish Saudi Arabia as a leading industrial and logistics hub. The adoption of Industry 4.0 technologies, as part of these initiatives, places a specific emphasis on the dairy sector (NILDP, 2021; Vision2030, 2021).

The SFDA's policies require investment in technologies such as sensors and GPS systems for tracking in warehouses and logistics. This systematic approach, starting from transportation and gradually encompassing the entire supply chain, demonstrates a strategic phased implementation. It not only mandates compliance but also facilitates a manageable transition for companies towards enhanced traceability capabilities.

This government-led approach significantly influences food safety, transparency, and regulatory compliance in the industry. By establishing mandatory use of traceability technologies, the government ensures an efficient tracking system throughout the supply chain, which is critical for managing safety risks and maintaining consumer trust. The SFDA's policy fosters a uniform compliance environment, ensuring all companies adhere to food safety standards and traceability practices equitably.

These findings offer valuable insights into the effectiveness of government policies in promoting technology adoption in the dairy industry. They highlight the potential for government intervention to act as a catalyst for technological advancement and create an environment conducive to innovation. However, further research is warranted to explore the broader implications of these policies. Investigating the challenges companies face in compliance, the impact on various stakeholders, and the long-term benefits of traceability technology adoption will deepen our understanding of this dynamic. Therefore, a proposition P10 is proposed as follows:

Proposition 10 (P10): Government policies positively drive the adoption of Food Traceability Technologies (FTT) in the Saudi dairy industry.

Rationale: This proposition is grounded in the study's findings which demonstrate the significant impact of government policies on the adoption of traceability technologies in the Saudi dairy sector. The SFDA, in implementing policies that mandate the adoption of technologies like sensors and GPS systems, plays a pivotal role in this process. These policies are part of a larger strategic framework that includes the National Industrial Development and Logistics Program (NIDLP) and Saudi Vision 2030, which collectively aim to modernise the industry and integrate it into the global supply chain network. The government's approach not only demands compliance but also supports companies in transitioning towards improved traceability capabilities. By necessitating the use of traceability technologies, the government is ensuring a more efficient and transparent supply chain, critical for managing safety risks and bolstering consumer trust. The study's findings highlight the efficacy of government intervention as a catalyst in fostering technological adoption and innovation within the industry. However, it also

points to the need for further exploration into the long-term effects and broader implications of these policies, including the challenges faced by companies in complying and the overall impact on stakeholders.

7.12 Vision 2030 and Technology Investment

The research found the significant influence of Saudi Arabia's Vision 2030 and technology investment on the transformation of the food industry, specifically the dairy sector, through automation and technology integration. The government's strategic initiative to propel the country into an industrial powerhouse has resulted in increased regulations that necessitate greater technology investment by dairy companies (Vision2030, 2021).

The rigorous regulatory requirements associated with Vision 2030 have been instrumental in compelling dairy companies to invest extensively in traceability technologies. The testimonies of the participants interviewed in this study corroborate the notion that these new requirements are part of the broader vision for 2030. This finding aligns with prior research suggesting that government regulations can stimulate the adoption of new technologies. De Castro et al. (2020) have highlighted the role of government regulations in encouraging technology adoption, and the present study adds empirical evidence in the context of Saudi Arabia's dairy industry.

These findings are consistent with the arguments put forth by Raj et al. (2020), who suggest that government regulations and technological infrastructure play crucial roles in driving technology adoption in different economic contexts. In particular, the research highlights the role of government regulations in stimulating the adoption of cutting-edge technologies, especially in developing countries like Saudi Arabia.

The proactive enforcement of stringent regulatory requirements by the Saudi government has compelled companies in the food industry, specifically dairy companies, to make significant investments in traceability technologies to align with the objectives of Vision 2030.

This finding underscores the crucial role of Saudi Arabia's Vision 2030 as an environmental factor in shaping the adoption of traceability technologies by dairy companies. It emphasizes the

significance of government policy in driving technological innovation, enhancing efficiency, improving product quality, and boosting consumer confidence. The findings contribute to the existing literature on technology adoption, providing valuable insights into the interplay between government policy and technology adoption in different sectors and contexts. Future research could build upon these findings and explore the impact of government interventions on technology adoption in diverse industries, further enriching our understanding of this complex relationship. Therefore, a proposition P11 is proposed as follows:

Proposition 11: Saudi Arabia's Vision 2030 positively motivates dairy companies to invest in traceability technologies, and aligning their strategies with national development goals.

Rationale: This proposition is drawn from the study's findings, which reveal the substantial role of Vision 2030 in shaping the technological landscape of the Saudi dairy industry. The government's strategic vision and associated regulations are instrumental in driving the companies towards increased investment in advanced technologies. This initiative is not only about regulatory compliance but is also aligned with the country's broader goal of becoming an industrial powerhouse and integrating cutting-edge technologies. The participants confirm that these investments are a response to the new requirements set forth by Vision 2030. The enforcement of stringent regulatory requirements under Vision 2030 has thus become a key environmental factor, compelling dairy companies to adopt advanced technologies. This move towards greater technology integration is not only about adhering to regulations but also about enhancing operational efficiency, improving product quality, and increasing consumer confidence in the dairy products.

7.13 Employees Training and Technology Adoption

The literature review highlights the critical role of training in the successful adoption of food traceability technologies by employees. Schillewaert et al. (2005) define training as the process through which a firm educates its workforce on using technological tools effectively, both in terms of quantity and quality. Given the complexity of food traceability technologies, it becomes imperative for Organisations to train and educate their employees before implementing these

tools. Such training initiatives have several benefits, including reducing employee stress and anxiety associated with new technology, increasing motivation, and enhancing employees' understanding of the technological benefits for their tasks.

The findings of this study support the significance of training in technology adoption. Most of the participants emphasised the provision of training programs to ensure the successful integration of technology within their Organisations. Notably, participants A, C, and D pointed out the importance of technology-specific training, recognizing that different technologies require distinct skill sets. This tailored approach to training ensures that employees are equipped with the necessary competencies to effectively utilise the implemented technologies.

Furthermore, participants in the study emphasized the use of seminars and workshops as effective training methods. Participant B, for instance, outlined a comprehensive approach to easing the adoption process, which involved pre-adoption workshops to prepare employees for the changes that would occur with the implementation of SCADA (Supervisory Control and Data Acquisition) technology. Subsequently, post-adoption workshops and seminars were conducted to train employees, where knowledge was disseminated by a select group of employees who had received prior training.

By providing training and workshops, Organisations aim to achieve multiple objectives. First, they equip employees with the technical skills required for operating new technologies, ensuring that they can effectively leverage the tools for their daily tasks. Second, the training initiatives seek to alleviate apprehensions and uncertainties among employees, making the transition to new technologies smoother and less stressful. By addressing potential ambiguity and fostering a deeper understanding of the technology's benefits, Organisations create a positive and supportive environment for technology adoption (Gangwar et al., 2015).

Building on the findings of this study, future research could delve deeper into the effectiveness of different training methods and their impact on technology adoption. Comparing the outcomes of various training approaches, such as workshops, seminars, e-learning, or on-the-job training, could shed light on the most efficient and beneficial methods for different types of food

traceability technologies. Additionally, investigating the long-term effects of training on technology adoption and employee performance could provide valuable insights for Organisations in sustaining technological advancements and optimizing their workforce's utilisation of technology.

Furthermore, exploring the role of employee feedback and engagement in the training process could be an essential area of study. Understanding how employee input and involvement in designing training programs can influence their acceptance and enthusiasm towards technology adoption would be valuable for Organisations seeking to enhance their technology implementation strategies. By considering employee perspectives, Organisations can tailor training programs to better suit their workforce's needs and foster a culture of continuous learning and technological advancement. Therefore, a proposition P12 is proposed as follows:

Proposition 12: Effective employee training programs positively influence the adoption of Food Traceability Technologies (FTT) in the Saudi dairy industry.

Rationale: The findings from this study clearly indicate that the success of implementing Food Traceability Technologies in the Saudi dairy sector is closely tied to the presence of specialised training programs for employees. Such training, as noted by P1, P3, and P4, needs to be specifically designed to address the unique requirements of different traceability technologies. This ensures that employees are not only technically proficient but also comfortable and confident in using these new systems. Tailored training programs help in mitigating the challenges associated with learning new technologies, reducing the anxiety and resistance often encountered during such transitions. They facilitate a smoother and more efficient adoption process by equipping employees with the necessary skills and understanding. The proposition underscores the significance of well-designed, technology-specific training as a key enabler for the successful adoption of traceability technologies in the Saudi dairy sector.

7.14 Workforce Localisation initiatives (Saudization)

The Saudization theme emerging from this study illuminates a distinct socio-cultural dynamic prevailing within the participating companies - the preponderance of Saudi nationals in senior

managerial roles. Saudization is a strategic policy initiative by the Saudi Arabian government aimed at increasing the employment of Saudi nationals and decreasing reliance on foreign labour (Alanezi, 2020). The distinct presence of Saudi nationals at the higher echelons of management may have far-reaching implications on the Organisation's culture and decision-making processes, including those associated with the adoption of new technologies.

Saudization and its resulting localisation of leadership are critical when considering the relationship between national culture and organisational culture. Hofstede (2001) emphasizes the influence of national culture on the organisational culture and management practices. Therefore, it is logical to deduce that a higher presence of Saudi nationals in leadership roles, as indicated in this study, could shape the organisational culture in a way that reflects Saudi Arabian societal values and traditions (Hofsted, 2001).

The insight provided by Manager G, implying that the organisational culture is influenced by the predominance of Saudi national managers, resonates with existing literature positing the influential role of management's cultural background on an Organisation's culture and operations (Khan & Law, 2018). This culturally driven managerial approach could affect how technology adoption decisions are made and implemented.

However, the study also revealed a conscious attempt by these companies to increase the proportion of Saudi employees at lower levels, as mentioned by Manager J. This could be seen as a strategy aiming at cultural congruence within the Organisation, facilitating the successful implementation of strategic decisions, including those related to technology adoption (Guiso, Sapienza, & Zingales, 2015).

Moreover, the push towards increasing Saudi representation within the workforce resonates with the government's Saudization policy (Alanezi, 2020). This indicates the role of external environmental factors, particularly government policies, in shaping organisational practices, including those associated with technology adoption.

According to Hofstede's model, Saudi Arabian culture exhibits high levels of uncertainty avoidance, masculinity, power distance, and collectivism (Alsheddi, 2020; Hofsted, 2001). The

presence of high uncertainty avoidance in the culture implies a preference for stability, a tendency to avoid risk, and a desire for clear rules and guidelines. Consequently, individuals in Saudi Arabian society may be more resistant to change and less inclined to embrace new and uncertain technologies. This resistance to change may explain the challenges faced by Saudi dairy companies in technology adoption, as mentioned by the participants.

Furthermore, the high-power distance characteristic of Saudi Arabian culture, which indicates a significant power gap between individuals, presents challenges for technology adoption. In a hierarchical society, decisions regarding technology adoption may be concentrated in the hands of a few individuals or authorities, resulting in slower and more bureaucratic processes. This finding aligns with the researcher's finding that top management often disregards the complexity of technology adoption and replaces employees who are unable or unwilling to learn to use new technologies with more skilled individuals.

Integrating these insights with the previous discussion on training and technology adoption, it becomes evident that cultural factors play a significant role in shaping technology adoption processes within the Saudi Arabian context. The emphasis on stability, risk avoidance, and clear rules may contribute to resistance to change and hinder the smooth adoption of new and uncertain technologies. Moreover, the hierarchical nature of the society and decision-making processes can lead to slower and more centralized decision-making, potentially impeding technology adoption efforts. Therefore, a proposition P13 is proposed as follows:

Proposition 13: The Saudization policy has a slightly negative impact on the adoption of new technologies in the Saudi dairy.

Rationale: This proposition is rooted in the findings of the study that underscore the complex implications of Saudization on technology adoption within the Saudi dairy sector. The policy's effect of increasing Saudi nationals in leadership roles translates into a specific organisational culture reflective of Saudi Arabian societal values, as identified by Hofstede's model. Characteristics such as high uncertainty avoidance, power distance, and collectivism may lead to a cautious approach towards new technologies, favouring stability and adherence to established

procedures. This cultural disposition can manifest as resistance to change, particularly regarding the adoption of new and potentially disruptive technologies. Furthermore, the high-power distance characteristic prevalent in Saudi culture may result in centralised decision-making processes. Such concentration of power in the hands of a few senior managers could slow down technology adoption due to bureaucratic hurdles. The study thus reveals that Saudization, while aiming to empower the local workforce, may inadvertently create challenges in adopting new technologies, primarily due to its significant influence on the organisational culture and decision-making dynamics.

7.15 Generalisability of the findings

The potential for extending the findings of this study beyond the dairy industry in Saudi Arabia, bolstered by the universal applicability of the TOE framework, has been thoroughly elaborated upon, rather than merely theoretically developed or tested.

Primarily, the study is applicable to sectors dealing with perishable food items, such as seafood, poultry, or fresh produce. These industries confront challenges similar to those of the dairy industry, particularly in relation to product safety and quality. The factors influencing the adoption of traceability technologies, as identified in this research, are applicable across these sectors.

Furthermore, the implications of this study are especially significant for regions sharing socio-economic and political characteristics with Saudi Arabia, where government policies are crucial in shaping industrial practices. In these regions, the findings, especially those highlighting the impact of government pressure and policies, could be instrumental in informing future strategies for traceability technology adoption.

While this study specifically focuses on the Saudi Arabian dairy industry, the challenges and solutions it identifies are relevant to industries worldwide that manage traceable technologies, particularly those dealing with perishable foods. Managers, both inside and outside Saudi Arabia, can benefit from applying the recommendations developed in this study, such as fostering a

culture of inclusion and engagement within their organisations. These strategies can be customised and implemented to suit their unique business environments.

For researchers outside Saudi Arabia, this study provides a valuable revised framework that could inspire further research into technology adoption in contexts where cultural factors, workforce localisation policies, or similar government initiatives play a significant role. Such research would expand and deepen the theoretical understanding of technology adoption across various settings.

7.16 Recommendations for the Managers

The researcher recommends the following strategies to address the challenges faced by managers in adopting traceability technologies in the Saudi Arabian dairy industry:

Foremost, it is imperative for managers to acknowledge the inherent complexity associated with traceability technologies. The process of introducing new technology transcends mere employee training. It necessitates comprehensive strategic planning that carefully evaluates the technological capabilities of the workforce, the intricacy of the implemented technologies, and the corresponding training demands.

Managers are also encouraged to foster a culture of inclusion and engagement within their Organisations. By incorporating employees into the decision-making process and eliciting their perspectives while devising strategies for technology adoption, organisations can facilitate a smoother transition towards these advanced systems. This participatory approach not only helps mitigate resistance towards the technological transition, but it also augments employees' commitment, enhancing their adaptability to the evolving technological landscape.

Addressing employee resistance to new technologies necessitates psychological and organisational interventions. Managers can leverage psychological strategies such as enhancing task autonomy, providing constructive feedback, and fostering a sense of ownership among the employees. These measures, as suggested by Battistelli et al. (2013), can contribute significantly towards overcoming resistance and fostering a culture of acceptance for technological changes.

In sum, the successful implementation and adoption of traceability technologies require a holistic, inclusive, and strategically planned approach that takes into consideration the technological, human, and organisational dimensions. This ensures not only the technological readiness of the organisation but also the willingness and preparedness of the employees to embrace and adapt to these changes.

7.17 Policy implications

In the face of evolving technological landscapes and the continuous drive towards digitalisation, there arises an urgent need for practical and considerate policymaking. Informed by the insights drawn from this research, the researcher proposes certain recommendations for more balanced and beneficial adoption of advanced traceability technologies, particularly in the dairy sector of Saudi Arabia.

Financial disparity represents a significant challenge in the adoption of advanced traceability technologies. Large corporations, with their expansive resources, can more readily absorb the costs involved with implementing new technologies than their smaller counterparts. Small-to-medium enterprises (SMEs), by contrast, often grapple with limited financial resources. Recognising this, it becomes incumbent upon policy makers to institute mechanisms that can alleviate the financial burdens imposed on these SMEs when they seek to adopt advanced technologies. Such mechanisms could take the form of financial incentives, such as soft loans, tax deductions, or even direct grants.

Yet, it is not merely a matter of providing financial support. A broader vision must seek to establish technological equity across all strata of business. To bridge the gap between large corporations and SMEs, policy makers could contemplate schemes that subsidise the cost of implementing traceability technologies. By doing so, they would not only contribute to levelling the technological field but also foster an environment of healthy competition, with businesses of all sizes having equal access to the advantages offered by advanced technologies.

In addition, Saudization policy which aimed at promoting the employment of Saudi nationals in the private sector, is a commendable initiative with profound socio-economic implications.

However, as the findings of the study suggest, it might inadvertently slow down the adoption of innovative technologies. The Saudi culture, characterised by a propensity towards risk-avoidance, a preference for clear guidelines, and a significant power distance, can potentially lead to resistance against technological change. In this context, policy makers might want to rethink aspects of the Saudization policy that limit the hiring of international talent who might be better equipped to handle new technologies.

Nevertheless, the revision of such a policy should not undermine the necessity of providing employment opportunities for Saudi nationals. Instead, it should be part of a broader strategy to enhance the skills of the Saudi workforce, making them more receptive to and competent with technological changes. This strategic approach calls for a substantial investment in cultivating a culture of lifelong learning and continuous professional development. To this end, the implementation of robust educational programs and incentives for ongoing training, particularly in the realm of emerging technologies, can be considered. These initiatives would foster a more tech-savvy workforce, enhancing the resilience and adaptability of the Saudi economy in an increasingly digital world.

7.18 Theoretical Contribution

This study's theoretical contribution lies primarily in its innovative approach to investigating technology adoption in the context of food traceability, especially within the dairy industry's supply chain. It uniquely combines existing theories of technology adoption with specific domain knowledge, thus advancing our understanding in several ways.

Firstly, the study provides a significant extension to the well-accepted Technology-Organisation-Environment (TOE) framework by Tornatzky et al. (1990) in context of dairy supply chain. Prior literature has applied this framework to understand technology adoption challenges primarily in context of information systems (Awa et al., 2016), with less emphasis on its applicability to traceability technologies in supply chains. This research, however, incorporates traceability technologies into the TOE framework, thus augmenting the model's versatility and applicability not just in an organisational context, rather in a supply chain context, similar to investigations

into Industry 4.0 Technology (Zhong & Moon, 2023), Blockchain technology (Gökalp et al., 2022; Orji et al., 2020), Artificial intelligence and robotics (Nam et al., 2021), Cloud computing (Zadeh et al., 2018), Big data analytics (Verma & Bhattacharyya, 2017), and smart logistics of SMEs (Shee et al., 2021).

By leveraging the TOE framework, this study goes beyond individual perceptions to encompass a wider array of factors that influence the adoption of traceability technologies. These include organisational factors, such as workforce localisation initiatives and management support, and environmental factors, such as government policy, Covid-19 and consumer pressure. Such a comprehensive view of technology adoption provides a richer, more nuanced understanding that can guide both academic research and practical implementation.

Moreover, the study contributes to the literature by bringing a cultural perspective to technology adoption. Despite the global relevance of technology adoption, most studies have been conducted in developed countries, such as the United States, Australia, and China (Hu et al., 2018). By examining the issue in the context of Saudi Arabia, a developing country with a distinct cultural and regulatory environment, this study enriches our understanding of how cultural and environmental factors can shape technology adoption.

Indeed, the study contributes to a new dimension to the theoretical discourse by incorporating Workforce Localisation initiatives, specifically the "Saudisation" policy in Saudi Arabia, as an environmental factor influencing technology adoption. Workforce Localisation initiatives represent government policies designed to increase the proportion of local citizens in the workforce, which can significantly impact organisational decision-making and strategies.

However, despite their potential significance, these initiatives have been notably absent from the technology adoption literature. This research contributes to addressing this gap by investigating the role and impact of Saudisation policy in shaping the adoption of traceability technologies in Saudi Arabia's dairy industry. This inquiry expands the TOE framework's environmental dimension, traditionally encompassing factors, to include government workforce policies.

By integrating workforce localisation initiatives into the theoretical model of technology adoption, the study provides a more complete and context-specific understanding of the environmental factors that influence technology adoption. This addition enriches the TOE framework, enhancing its applicability in diverse contexts and increasing its potential to guide both research and practice in technology adoption. This nuanced understanding could inspire future research on technology adoption in other contexts where workforce localisation policies or similar government initiatives are present, thereby broadening the theoretical understanding of technology adoption.

By bringing these different threads together, this study makes a substantial theoretical contribution. It not only expands the TOE framework to a new domain but also integrates multiple perspectives on technology adoption, thereby providing a more comprehensive understanding of this important phenomenon. The study's insights could serve as a foundation for future research, helping to build a more nuanced and culturally sensitive understanding of technology adoption. In addition, this research's exploration of Workforce Localisation initiatives as an environmental factor significantly broadens the scope of the TOE framework and contributes meaningfully to the existing literature on technology adoption. The study's findings provide a springboard for further research exploring the interplay of such government policies with technology adoption, thereby deepening our theoretical and practical understanding of this critical area.

7.19 Practical Implications

The practical contributions of this research can be grouped into three primary categories: enhancing industry practices, improving policy-making, and contributing towards sustainable development goals.

This research provides industry practitioners and managers with a clear understanding of the problems associated with current food traceability technologies in food processing, distribution, and retail. By proposing additional emerging and compatible technologies, the research offers practical solutions that can be integrated into food traceability processes. This will not only

optimise the supply chain but also potentially increase operational efficiency. In the aftermath of the COVID-19 pandemic, the research assures managers that the adoption of traceability technologies can enhance consumer trust and confidence in food products, particularly in dairy items.

In addition, the insights gleaned from this research can assist policymakers in designing effective traceability programs and establishing pertinent regulations. By providing an understanding of the barriers and enablers in the adoption of traceability technology, policymakers can develop regulations that promote the use of such technologies. Additionally, the research underlines the importance of comprehensive training within food companies, thus enabling policymakers to develop policies that foster a culture of continuous learning and skill enhancement.

Finally, this research makes substantial contributions to several United Nations' SDGs. It provides a practical solution for enhancing food safety, reducing waste, and promoting sustainable production and consumption patterns. Specifically, it aligns with SDG 3 (Good Health and Well-being) by improving food safety and reducing the prevalence of foodborne illnesses. It also supports SDG 12 (Responsible Consumption and Production) by advancing efficient food traceability systems that help to minimise food waste and losses, while also empowering consumers with information for sustainable consumption. Additionally, the research contributes to SDG 13 (Climate Action) by enabling a more resilient food supply chain that can adapt to climate-related disruptions and by promoting sustainable land use, thereby reducing the carbon footprint of food production. Overall, the implementation of effective food traceability technologies as explored in this research is instrumental in advancing these critical global sustainability goals.

In summary, the practical implications of this research encompass a broad spectrum of areas, from enhancing supply chain management and informing policy decisions to promoting sustainability and consumer well-being.

7.20 Summary

This discussion chapter delves into an intricate analysis of the study's findings regarding the adoption of food traceability technologies in the Saudi dairy sector. By revising the Technological, Organisational, and Environmental (TOE) theory framework and comparing the results with previous research, this chapter aims to further our understanding of the technology adoption landscape within the Saudi context.

A significant revelation of the study is that despite a widespread understanding among managers of the importance of embracing traceability technologies, Saudi dairy firms, particularly SMEs, still employ traditional methods such as Excel and manual reports. This finding is incongruous with Saudi Vision 2030's objective of transitioning towards Industry 4.0 with latest technologies.

Interestingly, the study identifies government pressure and policies as the key driving force behind the intent to adopt traceability technologies. This governmental influence could be linked to Saudi's cultural characteristic of high uncertainty avoidance as suggested by Hofstede (2001).

Contrary to expectations, the COVID-19 pandemic did not significantly influence the companies' decisions to adopt new food traceability technologies. This could be attributed to the positive experiences during the pandemic, where companies received considerable support from the government, leading to increased profits.

The study also notes that the complexity of a technology is not considered a barrier to adoption in the Saudi dairy sector. This finding is a divergence from previous research, which suggests that complexity can negatively impact technology adoption decisions.

Finally, employee resistance is identified as a major challenge for technology adoption, likely due to the neglect of technology complexity during the decision-making process. Hence, the chapter recommends user-friendly technologies and effective training strategies to overcome resistance and promote successful technology adoption.

In the next chapter, will be the conclusion, limitations of the study, and directions for future research in the field. It will encapsulate the essence of the entire research journey and suggest the paths for future scholarly pursuits.

8 Chapter Eight: Conclusion, Limitations and Future Research direction.

8.1 Introduction

This research study now reaches its final stage with this conclusive chapter, aiming to offer a thorough summary of the investigation into the adoption of food traceability technologies within the Saudi dairy sector. The researcher, in this chapter, will focus on presenting the key conclusions drawn from the findings, discussing the inherent limitations of the research, and suggesting future research directions.

In the first section, the central findings of the study will be concisely summarized, and their implications drawn. The findings discussion will revolve around how they contribute to the understanding of technology adoption within the context of the Saudi dairy industry.

Subsequently, the researcher will provide a candid assessment of the research's limitations. Acknowledging these constraints is integral as it not only lends credibility to the present study but also establishes areas that future research can explore for a more comprehensive understanding of the topic.

Lastly, potential future research directions will be presented. As this study forms a part of the continuing academic dialogue on the adoption of traceability technologies, there remain various perspectives to probe, complexities to comprehend, and further contributions to the theory and practice.

Conclusively, this chapter will encapsulate the research journey, summarising the study's major contributions, limitations, and potential future pathways in this dynamic field of study. It offers an opportunity for reflection on the insights gained and sets the stage for subsequent scholarly exploration.

8.2 Research Conclusion

The current research has deeply examined the adoption of food traceability technologies in the Saudi dairy industry, aiming to bridge a critical gap in both academic and practical understanding. The researcher has applied a revised TOE framework, emphasizing technological, organisational, and environmental factors that influence the intention of Saudi dairy firms to implement traceability technologies in their operations and distribution networks.

The main findings indicate a lag in the adoption of traceability technologies within the Saudi dairy sector, especially amongst small and medium enterprises. Despite awareness of the benefits of advanced traceability systems, the persistence of traditional methods such as manual reporting and excel sheet usage reflects a disparity between the reality on the ground and the goals of Saudi Vision 2030. This vision seeks to transform the Kingdom into a leading industrial powerhouse and a global logistics hub, with an emphasis on the food sector and a focus on automation and Industry 4.0 (NIDLP Plan, 2019).

The research further illuminates the influence of governmental pressure and policy on the intention to adopt technology, correlating strongly with the environmental factors in the TOE framework. The significant role of government policy aligns with findings by Haneem and Kama (2018), accentuating the impact of regulations on technological adoption decisions. The relevance of these findings within the Saudi context highlights the influence of cultural factors on technology adoption decisions, specifically the high uncertainty avoidance (Alsheddi et al., 2019; Khan & Qudrat-Ullah, 2020).

Interestingly, the study revealed that the COVID-19 pandemic had a minor influence on technology adoption decisions. This finding contrasts with the significant role the pandemic has played in accelerating digital transformation globally. However, it is understandable within the context of the considerable support provided to companies by the Saudi government during the pandemic.

Another critical insight pertains to the attitude towards technological complexity, which surprisingly, wasn't perceived as a significant factor when considering the adoption of a new

technology. This contradicts various studies which suggest technological complexity as a barrier to adoption (Gangwar et al., 2015; Narwane et al., 2022; Shi & Yan, 2016; M Rogers, 1983).

Also, the research identifies resistance to change amongst employees as a crucial challenge in adopting new technologies, affirming previous research by Khan et al. (2013). It underscores the importance of user-friendly technology and adequate training for successful technology adoption.

The study's findings have revealed a number of implications and recommendations for both practitioners and policy makers in the Saudi dairy sector. The researcher highlighted the need for policy makers to consider financial support strategies for small-to-medium enterprises (SMEs) to bridge the technological gap between them and larger corporations. By offering financial incentives, such as soft loans, grants, or tax deductions, policy makers could facilitate the adoption of advanced traceability technologies in SMEs, thus enhancing overall industry competitiveness.

This research also sheds light on the significance of technological equity across businesses of all sizes. Creating subsidy schemes could help underwrite the cost of implementing these technologies in SMEs, ensuring all businesses, regardless of their size, are technologically well-equipped.

Given the societal and cultural structure in Saudi Arabia, the study suggests a potential revision of the Saudization policy, allowing Organisations more flexibility in hiring foreign talent. The balance between local employment opportunities and organisational flexibility is a critical aspect to consider. Moreover, policy makers are encouraged to foster a culture of continuous professional development and lifelong learning, particularly in emerging technologies. This could build a tech-savvy workforce that is more adaptable to technological changes, ensuring the long-term sustainability of the Saudi economy in an increasingly digital world.

Moreover, the research underscores the significance of addressing the resistance to change, which is a major challenge for technology adoption. Therefore, the managers are recommended

to opt for user-friendly technologies and provide comprehensive training to help employees adapt to these technologies effectively.

Indeed, the findings of this research have both theoretical and practical implications. Theoretically, the study contributes to the existing body of knowledge on technology adoption in the dairy sector, specifically food traceability technologies. It extends the Technological, Organisational, and Environmental (TOE) framework by incorporating cultural factors and providing insights from the context of the Saudi dairy sector.

The practical implications of this research are multifaceted. For the dairy sector in Saudi Arabia, the research provides comprehensive insights into the motivators and barriers for the adoption of food traceability technologies in their supply chain. It highlights the importance of adopting these technologies to enhance food safety, supply chain efficiency, and operational performance. Furthermore, it points out the need for training and development programs to help employees adapt to the changes brought about by these technologies.

The research also has significant policy implications. The findings suggest that policy interventions can play a critical role in encouraging the adoption of food traceability technologies, especially among SMEs. By introducing policies that provide financial support to SMEs and promote technological equity, policy makers can help to drive technological advancement and competitiveness in the dairy sector.

Moreover, the study underscores the role of government in creating a conducive environment for technology adoption. By revisiting existing policies, such as the Saudization policy, and fostering a culture of continuous learning and professional development, the government can facilitate the successful integration of advanced technologies in the dairy sector.

8.3 Research Limitations and Future Research Direction.

In reflecting upon the investigation of this study into the adoption of traceability technologies within Saudi Arabia's dairy industry, it's important to acknowledge the unique characteristics that shape its design and its subsequent findings.

Firstly, the rich and in-depth qualitative insights drawn from this study were largely thanks to a careful selection of participants, with nine managers from the dairy industry sharing their invaluable perspectives. Although it might not encompass the whole industry, it represents an informative cross-section of experiences. Each voice added depth and nuance to the findings, painting a textured landscape of the industry's attitude towards traceability technologies. Further studies could explore the richness of these insights across an even larger sample or expanding to cover the entire food industry.

This study's findings were deeply embedded within the cultural and regulatory context of Saudi Arabia's dairy industry, which added layers of cultural specificity and regional relevance to the study. While this lends authenticity and deep contextual understanding to the study, these insights and conclusions may need to be adapted to apply directly to other countries. Herein lies a wonderful opportunity for future research to apply the same lens to different contexts, thus broadening our understanding of traceability technology adoption in diverse settings.

The study primarily relies on qualitative data, which allowed the researcher to delve into detailed narratives and lived experiences of the participants. While this might introduce an element of subjectivity, it presents an opportunity to reflect on the personal and often nuanced factors that influence decision-making processes within the industry. Future research could complement these findings with quantitative data to capture a wider range of influences.

Considering the study's timeframe, it provides a snapshot of the attitudes and tendencies towards traceability technology adoption at a specific point in time. As the industry and technology landscapes continue to evolve, future studies could update these findings, creating a living body of knowledge that adapts and grows with the industry.

Also, while the focus of the current research wasn't on the financial aspects of adopting traceability technologies, it paves the way for future research to delve into this area. Such an exploration could provide a comprehensive understanding of the economic dynamics of adopting such technologies.

Finally, a novel field to venture into would be an investigation into the awareness of Saudi customers regarding traceability. Since there is currently a dearth of literature on this topic, future research in this area could provide valuable insights into the demand side of traceability technology adoption.

8.4 Summary

As I draw this research journey to a close, it is essential to reflect upon the insights and lessons gained throughout the process. The journey into understanding the adoption of food traceability technologies in Saudi Arabia's dairy industry has been enlightening, offering rich perspectives and opening new avenues of thought.

Through a deep and meticulous examination of this complex subject, this research has provided key insights into the interplay of technological, organisational, and environmental factors that influence the intention of Saudi dairy firms to adopt traceability technologies. As a result, the research has shed light on the gaps between the aspirations of Vision 2030 and the current practices within the industry, especially among small and medium enterprises. The study has also underscored the profound role that government policy and cultural factors play in shaping the landscape of technology adoption.

However, like any journey, this research has not been without its limitations. These limitations, far from being obstacles, have acted as guideposts, illuminating potential paths for future exploration and inviting us to delve deeper. The scope of the research, while comprehensive, could be broadened further, incorporating diverse voices within the industry and extending to other sectors within the food industry. The primary reliance on qualitative data, while offering rich insights, also invites the inclusion of quantitative methods in future studies for a broader perspective.

And indeed, future research directions abound. The promise of a more inclusive exploration by involving employees at various levels, a broader investigation across different sectors of the food

industry, a deeper understanding of different training methods, and a novel investigation into Saudi customers' traceability awareness offers exciting potential for further studies.

In concluding, this research journey has not merely reached an end—it has, in fact, opened up a myriad of new beginnings. The knowledge gained and the questions raised are steppingstones leading us further into understanding the intricate dynamics of technology adoption in the Saudi food industry. The journey has been as enlightening as it has been rewarding, offering as much in terms of questions as it has in answers.

As the curtains draw on this research, it is the sincere hope of the researcher that it contributes to the growing body of knowledge on this subject and inspires further exploration. The journey continues, and as we step into the future, the goal remains to bring about change and progress within the Saudi Arabian dairy industry, ultimately enhancing the sector's performance and competitiveness, and ensuring food safety and security for all. Here's to the power of knowledge, and the unwavering pursuit of progress.

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Appendix 1: Semi-structured questionnaire

Semi-structure interviews

[one hour]

Demographic factors

1. **Company:**

- Name……. Location…….

2. **Interviewee:**

- Name……..…. Age…. Nationality…….
  Education…… Experience……

- What extent you are involved in strategic decision making within your company? (Add one to 5 scale: 1: not at all to 5: highest level of involvement)

Variable	Question
Introduction	• Could you briefly explain your business and technologies being used? • Do you use food traceability technologies? • If yes, what technology do you use for that (in processing, distribution, and retail units)? Are they enough or you are thinking of using the latest ones?

Variable	Question
	• When was the last time you acquired the food traceability technologies (in processing, distribution and retail units)? How old are they? • What are the barriers, challenges and limitations of the current traceability technologies? And what is your strategy to overcome them? • In case of any upgradation of technologies, did you see any key features that helped you choose?
Technological aspect (TA)	• What are the relative advantages that your supply chain gain from current traceability technologies? Do you feel that your company is now at par or over the market? • Do you think the adoption of traceability technologies have improved the operational efficiency of your firm? • Do you think there is a relationship between food traceability technologies and supply performance? Kindly explain how the supply chain efficiency increases or have no effect with application of technologies. • Do you consider the compatibility of traceability technologies when you think of any emerging ones for adoption? • What's your perception on the complexity of technology (i.e. difficulty in learning and using a system) when making an adoption decision? How it's important for your business?
Organisational aspect (OA)	• What are top management nationalities (i.e., are they all Saudi nationals or expatriates)? • How about employees' nationalities? Is it a multicultural company with employees of various nationalities?

Variable	Question
	• What is your company's culture? Does it support technology adoption or people, in general, are reluctant to use new technologies?
	• What is the role of top management regarding technology adoption? Are they proactive or slow in adoption decision?
	• How top management help the employees to ease the adoption process and overcome their resistance?
	• Do you think that top management have been supporting the implementation and use of traceability technologies?
	• If you have any new technology adopted recently, how are the employees coping up with these technologies?
	• Does the company offer training of those technologies? If yes, which kind of training (e.g. hands on practices)?
Environmental aspect (EA)	• Does COVID-19 affect your supply chain? If yes how?
	• Do you think COVID-19 and post- COVID-19 pandemic require a massive investment in food technologies? Does it pressure your company to adopt emerging food traceability technologies to get food safety and gain consumer trust?
	• Regarding consumers, is there any pressure (direct or indirect) from consumers to adopt traceability technologies? Can you explain please? Have you experienced anything wrong/bad without tracking and tracing within your business or supply chain?
	• Do you believe that using traceability technologies will help you gain more customers compared to competitors? • Do you think that you will increase your market share if you implement the latest traceability technologies?

Variable	Question
	• Do your competitors use traceability technologies in managing their business? Have they progressed over your business? • Is there any pressure from the government to adopt new traceability technologies, Saudi Vision 2030 in particular? • Does the government provide information and encourage you to implement technology such as tracking and tracing technologies in managing the business? • How about government support, do they support you (e.g. financial incentive) to adopt a new technology? • Can you tell us about vision 2030 and its effect on management decision regarding new technologies adoption?
Intention to adopt traceability technologies	• Which traceability technologies do you plan to adopt in the future? Have you identified them? What technologies in your knowledge can help your company? • Have you thought of using some specific technologies such as IoT, blockchain, RFID and switching to 5G network in running the food traceability as well as communicating with suppliers and customers? • What are the factors (e.g., technological, environmental and organisational) that will affect your adoption decision? • How the company's employees will be adapted to these technologies? Will the company offer hands-on training specific to those technologies? • What are the challenges you expect in the future? And how to overcome them?

Variable	Question
	• Will your suppliers and retail customers cooperate with the adoption of new technologies to track and trace the food quality? What way they are going to be benefitted?

Thank you.

Appendix 2: Ethics Approval

Dear DR. HIMANSHU SHEE,

Your ethics application has been formally reviewed and finalised.

» Application ID: HRE21-117

» Chief Investigator: DR HIMANSHU SHEE

» Other Investigators:

» Application Title: Leveraging Technologies in Food Traceability Improves Supply Chain Performance: A Qualitative Study of Saudi Food Sector

» Form Version: 13-07

The application has been accepted and deemed to meet the requirements of the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007)' by the Victoria University Human Research Ethics Committee. Approval has been granted for two (2) years from the approval date; 27/10/2021.

Continued approval of this research project by the Victoria University Human Research Ethics Committee (VUHREC) is conditional upon the provision of a report within 12 months of the above approval date or upon the completion of the project (if earlier). A report proforma may be downloaded from the Office for Research website at: http://research.vu.edu.au/hrec.php.

On behalf of the Committee, I wish you all the best for the conduct of the project.

Secretary, Human Research Ethics Committee

Phone: 9919 4781 or 9919 4461

Email: researchethics@vu.edu.au

Appendix 3: Information to Participants Involved in Research

You are invited to participate.

You are invited to participate in a research project entitled "*Leveraging Technologies in Milk Traceability to Improve Supply Chain Performance: A Qualitative Study of Saudi Dairy Industry*

This project is being conducted by a student researcher Mrs Afyaa Alessa (ID: 4625196) as part of her PhD study at Victoria University under the supervision of Associate Professor Himanshu Shee and Dr. Tharaka DeVass from Institute for Sustainable Industries & Liveable Cities.

Project explanation

- The research aims to explore technological, organisational and environmental factors that likely to motivate dairy firms' intentions to adopt emerging traceability technologies in their internal operations as well as in distribution network.
- NVivo, a qualitative software, will be used to analyse the interviews for theme supporting these factors as well as any new themes that may add to these factors.

- This research will provide managers with insights that likely to resolve the current problems in relation to tracking and tracing of milk in processing, its distribution and retailing. Moreover, it will inform managers about Post-COVID-19 business scenario where the adoption of trace and track technologies will enhance consumers' trust and confidence in milk consumption.

What will I be asked to do?

- The participants will be approached for their consent to participate by signing a consent form.
- Verbal consent will be collected prior to the start of the online interviews.

- A set of semi-structured interview questions will be provided early to let the participants know about the interview content. They will be given time to consult and prepare for the interviews.
- The information collected through interviews will be used for academic purpose only and strictly adhere to non-identification of the participants' details.

What will I gain from participating?

Summary of findings from this study will be shared with the participants of the dairy companies.

- It will inform the companies about the technological, organisational and environmental factors that affect their decision to adopt the food tracking and tracing technologies on top of their current practices.
- It will provide managers with a better understanding of their own businesses where they can take informed decisions about the future food traceability technologies and can compete in the market.
- The technology-enabled benefits include greater operational performance through quality monitoring, improved processes, better delivery through tracking and tracing at optimal cost.

How will the information I give be used?

The data gathered through interviews will be:

1. Analysed by NVivo Software for its content and theme.
2. The conceptual framework and research questions proposed by current literature will be assessed and modified according to thematic analysis.
3. The report summarising the interview will be provided to the company for verification.
4. Once agreed then it will be included in the thesis.

In case the participants discussed anything negative of the company due to their frustration, the report will not consider them unless they are found suitable. Or it will used anonymously. In either case participants will not be identified/ranked/scored.

What are the potential risks of participating in this project?

This is low-risk research as it involves interviews with human. Involvement of senior management and their approval for others to participate will help reducing the risk. The student researcher being a native to Saudi Arabia will be able to explain any issue/confusion arises during interviews. Supervisor will also monitor the situation to make sure interviews goes a smooth and friendly way.

In case the participants disclose some sensitive information about the company, or talk adversely, it will be kept confidential within the research team. Neither, it will be included in the report, nor will be communicated to the company.

How will this project be conducted?

1. The researcher and supervisor will take the interviews online from Melbourne. After email consultation with the team leader, the interview date and time will be scheduled considering the time zone difference between Melbourne and Saudi Arabia. Both research team and the participants can use either Skype, face time, WhatsApp etc. So, there will be no travel undertaken to Saudi Arabia.
2. The interviews will include three groups of participants comprising processing, distribution and retail units that comprise of milk supply chain. This might occur over one month considering their busy schedule.
3. Each semi-structured interview will take about 45 minutes. The consent form will be sent for their signature via email prior to the interview date with a request to send the signed copy back in a reply email. Those who fail to provide on time, a verbal consent will be collected prior to start of the interviews.

4. A semi-structured interview questions will explore the understanding of the technologies that company uses in food traceability. The interview questions will be structured around these technologies as well as the emerging technologies and their adoption possibility.
5. The interviews will be recorded using an external digital recorder.
6. The interviews will be content analysed by NVivo software.

Who is conducting the study?

- The student researcher, Afyaa Alessa - Email: Afyaa.alessa@live.edu.vu.au
- The supervisor, Associate Professor Himanshu Shee – Email: himanshu.shee@vu.edu.au
- The Associate Supervisor Dr Tharaka DeVass- Email: Tharaka.deVass@vu.edu,.au

Any queries about your participation in this project may be directed to the Chief Investigator/supervisor listed above.

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email researchethics@vu.edu.au or phone (03) 9919 4781 or 4461.

Appendix 4: Consent Form for Participants Involved in Research

INFORMATION TO PARTICIPANTS:

We would like to invite you to be part of a study on "*Leveraging Technologies in Milk Traceability to Improve Supply Chain Performance: A Qualitative Study of Saudi Dairy Industry*". The aim of this research is to explore technological, organisational and environmental factors that motivate dairy firms' intentions to adopt emerging tracking and tracing technologies in their internal operations as well as in distribution network. Further, it explores how the firms' culture moderates the technology adoption intention. Interviews will be undertaken with dairy companies (processing, distribution, and retail units) to drill down information on the current technology being used and the possibility of adopting new technologies that will help in food traceability. The interviewees will comprise senior members of the staff at dairy companies. These interviews do not have any potential risks for the participants as it includes only human with their experience in their respective areas. The qualitative data analysis software, NVivo, will be used to analyse the interviews data. The research will inform the company that the emerging technologies (e.g., Internet of things, Artificial Intelligence, cloud technologies) can benefit the food traceability by maintaining its quality during the food processing and its distribution to the customers.

CERTIFICATION BY PARTICIPANT

I, "[Click here & type participant's name]"

of "[Click here & type participant's suburb]"

Certify that I am at least 18 years old and that I am voluntarily giving my consent to participate in the study: "*Leveraging Technologies in Milk Traceability to Improve Supply Chain Performance: A Qualitative Study of Saudi Dairy Industry*." being conducted at Victoria University.

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed here under to be carried out in the research, have been fully explained to me by:

Afyaa Alessa and that I freely consent to participation involving the below mentioned procedures:

- Interview will occur over Skype/WhatsApp/phone as suits to both parties.
- Supervisor Associate Professor Himanshu Shee will also join the interviews. He may seek extra clarification if some part of the interviews is not clear or incomplete.
- In case the participants disclose some sensitive information about the company or talk adversely it will be kept confidential within the research team. Neither, it will be included in the report, nor will be communicated to the company.

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the researcher

Associate Professor Himanshu Shee

Email: Himanshu.Shee@vu.edu.au

Phone Number: +613 9919 4077

If you have any queries or complaints about the way you have been treated, you may contact the Ethics Secretary, Victoria University Human Research Ethics Committee, Office for Research, Victoria University, PO Box 14428, Melbourne, VIC, 8001, email Researchethics@vu.edu.au or phone +613 9919 4781 or 4461.