University of
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ENHANCING THE ADOPTION OF TEMPERATURE MONITORING TECHNOLOGIES: THE CASE STUDY OF SELECTED AUSTRALIAN VEGETABLE SUPPLY CHAINS

A Thesis submitted by

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ABSTRACT

The study seeks to understand the behavioural aspects influencing the adoption of temperature monitoring technologies (TMTs) among vegetable supply chain members in Australia. It contributes to current theory and practice and provides policy level inputs for enhancing uptake of TMTs to reduce fresh produce spoilage and sustain its nutritious value. The study utilised multi-theoretical frameworks through a combination of five seminal and modern theories of technology adoption. The tailor-made conceptual framework for the study focused on the current status of TMTs adoption, factors influencing its uptake and interventions to enhance its acceptance by members of vegetable supply chains. Three representative cases were purposively selected for the study that included growers, packers, transporters, distribution centres along with technology providers and industry experts. Data was collected through semi-structured interviews from 19 members of vegetable supply chains as well as three technology providers and three industry experts. Data was analyzed utilizing thematic analysis. Findings show that members of vegetable supply chains perceive temperature management as one of the key factors for preserving quality and extending shelf life of their produce; however, they did not proactively seek to utilise TMTs in their current operations. Resistance to adoption is deeply rooted in product-based issues (cost and compatibility of existing TMTs), and process-based factors (information sharing and product mixing). The presence of an individual's undesirable behavioural aspects (status quo bias, responsibility shirking) and overall social norms of the industry influence the adoption of TMTs. The study recommends five core actions for enhancing the uptake of TMTs along different echelons of vegetable supply chains highlighting dominant role of supermarkets, technology providers and government entities.

CERTIFICATION OF THESIS

I Moudassir Habib declare that the Thesis entitled *An Investigation into Australian Vegetable Supply Chains: Enhancing the adoption of Temperature Monitoring Technologies* is not more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references, and footnotes. The 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.

Date: October 4, 2023

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Student and supervisors' signatures of endorsement are held at the University.

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DEDICATION

To Almighty Allah and family

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ABBREVIATIONS

ASC/s	Agri-food supply chain/s
AUD	Australian dollars
CAS	Cold air storage
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DOI	Theory of diffusion of innovation
TAM	Technology acceptance model
ETAM	Extensions in TAM
FAO	Food and Agriculture Organization
FEFO	First-to-expire first out policy
FIFO	First-in first out policy
FLW	Food loss and waste
FPSCs	Fresh produce supply chain/s
ICT	Information and communication technologies
IoT	Internet of Things
LVRC	Lockyer Valley Regional Council
MAS	Modified atmosphere storage
PE	Perceived ease of use
PU	Perceived usefulness
RFID	Radio frequency identification tags
RW	Refrigerated warehouse
TMT/s	Temperature monitoring technology/ies
TOE	Technology-organisation-environment framework
TPB	Theory of planned behaviour
TRA	Theory of reasoned actions
UTAUT	Unified theory of acceptance and use of technology
WSN	Wireless sensor networks
SDGS	Sustainable development goals

CHAPTER 1: INTRODUCTION

1.1. Introduction

Agri-food supply chains (ASCs) around the world have been challenged with the rapidly evolving economic, social, and environmental issues. World population is expected to reach nine billion by 2050 (UNDESA, 2019) and ensuring food security is the defining challenge for agriculture (UNICEF, 2020). Urbanisation is expected to increase with an accelerating speed, and it is anticipated that urban areas will account for around 60% of the world's population in the year 2050 (an increase from 54% in 2016) (Fróna et al., 2019). At the same time, global economic growth is projected to increase by around 3% annually which would lead to a significant reduction in economic poverty in developing countries and a rise in the purchasing power of consumers (FAO, 2009). Parallel to the global food demand challenges, there are also problems of disruptions across ASCs due to pandemics like COVID-19 (Das & Roy, 2022), continued environmental degradation and climate change (Malhi et al., 2021). To meet these challenges, increasing production levels of food is essential but reducing significant current food loss and waste (FLW)[1] across different echelons of existing perishable food supply chains is a more pertinent solution which can be achieved through adoption of modern technologies (Benyam et al., 2021; Trevisan & Formentini, 2023).

FLW is an overarching challenge for ASCs in which approximately one third of the food produced for human consumption – equivalent to around 1.3 billion tonnes each year – is discarded (Munesue et al., 2015; Xue et al., 2017). The extent of food loss is similar across the globe, but stages and causes differ across the regions (Dou et al., 2016). For instance, the United States loses up to 40% of its food from production to consumption (Gunders & Bloom, 2017), and approximately 10% of fresh produce is wasted annually in Europe from farm to fork (Jedermann et al., 2014). The difference in the amount of FLW across two countries can be attributed to a number of factors

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[1] Food loss refers to decrease in the quality or quantity of edible food along supply chain operations. Food loss typically occurs during initial stages of supply chain such as in production and post-harvest processing. Food waste, a subset of food loss refers to produce that is not consumed at the end of the chain such as at retail or household level. Rezaei, M., & Liu, B. (2017). Food loss and waste in the food supply chain. *International Nut and Dried Fruit Council: Reus, Spain*, 26-27.

including consumption behaviour, packaging of produce and other logistical challenges (Iori et al., 2023). Realising the significant negative consequences of FLW for sustainability, reducing per capita food waste by 50% by 2030 is the objective of Target 12.3 of United Nations' Sustainable Development Goals (SDGs) (UN, 2015). Therefore, reduction in FLW is a most relevant and timely issue. Temperature management during different stages of ASCs (harvest to distribution) by utilising advanced technologies for monitoring and detecting deterioration of produce is considered to be one of the key aspects of reducing FLW (Onwude et al., 2020; Trevisan & Formentini, 2023).

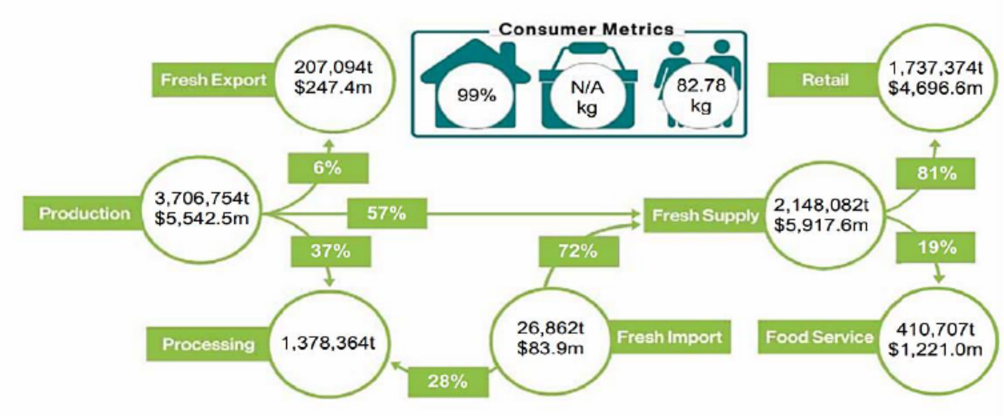
Temperature management along the food chain from post-harvest till delivery to consumer is considered to be one of the main factors affecting quality and safety of perishable produce (Ndraha et al., 2018; Zhou et al., 2022). To extend shelf life and avoid growth of foodborne pathogens in perishable produce, an optimum temperature must be maintained throughout the supply chain operations from production to consumption (Kroft et al., 2022; Raffo et al., 2021), termed as "food cold chain" (Centobelli et al., 2020, p. 103). Numerous temperature monitoring technologies (TMTs) are available to control and monitor the temperature throughout cold chain processes (Badia-Melis et al., 2018; Mercier et al., 2017; Ndraha et al., 2018; Shashi et al., 2021), however, its widespread adoption and adaptation in perishable produce chains is still a challenge (Ndraha et al., 2020). Therefore, the main objective of this research is to understand the phenomena of lack of adoption of TMTs in vegetable supply chains by analysing its current adoption status, factors affecting its uptake and interventions to improve its acceptance by the supply chain members.

This chapter introduces the highly relevant and important research topic of TMTs adoption in vegetable supply chains. To provide context to the study, Australian vegetable supply chains are broadly described. A problem statement of the study along with research questions are presented. An overview of the methodology and structure of thesis completes this chapter.

1.2. Vegetable production sector in Australia

Australia's vegetable sector encompasses a wide diversity of edible fresh produce which spans across varied climatic regions. The gross value of vegetable production increased by 13% in the year 2021 to 2022 to around AUD5.5 billion of which 57% is injected into fresh supply chains in Australia and 6% is exported to international markets (Hort Innovation, 2022). Figure 1 below shows overall distribution of vegetables into various market channels.

Figure 1
Distribution of fresh vegetables into different channels



Source: (Hort Innovation, 2022)

According to Horticulture Innovation's[2] Australian Horticulture Statistics Handbook of 2021-22, Australian farmers are growing 33 different types of vegetables, ranging from artichokes to zucchinis (Hort Innovation, 2022). The following Table 1 shows the top ten ranking of vegetable crops based on production volume in tonnes (t) and gross farmgate value in millions ($m) for the year 2021-22.

Table 1
Top ten vegetables produced in Australia based on production volume and production value

	Production(t)		**Gross Value($m)**	
1	Potatoes	1,462,065	Potatoes	830.20
2	Tomatoes	436,908	Tomatoes	645.10
3	Carrots	306,394	Leafy salad vegetables	589.20
4	Onions	266,429	Mushrooms	434.20
5	Head lettuce	134,726	Broccoli	289.90
6	Pumpkins	112,895	head lettuce	266.70
7	Sweet potatoes	102,754	Onions	248.70
8	Cucumbers	88,495	Carrots	247.90

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[2] Hort Innovation is a non-for-profit research organization dedicated to development of Australia's horticulture industry. Organization also provides statistical support to the industry. More information is available on https://www.horticulture.com.au/

9	Leafy salad vegetables	78,495	Cucumbers	229.90
10	Cauliflower	76,944	Capsicums	211.80

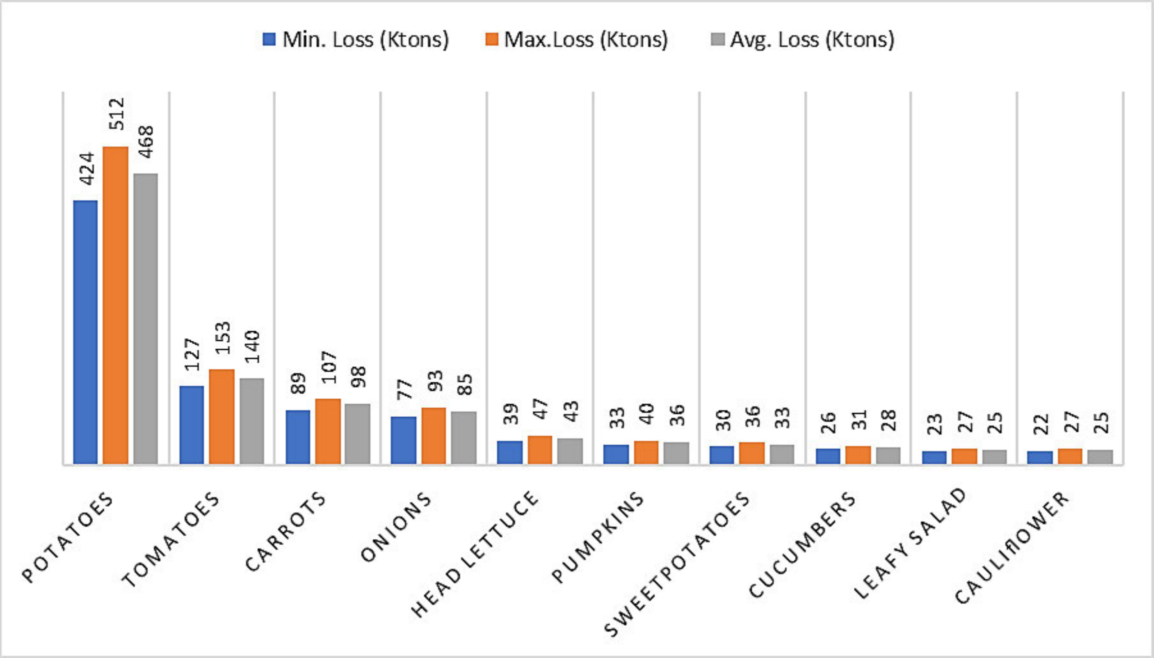
Source: (Hort Innovation, 2022)

Existing vegetable supply chains are faced with the challenges of increasing market complexity, and enhanced awareness of consumers about the quality and health benefits of fresh vegetables (Fracarolli, 2021). Due to the advent of modern technologies in agri-food, traditional vegetable chains are evolving and becoming more robust to meet changing consumer demands (Trivelli et al., 2019). The problem of FLW has been categorically mentioned as one of the key issues for the Australian agri-food sector (Sanad Alsbu et al., 2023)

1.3. Food loss and waste in the Australian vegetable sector

A significant amount of fresh produce loss and waste exists in Australian horticulture supply chains. Commonwealth Scientific and Industrial Research Organisation (CSIRO) carried out a study on mapping of losses in Australian fruit and vegetable supply chains (Juliano et al., 2019). The findings of the study suggested that 18 to 22% of fresh produce is lost during production and processing stage. Thereafter, 7 to 10% of fresh produce is lost during the production stage and the processing or packing stage accounts for around 22 to 25% (Juliano et al., 2019). Figure 2 below presents minimum and maximum production volume losses of top ten vegetable crops at the production and processing stage based on the above estimated loss values. This estimation is based on the values presented in the horticulture statistics handbook of Hort Innovation (Hort Innovation, 2022).

Figure 2
Estimated minimum, maximum and average loss of top 10 vegetables



Source: (Hort Innovation, 2022)

Previous research suggests multiple reasons for the significant amount of FLW in horticulture supply chains. Messner et al. (2021) stipulated that overproduction resulting in a surplus is a prevalent feature in Australian horticulture supply chains. Surplus food production is considered to be a common practice which leads to a high amount of FLW at the end.

Private quality standards[3] and its implementation by the supermarkets in Australian horticultural supply chains are also considered one of the dominant factors for FLW (Devin & Richards, 2018). The fresh produce market in Australia is concentrated with two supermarket chains (Coles and Woolworths) holding over 70% of market share (Tonkin, 2016). On certain cosmetic grounds[4], fresh produce is generally rejected by the retailer if it does not meet their standards, which also results in the creation of FLW in fresh produce chains.

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[3] Private quality standards are established and owned by non-government entities for meeting certain food safety and sensory qualities of fresh produce, and these are implemented on suppliers of fresh produce. Hobbs, J. E. (2003). Incentives for the adoption of good agricultural practices (GAPs). *Food and Agriculture Organization*, *1*.

[4] Refers to the physical condition of a fresh produce including colour, look, size and other visual appeal. Dusoruth, V., & Peterson, H. H. (2020). Food waste tendencies: behavioral response to cosmetic deterioration of food. *PloS one*, *15*(5), e0233287.

Ineffective management of cold chains and temperature abuse along different stages of fresh produce chains are also termed to be one of the key factors for a significant amount of FLW (Raffo et al., 2021). Temperature management across different stages of the chain (post-harvest to consumption) is considered integral to maintain quality and to extend the shelf life of fresh produce (Malin Göransson et al., 2018). Recent technological advancements in cold chain monitoring have enabled real time temperature tracking of produce. A fully automated real time cloud-based cold chain monitoring system can reduce FLW, preserve the quality and value of produce by enhancing its shelf life and maintain its nutritious value for end customers (Badia-Melis et al., 2018; Benyam et al., 2021).

1.4. Problem statement and justification of research

Keeping in view the availability and proven benefits of TMTs in perishable supply chains, it is considered that these should be widely utilised for effective cold chain monitoring. However, limited uptake of TMTs among vegetable supply chain members has been observed in prior literature (Ndraha et al., 2018; Vern et al., 2022). Previous research has cited several reasons for limited adoption of technologies in ASCs, which can be broadly classified into technical characteristics of available technologies and behavioural aspects of potential adopters (Annosi et al., 2021; Cook et al., 2022; Rejeb et al., 2022). Literature acknowledges the need for deeper understanding into the behavioural perspectives of potential adopters as it has attracted limited attention in previous studies (Foguesatto et al., 2020; Giua et al., 2022).

This study endeavours to understand the adoption process of TMTs in vegetable supply chains by understanding technological as well as behavioural aspects of the members of vegetable supply chains. It also provides insights into current perceptions and practices of temperature monitoring adopted by different stakeholders, including technology providers of TMTs and industry experts. The study aims to suggest interventions for enhancing the uptake of TMTs through various practice and policy-based measures.

1.5. Research objectives and research questions

The objective of this research is to investigate the process of adoption of TMTs across three selected Queensland-based vegetable supply chains. It endeavours to understand the current adoption status of TMTs in vegetable supply chains by comprehending individual behaviour within the contextual setting of agri-food supply chains.

First, the current adoption status of TMTs in vegetable supply chains is examined by assessing the perceptions of relevant stakeholders across the selected vegetable supply chains in Southeast Queensland, Australia. Current temperature monitoring practices across these chains (farm to distribution centre) are investigated. This leads to the first research question of the study on the current adoption status of TMTs.

RQ1: *To what extent temperature monitoring technologies have been adopted across vegetable supply chains?*

Adoption factors influencing the uptake of TMTs in three selected vegetable supply chains are investigated by considering practice and individual behavioural perspectives of relevant stakeholders. This leads to the second research question of the study.

RQ2: *What are the current practical and behavioural perspectives influencing the adoption of temperature monitoring technologies across vegetable supply chains?*

The final question is related to enhancing the uptake of TMTs in the three selected vegetable supply chains. It seeks to understand the factors that can enhance the adoption of TMTs to reduce FLW and to enhance sustainability of current vegetable supply chains.

RQ3: *How to enhance the adoption of temperature monitoring technologies across vegetable supply chains?*

1.6. Significance of the study

This study contributes to existing literature on the adoption of technologies in perishable food supply chains. The specific focus on the utilisation of TMTs in Australian vegetable supply chains enhances our understanding of the current status of cold chain monitoring practices, its adoption factors and uptake. Technological and behavioural insights about the adoption of TMTs provided from the study have significant implications for researchers, practitioners (who are working on improving the uptake of technologies in the agri-food sector) and policy makers.

The findings also provide significant insights to the suppliers of TMTs about the individual behaviours of potential adopters and social norms of the vegetable supply chains. These insights can be utilised to customise their current offerings and provide tailor-made solutions which can ultimately contribute to a higher uptake of TMTs in vegetable supply chains.

This study also contributes to addressing the policy level gap. It will provide broad policy measures that can be integral to enhance uptake of TMTs and reduce current FLW in vegetable supply chains. Finally, this study can provide guidelines to supermarkets for effectively engaging downstream members of vegetable supply chains in improving provenance and transparency of temperature monitoring. Overall, recommendations of the study will provide guidance on significantly reducing FLW in existing vegetable supply chains as well as positioning TMTs as a viable solution.

1.7. Methodology of the study

To understand the complex phenomena of TMTs adoption in vegetable supply chains, a constructivist paradigm was adopted. For an in-depth analysis of supply chain members’ behavioural aspects, a qualitative methodology was adopted by utilising case study research design, as suggested by Creswell (2013) and advocated by Seuring (2005) when studying supply chains. Three vegetable supply chains in Lockyer Valley Queensland, Australia were selected as cases to be studied in this research. Each case study consists of growers, packers, transporters, staff of distribution centres including technology provider of TMTs and experts. The research follows a combination of three sampling strategies employed at different stages of the study. A criterion sampling strategy was employed at the initial phase for the selection of case study. Critical stage sampling strategy was utilised in the second phase where cases were selected that could provide rich information. Finally, a snowball sampling strategy was employed in which respondents identified other potential participants from the upstream operations of supply chain.

Data collected through semi-structured interviews by employing interview guide. Data was then analysed utilising thematic analysis while Nvivo software was also used for graphical presentation of findings. A six-phase process of thematic analysis by

Braun and Clarke (2020) was adapted to conduct an in-depth analysis of collected data.

1.8. Outline of thesis

Chapter 1 has provided an overview and background of research. The vegetable industry context along with research objectives and questions are described. The methodology of the study is also briefly discussed, and the significance of the study is presented.

Chapter 2 provides a review of previous literature by elaborating unique characteristics of agri-food supply chains. Cold chains and their importance are described and theories on technology adoption are presented. Gaps in literature is identified, and a theoretical framework for the study completes this chapter.

Chapter 3 outlines the methodology of the study by providing details of research paradigms and data collection procedures employed in this study. The process of data analysis along with its reliability and validity is presented at the end of the chapter.

Chapter 4, **Chapter 5** and **Chapter 6** present findings for each research question respectively. Chapter 4 provides findings of RQ1 by investigating the current adoption status of TMTs in vegetable supply chains. RQ2 findings are presented in Chapter 5, focusing on the factors inhibiting the adoption of TMTs in vegetable supply chains. Chapter 6 presents the findings of RQ3, delineating practice and behavioural based interventions to improve the uptake of TMTs in vegetable supply chains.

Chapter 7 discusses the findings of the above three research questions in turn, connecting it with previous research and outlining its implications. **Chapter 8** concludes the study by enumerating its theoretical, practical and policy level contributions. Limitations of the study is also discussed and opportunities for further research are presented.

1.9. Chapter Conclusion

The chapter has introduced the topic of the study by explaining its relevance to agri-food sector. A description of the Australian vegetable supply chain and its key challenge of food loss and waste sets the context of the study. The problem statement along with the research objectives and questions are presented. Next chapter will present an overview of previous literature on the important aspects of agri-food supply chains and technology adoption in fresh produce supply chains.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

As indicated in Chapter 1, the purpose of the study is to investigate, understand and explore factors regarding the adoption of TMTs in fresh produce supply chains in the context of Australia’s vegetable industry. For comprehensive understanding of technology adoption in the agri-food sector, this chapter is divided into three parts.

Part A provides an overview of the agri-food supply chains, their unique characteristics, and its digitalisation. Part B discusses cold chain management in fresh produce by outlining its relevant technologies and processes. The final part of the chapter presents an overview of the process of technology adoption and its models illustrated in prior literature. Chapter concludes with the identification of gaps in the literature and theoretical framework of the study.

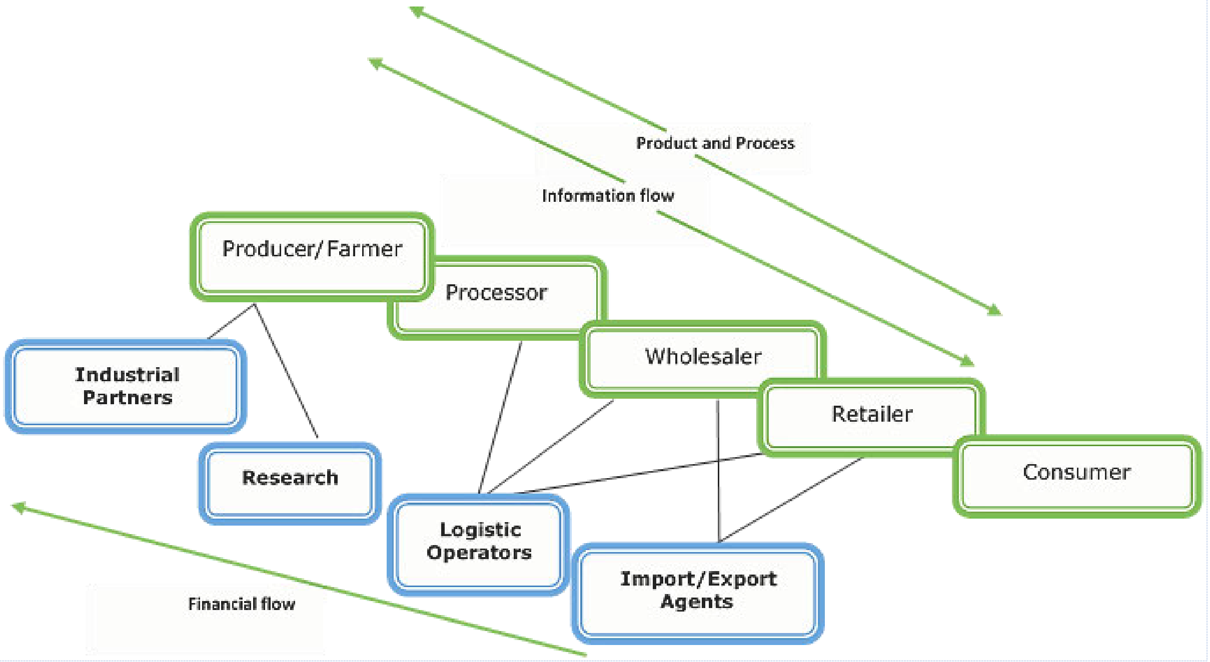
Part A: Agri-food supply chains

This part of the chapter introduces the concept of agri-food supply chains (ASCs) and their unique characteristics compared to classical supply chains. In addition, it also discusses the digitalisation of these chains and provides an overview of the historical development of digital technologies. It concludes with an overview of available digital technologies and their impact on (ASCs).

2.2. Agri-food supply chains

The term "agri-food" refers to the business of producing and distributing food agriculturally (Barbosa, 2021). Like hunting, fishing or gathering, the concept of supply chain is integral to agri-food. It was initially proposed by scholars in the discipline of agricultural economics and management sciences (Marsden et al., 2000). The agri-food industry has embraced and recognised supply chain management concepts for its competitiveness (Tsolakis et al., 2014). ASCs consist of set of activities related to the movement of agricultural products from "farm to fork" (Tsolakis et al. (2014, p. 48), consisting of a sequence of activities including farming/production, processing, transportation, warehousing, and marketing (Iakovou et al., 2012). These operational activities are supported by financial, logistical, and technical services by providing five multi-dimensional flow types: physical flow, financial flow, informational flow, process flow, energy, and resources flow. Continuous evolution of agri-food systems further embraces effective coordination of secondary actors, namely industrial partners, research institutions, service providers, and market actors. A conceptual diagram of agri-food supply chains is depicted in Figure 3 below taken from (Tsolakis et al., 2014). The green boxes depict different operations of the chain where one actor can perform multiple roles, while the blue boxes show coordinating role of secondary actors. In other words, ASC covers the entire chain activities ranging from production, processing, distribution, and retailing to consumers (Luo et al., 2018).

Figure 3
Conceptual diagram of agri-food supply chains (Tsolakis et al., 2014)



In recent literature, ASCs are referred to as “food systems” (Béné et al., 2019, p. 117; Ingram, 2011). They have been characterised as a complex system that encompasses social, economic, health, political, and environmental challenges at different scales throughout transforming food products from raw form to a ready to eat shape (Peano et al., 2015).

2.3. Nomenclature of agri-food supply chains

ASCs exhibit some unique characteristics which differentiate it from classical supply chains, raising the need for unique/distinctive managerial capabilities

(Moazzam et al., 2018). Vorst (2006) characterised ASCs, based on the nature of product characteristics such as limited shelf life, short life cycles, seasonality in harvesting and production operations, variability in the farm inputs and outputs, special requirements during transportation and refrigeration, increased complexity of business operations and limited capacity of actors. Romsdal et al. (2011) synthesised three critical aspects of ASCs which differentiate them from other commodity-based supply chains. The first aspect is product characteristics which include product perishability, product complexity, product variety, product life cycle, and product variability. The second aspect is market characteristics which have delivery lead time and variability, uncertainty in demand, and complex inventory management. The third characteristic is related to manufacturing system characteristics which include supply uncertainty, manufacturer lead time and complexity of processes.

ASCs are evolving to meet broader challenges such as increasing world population and growing future food demands due to rapid urbanisation, emergence of global chains, concerns for food quality and safety, climate change, government regulations, and the need for food traceability from farm to fork (FAO, 2019). Therefore, there are unique characteristics of ASCs which differentiate them from classic supply chains, and it needs special consideration in terms of ensuring their efficiency and sustainability (Miranda et al., 2019; Tsolakis et al., 2014).

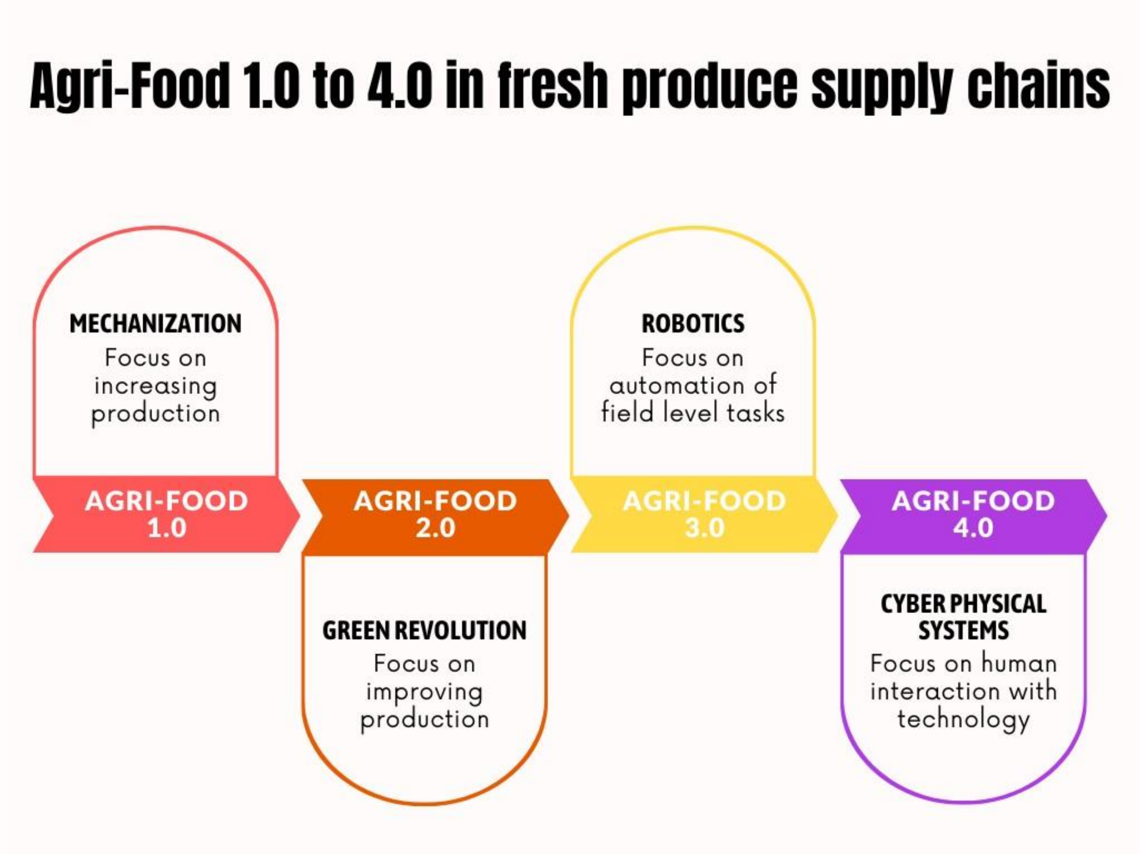
According to FAO (2019), the primary natural resources including food, energy, and water, are becoming scarce. Consequently, various steps should be taken to address this situation such as reducing food waste. Similarly, it has been estimated that the world population will be nine billion by 2050, which calls for increasing food production capacity by 70% (FAO, 2019), and reduction of FLW (currently standing at 30%) (Irani et al., 2018). Producing enough food, appropriately distributing it, and minimising its wastage are some of the critical challenges the agri-food industry faces, which calls for the industry to become more sustainable (FAO, 2019).

2.4. Digitalisation of agri-food supply chains

Digitalisation describes a process of converting analogue information into a digital one. In a similar context, digital transformation or digitalisation is an ongoing socio-technological change process aiming to apply digital innovations across different functions of an entity (Klerkx et al., 2019). Digitalisation is becoming a subject of considerable interest in the literature due to its relevance in addressing social problems and contributing to developing industries and societies (Annosi et al., 2020). Nowadays, exponential growth in digital technologies is reshaping how industries operate and perform. Similarly, these digital technologies have also entered into the field of agri-food supply chains.

From a historical perspective, ASCs have evolved rapidly since the industrial revolution of 19th century (Corallo et al., 2018). Likewise, "Industry 1.0" and "Agri-food 1.0" have been characterised by the industrial systems' mechanisation to improve productivity and efficiency. "Agri-food 2.0" in the 1950s was related with the use of electricity, and the focus was primarily on electrical machines that allowed increasing production capacities. This period is also remembered as the "green revolution" due to the emergence of synthetic pesticides and fertilisers. "Agri-food 3.0" arose at the end of the 20th century, marked by the development of robotics and automatisation. These new technologies allowed the agriculture industry to complete field-level tasks such as sowing, harvesting, and automatisation of greenhouses, as well as enhanced progress in production techniques. Currently, the agri-food industry is influenced by the techniques, methods, and strategies proposed by "industry 4.0," which is characterised by advances in cyber-physical systems, including advances in human interaction with machines through digital technologies (Yahya, 2018). Therefore, the current period known as "Agri-food 4.0" focuses on adopting sustainability practices emphasising social, economic, and environmental issues related to ASCs (Miranda et al., 2019). An overview of the characteristics of the evolution of technologies is presented in Figure 4 below.

Figure 4
Digitalisation of agri-food supply chains



Source: (Corallo et al., 2018)

As discussed in the previous section, challenges in ASCs are complex, due to the presence of uncertainty and risks as compared to other supply chains; therefore, to achieve robustness, resilience, and sustainability; agri-food chains need to move away from business as usual to developing new solutions and implementing innovative technologies. Along these lines, digitalised agri-food chains allow actors to monitor risks in real-time and devise plans accordingly for its resolution. Table 2 provides a comprehensive overview of how digital technologies transform the current activities and essential functions of ASCs. The table also exhibits the functional, economic and environmental examples of impacts of different digital technologies in ASCs.

Table 2

Comprehensive review of digital technologies in agri-food supply chains

Technology	Impact on agri-food supply chain			References
	Functional	**Economic**	**Environment**	
Internet of Things (IoT)	• Monitoring real-time environment • Tracking and traceability improvement	• Increasing operational efficiency, reduce food waste • Enhancing consumer satisfaction	• Reducing waste to minimise the ecological footprint • Reducing water and other chemical use	(Gómez-Chabla et al., 2019; Lezoche et al., 2020; Shi et al., 2019)
Block chain technology	• Improving real-time visibility, transparency and reliability	• Markets becoming more efficient • Reducing transaction costs • Yielding consumer satisfaction	• Waste reduction	(Feng et al., 2020; Rana et al., 2021; Tripoli & Schmidhuber, 2020; Zhao et al., 2019)
Big data analytics	• Effective risk management • Prediction and prescription analytics of future business activities	• Operational efficiencies and cost reduction • Optimum planning and enhanced business performance • Increase yielding, market information-based decision thereby leading to maximum profit acquisition	• Better use of available natural resources, thereby reducing water and another natural resource footprint	(Himesh et al., 2018; Kamble et al., 2020)
Artificial intelligence	• Automated activities	• Reducing labour costs and other cost inefficiencies • Reduce human errors related costs	• Reducing waste of natural resources	(Eli-Chukwu, 2019; Smith, 2018)

Part B: Cold chain management

This part of the chapter provides an overview of the cold chain management process in fresh produce supply chains and discusses its importance. It also explores existing cold chain monitoring technologies and its characteristics in ASCs.

2.5. Cold chains and its importance in fresh produce

Cold chains are becoming a significant part of the modern global perishable industries. Singh et al. (2018, p. 532) define cold chain management as "the process of planning, implementing and controlling the flow and storage of perishable goods, related services and information to enhance customer value and ensure low costs". After harvest, fresh produce like vegetables and fruits remain alive and have vital signs, and to keep these in their optimum condition, maintaining suitable temperature along the supply chain is one of the integral environmental factors which has direct implications on deterioration and post-harvest shelf life (Centobelli et al., 2020), so keeping cold chain integrity is crucial to reduce FLW, maintaining the quality of fresh produce and extending its shelf life (Han et al., 2021).

Within the overarching research area of cold chain management, food cold chains are rapidly growing due to increasing demand for high-quality fresh produce by consumers and the problem of FLW (Centobelli et al., 2020). Consumers are becoming more health conscious with the improvement in their living standards, and therefore demand for higher quality fresh produce is increasing (Chen et al., 2019). Temperature is a critical factor affecting the quality of fresh produce, i.e., temperature variability across the chain aggravates the produce spoilage (Surucu-Balci & Tuna, 2021). Therefore, the integrity of cold chain logistics thrives as a competitive advantage for enterprises to cultivate loyal customers and stand out from the competition (Dai et al., 2020). Lim et al. (2021) linked effective operations and sharing of produce traceability in terms of temperature monitoring in cold chain transportation with the positive consumer sentiments leading to repetitive purchase of fresh produce in long run.

The cold chain is also intimately linked with FLW throughout the literature. FLW is considered to be a "wicked problem" in the fresh produce supply chains due to its magnitude and threats to sustainability (Richards et al., 2021,p. 482). Food loss refers to the food that gets spoiled, spilled, or otherwise lost during the operations of supply chains like production, harvesting, transportation, and retail before reaching the consumer. In contrast, food waste refers to food not consumed at the household level. The magnitude of FLW is overwhelming, as the Food and Agriculture Organization (FAO) estimated that approximately 30% of our food is lost, amounting to about US$940 billion per year (Hanson et al., 2016). FLW also harms the environment and natural resources such as water, soil, land, and energy go to waste when food is not consumed (Sakoda et al., 2019). Dumping food is also linked with methane emission, a potent greenhouse gas that negatively contributes to climate change. The report by FAO (2014) titled "Food Wastage Footprint: Impacts on Natural Resources" estimated that 3.3 gigatons of carbon dioxide are produced from food waste, ranked as the third top greenhouse gas emitter after the United States and China. FLW also has social impacts as its coexistence causes hunger in different parts of the world by limiting access to safe and nutritious food for over a billion people (FAO, 2019).

Fresh produce like vegetables and fruits are very susceptible to loss due to their perishable nature and shorter shelf life (Surucu-Balci & Tuna, 2021). It is estimated that around 50%, or one of two vegetables or fruits go uneaten (FAO,2020) . One of the primary reasons for these losses is mainly linked to the lack of proper temperature control across the supply chains of fresh produce (Santos et al., 2020; Surucu-Balci & Tuna, 2021).

In the context of Australia, it was calculated that FLW costs the Australian economy about $20 billion annually. In 2017, Australia's National Food Waste Strategy was launched in an attempt to quantify FLW and devise strategies to reduce it. According to the National Food Waste Baseline report, it was estimated that in 2016/17, 7.3 million tonnes of food waste was generated across the entire supply chain. The report also revealed that primary production was responsible for 31% of this waste, processing for 24%, consumers for 34%, and retailers for only 3% (Verghese & Lockrey, 2019). A recent report by Commonwealth Scientific and Industrial Research Organisation (CSIRO) on mapping the fruits and vegetable losses by Juliano et al. (2019) stated that at the national level, horticulture supply chains at the production, processing and packing stage is losing 18 to 22% of its fruits and vegetables. At the production stage, these chains lose between 7 to 10%, while the remaining loss occurs at the processing and packing stage.

Temperature control and monitoring also impact fresh produce's shelf life and sensory quality (Tort et al., 2022). A single temperature disturbance or deviation at any stage of the supply chain can undermine the whole chain's efforts, leading to product spoilage and too-early ripening of fresh produce, leading to quality loss and reduced shelf life at the end of the chain. Thus, improper temperature control across any stage of the fresh produce supply chain leads to loss of nutritional value of the produce and in the end, revenue loss for producers (Aung & Chang, 2014; Mahajan et al., 2014).

Temperature control across the cold chain operations of fresh produce supply chains is considered to be one of the most uncomplicated procedures to delay its deterioration, extend its shelf life, maintain quality and safety and, in the end, reduce significant amount of FLW (Ndraha et al., 2018). In numerous scenarios, temperature control across the chain has positively impacted fresh produce's quality and shelf life. For instance, Managa et al. (2018) investigated the impact of temperature change across different activities in the lettuce supply chain. Researchers found that temperature variations significantly affect the visual quality and nutritional value of lettuce at retail, leading to economic and food loss. Furthermore, Brown et al. (2014) proved that maintaining temperature could save food, amounting to GBP 283.8 in the United Kingdom alone. Thus, temperature management along the food chain is integral to reducing FLW, enhancing shelf life, improving quality, and increasing customer satisfaction.

2.6. Cold chain processes in fresh produce

In the vegetables and fruits growing sector, cold chain generally starts right after harvesting fresh produce. Harvested product is precooled to bring its temperature down to appropriate food-specific storage conditions. After storage, depending on the market demand, fresh produce is then transited in refrigerated transport through land, air, or sea to other storage facilities or distribution centres. A distribution centre is critical in the cold chain because produce from different points is combined, sorted, and then distributed to relevant markets (Mack et al., 2014). The cold chain ends when consumers get fresh produce and put it in a domestic refrigerator. Every step in the cold chain is critical and significantly impacts food quality, safety, and waste (Mercier et al., 2017). Cold chain management processes can be broadly classified into three stages, which are: pre-cooling, storage, and transportation.

2.6.1. Pre-cooling stage

At this stage, field heat from the harvested produce is extracted. This stage is aiming to slow down the physiochemical activities in fresh produce, minimise the destruction of nutrients, and reduce the shocks of temperature fluctuations in the subsequent cold chain operations (Han et al., 2021). There are a variety of pre-cooling techniques, including hydro-cooling (Reina et al., 1995), room cooling (Thompson, 2016), vacuum-cooling (McDonald & Sun, 2000), forced air-cooling (Thompson, 2016), and cryogenic cooling (Curtis et al., 1995). Hydro-cooling uses chilled or cold water to lower the temperature of the fresh produce before storing it in a cold room. Room cooling is a traditional method in which product is placed in a cold room to remove field heat from produce. In vacuum-cooling, moisture from the crop is evaporated through lowering pressure. Vacuum-cooling is used when rapid cooling of the product is required. Forced air-cooling is usually achieved by creating air pressure which allows the cold air to circulate around the warmer product and then flow back into the refrigeration unit for re-cooling. Cryogenic cooling consumes liquid nitrogen or dry ice in a tunnel where the product is passed through the liquid nitrogen and the product temperature drops rapidly. It is usually used for frozen foods.

The choice of using a pre-cooling technique depends on several factors, including mechanical properties of the fresh produce, economic factors, harvest volume, and market demand (Duan et al., 2020). For instance, a forced air-cooling technique works well for pre-cooling strawberries, whereas with tomatoes, it causes physical damage and bruises due to higher air pressure on delicate outer skin (Mercier et al., 2017).

Several studies claim that pre-cooling is the most important and critical stage for maintaining quality and storage of perishable produce across the supply chain (Brosnan & Sun, 2001). Recent research is mainly focused on enhancing rapid and uniform cooling of fresh produce (Han et al., 2018), reducing energy demand (Wu et al., 2019), and preventing or reducing food losses at this stage (Tagliavini et al., 2019).

2.6.2. Refrigerated warehouse

After the pre-cooling stage, fresh produce is transferred to a refrigerated warehouse (RW) which serves mainly to provide a stable and long term low-temperature environment to conserve their quality (Han et al., 2021). RW is critical to maintaining temperature, regulating transport capacity, and sustaining a balance in demand and supply. There are two main types of RWs: Cold Air Storage (CAS) and Modified Atmosphere Storage (MAS). CAS utilises air as a cooling medium, while MAS utilises CAS. It also adjusts the composition of the storage atmosphere by regulating the level of carbon dioxide and oxygen (She et al., 2018).

In recent years, most of the research has been directed at balancing the electric-power demand of cold storage facilities regarding fresh produce quality (Akerma et al., 2020). Uniformity of airflow and heat transfer during opening and closing doors of cold storage is getting considerable interest in recent research (Mditshwa et al., 2018). In addition, increasing research efforts are devoted to developing and optimising refrigeration systems and innovative technologies for reducing energy consumption (Bouzembrak et al., 2019).

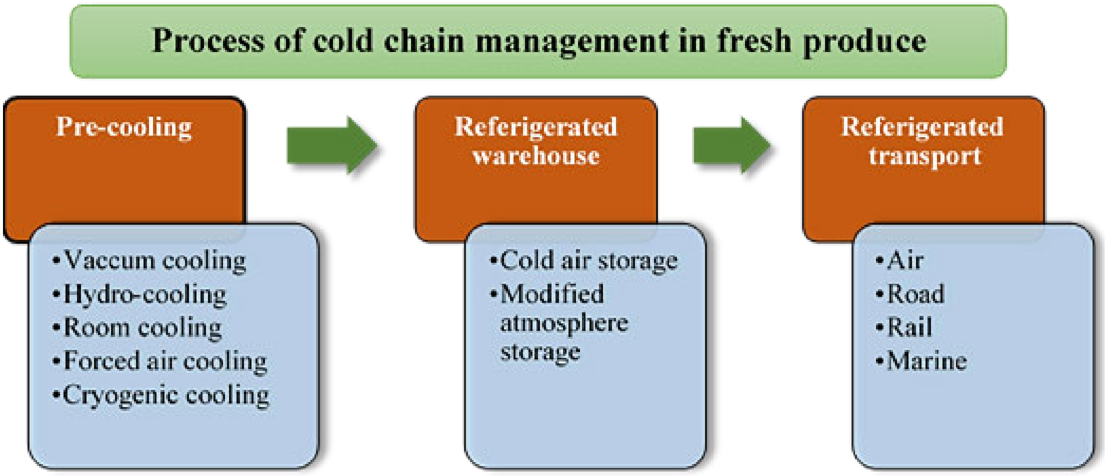
2.6.3. Refrigerated transport

Refrigerated transport links upstream and downstream members of the fresh produce supply chains and is an essential component in the post-harvest storage, handling, and distribution of fresh produce (Al-Dairi et al., 2022). There are numerous refrigerated transport modes, including air, marine, road, and rail. The selection of refrigerated transport depends on the market demand, economic value, cost, and consumer demand (Nath et al., 2018).

Refrigerated transport via roads is the most common inland and this is the focus of recent research. The primary purpose of refrigerated transport via road is to maintain the temperature of the produce rather than reduce it (Tort et al., 2022). According to a recent report of United Nations Environment Program on refrigeration, air conditioning and heat pumps, it is estimated that around 4 million refrigerated vehicles are in service around the globe to transport fresh food, and it is forecasted that this will grow by 2.5% each year by 2030 to meet the increasing demand of consumers worldwide (UNEP, 2022).

Unlike other post-harvest operations, transportation is one of the delicate processes in fresh produce supply chains due to presence of temperature fluctuations and other related complexities including lack of coordination among actors and long distances. Lack of proper temperature management in transportation of fresh produce is one of the main reasons for FLW, where 30-49% of the losses are reported in transport due to fluctuation in temperature and other mechanical damage (Al-Dairi et al., 2022). Sensitive and delicate fresh produce is often roughly handled in the transportation stage, which causes deterioration in the product quality. Therefore, recent research on cold chains is mainly focused on the homogeneity of temperature, humidity, and new technologies development to reduce the negative impact of transport mishandling (Yavas & Ozkan-Ozen, 2020). Cold chain processes involve in fresh produce chains are depicted below in Figure 5:

Figure 5
Cold chain processes in fresh produce supply chains



2.7. Technological trends in cold chain monitoring applications

It has been demonstrated above that there are considerable challenges with the cold chain of fresh produce, such as FLW, food safety, quality, shelf life, and changing consumer demands. Therefore, an intelligent system based on technologies would aid in reducing these challenges. The focus of this system would be to provide full traceability of temperature across all the agents in the fresh produce supply chains (Badia-Melis et al., 2018).

There is a vast array of sensor technologies in the market to monitor and control temperature and other environmental factors such as humidity, carbon dioxide, and ethylene; however, the scalability and its embeddedness across the actors of the supply chain is still a challenge due to numerous factors which are discussed in Section 2.8 below. Radio Frequency tags (data loggers), wireless sensor networks, thermal imaging, and the internet of things (IoT) are some of the evolving technological trends in cold chain management processes of fresh produce chains.

2.7.1. Radio frequency identification and wireless sensor networks

Applications of Radio Frequency Identification (RFID) and Wireless Sensor Networks (WSN) in various sectors of the agri-food industry, especially in cold chain management, have gained considerable interest in recent years (Pan & Liu, 2021). RFID is an emergent technology that can record product's history, including temperature, and provide accurate information about its status throughout different stages of the chain (Costa et al., 2013). RFID tags are instrumental in replacing the old bar code and contribute to the real-time visibility of products and objects, regardless of their geographical location (Zhou, 2021). A complete RFID system consists of three parts: tags, readers, and antennas. Radio signals are emitted from the reader to activate the tag and allow the data to be received. The communication between the tag and transceiver is activated through the reader which then decrypts the encrypted data store in the tag and transmits it for further processing through the antenna (Mosadegh Sedghy, 2018). RFID tags can be passive, semi-passive, and active. Passive and semi-passive tags send their data by reflection or modulation of the electromagnetic field. Passive tags do not have a battery, while semi-passive tags have a battery but only to charge the sensor and recording logic. Active tags have a battery and provide real time information upon its access and therefore these tags are expensive as compared to others (Badia-Melis et al., 2015).

RFID tags and sensors are now widely connected through WSN, consists of spatially distributed sensors connected through the internet and one or more sink nodes. Sensors monitor real-time environmental conditions such as temperature, vibration, motion, and geographical location (Badia-Melis et al., 2018).

Researchers posit that embedding RFID tags with WSN provides multiple benefits in effective cold chain management (Aung et al., 2011). Firstly, combining these two technologies offers richer information that facilitates better decision support and proactive localised management, thereby achieving higher safety of fresh produce across different cold chain activities (Kang et al., 2012). Secondly, if RFID technology is embedded into WSN, the tags and sensors can build a more intelligent network by sharing sensors and transmission capabilities. For instance, longer data transmission can be achieved, and further related information like location and other environmental conditions can be sensed, which is integral to the shelf-life estimation of fresh produce

(Alfian et al., 2017). An overview of data loggers that can be utilised in cold chain monitoring of fresh produce supply chains are presented below in Table 3.

Table 3

Various types of data loggers for cold chain monitoring of fresh produce

Type	Technology	Features	Uses	Data	Examples
Conventional temperature loggers	Connected through USB or via NFC	• Temperature data at a certain stage • Manual collection process	• Field temperature monitoring • Packing sheds • Cold rooms • Warehouses • Aircraft cabins • Ship containers	• Quality control • Reactive approach	• Sensitech • Flashlink • Deltatrak
Wireless temperature monitors (Non-sim based)	RFID technology and GPS technology	• Real time data • Automated email notification • Physical location	• Remote data monitoring • Weather stations • Product on the go temperature monitoring	• Real-time • Sharing information • Proactive approach	• Sensitech • TempTale • Blulog

Type	Technology	Features	Uses	Data	Examples
Wireless temperature monitors (Sim-based)	RFID+GPRS Technology	• View real-time data • Automated email and SMS notifications • Sharing the product's physical location using SIM/Tower locations	• Remote data monitoring • Product on the go temperature monitoring	• Real-time data about the quality • Sharing information with different stakeholders across the chain • Proactive approach to temperature issues across the supply chain	• Vacker • Emerson-Go real time • Sendum

2.7.2. Thermal imaging

A thermal imaging camera is utilised to record the infrared radiation from produce and converts it into a visible image which can then be used to record the temperature from the image (Ishimwe et al., 2014). Thermal imaging depends on emissivity, which means that the ratio of energy emitted from an object in comparison to a black body at the same temperature and can vary from 0 (perfectly white) to 1 (perfectly black) (Gowen et al., 2010).

This technology is used as an alternative in cases where it is possible to reduce the number of sensors within a system. Badia-Melis et al. (2017) investigated the feasibility of temperature measurement through thermal imaging technology in pallet covers where putting sensors was not practically feasible. Furthermore, Chen et al. (2013) also revealed the importance of thermal imaging technology in food safety. In this study, the authors suggested that as food travels through different stages, temperature variations can be effectively captured through thermal imaging technology. The use of thermal imaging technology is common in the fresh produce industry; however, there is still a lack of comparative studies to gauge the temperature of produce collected through actual probes to that captured through this technology (Rattanakaran et al., 2021).

2.7.3. Agri-food internet of things

The internet of things (IoT) is a network that connects objects with the ability to identify and interact to reach an agreed goal (Giusto et al., 2010). The primary purpose of IoT is to facilitate the exchange of information between interconnected devices irrespective of their locations (Zhong et al., 2017).

IoT has been emerged as an efficient system in the cold chain monitoring of fresh produce because of the enormous number of devices connected to the internet, as well as widely availability of internet and service providers (Naeem, 2019). Although applications of IoT are well established in agriculture, its utility in food supply chains has gained significant interest in operations like risk management along the chain, food traceability, ongoing monitoring of fresh produce, and development of intelligent packaging (Onwude et al., 2020; Popa et al., 2019; Tsang et al., 2018).

Numerous research studies have clearly identified the benefits of deployment of IoT in cold chains. For instance, Gupta et al. (2019) evaluated the scope of IoT applications in improving the performance of a fresh produce supply chain in which the logistic activities are outsourced to a third party. The authors found that incorporating IoT into cold chain management activities can improve farm profit by allowing chain members to identify spoilage of products in advance and rerouting it accordingly. Similarly, a review article by Ben-Daya et al. (2019) asserted that IoT sensors enable efficient collection of data to provide real-time visibility into every aspect of a chain.

Fresh produce supply chains are transforming and becoming more data-driven due to the availability of advanced and cost-effective sensors (Rejeb et al., 2021). However, agriculture sector is comparatively less digitalised as compared to other (Kodan et al., 2022). For instance, manufacturing, pharmaceutical industry and finance are adopting IoT, and great effort has been vested in enhancing its uptake (Badarinath & Prabhu, 2017). Therefore, the next section of the chapter will focus on adopting technologies in agriculture by providing an overview of prior literature. Table 4 below briefly outlines specific applications of IoT in the fresh produce chains.

Table 4
A review on applications of IoT in fresh produce supply chains

Technology	Applications	References
Internet of Things (IoT)	Improved food security and control	(Balamurugan et al., 2020; Beker et al., 2016)
	Chain transparency and traceability	(Grecuccio et al., 2020; Maksimović et al., 2015)
	Improving sustainability and reducing waste	(Andreopoulou, 2017; Cho et al., 2017; Jagtap et al., 2019)
	Transport/logistics optimisation	(Adarsh Kumar et al., 2020; Reddy et al., 2020)

Part C: Technology adoption in agri-food supply chains

This part of the chapter provides a comprehensive overview of the technology adoption literature in the context of agriculture and specifically in agri-food supply chains. It starts with exploring the definition of adoption and its relationship with farmers' decision-making processes. It then briefly discusses factors affecting technology adoption in agriculture. Following this, specific factors are identified from the literature about technology adoption in fresh produce supply chains. Conceptual models of technology adoption are presented, and it concludes with the study's theoretical framework.

2.8. Technology adoption in agriculture – definition and its relationship with farmer's decision-making processes

The concept of technology adoption in agricultural practices has always been ambiguous. Previously, adoption was often discussed as a binary concept, i.e., adoption versus non-adoption (Stoneman & Kwon, 1996). Recently, the concept of technology adoption has been changed and considered as a gradual process.

In this context Wilkinson (2011) lists some characteristics of adoption and presents that it as a dynamic and complex process rather than a static or binary one where certain aspects of a technology can be adopted while others cannot be easily embraced.

Adoption refers to the decision process of an organisation or an individual to make use of an innovation (Rogers, 2010). He defines the adoption process as "the process through which an individual or other decision-making unit passes from first knowledge of an innovation to forming an attitude towards the innovation, to a decision to adopt or reject, to the implementation of the new idea, and to confirmation of this decision" (Rogers, 2003, p. 121).

In agriculture, adoption of an innovation, new practice or technology is predominantly affected by the decision-making process of farmers (Rogers, 2010), therefore understanding the factors affecting the farmer's decision-making process is gaining momentum in recent literature (Hayden et al., 2021; Rose et al., 2018).

A farmer’s decision-making process is extremely complex and rarely purely rational (Burli et al., 2021). Therefore, to understand this process, one needs to take into account a wide range of complex individual-level factors, socio-temporal dynamics, contextual and institutional settings including the farmer's interactions (Reimer et al., 2014).

Pure economics research suggests that farmers are perfectly rational profit maximisers, and they make decisions based on careful analysis of factors leading to maximising utility from their actions (Anderson et al., 1977; Rougoor et al., 1998) and to which Nuthall and Old (2018) refer as a formal decision-making process. However, considering all relevant factors in the decision-making process, research suggests that the majority of the farmers do not tend towards the formal decision-making process (Hardaker & Lien, 2010). For instance, Nuthall and Old (2018) clearly identified the role of intuition in a farmer's decision-making process. Similarly, in the case of Irish farmers, it was found that that their decision-making process is not largely influenced by financial factors. As Hayden et al. (2021) stated, farmers do not conduct detailed financial analyses before proceeding with a strategic farm expansion strategy.

How digital technologies have been adopted on farms has been a consistent focus of inquiry in rural and agricultural studies. Generally, studies tend to fall into three main research foci:

1. understanding farmers, farm characteristics and economic conditions (Pathak et al., 2019);
2. structural conditions for adoption (government regulations and location i.e., regional versus urban) (Marshall et al., 2021); and
3. type and nature of technology (Liu et al., 2021).

Given that this study aims to investigate and explore individual, technological, and institutional factors of digital technology adoption, the challenges are mainly divided into five categories. These are farm-level characteristics, farmer characteristics, economic factors, behavioural and psychological factors, and technological-related factors, as discussed below.

2.8.1. Farm-level characteristics

Understanding farm-level characteristics provide insights into adopting technologies at a specific time. Shang et al. (2021) reviewed 32 empirical farm-level studies on the adoption of digital and precision farming technologies. They found that farm size is positively related to the uptake of technologies. Large farms are more susceptible to adopting new technologies due to economies of scale and are most likely to afford the initial investment (Prokopy et al., 2014; Tamirat et al., 2018a). Similarly, in the case of digital technologies adoption, Gloy and Akridge (2000) found a positive relationship between farm size and computer adoption; however, they described the effect as insignificant. In the same pattern, it is also speculated that technology providers also target larger farms as they have the potential for higher sales volume (Tamirat et al., 2018a).

The biophysical condition of the farm is also correlated with the uptake of technology at the farm level. For instance, yield variability and location of the farm are found to be a significant factor in the study of Barnes et al. (2019) exploring the adoption of precision agricultural technology in Europe. Researchers concluded that farmers with high-yielding quality land might anticipate more significant benefits from adopting a technology than a farmer with low-quality yield land.

Land ownership and its impact on technology adoption were also discussed in different studies. The study of Gao et al. (2019) explicitly stated that land tenure security has impact on the adoption of green control technology across 443 family farms in two provinces of China. These authors posited that the more secure the land tenure of the farm is, the higher the probability of adopting new technologies. Similarly, Yang et al. (2022) examine the impact of land tenure stability on the adoption intensity of sustainable agricultural practices among banana farmers in China. The authors concluded that farmers' intensity to adopt sustainable agriculture practices was highly increased (by 30.55%) when they held higher stability of land tenure. Farm succession planning could be an essential factor influencing farmers' adoption decision of digital farming technologies; however, Paustian and Theuvsen (2017) found it statistically insignificant in their study of precision agriculture technologies in German farmers.

2.8.2. Farmer demographics

The demographics of farmers are often researched in farm-level studies to understand the adoption of certain technologies. In these, the farmer's age and education level have been pointed out as critical factors.

There has been inconclusive evidence of the relationship of farmer’s age with technology adoption. It is often perceived that farmer's age is a barrier to the adoption of complex digital farming technologies. The study of O’Shea et al. (2018) reflected that aged farmers hold a conservative attitude towards new technologies and are risk averse, while younger age farmers have an innovative attitude and are more risk takers and hence more open to trying new technologies on their farms. In addition to this, Vecchio, Agnusdei, et al. (2020) studied the adoption of precision agriculture technologies by 200 Italian farmers and concluded that farmers whose age were 43 years or less are more ready to adopt as compared to those who were above this age. In the Australian context, Zuo et al. (2021) studied the adoption of drone technologies across 991 farmers of broadacre, horticulture, and livestock in New South Wales, Victoria and South Australia. These researchers found that early users are more likely to be male, younger, and highly educated. However, they found a lack of significant association between farmer's gender and age in adoption of drones in the future,. In the same line, Pivoto et al. (2019) also observed that age is not a significant factor in technology adoption. While studying factors influencing the adoption of smart farming in Brazil, these researchers found that aged farmers adopt those technologies that are less labour intensive such as autopilot spraying, compared to younger ones. Therefore, the relationship between the farmer's age and technology adoption is not conclusive throughout the literature and depends on the contextual parameters and nature of the technology (Barnes et al., 2019; Shang et al., 2021). Education level of the farmer is also an essential factor in relation to the uptake of technologies on farms. It seems that education attainment of the farmer exerts a positive effect on the adoption of new technologies. The rationale behind this is the assumption that farmers with a higher level of education might better understand technologies, their applications, and their usefulness (Daberkow & McBride, 2003). Likewise, Caffaro and Cavallo (2019) found that a low level of education is positively associated with the perceived economic barriers, which in turn negatively affect the adoption of smart farming technologies among the farmers in North-Western Italy. In the Australian context, using drones in the future among farmers is also significantly associated with a higher level of education (Zuo et al., 2021).

2.8.3. Economic factors

Historically, farmer's behaviour as profit maximisers has been studied in adoption studies since the pioneering work of Griliches (1957). Increasing the uptake of technologies by the farmers to maximise their profits and/or to reduce costs has been the target of extension and policy efforts for decades. Initially, understanding the adoption of technologies or practices was mainly related to addressing the problem of low financial returns; however, the focus has recently been shifted towards more sustainability of the farms (Weersink & Fulton, 2020).

The key factor discouraging technology adoption is its initial investment. According to Long et al. (2016), initial cost of most technological innovations is prohibitive and hence reduces the farmer’s acceptance of technologies. The study by Jerhamre, Carlberg, and van Zoest (2022) on artificial intelligence in the arable farming context concluded that the most important factor that slows down the uptake process of smart farming technologies is the initial investment/cost of the technology which doesn’t include only the direct financial layoff that a farmer is going to spend on the acquisition of technology, but it also consists of the effort of getting information about it and other indirect costs like labour hours to understand the technology. In the same pattern, most economic models assume that a farmer's decision to adopt a technology is based on maximising the present value of discounted future earnings; hence, two central elements are entering in this decision-making process which are risk (uncertainty about future earnings) and information acquisition through learning (J.P. Chavas & C. Nauges, 2020). Uncertainty about future return is a key aspect of technology adoption, especially in agriculture (Ahmed et al., 2020). Farming is a risky business; therefore, farmers are more susceptible to risks. They pay attention not only to expected returns but also variations in these returns in the future (J.P. Chavas & C. Nauges, 2020). The role of business cases or cost and benefit analysis is considered to improve the adoption of technologies in agriculture; however, the complexity of factors in agriculture and the heterogeneity of risks in this sector make it harder to develop cost and benefit analysis of certain technologies.

Recently, behavioural economics studies are entering into understanding the technological adoption in agriculture (Streletskaya et al., 2020; Weersink & Fulton, 2020). These studies mostly aim to unpack the “black box” of human decision-making and explore how human cognition and preferences are forming human decision-making and how humans are deviating from theoretical economic behaviours. For instance, Chouinard et al. (2008) found that some farmers are willing to forego some profits to be engaged in stewardly farm practices. Similarly, the study of Weersink and Fulton (2020) postulated that understanding technology adoption is not only based on the motive of profit maximisation but also on other factors aside from this driving behaviour change and therefore relying only on generic economic models could generate an overestimation or underestimation of the extent of adoption in the context of agriculture.

2.8.4. Psychological and behavioural factors

Understanding farmers' psychological and behavioural factors is getting more interest in the recent literature on technology adoption (Giua et al., 2022; Hüttel et al., 2022). Despite its importance in explaining the farmer's behaviour in adopting technology, little attention has been given to understanding the psychological factors.

For instance, a review and reflection on farmer's adoption of sustainable agricultural practices by Foguesatto et al. (2020) reported that there are very few studies to understand the psychological factors of farmers in innovation adoption.

Previous studies on understanding the psychological and behavioural factors have used the models discussed below in Section 2.11. However, current studies primarily focus on recent literature concerning understanding farmers' cognitive and psychological phenomena and decision-making processes. Contemporary literature goes beyond the psychological models of technology adoption and assimilates more factors such as attitudes, emotions, and intuitions.

The attitude of farmers has been studied vastly throughout the literature. Most of the studies focusing on the psychological factors of the farmers used the theory of planned behaviour which is discussed in Section 2.11.2. Attitude means “a psychological tendency that is expressed by evaluating a particular entity such as innovation and/or technology with some degree of favour or disfavour” (Eagly & Chaiken, 1998, p. 269). Numerous social psychologists have confirmed that an individual's attitude affects their behaviour and intentions (Davis, 1989; Fishbein & Ajzen, 1975). Studies regarding the adoption of new technologies and practices in agriculture concluded that farmers' attitude impacts the uptake of a technology. In the case of Malaysian farmers, Adnan et al. (2018) found that the attitude of farmers has a positive and significant influence on the intention of adopting green fertiliser technology. Similarly, understanding factors of adoption of smart farming technologies across France, Germany, Greece, the Netherlands, Serbia, Spain and the United Kingdom, Knierim et al. (2018) through empirical data found that positive attitudes of farmers regarding new technologies are the strongest predictor of their behaviour to use the technology in long run. In the case of the adoption of the IoT in agriculture, Pillai and Sivathanu (2020) went beyond the attitude of a farmer and found that the personal values of the farmer have a strong influence on adoption behaviour, and hence attitude can be impacted through their personal values. A recent study by Gerli et al. (2022) mentioned the role of emotions in the context of smart farming technology adoption and skill development. The researchers posited that the attitude of the farmers is shaped by the emotions that they feel about the smart devices and applications. Furthermore, these researchers also added that emotions of the farmers are the building blocks for the farmer’s attitude towards information seeking and learning about new technologies.

Intuition is also a critical component of a farmer's decision-making process (Nuthall & Old, 2018). Intuition has been referred to as a personal cognitive resource Eraut (2000), while Hogarth (2010) describes it as a person's cultural capital. In farmers' decision-making processes, heuristics and intuitions are used interchangeably and referred to as cognitive bias (Mankad, 2016). The concept of intuitive decision-making is particularly relevant in agriculture as most farms are small or family businesses with family members on board, so the main decision maker is either an owner or sole proprietor, consulting family members in making decisions (Nuthall & Old, 2014). Studying farmers' decision-making processes in terms of technology adoption is a promising study area, and more research is needed in this context.

2.8.5. Technological factors

Technological factors are those factors that are relevant to a specific technology and can be either be an enabler or inhibitor to its uptake by farmers. Certain factors are commonly discussed through the lens of diffusion of innovation theory and the technology acceptance model which are both discussed in Sections 2.11.1 and 2.11.3 respectively. In a recent review on the adoption and diffusion of digital farming technologies, Shang et al. (2021) identified complexity, compatibility, trialability, and data safety challenges of a technology as factors that can constrain its adoption in agriculture.

Complexity of technologies, especially the digital ones have been considered to be common. In the case of Brazilian grain farmers, Pivoto et al. (2019) conveyed that complexity in manipulating data and understanding smart farming technologies and their usability is a constraint for their adoption. Similarly, an overview of agriculture 4.0 by da Silveira et al. (2021) also postulated that the operational complexity of these technologies is one of the dominant factors for its scaling up across the farmers.

Compatibility of new farming technologies with the existing machinery and infrastructure is also denoted as a factor affecting its industry-wise adoption (Aubert et al., 2012). Kache and Seuring (2017) identified that interoperability and integration with existing technologies is a top concern for its users in terms of IoT adoption in supply chains. Similarly, in precision agriculture technologies, compatibility with existing farm infrastructure is considered crucial for its large-scale adoption at the farm level (Blasch et al., 2022).

Data security and safety are the most recent and one of the prominent factors which some scholars believe may present a risk to the effective implementation of digital technologies in agriculture (Lee et al., 2019; Phillips et al., 2019). Farmers are also resistant to sharing data with other supply chain members due to fears of data abuse, bad publicity, and data security which negatively affect the uptake of digital technologies (Qian et al., 2022).

2.8.6. Social factors

Social networks among farmers have a considerable impact on farmer's learning and decision-making processes, which then significantly correlate to the adoption of technologies (Maertens & Barrett, 2013). Similarly, a meta-analysis by Ramirez (2013) also established that farmer networks, either peer-to-peer and/or with other actors, are more influential in sharing information. Learning is a social process and hence it is mainly bound up within network relations (Lankester, 2013). Research on adoption and diffusion of technologies clearly suggests that the most common source of information and ideas exchange for a farmer is another farmer (Oreszczyn et al., 2010; Skaalsveen et al., 2020). Social ties between these networks influence the farmer’s attitudes, awareness, and uptake of new technologies (Wood et al., 2014). It is also worth mentioning that Pivoto et al. (2019) noticed that sometimes interaction with other farmers, who have a negative attitude to a technology, also negatively affects the adoption of technology. A possible interpretation is that it happens when other farmers hold adverse attitude towards a technology and negative opinion diffuses more easily and quickly in the social network.

Peer effect has also been described as a decisive factor in technology adoption. Peer effect refers to the influence of social interaction on an individual behaviour in a specific group (Manski, 2000). Several studies have shown that peer effects have widespread impacts in technology adoption, such as the study of Krishnan and Patnam (2014) on Ethiopian farmers' fertiliser technology adoption behaviour.

2.8.7. Institutional factors

Institutions are considered “rules of the game in a society” (North, 1990, p. 3), as they devise human interaction with each other (Ostrom, 2009). Institutions consist of formal or informal rules, organisations and beliefs which directly relate to human behaviour and technology adoption (Hodgson, 2006).

Different institutional factors are highlighted in the literature that directly impact on agriculture technology adoption. In the case of the adoption of smart farming technologies, Giua et al. (2022) synthesise that the organisational environment in which farmers work has an impact on the uptake of technologies. Furthermore, the effect of advisory services like tech providers, professional associations and government extension support has also been positively considered in technology adoption (Charatsari et al., 2020).

In precision farming technology adoption, Reichardt and Jürgens (2009) acknowledged the importance of government support, such as subsidies and credit facilities that can enhance farmer income and thus, they can start thinking of adopting new technologies. Similarly, strict rules and regulations regarding environmental conservation can compel farmers to uptake new technologies on the farm (Barnes et al., 2019). Table 5 below provides an overview of factors and their relationship with the adoption of different technologies in agriculture.

Table 5
Overview of the factors affecting technology adoption in agriculture

Factors	Indicators	Technology	Impact	References
Farm characteristics	Farm size Yield quality and variability	DT & PAT	+	(Prokopy et al., 2014; Shang et al., 2021; Tamirat et al., 2018b)
	Land ownership	ICT	+	(Gloy & Akridge, 2000)
	Succession planning	PAT	+	(Barnes et al., 2019)
		GCT	+	(Gao et al., 2019)
		SAP	+	(Yang et al., 2022)
		PAT	-	(Paustian & Theuvsen, 2017)
Farmer characteristics	Age	DT	-	(O'Shea et al., 2018)
		PAT	-	(Vecchio, Agnusdei, et al., 2020)
		Drones	-	(Zuo et al., 2021)
		SFT	^	(Pivoto et al., 2019)
	Education level	PAT	+	(Caffaro & Cavallo, 2019; Daberkow & McBride, 2003; Zuo et al., 2021)
Economic factors	Initial investment/Cost of technology	CSAT	-	(Long et al., 2016)
		SFT	-	(Jerhamre et al., 2022)
	Uncertain future returns	SFT	-	(Ahmed et al., 2020)
		SFT	-	(J.-P. Chavas & C. Nauges, 2020)
	Economic profit/ behavioural economics	SFT	^	(Chouinard et al., 2008)

Factors	Indicators	Technology	Impact	References
Psychological & behavioural factors	Attitude	GFT	+	(Adnan et al., 2018)
	Emotions	SFT	+	(Gerli et al., 2022)
	Personal values	IoT	+	(Pillai & Sivathanu, 2020)
	Intuition	TA	^	(Nuthall & Old, 2018)
	Entrepreneurial orientation	PAT	+	(Vecchio, De Rosa, et al., 2020)
Technological factors	Complexity	SFT	-	(Pivoto et al., 2019)
	Compatibility	PAT, DT	+	(Aubert et al., 2012; Kache & Seuring, 2017)
	Data safety	SFT	-	(Lee et al., 2019; Qian et al., 2022)
Social factors	Social network	DT	+	(Maertens & Barrett, 2013)
	Peer effect	DT	+	(Krishnan & Patnam, 2014)
Institutional factors	Organisational environment	SFT	+	(Giua et al., 2022)
	Role of advisory services	DT	+	(Charatsari et al., 2020)
	Government support /credit facility	DT	+	(Reichardt & Jürgens, 2009)
	Government regulations	DT	^	(Barnes et al., 2019)

DT= Digital Technologies, PAT= Precision Agriculture Technologies, ICT=Information Communication Technologies, GCT= Green Control Technologies, SFT=Smart Framing Technologies, IoT= Internet of Things, TA= Technology Adoption, CSAT=Climate Smart Agriculture Technologies, SAP=Sustainable Agriculture Practices

** + = Positive relationship, - = Negative relationship, ^ = Can be positive or negative

2.9. Technology adoption challenges in fresh produce supply chains

Understanding the adoption challenges of technologies in fresh produce supply chains (FPSC) is getting momentum in recent literature (Benyam et al., 2021; Narwane et al., 2022; Shoji et al., 2022). The supply chain of fresh produce is characteristically complex due to the nature of the produce's quality, safety, spoilage, seasonality, shelf life, storage and environmental conditions (Van Der Vorst & Beulens, 2002). Consumers are now more interested in the transparency and integrity of chains, which compels food supply chain actors to deploy technologies that can transform the current practices and provide agile information across the chain (Villalobos et al., 2019).

IoT has been considered to be one of the most prevalent and essential technologies to facilitate information sharing across FPSC through maintaining quality and freshness; however, there are numerous challenges.

Aamer et al. (2021) comprehensively reviewed the adoption challenges of IoT in fresh food supply chains. They reviewed 72 peer-reviewed articles published between 2010 to 2020 across 43 journals. They suggested 15 challenges classified into five main themes, which were technical, financial, social, operational, educational, and governmental. Furthermore, they also identified that technical, operational, and financial are the top three researched themes while the other two have received less attention in the published research. Another recent peer-reviewed article by Narwane et al. (2022) on identifying challenges of IoT adoption in the context of Indian fresh produce supply chains identified 24 factors. These authors also ranked these factors and hypothesised that technological factors such as lack of interoperability, trust issues, absence of security, and network challenges are the prominent areas of investigation.

Annosi et al. (2021) highlighted the role of coordination mechanisms and practices among supply chain actors and how these processes impact the adoption of digital technologies in FPSCs. The authors posited that coordination is one of the significant adoption challenges among different-sized firms along the supply chain of fresh produce. Furthermore, digital mindset and lack of it is one of the integral psychological factors constraining the adoption of digital technologies in fresh produce supply chains. Table 6 below presents an overview of the key challenges in adopting IoT in FPSCs.

Table 6
IoT adoption challenges in fresh produce

Theme	Key Challenge	References
Technical	Complexity	(Lezoche et al., 2020; Pillai & Sivathanu, 2020; Wen et al., 2018)
	Interoperability	(Ben-Daya et al., 2019; Guirado-Clavijo et al., 2018)
	Reliability of internet/ network	(Astill et al., 2019; Mustafa & Andreescu, 2018)
	Technical skills	(Lee & Lee, 2015; Lezoche et al., 2020)
Financial	Capital/initial investment	(Aryal et al., 2018; Lezoche et al., 2020; Pillai & Sivathanu, 2020)
	Operations and/or maintenance cost	(Anish Kumar et al., 2020; Verdouw et al., 2019)
Social	Collaboration among supply chain members	(Accorsi et al., 2017; Verdouw et al., 2019)
	Data security and trust among supply chain members	(Astill et al., 2019; Verdouw et al., 2019)
Psychological/ Behavioural	Digital mindset	(Annosi et al., 2021; Annosi et al., 2020)
	Ease of use	(Lezoche et al., 2020; Ndraha et al., 2018)
Governmental	Governmental regulations and policies	(Bouzembrak et al., 2019)

2.10. Agricultural technology adoption studies in Australia

Digital agriculture has been described as a revolution for the Australian agricultural industry (Huberty, 2015). A road map of Australian agriculture to reach a value of AU$100 billion by 2030 points out that it can be achieved through innovation and an increase in value through adopting digital technologies (Thomas, 2018). Perrett et al. (2017) estimated that improved decisions resulting from digitally generated information would increase the value of Australian agriculture by over AU$20 billion annually. Australian farmers have a strong reputation for innovation (Lowenberg-

DeBoer and Erickson, 2019), and also some notable technologies have originated from Australia such as soil moisture sensors and grain protein mapping (Lamb et al., 2008); however, the digitalisation and technology adoption in Australian agriculture is still considered to be immature and adoption as ad hoc (Blackburn & Gartner, 2017; Hansen et al., 2022).

The adoption of precision agriculture technologies in Australian agriculture has received more attention in the literature. Jochinke et al. (2007) studied the adoption of precision agriculture technology in the Australian broadacre cropping system. The authors carried out a cost and benefit analysis of adopting and comprehended that farmer’s age, education level, and collaboration among farmers and chain members affected the adoption of precision agriculture technologies. Similarly, a research project was also recently completed on the adoption of precision systems technology in vegetable production (Hort Innovation, 2020). The project has concluded that there is a high scope for adopting precision agriculture technologies in vegetable supply chains; however, fit-for-purpose extension pathways and understanding specific regional issues while considering demographics is imperative for increasing its adoption.

Recently, a shift has been observed from precision agriculture technologies to decision agriculture technologies in Australian agriculture (Zhang et al., 2017). With the advancement in digital technologies and big data analytics, increasing volumes of data can be captured, processed and manipulated through complex software tools, creating an opportunity for decision agriculture technologies (Wolfert et al., 2017).

Hansen et al. (2022) reviewed the current status and future of digital technologies in Australian agriculture. The authors focused on the technical, governance and social factors of digital technologies adoption. They mentioned that the fragmentation of digital technologies, absence of enabling legislations and policy, coordination between technology providers and users, and lack of a value proposition are the biggest challenges in deploying technologies. Furthermore, they recommended that a clear value proposition along with supportive legislation and policies can enhance digital technologies’ adoption in agriculture. In the same context, Marshall et al. (2022) studied agricultural technology adoption in south-eastern Queensland and found that the digital divide between the rural and urban areas of the country is one of the reasons for less adoption of technologies in agriculture.

2.11. Review of technology adoption models

Theoretical frameworks or models can provide a structured way of thinking and illustrate the method to investigate the impact of different factors in the technology adoption process. There has been a proliferation of numerous models in the last 70 years in various fields such as information systems, computer science, consumer behaviour and agriculture to demonstrate different variables and to fully capture the technology adoption process (Liu et al., 2018; Tey & Brindal, 2012).

The most prominent theoretical frameworks and models which have been studied are diffusion of innovation theory, the theory of reasoned action, the theory of planned behaviour, technology acceptance model and technology organisation and environment. Other cognitive models have also been employed, such as social cognitive theory and the theory of interpersonal behaviours to understand this complex process. Taherdoost (2018) suggests that more than one theoretical approach or model is necessary to understand the complex dilemma of human behaviour, the issue involved and related contextual factors, which this study has adopted as its theoretical framework.

A review of relevant literature on theories and models of the innovation adoption process is presented below to understand how individuals, groups and organisations tend to adopt innovative practices. Based on these models, a theoretical framework for the study is developed.

2.11.1. Roger's diffusion of innovation

E.M. Rogers in 1962 proposed the theory of diffusion of innovation (DOI) which is considered to be a foundational social science theory explaining the adoption of new practices or technologies. DOI has been instrumental in showing how, why and at what rate an innovation can be spread through social systems in an organisation or other group settings.

The adoption of innovation is a process that is communicated through certain channels over time and within a particular social system (Rogers, 2003). Innovation adoption is a complex process and each individual or group has a different level of adoption depending on their contextual and social outlook. Hence, a population can be segregated into five main categories (from earliest to latest adopters): innovators, early adopters, early majority, late majority, and laggards. The foundation of DOI is that innovation adoption is a social process involving four main elements. These elements are: a) precursors for adopting innovation, b) the communication process, c) adoption in a social system and d) time duration.

According to Rogers (2003), the process begins with innovation. Innovation may be an idea, product, practice, process, or an element of a process that is perceived as new by the potential adopters and is acknowledged as to be adopted. Furthermore, DOI explains certain characteristics of innovation which are relative advantage, compatibility, complexity, testability, and distinctiveness.

Relative advantage is the extent of the user's perception in considering innovation as better than the current practice, idea, or product it replaces (Rogers, 2003). The more the relative advantage of the innovation for the individual or organisation is, the faster it will be adopted. Relative advantage can be economic, comfort, social prestige, and environmental; however, there is no absolute rule that describes relative advantage because it depends on an individual perception and expectations of the users.

Compatibility is the degree to which innovativeness can be perceived to be aligned with the potential adopters' current values, needs, attitudes and experiences (Rogers, 2003). The more aligned the innovation is, the sooner and more quickly it can be adopted. Furthermore, complexity is the perception of the user to the degree that the innovation is difficult to understand and use. The more complex it is, the later it will be adopted. Complex innovation tends to be adopted more slowly because its users will need more time to develop skills for its use.

Testability is the extent to which an innovation can prove its value to potential adopters (Rogers, 2003). Verifiable innovations are easy to adapt to the ones that cannot be easily ascertained. Distinctiveness is the degree of visibility of the results to the adopters (Rogers, 2003). The more visible results stimulate the adoption process.

Communication, social system and time duration element in DOI refer to the process of creating, sharing and obtaining information among the potential adopters to reach a mutual understanding of innovation (Rogers, 2003). The main foundation of DOI is that the process of diffusion of innovation is a universal social process and the potential adopters must share their knowledge and experiences with others in the society to spread out the innovation process quickly. In other words, the social system constitutes the interrelated individuals, groups or units which are engaged in similar problem solving with a common goal. The social system includes and can be affected by key factors such as norms, behaviours and social structures (Rogers, 2003).

DOI has been extensively reflected in previous studies to predict adoption of innovation and technologies in different lines of research, such as in enterprise resource planning by Hsu et al. (2008), in marketing by Raynard (2017), in education by Sahin (2006) and in public policy (De Vries et al., 2016).

In agriculture, DOI has also been applied in the uptaking and spreading of technologies in extension services (Diederen et al., 2002). Furthermore, DOI is synthesised with other models, such as the theory of planned behaviour (TPB) discussed in Section 2.11.2 and the technology acceptance model (TAM) presented in Section 2.11.3, to get more insights into an individual behaviour. For instance, Tey and Brindal (2012) developed an integrative framework based on DOI and TPB to show multi-dimensional factors influencing the adoption of precision agriculture technologies.

2.11.2. Theory of reasoned action and theory of planned behaviour

It was assumed during the era of 1960s and 1970s that attitude determines behaviour but nevertheless scientifically proven. Ajzen and Fishbein (1975) conducted a study on attitude and behaviour to determine its relationship, but little evidence was found, hence proving that the assumption was false. They proposed that instead of attitude, that intention is strongly related to the behaviour in volitional control (individual's control), and the conceptual basis for the theory of reasoned actions (TRA) was proposed.

TRA is a series of social-psychological concepts and constructs linked together to understand and explains human intentions, subsequently, behaviour. This theory is based on the expectancy-value model, which assumes that human behaviour is rational and based on getting value from an action or activity. TRA suggests that intentions predominantly shape human behaviour. In TRA, the intention is the degree to which someone engages in a certain behaviour and the future likelihood of engaging in that specific behaviour. People are likely to act if it is planned rather than not (Fishbein & Ajzen, 1975).

Intentions in TRA are based on two factors: the attitude and the social norms of the person in the volitional control environment (Fishbein & Ajzen, 1975). Attitudes are shaped by a series of beliefs which in turn value the effect of the behaviour. For instance, if the outcome of the behaviour is seen as positive, healthy, beneficial, or desirable, then the individual's attitude will be positive, subsequently there is a greater likelihood of engaging in the behaviour, otherwise vice versa. In addition to this, the intention is also influenced by subjective norms. Subjective norms are the social pressure and perceptions of the expectations of peers and influential people for an individual, such as peer groups or family members (Fishbein & Ajzen, 1975). For instance, a suggestion of technology uptake for peer groups will create positive subjective norms, which will, in turn, develop an intended behaviour. Volitional control is an individual's ability to decide and have a will to engage in the behaviour.

TRA has been widely applied in investigating and predicting human behaviour in different fields, such as in marketing by Paul et al. (2016), in the health sector by McEachan et al. (2016), and in public policy (Tuck & Riley, 2017). In agriculture, it has also been used in predicting human behaviour in adopting innovative technologies, such as the study of Borges and Oude Lansink (2016) in understanding and predicting dairy farmers’ behaviours in uptaking technologies. Similarly, Rehman et al. (2007) surveyed 135 dairy farmers on understanding and adopting new technologies on their farms utilising TRA. They found that TRA is a useful approach that can provide interesting descriptions of the farmers and their behaviour.

TRA provided a foundation in predicting human behaviour under the volitional control situations which do not need any expertise, resources or social collaboration. This theory has been criticised because of its limited applicability, hence, Ajzen and Fishbein (1980) added a new construct to the theory named perceived behavioural control, through which the theory of planned behaviour (TPB) was presented.

The construct of perceived behavioural control is similar to self-efficacy theory. However, self-efficacy is the extent of an individual's perception of the ability to perform a behaviour (Ajzen, 2002). In contrast, behavioural control is the perceived control of the performance of the behaviour (Ajzen & Fishbein, 1980). In other words, perceived behavioural control is an individual's perception of how easy or difficult it is to perform a behaviour. The behavioural control of a person is directly impacted by a set of control beliefs, including the factors that help or hinder the performance of the behaviour. In summary, according to TRA and TPB, attitude, subjective norms, volitional controls, and behavioural control affect a person's intentions and behaviour.

TPB has been instrumental in predicting the behaviour of farmers in diversifying their businesses, as studied by Hansson et al. (2012), in conservation management by

Mastrangelo et al. (2014), and in climate-smart technologies adoption (Mishra et al., 2014).

TPB has also been criticised and some researchers suggest that it is not a complete solution to the current challenges of human behaviour. They suggest that TPB does not include the role of habits and emotions which is also a strong predictor of human behaviour (Taherdoost, 2018). In addition to this, some researchers have pointed out that human behaviour is continuously evolving and it changes after any interaction with a new system or innovation and hence it has the shortcoming of explaining the human behaviour in different contexts, which proposes a challenge in predicting human intentions in changing situations, and hence it gave birth to the theory of interpersonal behaviour developed by Triandis (1979) which incorporated the role of habits, social and emotional factors in affecting human behaviour. Figures 6 and 7 graphically presents TRA and TPB respectively.

Figure 6
Theory of reasoned action (Fishbein & Ajzen, 1975)

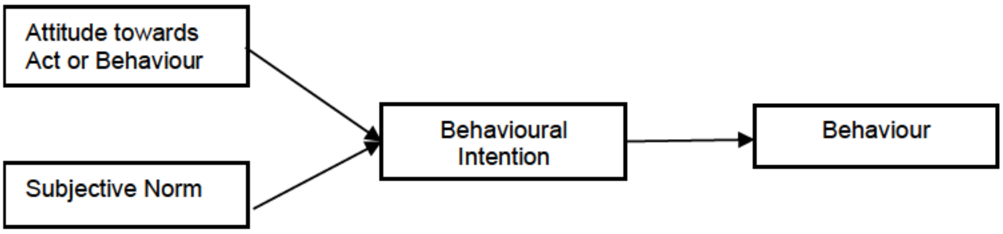
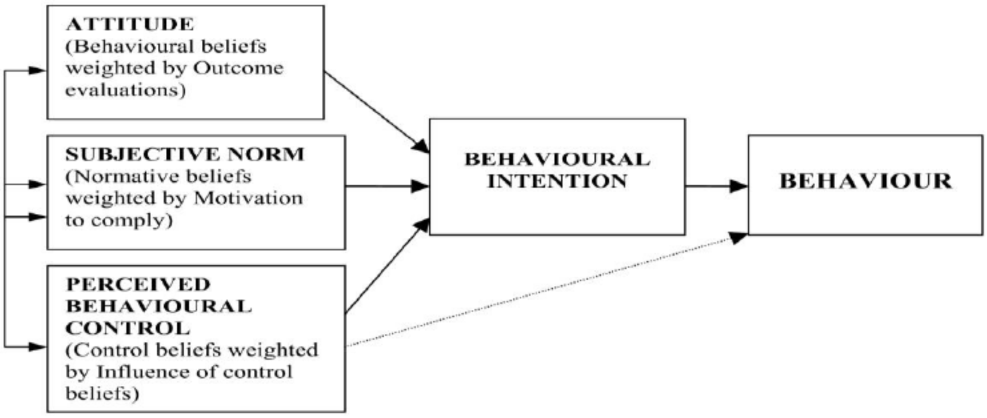


Figure 7
Theory of planned behaviour (Ajzen & Fishbein, 1980)



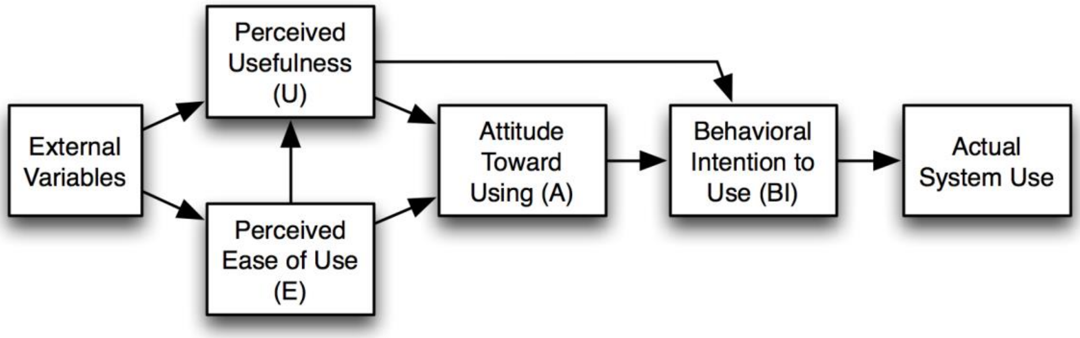
2.11.3. Technology acceptance model

Davis (1985) introduced Technology Acceptance Model (TAM), developed on the theoretical underpinnings of TRA and TPB. Likewise, TRA and TPB, TAM also considered that human behaviour is shaped by intentions and attitudes; however, TAM did not consider the role of social influences i.e., subjective norms in determining human behaviour. TAM is specifically tailored for the adoption and acceptance of information systems and technologies (Lai, 2017). TAM proposed that a new technology or system’s perceived ease of use (PE) which is a person's belief that the new system or technology will be easy to use and perceived usefulness (PU), which is a person's belief that the new system or technology will improve his/her job performance has a strong impact on human behaviour related to the adoption of technological innovation. The model postulated that external variables such as system characteristics, development and the training process of a new technology determine PE and PU. This model also assumed that PU could be influenced by PE and a combination of both, building an attitude towards using the technology which can shape the behavioural intention of humans and leads to the actual use of the technology. The behavioural intention of a person can also be influenced by the perceived usefulness of technology.

TAM has been applied, validated and replicated by researchers and practitioners across different disciplines, such as in education by Akman and Turhan (2017), in marketing technologies by Kim and Woo (2016), and in computer science and mobile technologies (Mugo et al., 2017). This model has been considered one of the robust models across different technologies and cross-sectional studies in agriculture (Taherdoost, 2018). Kurosh and Saeid (2010) used TAM in integration with the innovative characteristics of precision agriculture technologies and found out that certain characteristics of the technology, such as observability, trialability and attitude to use positively affect intention to adopt. The authors also found that intention to adopt is the most important factor in technology adoption, however, PE and PU indirectly influence the intention to adopt of precision agriculture technologies. Similarly, the behavioural attitude of the agricultural consultants and experts is one of the important determinants which affect the intention to use and adopt precision agricultural technologies by farmers (Far & Rezaei-Moghaddam, 2017).

TAM been criticised for excluding social factors and generally not providing sufficient understanding from the system designer's perspective by not offering characteristics for technological adoption (Hwang et al., 2016). In order to overcome the shortcomings of TAM, some other factors were added to explain the predictability and specificity of human behaviour and these models are being denoted as Extensions in TAM (ETAM) (Venkatesh & Davis, 2000). Figure 8 below presents a conceptual diagram of TAM.

Figure 8
Technology acceptance model (Davis & Venkatesh, 1996)

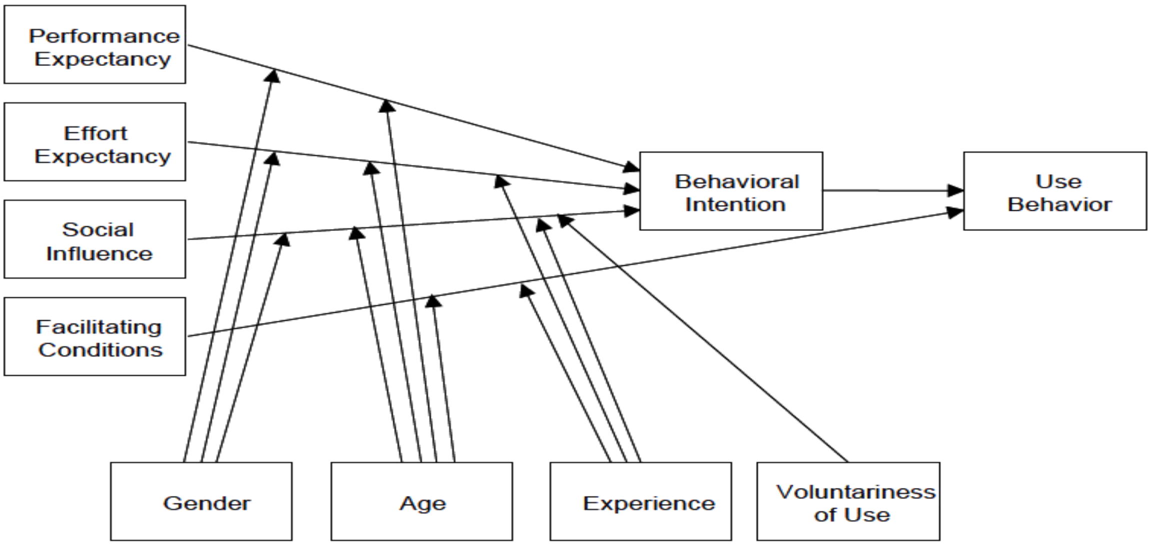


2.11.4. Unified theory of acceptance and use of technology

To overcome the shortcomings of TAM, Venkatesh et al. (2003) studied the previous models and presented the Unified Theory of Acceptance and Use of Technology (UTAUT). This unified model has four predictors of user's behavioural intentions which are: performance expectancy (the degree to which an individual believes that using the new system will attain gains in job performance); effort expectancy (the degree of ease associated with the new system); social influence (the degree to which an individual feels socially important with the use of a new system); and facilitating conditions (the degree to which an individual believes that organisational and technological environment exists to support). This model also integrates demographics such as age, gender, and experience and behavioural factors such as voluntariness of use.

This model has been empirically tested in different lines of study such as in education by Lawson-Body et al. (2018), in technologies adoption studies by Nysveen and Pedersen (2016) and also in agriculture (Engotoit et al., 2016). Ronaghi and Forouharfar (2020) studied the adoption of IoTs in the Middle East utilising the UTAUT model. They posited that performance expectancy, effort expectancy, social influence and facilitating conditions positively impact the intention to use IoT technology. They also mentioned that as the age of the farmer is increasing, acceptance of new technologies hardly happens. Similarly, high-income individuals are rarely risk takers and reluctantly adopt new technology.

Figure 9
Unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003)



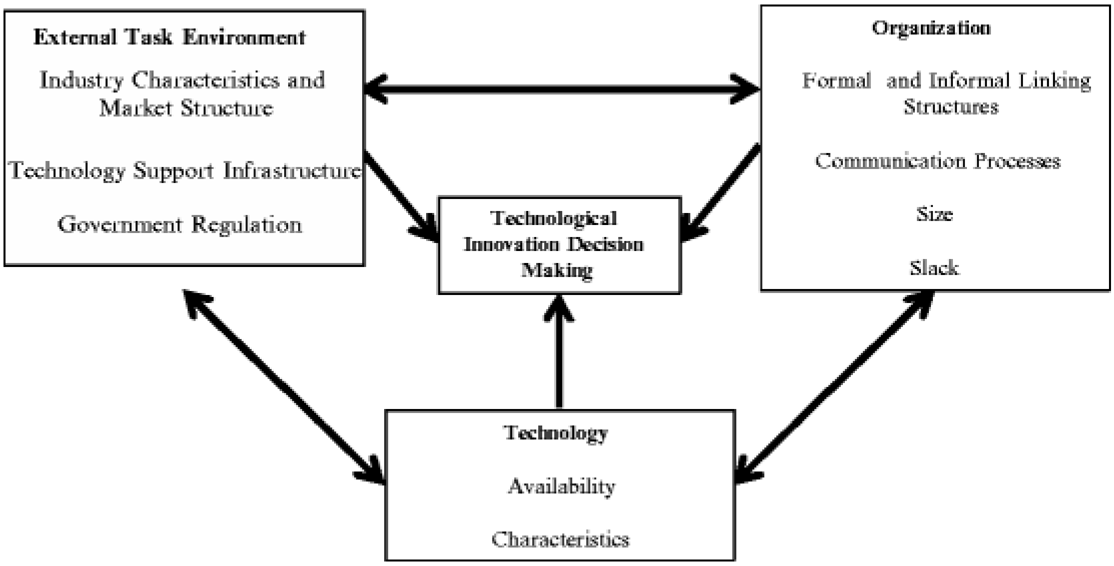
2.11.5. *Technology-organisation-environment framework*

This framework presented by Tornatzky and Fleischer (1990) is the first of its kind in the literature which proposes a generic set of factors to determine the likelihood of an innovation adoption. This framework identifies three aspects of an enterprise that influence the adoption of new innovation, which are technological context, organisational context and environmental context.

Technological context describes the internal and external technologies available to a firm, organisational context captures descriptive measures such as size, top management support, organisational readiness and technical capacity, organisational culture and quality of human capital (Kuan & Chau, 2001; Sabherwal et al., 2006). Environmental contexts are the operational facilitators and inhibitors in which competitive pressure, government regulations and technology support infrastructures such as access to ICT and consultants are dominant (Sabherwal et al., 2006).

This framework has been utilised extensively in adopting farm management information systems in the context of agriculture (Junior et al., 2019). Figure 10 below presents an overview of TOE framework:

Figure 10
Technology-Organisation-Environment Framework (Tornatzky & Fleischer, 1990)



2.12. Gaps in literature

Literature review has recognised that the nature of agri-food supply chains (ASCs) is more complex and has certain unique characteristics (as discussed in Section 2.2) which makes its management more challenging (Moazzam et al., 2018; Romsdal et al., 2011). In addition to this, these chains are also facing continuous challenges such as increasing world population, climate change, food wastage, price volatility, sustainability, and power and governance issues (FAO, 2019; Miranda et al., 2019).

Technology uptake and digitalisation of agri-food chains have a significant role to play in facing the above challenges (Ali & Govindan, 2021; Prause et al., 2021). However, the adoption of technologies and digitalisation of ASCs is still considered to be a challenge (Vern et al., 2022). Effective implementation of these digital technologies into the agri-food supply chains requires addressing various types of challenges perceived by the stakeholders (Panetto et al., 2020), including an understanding of their behaviour, psychology and contextual factors (Giua et al., 2022; Shang et al., 2021). In the same vein, a review article by Foguesatto et al. (2020) on understanding and reflections on farmer's adoption categorically mentions that the psychological and behavioural factors of farmer's decision making are poorly represented and measured across the literature on technology adoption.

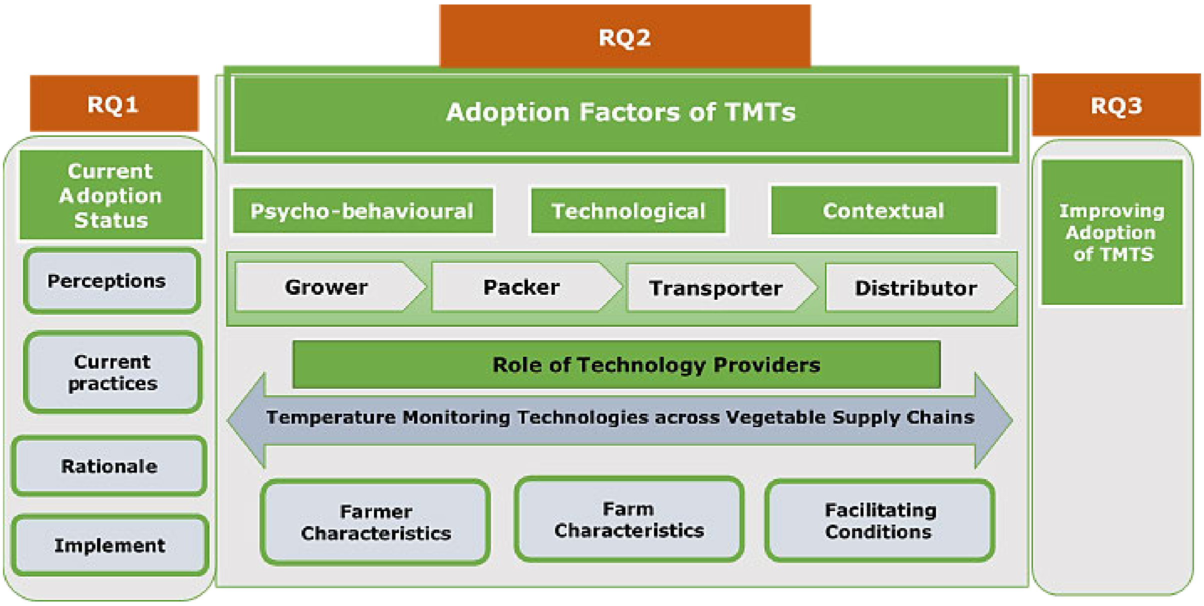
Han et al. (2021) comprehensively reviewed the previous research on cold chain logistics and identified Industry 4.0 adoption as a future research area that requires understanding from multi-disciplinary perspectives. Similarly, it also graphically presented the literature statistics on cold chain management between the year 2002 and 2020, which suggests that cold chain management is getting attention among researchers. In addition to this, Aamer et al. (2021) clearly stressed the need for conducting future research in the field of IoT, its application in cold chain management and adoption challenges in ASCs. Therefore, this study is an attempt to fill this gap by understanding the psychological, behavioural, and contextual factors of the industry in this case.

2.13. Theoretical framework of the study

Review of the predominant theories and models of technology adoption as discussed in Section 2.11 above clearly suggests that the adoption of technology in the context of agriculture is a complex phenomenon that calls for an integrated theoretical framework. Numerous scholars strongly support the application of multiple theories and constructs in the technology adoption literature. For instance, Mohr and Kühl (2021) applied TAM of Davis (1989) and TPB of Fishbein and Ajzen (1975) to investigate the behavioural factors of farmers influencing the adoption of artificial intelligence. Similarly, Laksono et al. (2022) also combined the TPB and TAM models to examine the psycho-behavioural perspectives of the farmers in the adoption of geographical indication technology. Adnan et al. (2019) combined the DOI of Rogers (2003), TPB and TAM to examine the decisions of Malaysian farmers regarding the adoption of green fertiliser technology.

In the same context, the theoretical framework of this study presented below in Figure 11 provides an integrated view of the adoption of temperature monitoring technologies in the vegetable supply chains. This framework combines factors from the DOI, TPB, TAM and TOE to answer three research questions of the study.

Figure 11
Theoretical framework underpinning research questions of the study



2.14. Chapter conclusion

This chapter presented the previous literature on three key interdisciplinary topics, which are: specific challenges of agri-food sector and its digitalisation, fresh produce cold chain management process and practices in fresh produce supply chains, and models of technology adoption. The chapter also identified that while there is a growing body of literature on the adoption of technologies in agriculture, an opportunity still exists to study the adoption of cold chain management digital technologies in the fresh produce sector in Australia.

Building on prior literature, this chapter finally presented a theoretical framework identifying key research questions. Upon this foundation, Chapter 3 will discuss the methodology of the study, outlining the research objectives, research questions, data collection and analysis techniques adopted for this study.

CHAPTER 3: METHODOLOGY OF THE STUDY

3.1. Introduction

This chapter is based on Chapter 2 which has identified the research gap and problem. According to Slife et al. (1995), the philosophical ideas of a researcher are mainly influencing the state of inquiry and hence, it is suggested that the researcher has to explicitly present their philosophical foundations. Therefore, this chapter aims to:

- clarify the researcher's perspective about the state of inquiry;
- identify appropriate methodological foundations to answer the stated research questions; and
- ensure the reliability, validity, and communicability of the outcomes to the target audience.

This chapter illustrates the fundamental methodological approach of the study to address identified research gaps. The chapter is organised as follows. Section 3.2 puts forward research questions of the study, Section 3.3 presents an overview of research paradigms and designs, and then the selection of an appropriate research paradigm and design for this study. Section 3.6 discusses an overview of the inquiry strategy and then selects an appropriate mode of inquiry for this study. Section 3.8 focuses on data collection, section 3.12 outline data analysis process and finally, the study's ethical considerations are discussed in section seven.

3.2. Research questions

The focus of this study is to identify the knowledge gaps and theoretical underpinnings around the adoption of temperature monitoring technologies (TMTs) in the vegetable supply chains by studying three selected case studies in Queensland, Australia.

The following three research questions are then presented:

RQ1: *To what extent temperature monitoring technologies have been adopted across vegetable supply chains?*

RQ2: *What are the current practical and behavioural perspectives influencing the adoption of temperature monitoring technologies across vegetable supply chains?*

RQ3: *How to enhance the adoption of temperature monitoring technologies across vegetable supply chains?*

3.3. Methodological foundations of the study

The methodology of this study is composed of three sections: research paradigms, research designs, and research ethics. In social science, the methodology is analogous to a road map that guides the researcher to answer the underpinning questions (Jonker & Pennink, 2010). The methodology of a study is based on the researcher's philosophical view of reality and its methods of uncovering (Blaikie & Priest, 2019); therefore, it is imperative that the researcher must have clarity about the different elements of the methodology. The following sections briefly explain different research paradigms and designs with the aim of selecting appropriate ones for this study.

3.3.1. Researcher philosophical orientation

It is important to explicitly discuss researcher's philosophical perspectives as it will influence the study's paradigm and design selection. Researcher's ontological stance is that there are multiple intangible realities that are socially and contextually constructed. Comprehending the essence of these realities needs a deeper understanding of individuals or groups who hold it. Researcher of the study also believe that understanding human behaviour is a complex phenomenon embodied in social actors' words and actions. To understand social constructs, a researcher must collect data about a phenomenon from those who have experienced it, which requires the psychological and emotional engagement of the researcher with the participants, which explains my epistemology.

3.3.2. Overview of research paradigms

The research paradigm is a researcher's underlying philosophical beliefs and orientation for viewing, analysing, and articulating a research phenomenon (Creswell & Creswell, 2017; Mackenzie & Knipe, 2006). It constitutes a researcher's core perspectives, abstract beliefs, and principles which inform the meaning and making sense of the research data. The research paradigm consists of four main hierarchical elements: epistemology, ontology, methodology, and axiology (Krauss, 2005; Lincoln & Guba, 1985).

Epistemology illustrates what counts as knowledge and how we come to know about reality or truth (Cooksey & McDonald, 2019; Hofer, 2001). It deals with the nature and forms of knowledge and how we can transfer the acquired knowledge to other human beings (Kivunja & Kuyini, 2017). Epistemology comprises how the researcher uncovers knowledge in the social context (Krauss, 2005). Ontology refers to the underlying assumptions, propositions, and beliefs we develop to make sense of a social phenomenon (Blaikie & Priest, 2019; Silverman, 2013). Methodology is a broad term that describes the research design, including methods and approaches to collecting data and its underlying assumptions and limitations (Creswell & Creswell, 2017). In sum, methodology is a systematic process of collecting data for the research. Axiology refers to the ethical considerations in conducting the research, including providing information about the research to the participants, getting their consent, and keeping confidentiality and privacy (Mertens & Ginsberg, 2009). Thus, epistemology, ontology, methodology and axiology characterise the research paradigm of a research study.

Social science researchers have developed several paradigms to understand complex human behaviour (Babbie, 2011). Denzin and Lincoln (2011) identified seven paradigms which were positivist/post-positivist, constructivist, feminist, ethnic, Marxist, cultural studies, and queer theory; however, these paradigms have been categorised by Creswell and Creswell (2017) into four, including post-positivism, constructivism, advocacy/participatory and pragmatism. The epistemology, ontology, methodology, and axiology of these paradigms are described below in Table 7 below.

Table 7
Description of research paradigms

Paradigm	Epistemology	Ontology	Methodology	Axiology	Reference
Positivism	Objectivist	Naïve Realism	Experimental/ quantitative	Beneficence	(Fadhel, 2002; Searle, 2015)
Constructivism / interpretivism	Subjectivist	Relativist	Naturalist/ qualitative	Balanced	(Guba & Lincoln, 1994; Morgan, 2007; Punch, 2013)
Critical/ transformative	Transactional	Historical realism	Dialogic	Culturally	(Kivunja & Kuyini, 2017; Lincoln & Guba, 1985)
Pragmatic	Relational	Non-singular reality	Mixed methods methodology	Value-laden	(Kivunja & Kuyini, 2017)

A positivism paradigm advocates that reality is objective, singular, and apprehensible through scientific methods of investigation (Searle, 2015). Fadhel (2002) postulated that human behaviour could be understandable through experimentation, observations, and rigorous scientific methods. This paradigm relies on that human behaviour is the result of a cause-and-effect relationship; hence, it can be quantified. This paradigm rests on the formulation of a hypothesis and then testing that hypothesis through a rigorous scientific method. Post-positivism is contemporary empirical research based on quantitative methods of investigation. This paradigm still has space in social science research as it can explain social patterns, regularities, and associations in longitudinal studies and surveys (Pawson & Tilley, 1997). This world view is useful for testing and validating a theory or concept within a large study population; hence, generalisability can also be an outcome through this paradigm (Johnson & Onwuegbuzie, 2004). However, critics of this paradigm suggest that in the social context, the reality is not objective and can be created through human interactions; hence, understanding a broad conceptualisation of reality through social interaction cannot be justified through experimentation (Stahl, 2003).

The central theme of the constructivist/interpretivist paradigm is comprehending that human interactions have subjective meaning (Guba & Lincoln, 1994). This philosophy assumes that reality is socially constructed, and to understand the essence of reality, a researcher has to make an effort to “get into the head of the subject being studied” (Kivunja & Kuyini, 2017, p. 33). In this paradigm, constructs are embedded and grounded in the data (Corbin, 1990). Researchers make sense of the data through their cognition and thinking processes while interacting with the study participants (Punch, 2013). On the other hand, knowledge created through this paradigm may not be generalisable, and results are open to a researcher’s bias and hence not suitable in some research settings (Johnson & Onwuegbuzie, 2004).

Pragmatism paradigm supporters argue that reality or knowledge about a world phenomenon needs a collective philosophical approach instead of a mono-paradigmatic orientation. Knowledge acquisition about a phenomenon cannot be solely understandable through scientific or experimentation methods, as advocated by positivists, but it also requires a lens of social and cultural reality, as supported by constructivists (Creswell & Creswell, 2017). This belief gave rise to a mixed-method philosophy termed pragmatism.

3.4. Justification of the research paradigm

The selection of an appropriate methodological research element depends on the researcher’s world view, the nature of the study including research questions, data type, such as numerical or narrative, and research field, for example natural science or social science. According to Patton (1990), staying with a single paradigm improves the methodological foundations of the study and overcomes the paradigmatic deficiencies; however other researchers do support multi-paradigmatic approaches. Firstly, this thesis will adhere to one research paradigm. This research applied a constructivist/interpretivist paradigm as this assumes that reality is not objective and can be created through social interactions and every individual across the vegetable supply chain has a different meaning of reality. Literature in the previous chapter suggests that there is a plethora of research on the adoption of technologies in other industries, such as information technology, allied health, and business management; however, there is still a gap in understanding adoption in agriculture. In addition to this, the focus of this research is to understand behaviours and psychological factors of members across the chain concerning the adoption of technology, so every member across the chain has a different meaning of this phenomenon. Following are the main points which support that this research should follow a constructivist paradigm:

- The researcher’s perspective is that reality has multiple meanings, and context is essential to understanding and communicating knowledge about reality.
- Adoption of technologies across a chain is a multi-level phenomenon, and understanding such complex phenomena requires a deep understanding of the chain stakeholders.
- This field lacks a body of coherent underpinning theory, so it requires an exploratory and investigative approach to discover the dynamic and complex nature of the phenomena across multiple levels.

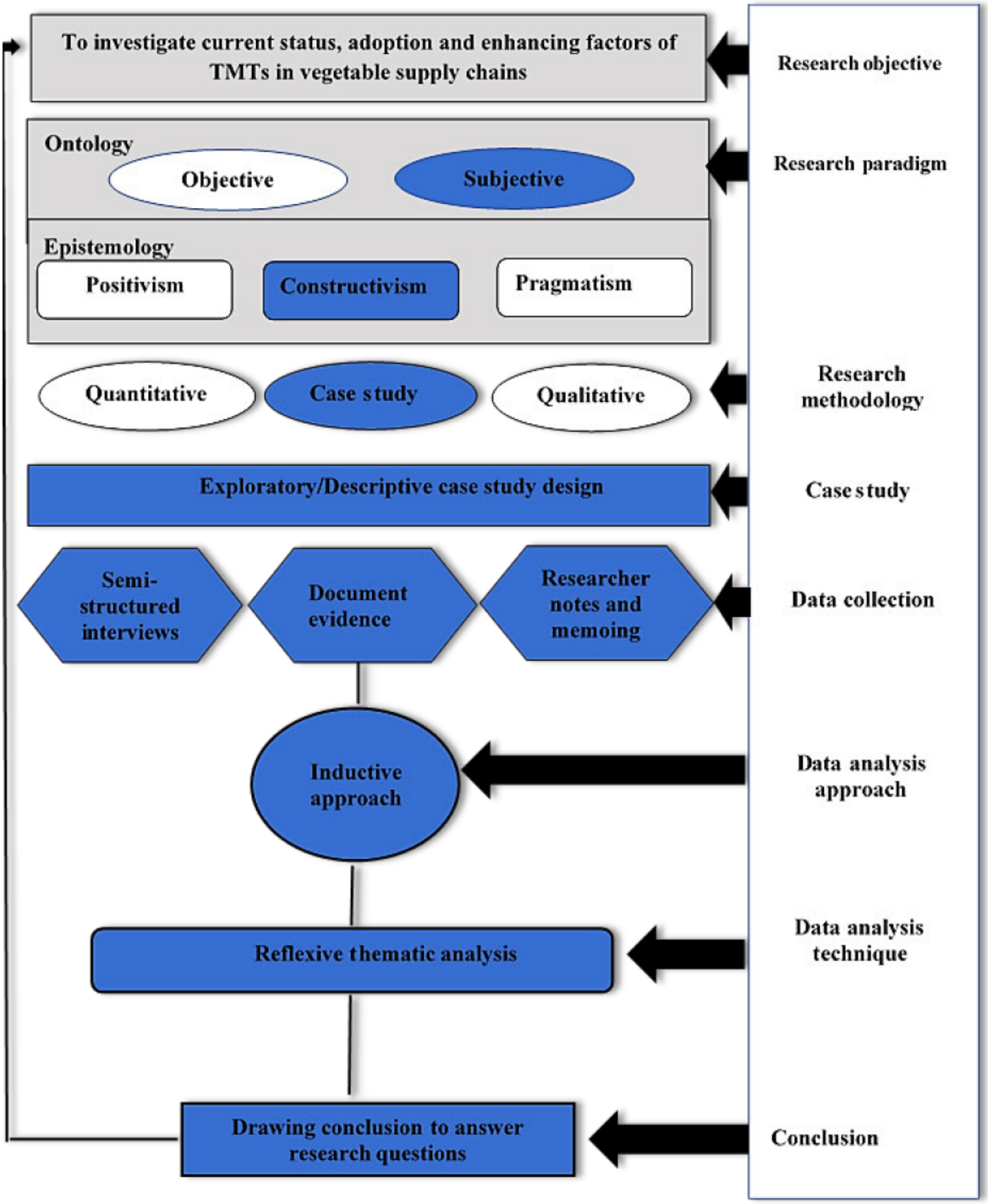
3.5. Research design and approaches

A research study can be classified into exploratory, explanatory, descriptive, or predictive, depending on the nature of the study and its objectives (Marshall & Rossman, 2014). An exploratory research design is utilised to explore a phenomenon that has not been investigated in detail in the past, and an explanatory design is adopted to explain the phenomena. Descriptive research design describes the phenomena in detail by illustrating facts and figures, and predictive design predicts the outcomes of the phenomenon by keeping certain variables in view. A research study can also be classified into qualitative, quantitative, and mixed, based on the nature of the data (Creswell & Creswell, 2017). Quantitative research includes experiments, surveys, and numbers, based on the deductive approach to data analysis, while qualitative research includes interviews, observations, and ethnography as a data source through case studies and a narrative approach. Mixed methods utilise quantitative and qualitative data sources and combine data analysis approaches such as experiments and interviews to get results (Creswell & Creswell, 2017; MacIntosh & O’Gorman, 2015).

The constructivist paradigm is aligned with the descriptive and exploratory design of the research and qualitative methodology is appropriate for this research study. Previous research on the adoption of technologies in agriculture has largely been focused on certain parts of the chain and on some specific technologies. This burgeoning stream of literature has emphasised an adoption of technologies on a larger population using surveys and other quantitative techniques. The inherent rigidity of the questionnaires and other quantitative methods cannot explain the technology adoption phenomenon in detail (Punch, 2013). In addition to this, the understanding of the general adoption of technologies in the vegetable industry in Australia focusing on TMTs is understudied.. Hence, this study aims to describe and investigate the adoption of TMTs in the Australian vegetable sector, and therefore the research design should be descriptive and exploratory. Semi-structured interviews will be undertaken, and case study method will be followed as a strategy of inquiry.

In summary, this research will follow constructivist/ interpretivist epistemology and have a subjective definition of reality. As the research design is descriptive and exploratory so the strategy of inquiry is completing case studies, and data will be qualitatively collected through semi-structured interviews. An inductive approach will be employed for the analysis of collected data. Figure 12, adapted from O'Gorman and MacIntosh (2015, p. 51), highlights the methodological framework of the study.

Figure 12
Methodological framework of study (MacIntosh & O'Gorman, 2015)



3.6. Strategy of inquiry

Literature suggests an array of different strategies of inquiry, such as case studies, surveys, simulations, experiments, and action research (Creswell, 2009). However, in terms of qualitative research, Creswell and Creswell (2017) grouped it into four main categories: ethnography, grounded theory, case studies, and phenomenological. Collis and Hussey (2013) added action research, feminist perspective, hermeneutics, and participatory inquiry to the list while discussing business research inquiry strategies. For the simplification and nature of this research, Table 8 below illustrates the dimensions of inquiry strategy (Creswell & Creswell, 2017).

Table 8
An overview of inquiries methods in qualitative research

Inquiry strategy	Aim	Data collection technique	Data analysis procedure
Ethnography	Focus on social/cultural aspect	Interviews, observations, and referrals to historical records	Descriptive analysis and interpretations
Grounded Theory	Developing theory from the data within	Open interviews until theory development	Descriptive, open coding, coaxial matrix development
Case studies	Analysing single or multiple case studies	Semi-structured interviews, observations, field notes	Statements, Descriptive, Thematic, and content analysis
Phenomenological studies	Understanding experience of a phenomena	Interviews with the participants related to the phenomena	Descriptive, thematic content

Section 2.12 in the previous chapter identified that there is a plethora of research available on the adoption of technologies in agriculture; however, scarcity still

exists on understanding the underlying psychological and behavioural factors of technology adoption, specifically TMTs adoption in the context of the Australian horticulture industry. Based on this, therefore, the first challenge is to describe the context of vegetable value chains in Australia as a case study. Therefore, this research will follow the case study approach as an inquiry strategy.

3.7. Case study approach

The case study is a research method utilised to create an in-depth and multi-faceted understanding of complex phenomena in a real-life context (Forrest-Lawrence, 2018). Yin (2018, p. 2) suggests that a case study approach can be used when “main research questions are ‘how’ or ‘why’ questions, and you have little or no control over behavioural events, and your focus is a contemporary phenomenon”. In this study, there are three main criteria to consider the case study approach. Firstly, this research aims to understand the “how and why” perspectives of technology adoption in the context of vegetable supply chains in Australia, and secondly, this research is also attempting to gain a deeper understanding of different psychological, social, and organisational barriers towards adoption of TMTs in the case of vegetable chains. Thirdly this research will also explore the existing temperature monitoring practices across different stages of the vegetable supply chains.

3.7.1. Developing a case study protocol

Yin (2009) suggested that developing a case study protocol increases the reliability of the case study method. Developing a case study protocol is desirable in the case of a single case study; however, it is essential to have a protocol in multiple case studies. According to (Yin, 2009), case study protocol consists of the following:

- an overview of the study, including its objectives and scope,
- a detailed plan of the field procedures, including access to data, the privacy of the case study informants, and
- questions to be asked and reporting of each case study.

The case study protocol is an essential component of utilising the case study approach as a strategy of inquiry as it guides the researcher to anticipate problems while conducting case study research; therefore, a case study protocol (attached as

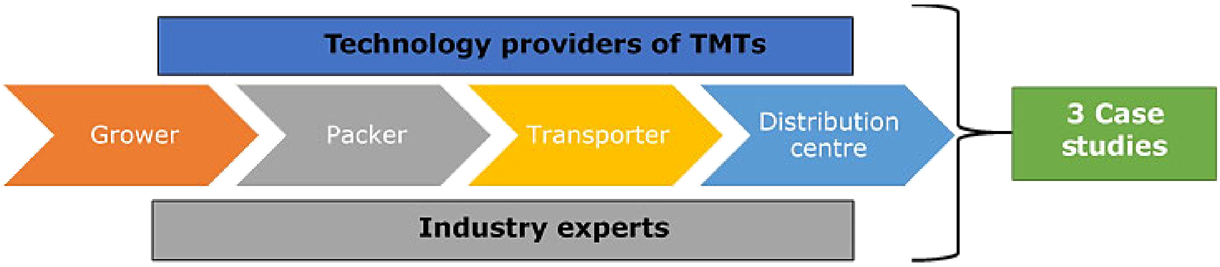
Appendix A) was also developed at the start of the study. Defining and selecting cases is also critical while conducting case study research; hence, it is described below.

3.7.2. Unit of analysis

Defining the unit of analysis is an integral component of qualitative study as it represents the boundaries of a study (Yin, 2009). In this study, the unit of analysis is a case. A case can be an individual, event, entity, or program having complex and distinct interactions (Yin, 2009). In this research, actors along each vegetable supply chain, along with technology providers of TMTs and experts, is a case.

Horticulture supply chains are complex interconnected networks having multiple channels of product flow from grower to consumer (Spencer & Kneebone, 2012). For this reason, this study follows a linear process of product flow from producer to distribution centre; hence each case study includes a grower, packer, transporter, central market or distribution centre member from the supply chain, and technology provider. Data were collected from three supply chains of vegetables including technology providers and experts. The first chain was engaged in providing broccoli to central markets in Brisbane and Sydney. Some of their produce was also exported. The second chain was primarily providing broccoli and shallots to central markets across Australia. The third chain was supplying Asian vegetables (mainly cucumbers) to the central market in Brisbane and Sydney. Experts are directly or indirectly involved with the improvement and development of horticultural supply chains and or working with allied organisations or in research institutions. Figure 13 below shows participants of case studies in this study.

Figure 13
Unit of analysis of the study



3.7.3. Sampling strategy

Sampling is selecting an appropriate “portion, piece or segment of a whole” (Onwuegbuzie & Leech, 2007a, p. 105). The scientific-based selection also adds credibility to the research and findings (Onwuegbuzie & Leech, 2007b). In quantitative analysis, the main objective of the sampling strategy is to obtain a large number of data which is statistically significant within the population with the aim to generalise its results; however, in qualitative research, this is not the case (Onwuegbuzie & Leech, 2007a). Sampling strategies generally can be classified into two main categories: probability (random) and non-probability (non-random) based sampling. A qualitative study employs probability or random sampling to generalise its interpretation, while a non-probability sampling strategy is used when the study objective is to get insights into real-life phenomena, events, or individuals (Onwuegbuzie & Leech, 2007a).

As this study aims to explore and gain insights into adopting temperature monitoring technologies in the vegetable supply chain, it will utilise a non-random sampling strategy. There are sixteen strategies identified by Miles and Huberman (1994) for non-random sampling. This study will follow a combination of three sampling strategies employed at different stages of the study. In the initial phase, a criterion sampling strategy was utilised. There were two criteria set for selecting a case for the study. The first criterion was that only a vegetable supply chain should be considered to be a case, and the second was that the vegetable grower should be based in southeast Queensland, mainly in the Lockyer Valley Regional Council (LVRC) area of the state of Queensland in Australia. In the second stage, a critical stage sampling strategy was utilised in which cases were selected that could provide rich information about the adoption of TMTs. In the third stage, during data collection, a snowballing technique was used in which the researcher asked participants to identify and recruit other participants in the upstream operations of the chain for this study.

There is agreement that interpretations from the qualitative study cannot be generalised; however, qualitative researchers still have discrepancies about the sample size. The sample size in qualitative research should not be too small that it cannot achieve saturation, and on the other hand, it should not be too large where deep understanding is not achievable (Sandelowski, 1995). Creswell (2002) recommended that qualitative researchers should do at least three to five case studies in a case study-based research. It is to mention that a case study can be an individual, entity, process, or organisational phenomenon that is socially extricable to study. Marshall et al. (2013) suggested a range of fifteen to thirty respondents to be involved in the interviews for case studies. Therefore, to achieve saturation in the research, twenty-five interviews were conducted.

3.7.4. Case study site

Lockyer Valley Regional Council (LVRC) was chosen as the case study site for this research, and vegetable supply chains were selected as the primary focus. The estimated population of this regional council in 2022 was around 42,663, with a population density of 18.77 persons per square kilometre. Agriculture is the most productive industry in LVRC, having an output of AUD$376 million during year 2020/21 (ID, 2023). This council was selected as a case study site for the following main reasons.

1. Firstly, vegetable production is the largest agricultural commodity, accounting for 44.3% of the whole agricultural output. Lockyer Valley represents 5% of Queensland's total agriculture output demonstrating a high-level of contribution to the vegetable production industry in the state. In addition to this, agriculture is the leading employer as it generated 2,833 local jobs in 2021/22 (ID, 2023).
2. Secondly, the researcher and supervisors have easy access to the different vegetable growers, other members of the chain, experts, and technology providers of TMTs.

3.8. Data collection techniques

Data was collected from multiple case study participants through a blend of different methods. It is suggested that employing more than one method for data collection allows a deeper understanding of the phenomena (Creswell & Creswell, 2017). Data collection techniques for this research are explained below:

3.8.1. Semi-structured interviews

The interview is considered to be one of the most important sources of case study evidence as it allows the researcher to engage in a conversation with the key informant and is likely to be more fluid than rigid (Yin, 2009). There are numerous typologies around the structure and rigidity of interviews (Fielding & Thomas, 2008). Yin (2009) has discussed three types of interviews in the context of case study research: formal survey, focused interview, and in-depth interview. Fontana and Frey (1994) generally classified interviews based on structure as structured, semi-structured, or open-ended interviews.

Structured or formal survey interviews employ a rigid style where questions are standardised, the interviewee uses the exact wordings for each question, and sometimes response outcomes are pre-coded. A semi-structured or focused interview is the type of interview where a list of questions is developed and used as a guide for a more conversational style. An unstructured or in-depth interview is a type of interview where the questions are not pre-planned, and investigation into a phenomenon is required. Developing an interview guide is essential to improve the content validity and reliability of the data (Fielding & Thomas, 2008; Yin, 2009).

In the case of this study, semi-structured or focused interviews were employed as they allowed the researcher to probe a deeper understanding of the phenomena (Roulston & Choi, 2018; Van den Berg & Struwig, 2017). Semi-structured interviews allowed efficient collection of qualitative data and the ability to reword or attune interview questions according to the situation (Robson, 2011).

3.8.2. Expert interviews

In qualitative research, experts are considered to have specialised and insider knowledge about a particular issue. The other benefit of having expert interviews is that it reduces the researcher's time for more data collection (Creswell & Creswell, 2017). In the case of this study, vegetable supply chain and technology adoption experts who have worked in this field for more than ten years were interviewed. At the start, three experts were approached through a referral from the supervisory team, and then a snowballing technique was utilised to access more experts.

3.8.3. Documentary evidence

Documentary evidence enhances the richness of the data as sometimes it confirms the findings of the data from a different source, thereby enhancing the reliability and validity of the study (Yin, 2009). In this case, documentary data took various forms depending on the case study. These documents comprised the farm's temperature monitoring practice memos, communication documents across the chain (recording temperature at each part of the chain), and quality assessment documentation. This data was collected from the supply chain participants to comprehend temperature monitoring practices.

3.9. Fieldwork process

At the start of the study, three main steps were followed to secure participation from vegetable chains.

3.9.1. Step 1: Initial contact with the farms

Initial approaches were made to the chief executive officer/owner of a vegetable-producing farm located in the Lockyer Valley district in Queensland, Australia. At the start of the study, the researcher approached an established vegetable-producing company referred by one of the supervisory team members. The researcher and the supervisor met with the company's two directors to discuss the proposed research, its benefit to the company and the overall vegetable industry, research ethics, and confidentiality. Participation in the study was sought; however, the company declined to be part of the study. After this, another vegetable farming company was approached by the researcher through the referral of one of the supervisory team members. A detailed meeting was carried out with the international marketing manager and the company owner. During the meeting, the study's purpose, benefits, and design were discussed, and the company's collaboration was sought. After the discussion, the company agreed to be part of the study, and a formal engagement plan (attached as Appendix B) was shared. The company's owner was then asked to approach their chain partners to be part of the study; this was the first case study of this research.

A Queensland Department of Agriculture and Fisheries extension officer referred the second vegetable chain. At the start, the farm owner was reluctant to engage; however, the researcher conducted some temperature monitoring experiments to show their importance. Temperature loggers (free of cost) were provided to the farmers to show them the temperature variability of their produce across different operations of the chain. After these experiments, the farm management realised its importance and agreed to be part of the study. It was also made clear to the farm management that this research strictly follows a confidentiality agreement, so their information will be only used for research purposes. The farm management was then asked to connect the researcher with other chain partners such as a transporter and market agent.

The third vegetable grower approached the researcher as part of the study. The researcher presented at a grower association meeting and demonstrated the importance of temperature monitoring and using technologies for this purpose. A meeting was carried out with the management of the farming company to discuss the research purpose, engagement plan, research ethics process, and their collaboration was sought. The researcher also requested during the meeting to be connected with other chain partners throughout the study.

Another vegetable-producing company was also contacted for data collection. A research collaboration meeting was held in which information, purpose, and engagement plan were discussed. After the meeting, the researcher tried to reach them again; however, they did not respond.

3.9.2. Step 2: Approaching other chain partners

As discussed above, the farm owners or managers in the first step were asked to contact other chain partners such as packers, transporters, and market agents to be part of the study. Appointments were made with the chain partners through email or phone, and an information sheet (attached as Appendix C) and consent forms (attached as Appendix D) were provided. Before engaging in this research, consent forms were signed by the chain partners. In addition, these chain partners were also asked to refer another partner from the upward stream operations of the chain to be part of the study. The researcher also approached technology providers through a referral from the Queensland Department of Agriculture and Fisheries' supply chain innovation team. Information sheets and consent forms were shared with the technology providers, and they were interviewed either face-to-face or over the phone.

3.9.3. Step 3: Approaching experts

At the start of the data collection, a list of experts was developed who directly work with members of the vegetable supply chains across the region on improving practices around temperature monitoring, enhancing the quality of fresh produce, and reducing food loss. Some of the experts were also referred by the researcher's supervisory team. An email including details of the study, ethics, and concept plan was shared with these experts, and their participation in the study was sought (attached as Appendix E).

Some experts were unavailable; however, others agreed to be interviewed, and most of these interviews were conducted online.

3.10. Field procedures

This section explains how the above-stated methods were implemented in the field.

3.10.1. Conducting interviews

Data for this research was collected through semi-structured interviews as it suits to understand the perspectives, expressions, and feelings of the supply chain participants in the case of qualitative research (Qu & Dumay, 2011). The interview followed an interview guide (attached as Appendix F) which lays out procedures and steps the researcher must follow during the interview process. For each chain member, separate interview guides were developed (attached as Appendix F, G and H) to obtain more comprehensive and up-to-date information from each participant (Kallio et al., 2016).

As Majid, Othman, Mohamad, Lim, and Yusof (2017) suggest, piloting a research interview is essential to test research questions and have a pre-practice of conducting an interview. Before entering the field, three pilot interviews were conducted. Two of these interviews were conducted with the PhD students who were at that time collecting data through interviews, and one interview was conducted with a grower. Pilot interviews allowed the researcher to refine research questions and reword them to make them more precise and understandable. These pilot interviews were recorded to check audio transcriptions and were then critically listened to by the researcher. This process identified that the researcher needed to focus on his style of asking questions, listening to the participants, and adding more probes like “why you think like this” and “how you are doing this” to elicit more detail and deep knowledge from participants.

During fieldwork, most of the supply chain case interviews were conducted face-to-face at the interviewee’s workplace, as suggested by Miller (1995), to understand their feelings and facial expressions. The researcher made sure to present himself as compatible with the work requirement and use appropriate language as part of the engagement process. At the start of the interview, the researcher introduced himself and then explained the main objectives and scope of the study and assured the participant that this study was for academic purposes only. The researcher also explained that this study follows strict ethical guidelines and that participants' personal and business identities would be anonymously represented. The interviewee was also provided with an information sheet detailing the research's nature, scope, and objectives. Before engaging in an interview, the participant signed a consent form. The researcher asked permission to record the interview for transcription, and all participants agreed to be recorded.

The primary purpose of the interview process was to gain trust and enhance the engagement of the participants, so the interview was started more conversationally. Jacob and Furgerson (2012) suggested that building rapport with the interviewee is vital; therefore, in the initial phase, more detailed background information like demographics and their farm or business background information and temperature monitoring management practices questions were asked. In the later stages of the interview, more in-depth questions related to the adoption of temperature monitoring technologies were asked. During this process, the researcher also probed the interviewee to have more in-depth knowledge, as suggested by McGrath et al. (2019). The interview ended with some feedback questions and recommendations for improvement. Twenty interviews were conducted from various actor of the vegetable supply chain including growers, packers, transporters and distribution centre staff members. However, one interviewee (transporter) from case study 2 did not want to be recorded and be part of the study after one week of the interview; therefore, the transcription of that interviewee was deleted and not included in this research. To understand the perspectives of temperature monitoring technology providers, three participants from technology provider companies were interviewed. All these providers were interviewed by phone and one technology provider was interviewed face-to-face.

All the interviews were recorded using a Sony recorder and transcribed through Trint (accessed at www.trint.com). Trint is paid online transcription website which uses artificial intelligence to transcribe speech to text. Initially, all interview transcripts were uploaded to Trint for transcriptions, and then the researcher listened to every interview and read the transcription and corrected if there were any discrepancies. The researcher also transcribed poor-quality recordings manually. Table 9 below provide information about details of interviews.

Table 9
Interview participants

Supply chain stage	Case study 1	Case study 2	Case study 3	Total	Interaction
Growers	2	2	2	6	F2F*
Packers	1	1	2	4	F2F
Transporters	2	2	2	6	F2F
Distribution centre staff	1	1	1	3	F2F
Vegetable supply chain Interviews	6	6	7	19	
Technology providers	1	1	1	3	F2F & online
Total	7	7	8	22	

(* refers to face-to-face interaction)

3.10.2. Horticulture supply chain and technology adoption experts

Expert interviews are important in exploratory research as they reduce the data-gathering process and provide insider knowledge of the phenomena (Bogner & Menz, 2009). As suggested by Meuser and Nagel (2009), experts were approached based on the formal status of the researcher and supervisory team of the study. These experts were known to the researcher and research supervisory team. In the initial stage of the study, seven experts were shortlisted to be interviewed for this study based on their previous and current professional experience working in the Australian horticulture sector, especially in vegetable supply chains and technology adoption. An email was sent to the experts, including a brief study overview, information sheet of the study and a consent form (attached as Appendix E). Six experts replied, of whom three agreed to be interviewed, and three declined. In total, twenty-five interviews conducted with the supply chain actors, technology providers and experts.

Interviews with the experts followed an interview guideline, and all interviews were conducted online through Zoom. Interviews started as a general conversation on practices of temperature monitoring along vegetable supply chains and issues with the uptake of these technologies.

More specific questions on barriers to the adoption of temperature monitoring technologies were asked, and then interviews concluded with recommendations and strategies for improving temperature monitoring technologies in vegetable supply chains. Details of the expert's interview is presented in Table 10 below.

Table 10
Expert's interview for the study

Expert	Experience in	Agency	Interview duration	Interaction
Expert 1	Temperature monitoring technology adoption	Government	45 minutes	Online
Expert 2	Agriculture technologies	Academic	1 hour	Online
Expert 3	Horticulture supply chain practice improvements	Government	34 minutes	Online

3.11. Establishing quality of research design

Case study as a strategy of inquiry and its ability in exploring a phenomenon in a natural setting has been utilised widely in qualitative research; however, this method is also inheriting weaknesses in its validity and reliability. Yin (2009) suggested four tests to establish the quality of case study research, and these tests are listed below.

- Construct validity, which refers to the identification of concepts based on established literature review and correct operational measures to the concepts,
- Internal validity refers to establishing a relationship among concepts where some conditions of the study or concepts lead to others.
- External validity refers to the identification of domains where the findings of the study can be generalised.
- Reliability refers to the rigour of data collection procedures and utilisation of the exact methods with the same results.

Yin (2009) also identified several tactics for conducting the case study research method to deal with its quality. These tactics, along with the procedures applied in this research, are presented in the Table 11 below.

Table 11
Case study design validity in the study

Test type	Quality tactic	Elements applied to this research
Construct validity	• Concepts and operational measures based on literature • Multiple sources of evidence • Case study report drafts	• Research design and constructs based on literature • Numerous sources of evidence through three case studies • Composing case study reports and developing case study protocols
Internal validity	• Pattern matching and explaining these concepts	• Patterns identified from the data through manual analysis and also through computer-aided software • Codes collated into categories and categories into themes to provide a chain of evidence
External validity	• Replication and generalisation of the case study results	• Employing multiple case study designs so that results are more robust • With in-case analysis to improve the generalisability of results
Reliability	• Use of case study protocols • Developing case study databases	• Case study protocols developed • Interview guides developed

3.12. Data analysis

Qualitative data analysis encompasses the processes of bringing order, structure, and meaning to the collected data. This involves data condensation, data display, drawing patterns from the data, casual flows, and propositions (Miles et al., 2018). In this study, the transcribed interviews were analysed utilising thematic analysis and NVivo software for graphical presentation of data.

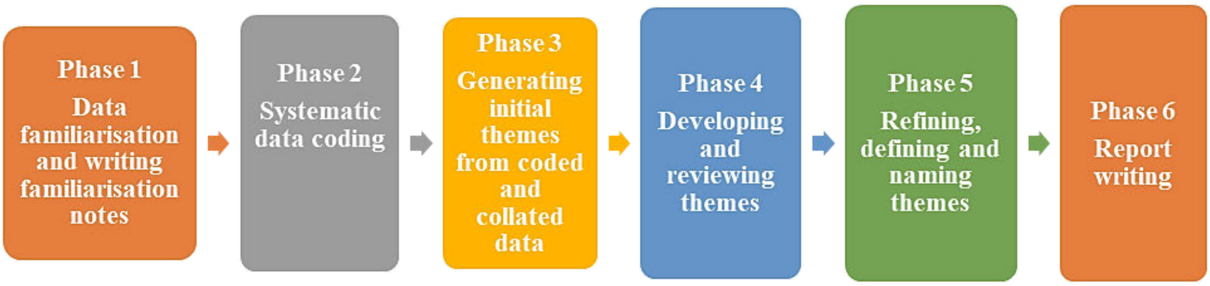
3.12.1. *Thematic analysis*

Thematic analysis is a method for identifying and analysing patterns of meaning in qualitative data (Braun & Clarke, 2006). This method is employed in this study to identify common themes expressed by the vegetable supply chain members in the interviews and to illustrate which themes are important to the description of the study. Theme represents something important in the data in relation to the research questions and embodies some sort of meaning (Braun & Clark, 2006). Overall thematic analysis involves listening, transcribing, writing up, reading and re-reading of qualitative data which forms a picture in the mind of the researcher. These pictures need to be reported in a systematic way so that others can see them and understand how a researcher comes to the findings and conclusion of a research study (Braun & Clarke, 2006).

This research incorporates an inductive approach in the identification of themes from the interview data. As themes from the qualitative data can be identified through the inductive approach of Boyatzis (1998), or deductively (Crabtree & Miller, 1992). An inductive approach means that themes are strongly linked with the data while deductive thematical analysis tend to be driven by the researcher's theoretical interests in the area and is more analysis driven (Braun & Clark, 2006).

Figure 14 below adapted from Braun and Clarke (2020, p. 331) shows a "six-phase process for data engagement, coding and theme development":

Figure 14
Six-phase process of thematic analysis adapted from (Braun & Clarke, 2020)



Step one

Microsoft Word document created by transcribing and exporting all the interviews with each member of vegetable supply chain. Recordings of interviews were listened to again and tallied with the provided transcription for any error or omission. This process allowed familiarisation with the data and understand the breadth and depth of the content. At this stage, initial ideas and patterns started emerging which were recorded in each document as comments for further use in analysis.

Step two

This step included generation of the initial codes from the interview transcripts. Code is an idea that seems interesting to the researcher and that is related meaningfully to research questions (Boyatzis, 1998). Initial codes assist the researcher to organise interview data into meaningful groups of information (Tuckett, 2005). In this study, the researcher used open coding which means there were no predeterminant codes. Initially, the coding process was carried out in Microsoft Word and in NVivo software, in which data was condensed into chunks of information as shown below in Table 12. These initial codes were discussed with the supervisory team for comments and suggestions.

Table 12

Examples of initial codes extraction from interview

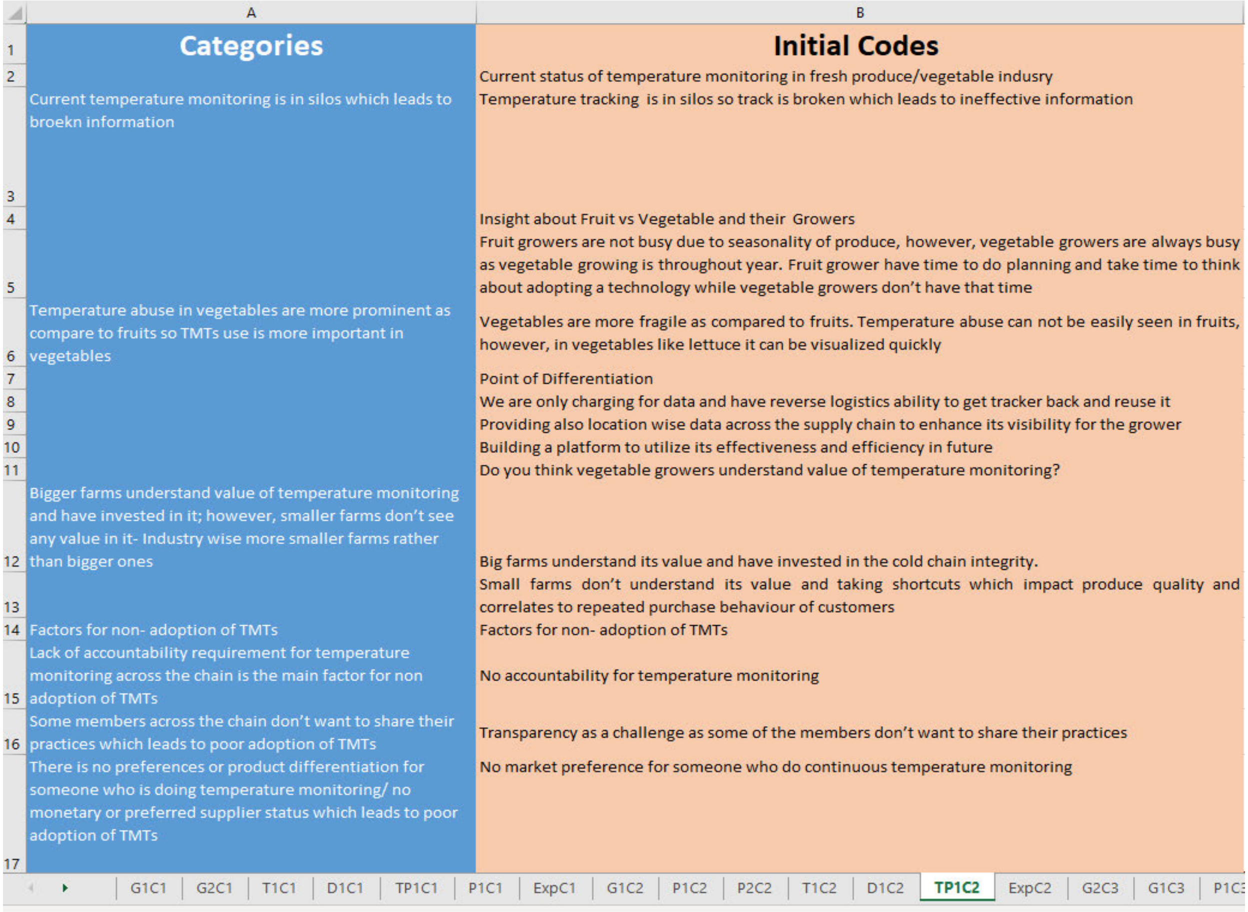
Interview Transcripts	Initial Summary/Codes
Q: Do you think vegetable growers understand the value of temperature monitoring? *I think big businesses do like in* [redacted] *and all of that understand the importance of time and temperature. I mean fundamentally their standards are critical and they have found that it is important for them and some of the businesses have actually put a lot of money into developing their infrastructure to make sure that they have good cool chain integrity.*	Big farms understand its value and have invested in the integrity of their cold chains.
Q: In your opinion, what are the main barriers to the adoption of temperature monitoring technologies in your business? *Cost and again, my opinion is, if you really want to see from start to finish, protect yourself all the way, at least every crate would need it. At the moment it is sort of like a token thing where you put 40- or 50-dollars tracker and want to know where it went and*	Cost main issue in technology adoption. Sensor is costly and currently it's like a token thing. Reliability of current technology and assistance in decision making questionable.

that is it. And then reliability of that technology and getting something out from technology.	

Step three

According to Braun and Clarke (2006), theme is a concept or pattern which assimilates similar and interesting information about data and/or research questions of the study. During this step the initial themes were gathered from coded and collated data. After this, initial codes from each interview were exported from Microsoft Word to a single file of Microsoft Excel. Microsoft Excel can be a useful tool for organising data into categories and developing themes (Bree & Gallagher, 2016) Each tab in the Microsoft Excel file was representing codes from a single interview. The codes were read again and succinctly labelled into groups called categories depicted in Figure 15 below. Categories represent groups of similar codes (Braun & Clarke, 2006). This helps in not only reducing the pieces of data but also acts as an intermediary concept, leading to themes.

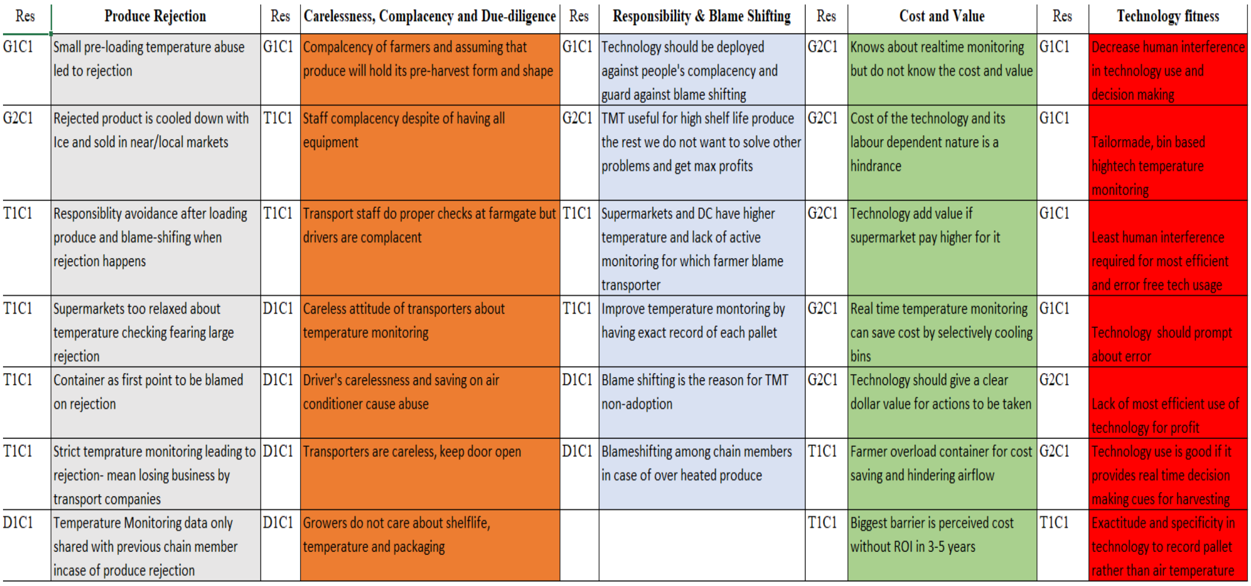
Figure 15
An example of generation of categories from initial codes



	A	B
1	**Categories**	**Initial Codes**
2	Current temperature monitoring is in silos which leads to broekn information	Current status of temperature monitoring in fresh produce/vegetable indusry Temperature tracking is in silos so track is broken which leads to ineffective information
3		
4		Insight about Fruit vs Vegetable and their Growers
5		Fruit growers are not busy due to seasonality of produce, however, vegetable growers are always busy as vegetable growing is throughout year. Fruit grower have time to do planning and take time to think about adopting a technology while vegetable growers don't have that time
6	Temperature abuse in vegetables are more prominent as compare to fruits so TMTs use is more important in vegetables	Vegetables are more fragile as compared to fruits. Temperature abuse can not be easily seen in fruits, however, in vegetables like lettuce it can be visualized quickly
7		Point of Differentiation
8		We are only charging for data and have reverse logistics ability to get tracker back and reuse it
9		Providing also location wise data across the supply chain to enhance its visibility for the grower
10		Building a platform to utilize its effectiveness and efficiency in future
11		Do you think vegetable growers understand value of temperature monitoring?
12	Bigger farms understand value of temperature monitoring and have invested in it; however, smaller farms don't see any value in it- Industry wise more smaller farms rather than bigger ones	Big farms understand its value and have invested in the cold chain integrity.
13		Small farms don't understand its value and taking shortcuts which impact produce quality and correlates to repeated purchase behaviour of customers
14	Factors for non- adoption of TMTs	Factors for non- adoption of TMTs
15	Lack of accountability requirement for temperature monitoring across the chain is the main factor for non adoption of TMTs	No accountability for temperature monitoring
16	Some members across the chain don't want to share their practices which leads to poor adoption of TMTs	Transparency as a challenge as some of the members don't want to share their practices
17	There is no preferences or product differentiation for someone who is doing temperature monitoring/ no monetary or preferred supplier status which leads to poor adoption of TMTs	No market preference for someone who do continuous temperature monitoring

Initial themes were developed from categories and presented in one tab in Microsoft excel as shown in Figure 16 below. The top arrow contained initial themes with the categories of information along with the interview respondents which were pasted underneath it. These themes were then discussed again with the supervisory team for comments and suggestions.

Figure 16
Developing initial themes from the data



Res	Produce Rejection	Res	Carelessness, Complacency and Due-diligence	Res	Responsibility & Blame Shifting	Res	Cost and Value	Res	Technology fitness
G1C1	Small pre-loading temperature abuse led to rejection	G1C1	Compalcency of farmers and assuming that produce will hold its pre-harvest form and shape	G1C1	Technology should be deployed against people's complacency and guard against blame shifting	G2C1	Knows about realtime monitoring but do not know the cost and value	G1C1	Decrease human interference in technology use and decision making
G2C1	Rejected product is cooled down with Ice and sold in near/local markets	T1C1	Staff complacency despite of having all equipment	G2C1	TMT useful for high shelf life produce the rest we do not want to solve other problems and get max profits	G2C1	Cost of the technology and its labour dependent nature is a hindrance	G1C1	Tailormade, bin based hightech temperature monitoring
T1C1	Responsiblity avoidance after loading produce and blame-shifing when rejection happens	T1C1	Transport staff do proper checks at farmgate but drivers are complacent	T1C1	Supermarkets and DC have higher temperature and lack of active monitoring for which farmer blame transporter	G2C1	Technology add value if supermarket pay higher for it	G1C1	Least human interference required for most efficient and error free tech usage
T1C1	Supermarkets too relaxed about temperature checking fearing large rejection	D1C1	Careless attitude of transporters about temperature monitoring	T1C1	Improve temperature montoring by having exact record of each pallet	G2C1	Real time temperature monitoring can save cost by selectively cooling bins	G1C1	Technology should prompt about error
T1C1	Container as first point to be blamed on rejection	D1C1	Driver's carelessness and saving on air conditioner cause abuse	D1C1	Blame shifting is the reason for TMT non-adoption	G2C1	Technology should give a clear dollar value for actions to be taken	G2C1	Lack of most efficient use of technology for profit
T1C1	Strict temprature monitoring leading to rejection- mean losing business by transport companies	D1C1	Transporters are careless, keep door open	D1C1	Blameshifting among chain members in case of over heated produce	T1C1	Farmer overload container for cost saving and hindering airflow	G2C1	Technology use is good if it provides real time decision making cues for harvesting
D1C1	Temperature Monitoring data only shared with previous chain member incase of produce rejection	D1C1	Growers do not care about shelflife, temperature and packaging			T1C1	Biggest barrier is perceived cost without ROI in 3-5 years	T1C1	Exactitude and specificity in technology to record pallet rather than air temperature

Step four

The fourth step consisted of developing and reviewing the initial themes. These themes were modified according to the codes and categories developed in the last step. Categories from each interview were carefully reviewed and their suitability with initial themes determined. . In this step, categories from each interview were carefully read again to review their suitability with the initial themes. In Microsoft Excel categories were highlighted and combined under revised themes as shown in Figure 16 above.

Step five

In the fifth stage, the themes were defined and refined by identifying the essence of each theme and determining what aspect of the data each theme captures as reported by Braun & Clarke, (2006). For each individual theme, a detailed analysis was conducted, while identifying the story behind the theme, and how the overall story emerges from the data.

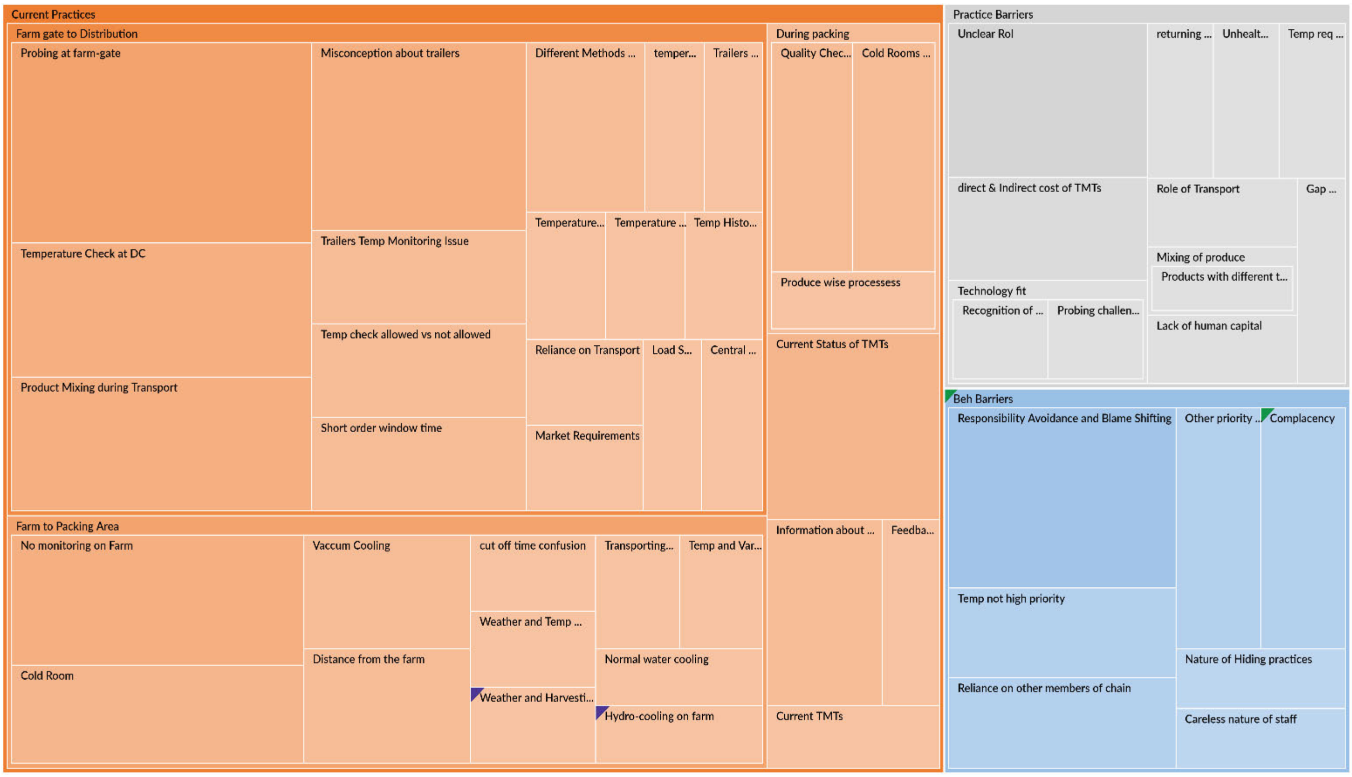
Step Six

In the final step, findings from the thematic analysis of data are presented in Chapters 4, 5 and 6 based on the research questions of the study.

3.12.2. *NVivo software analysis*

QSR NVivo software was also used in this study to increase the reliability of data analysis through graphical representation of codes, categories and themes as identified in the manual thematic analysis. QSR NVivo allows for a more critical view of the results, enabling researchers to draw graphical presentations from the analysis of qualitative data (Sotiriadou et al., 2014). Therefore, this enabled the utilisation of two main graphical representations. The first one was the hierarchy chart of codes as presented in Figure 17 below.

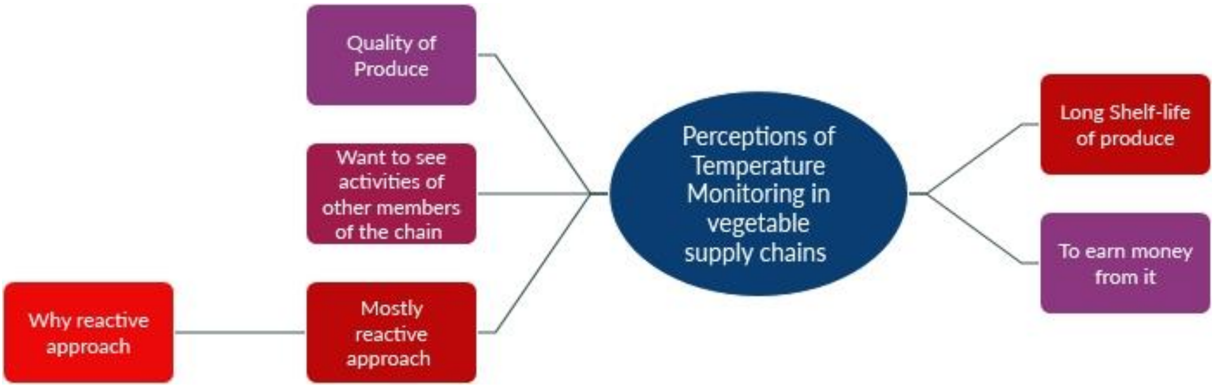
Figure 17
Hierarchy chart through NVivo 12



A hierarchy chart helped to visualise prominent themes of this study. For instance, in the current practices of TMTs, three main prominent categories and codes were identified including farmgate to distribution, farm to packing area and during packing. It also illustrates that greater discussions take place from the farmgate stage to the distribution stage than at any other stage during the supply chain.

The second graph was mind map generated from the coding process as shown in Figure 18 below. This helped to initially draw maps from reading of the data to synchronise my thinking process for further analysis.

Figure 18
Initial mind map created through NVivo 12



3.13. Ethical considerations

This study was approved by the University of Southern Queensland research ethics committee having approval number H19REA097 (approval email attached as Appendix I), which follows a strict ethical consideration process. To obtain informed consent, participants were orientated verbally and in writing with the research objectives, privacy, and confidentiality protocols of the study. The participants were also assured that they could withdraw from the study at any time. As part of the university ethics committee requirements, the identities of the participants and business firms remained confidential. The researcher was also cognisant of not sharing any name or identity with any other participant and business across the chain.

Data management, including storage and protection, is also an important ethical issue (Gibson & Brown, 2009). In this research, the audio files of the interviews were stored in the researcher's work computer and password protected. All the interview transcripts were de-identified and given codes that the researcher could understand. The hard copies of the consent forms and any other documentary evidence obtained during the data collection process were kept in a locked filing cabinet.

3.14. Chapter conclusion

This chapter outlined the research questions of the study and methodology of addressing them through qualitative research design. A case study approach was utilised using semi-structured interviews. The data collection and analysis were also described to ensure trustworthiness, credibility, and reliability of findings. This research consisted of three case studies, as the purpose was to take a deep dive to understand the phenomena and contribute to the issue of temperature monitoring technology adoption in the Australian vegetable supply chains. Findings of the study are presented in the following chapters.

CHAPTER 4: CURRENT ADOPTION STATUS OF TMTs IN VEGETABLE SUPPLY CHAINS

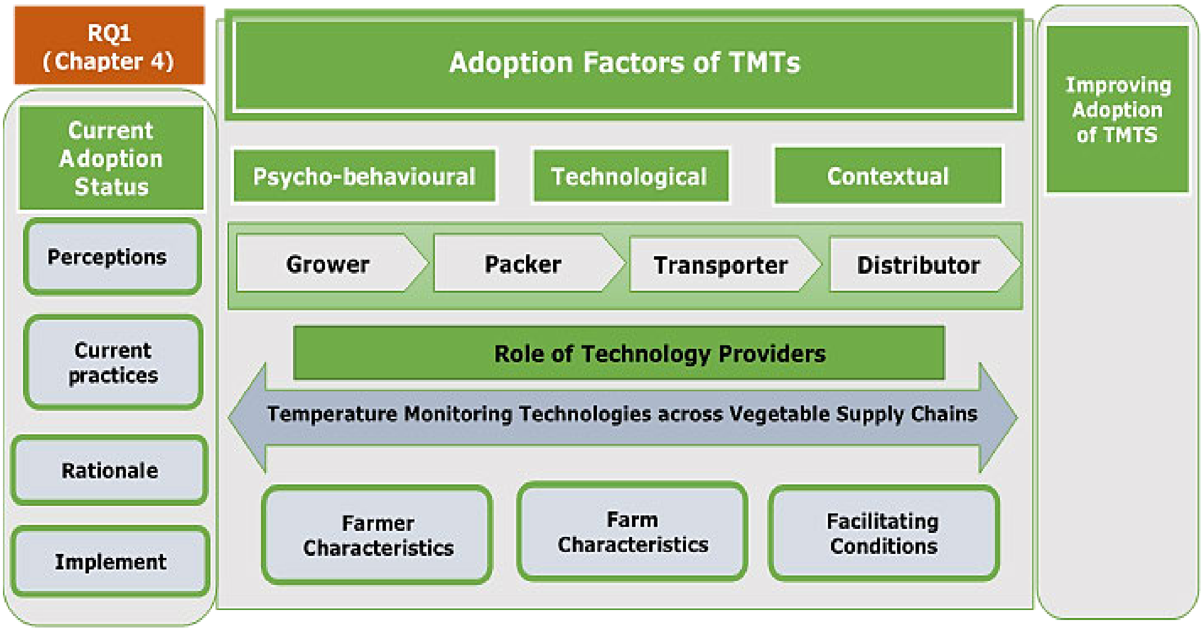
4.1. Introduction

Temperature monitoring technologies (TMTs) adoption across fresh produce supply chains remains a challenge (Ndraha et al., 2018). Understanding this challenge in vegetable supply chains warrants significant insights into comprehending the perceptions of chain members about temperature monitoring and their current cold chain practices.

This chapter aims to answer Research Question 1 (RQ1)

"To what extent temperature monitoring technologies have been adopted across vegetable supply chains?".

Figure 19
Research question addressed by Chapter 4 – current adoption status of TMTs



The findings of RQ1 are divided into three parts.

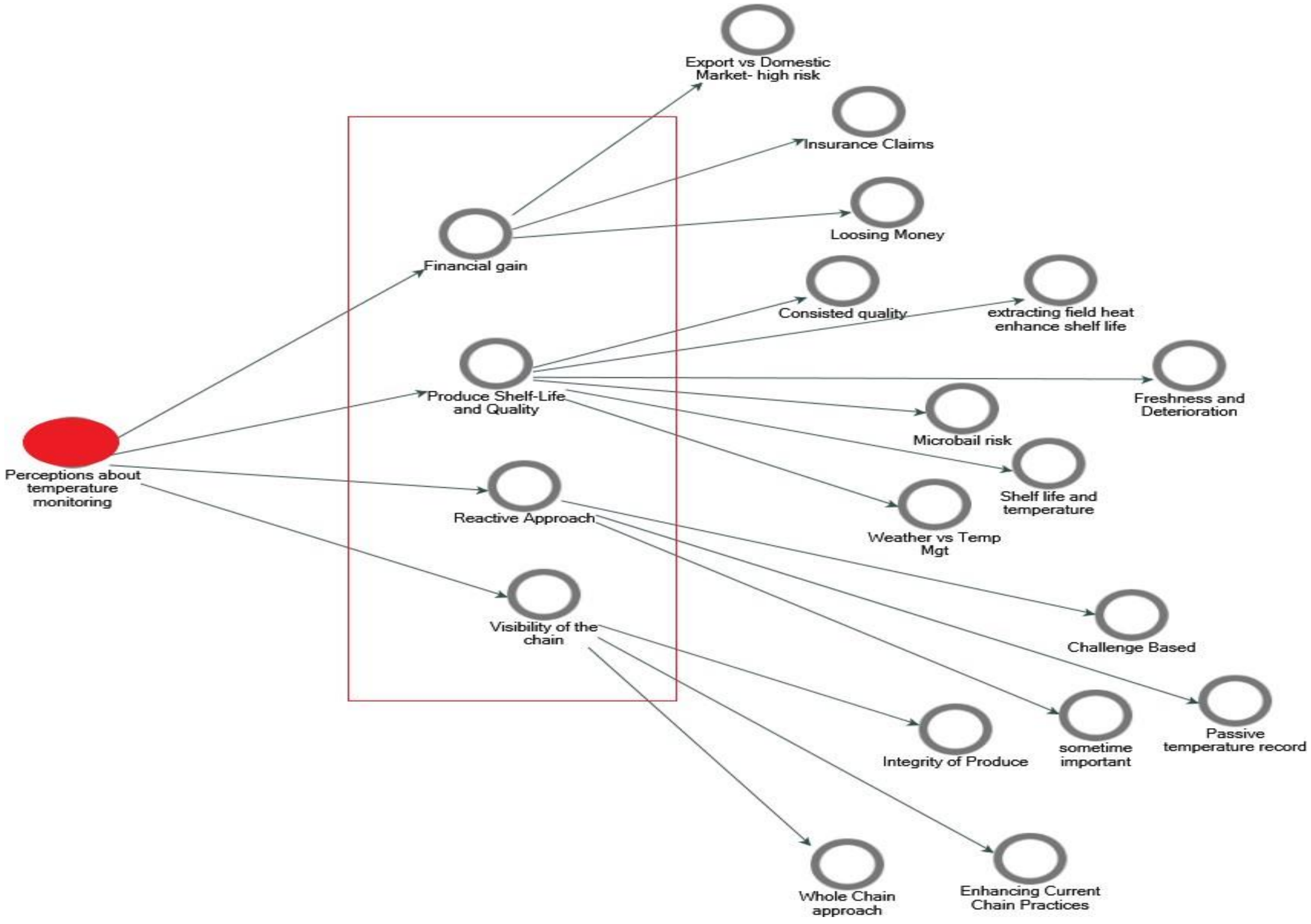
- Section 4.2 discusses the perceptions of vegetable chain members about temperature monitoring.

- Section 4.3 briefly outlines the existing cold chain management practices at each stage of the chain.
- Section 4.4 shows the rationale for variation between the perceived importance of temperature monitoring and existing relevant practices.

4.2. Perceptions about the importance of temperature monitoring

Temperature management and monitoring appeared universally important across all the members of the vegetable supply chains. Findings suggest that the perceptions of the chain members about temperature monitoring can be classified into four main themes presented, in Figure 20 below, generated and analysed through NVivo 12.

Figure 20
Perceptions of vegetable supply chain members about temperature monitoring through NVivo 12



Enhancing shelf life and maintaining quality of fresh produce were quoted as the prominent dimension of temperature monitoring. Economic incentives and visibility of the chain were identified as other overarching themes of temperature tracking along the chain. Moreover, a reactive approach has been observed among the actors of the vegetable supply chain regarding temperature monitoring. A reactive approach means that temperature monitoring becomes important at the time when the vegetable supply chain is facing disruption.

Growers associated temperature management with the quality and shelf life of their fresh produce. They believed that if the temperature of produce is adequately managed right from the harvest to distribution, then they have more time to sell it and can access distant markets, including overseas. Growers described temperature management as “extracting field heat-out from their produce and linking it with the shelf-life extension” (Grower 1 Case study 1) (G1C1).

Quality of the product and prolonging of shelf life are also used interchangeably, and temperature management is deemed essential. "Yellowing of broccoli," as mentioned by grower 2 in case study 2 (G2C2) is due to not properly managing the temperature, leading to rejections at the distribution centre. Quality and shelf life are symbolically related to financial gains by every chain participant, as quoted by grower 2 in case study 1 (G2C1), "affecting bottom line when [it] reaches to [the] market".

Growers mentioned that temperature monitoring is also important for them as they endeavour to be aware of the real-time changes across the supply chain. They view TMTs as a valuable tool to check the "operations of upstream chain members” as stated by grower 1 in case study 3 (G1C3). Some growers also perceived that utilisation of these technologies could assist in verifying the suitability of transport companies for their produce to be appropriately handled.

Transport companies along the chain consider temperature monitoring more critical to their business operations as it has direct financial implications because of "insurance claims"[5], as cited by transport company 1 in case study 1 (T1C1). They use modern trailers equipped with advanced TMTs to facilitate growers in delivering their products within the required market specifications. In addition, transport companies keep temperature records as evidence to put forth to the grower in case the product is

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[5] Due to complex business nature of agri-food supply chains, insurance companies are working on providing tailor-made solutions to recover losses. For example: https://www.wfi.com.au/farm-insurance/fruit-and-vegetable

rejected by the customer (the distribution centre) due to substandard quality or persistent varied temperature. Thus, this record can be utilised to verify or deny the alleged claim.

Furthermore, a reactive approach has been perceived among the vegetable supply chain members regarding cold chain monitoring. Managing product's temperature along the supply chain is considered necessary when disruption occurs, or the final product is rejected. Chain members do not see any value in proactively tracking temperature as fresh produce is transitioning from farm to plate, as quoted by grower 1 in case study 2 (G1C2), "well, it [temperature monitoring] is important, but it's when there are challenges to the supply chain, you know, when it gets to the end, realistically".

In summary, all members across the vegetable supply chain appreciate the importance of temperature monitoring to improve the shelf life and quality of produce, to achieve higher economic outcomes at the end, and to improve visibility; however, the approach to monitoring is more reactive, especially among growers and packers. Table 13 below presents excerpts from the interviews of supply chain members to highlight the importance of temperature monitoring in vegetable supply chains.

Table 13

Vegetable supply chain member's perception of temperature monitoring

Dimensions	Growers	Packers	Transporters	Distribution centre
Enhancement of shelf life & quality	All the theories tell that shelf life increases if temperature is reduced as quick as possible and stays like it –Grower 1 Case study 1 (G1C1) Dying process starts at the time when we cut broccoli, so how you going to keep it alive is through temperature monitoring – Grower 1 Case study 1 (G1C1) The basic rule is to get the field heat out of the product quickly to extend your product shelf life – Grower 2 Case study 1 (G2C2)	Produce deteriorates and the difference is shelf life – Packer 1 Case study 1 (P1C1) Temperature is important otherwise, there would be no fresh product – Packer 1 Case study 2 (P1C2) If you've got any sort of temperature abuse, suddenly the quality is compromised very quickly – Packer 2 Case study 2 (P2C2)	Because you know yourself that even if you put something [fresh produce] on the bench as opposed to put in the fridge it deteriorates so it's the game of shelf life – Transporter 1 Case study 3 (T1C3) If vegetables are in the right temperature, then it's going to last long – Transporter 1 Case study 2 (T1C2)	Will significantly have their [fresh produce] shelf life enhanced and or their microbial risk reduced by not having temperature spikes in them –Distributor 1 Case study 1 (D1C1) Different [vegetable] products need to be stored at the ideal temperature so that a prolonged shelf life and the quality of the product is maintained through to the customer – Distributor 1 Case study 2 (D1C2)

Dimensions	Growers	Packers	Transporters	Distribution centre
Financial gain	You know if you talk [about] broccoli which is sensitive crop to temperature you will end with the yellowing, ethylene damage on the broccoli creating as then obviously you lose money – Grower 2 Case study 1 (G2C1)	And it is all about money at the end of the day either from the customer or from other chain member – Packer 2 Case study 2 (P2C2)	Definitely, Insurance to start with because every time the load gets knocked back, the first thing the (growers) say is what's wrong with the trailer? – Transporter 1 Case study 1 (T1C1)	All is the money that matters at the end of the day. So, the main focus of cold chain here is to maintain the freshness to get competitive price – Distributor 1 Case study 2 (D1C2)
Visibility of the Chain	As a grower and producer, I don't know what the temperature of my produce is when I send it away and when it reaches a market – Grower 1 Case study 3 Grower 1 (G1C3) You need to know that something's gone wrong before and whether the transport company is doing the right job – Grower 2 Case study 3 (G2C3)	We monitor the temperature because we want to make sure the good quality is consistent – Packer 1 Case study 1 (P1C1) Temperature monitoring is important to check up on someone along the chain – Packer 1 Case study 3 (P1C3)	Because it (temperature monitoring) can make people see (what they are doing) – Transporter 1 Case study 2 (T1C2)	Keeps the integrity of the products – Distributor 1 Case study 2 (D1C2)

Dimensions	Growers	Packers	Transporters	Distribution centre
Reactive Approach/ contingent usage	Well, it [temperature Monitoring] important, but it's when there's challenges to the supply chain, you know, when it gets to the end, realistically – Grower 1 Case study 2 (G1C2) No one really cares about it [temperature monitoring] as long as you deliver in specs (specifications) – Grower 2 Case study 1 (G2C1)	we can say its [temperature monitoring] important but sometimes it is not really important – Packer 1 Case study 1 (P1C1)		

4.3. Current temperature monitoring practices along the chain

Numerous temperature monitoring practices were identified along the vegetable supply chains investigated in this research. Findings suggest that different methods of temperature monitoring practices are utilized across the chains investigated in this study. In order to understand these practices in detail, operations across vegetable supply chains are classified into three main activities including farm to packing facility, during packing and grading, and farm gate to the distribution centre. Each of these operations along with its temperature monitoring practices are explained below in detail:

4.3.1. Farm to packing facility

During this stage, fresh vegetable produce is harvested and shifted to the packing facility. Numerous growers have their own packing facilities due to its importance for business operations.

Most of the growers and packers cited that temperature management at this stage is considered least important as they do not see any value in it. Lack of continuous temperature monitoring was found at this stage of the chain. For instance, packer 1 in case study 1 highlighted that after harvesting, produce is setting in the sun for around two hours: "we will cut like fifty bins of broccoli, and it will normally take one and half to two hours. so that means some broccolis are setting on the paddock for more than two hours sometime". Produce from the farm is usually transported to the packing facility in open trucks or trailers in bins without any temperature management. Distance of the farm to the packing area is found to be one of the main determinants for non-compliance at this stage. Three growers who were found to be concerned about the quality of their produce and temperature abuse at this stage have invested in temperature-controlled trailers to shift their produce from farm to packing facility, as mentioned by grower 1 in case study 2 "when broccolini gets picked up at the farm, it goes into an air-conditioned trailer where [it] sits in trailer until it reaches to packing shed".

Our findings suggest that in-field temperature management is also linked with two other main factors which are weather and market demand. These factors are outside the control of the grower and packer. They are considering the current and predicted temperature of the day, on which they base their harvesting decision. They plan to harvest produce early in the day to get the product at low field heat, as quoted by grower 1 in case study 1 "I think there will be a particular time of the day that we will stop harvesting because it is too hot". In other cases, hydro-cooling[6] or vacuum-cooling[7] technologies are utilized depending on the market demand to bring the produce temperature down. They only use these technologies where it is absolutely required.

Some growers only use cold rooms to extract field heat from freshly harvested produce. Grower 2 in case study 3 explained that they are keeping harvested produce at normal room temperature and then storing it in the cold room to remove field heat: "I have been told not to put your produce straight in [the] cold room and let it cool inside the shed and then put it in the cold room".

Overall, findings show that growers point to the lack of proper processes and procedures for managing and monitoring the temperature of vegetables at this stage, which affects their quality and shelf life in later stages.

4.3.2. During packing and grading

During this stage, freshly harvested produce is inspected, cleaned, graded and packaged. Temperature management during this stage has been found to be considerably better compared to the in-field farm to packing facility stage.. Numerous procedures and processes were identified at this stage for managing the temperature of vegetables.

In case study 1, packer 1 cited that produce from the farm is put in the cold room and then packed on another day: "we will harvest it today and then we bang them into the cold room and pack it the next day". Cold rooms are typically set at 2 – 3 °C and are used to bring down the core temperature of produce. Market specifications for the broccoli is provided in appendix J.

In case study 2, temperature monitoring during packing is different and depends on the nature and sensitivity of the crop towards temperature variations. For instance, broccolini is bunched and packed in a temperature-controlled packing facility, and then

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[6] Hydro-cooling uses chilled or cold water to lower the temperature of the fresh produce before storing it in a cold room. Reina, L., Fleming, H., & Humphries, E. (1995). Microbiological control of cucumber hydrocooling water with chlorine dioxide. *Journal of Food Protection*, 58(5), 541-546.

[7] In vacuum-cooling, moisture from the crop is evaporated through lowering pressure. Vacuum-cooling is used when rapid cooling of the product is required. McDonald, K., & Sun, D.-W. (2000). Vacuum cooling technology for the food processing industry: a review. *Journal of Food Engineering*, 45(2), 55-65.

it is shifted to a cold room where it is kept for two to three days before dispatching to the distribution centre as quoted by packer 1 in case study 2: "we have a pack room which sets at 13 to 15 °C where broccolinis are packed and then transferred to [a] cold room in bins", while temperature management practice for shallots is different. The same packer described that shallot are transferred from the farm directly to the cold room (without taking into packing area) where they stay for three to four days.

Generally, packers in all case studies consider cold room checks as an alternative to overall temperature management at this stage. To manage the quality of the produce, packers claimed that they keep a sample of produce in the cold room to monitor its shelf life. At the end, some packers also record the temperature of the produce pallet before loading it into the container[8].

In summary, occasional temperature monitoring has been recorded at this stage. The packers are only considering the temperature of cold rooms as a proxy for cold chain monitoring practices.

4.3.3. Farmgate to distribution centre

At this leg of the supply chain, monitoring of the cold chain was found to be notably better as compared to the two previous stages, in-field farm to packing facility stage and the during packing and grading stage”. This is the critical point in the chain where produce is accepted or rejected based on temperature and other quality parameters such as size, colour and maturity are determined at the distribution centre. The temperature monitoring processes were found to be relatively similar across all three case studies.

Growers and packers use trailers equipped with continuous temperature monitoring technologies to transfer their produce from the farm gate to the distribution centre. At the farm gate, the packer and driver of the trailer randomly probe certain pallets of vegetables, and temperature is recorded manually, which is prone to errors. Thus, in the case of rejection at the distribution centre, transport companies may not find it convenient to verify the temperature at the loading point. Packer 1 in case study 1 noted, "we only check the temperature before it is dispatched. We just prop randomly, check a pallet and if a pallet is good [then] we send it to them. Drivers also do random checks on pallets. We only record unless we got some problem".

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[8] Transport trailer in which fresh produce is transferred to distribution centre.

Packers and transporters also mentioned that product mixing is a persistent problem where a variety of produce with different core temperatures are loaded into a single container, leading to deterioration and possible rejection. Transport companies have also complained that packers tend to exceed the maximum safe load allowed on a container in search of saving money, which can also lead to potential damage and rejection of produce. In some cases, when they are asked to follow load rules, they then resort to arguments which lead to a business loss, as transporter 1 in case study 1 quoted: "so all of a sudden you see a different company coloured truck picking it up with the same fridge company on the front with the same capacity".

Transport companies' representatives also attributed temperature variation at this leg of the chain due to the current process of placing purchase orders by the big supermarkets. Growers are given a very small window (usually less than 24 hours) to fulfil an order which leads to improper temperature management and certain cooling practices such as hydro-cooling and adequate time in a cold room are compromised, as quoted by transporter 1 in case study 1, "supermarket chain places order in no-time which does not provide enough time to the grower to properly perform temperature management practices before sending it out".

At the distribution centre, the current temperature of fresh produce is used as a proxy of quality, and they are not concerned with the history of temperature spikes throughout the chain. Transport companies claimed that if supermarkets resorted to rigorous temperature monitoring (including spikes), it might lead to mass rejection and empty shelves. Consequently, when the product arrives at the distribution centre, some parameters are recorded along with temperature while ignoring temperature history as quoted by the distribution centre staff 1 in case study 2: "we don't [monitor temperature] upstream from us, but certainly once it becomes under our control, then yes, we do. We take product temperatures on arrival, and that's basically to determine the quality".

Different methods and tools were found to be utilised by the chain actors for temperature recording which leads to discrepancies in the data. Transport companies use simple probes[9] for checking temperature, while distribution centres employ laser

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[9] It is a type of sensor which can be used to measure surface temperature of fresh produce by physically touching a product or pallet of fresh produce

guns[10] due to their efficiency. In addition to this, transport companies also claimed that in some distribution centres, drivers are allowed to record delivery temperature data, while in others they do not have access to do it, as quoted by transporter 1 in case studies 2 and 3: "in some depot drivers can probe it whereas in others our driver cannot probe it as its their [distribution centre] requirements". This means that distribution centres across the three vegetable supply chains studied in this research, lack uniform policies regarding provenance of temperature information to related stakeholders.

Finally, temperature data is not communicated effectively throughout the supply chain as a matter of routine despite its critical nature. In fact, it is only shared in case of product rejection at the end of the supply chain, as quoted by packer 2 in case study 2, "we don't get any feedback unless it's negative". In other words, temperature data is least utilised in making decisions regarding improving product quality and overall supply chain performance. Details of vegetable supply chain processes along with temperature monitoring practices are presented in Table 14 below.

Table 14
Temperature management practices across vegetable supply chain

Vegetable Product Flow

Stages	Farm to pack	During packing	Farmgate to distribution
Description of activities	- Harvesting & transporting to pack house	- Cleaning, grading and packing	- Transporting and handing over
Temperature monitoring status	- No temperature monitoring	- Occasional temperature monitoring	- Continuous temperature monitoring
Temperature monitoring practices	- No-monitoring on farm - produce setting in open environment - Shifting produce through open trucks - Occasional Hydro-cooling and	- Controlled packing environment in some instances - Temperature control equipped cold rooms	- Temperature-controlled transport - Product mixing on trailer as a challenge - Small window for order affect temperature practices

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[10] Infrared thermometers called laser guns are utilized for measuring temperature of objects without physically touching the product by calculating the amount of reflected and emitted energy from the object. Diwanji, M. M., Hisvankar, S. M., & Khandelwal, C. S. (2020). Temperature Measurement using Infrared Contactless Thermal Gun. 2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing (ICSIDEMPC)

	vacuum-cooling depending on weather and market demand		- Temperature historical data is not considered at DC - Different tools for temperature monitoring at DC - Ineffective feedback mechanism

Overall, from the above discussion on the perceptions about the importance of temperature monitoring and current practices of the chain actors, it can be observed that there is the presence of a perception-practice chasm among vegetable supply chain members about existing temperature monitoring practices. Table 15 below describes some of the significant discrepancies to highlight the vast gap between theory and practice.

Table 15
Discrepancy between perceived value of temperature monitoring and practices

Supply chain member	Perceived importance of temperature monitoring	Current temperature monitoring practices
Grower	Appreciates the importance of extracting field heat out from produce as soon as possible	Lack of temperature monitoring practices on farm
Grower/packer	Lowering temperature of produce leads to its extended shelf life	Occasional temperature monitoring before farmgate
Packer/transporter	Improve visibility of chain activities	Lack of sharing temperature data along the chain unless a challenge is there at purchasing point
Grower/ distribution centre	Financial gain at the end of chain	Temperature based business decisions are not utilised

4.4. Rationale behind the perception-practice chasm of temperature management

As discussed above, findings show an apparent disparity between the awareness level of supply chain members regarding the importance of temperature monitoring and their actual practices of temperature management along different phases of the vegetable supply chain. Thus, it is clear that realising the importance of TMTs is insufficient for creating the desired level of temperature monitoring. This section pinpoints the reasons behind the current practices adopted by supply chain members to monitor and manage temperature adequately.

4.4.1. Reliance on experiential knowledge and informal methods

Insistence on experiential knowledge and informal methods was found to be one of the significant reasons that demonstrated the discrepancy between the perceived importance of temperature monitoring and actual practice. Findings suggest that growers and packers do not see any challenge in managing the temperature of their produce across the initial stage of the supply chain, which then affects the quality of produce at later stages. For instance, packer 1 in case study 1 mentioned that they do not have any issue with the temperature management at their end and quoted, "we do not monitor temperature. We are just using experience that it's alright".

In addition to this, due to a lack of time and resources, growers and packers are making quality and temperature management decisions based on their experiences, as mentioned by grower 2 in case study 1: "we are just using experience that it’s alright as it is in our experience that it is under control now. So, we make decisions by experience. We do not make decisions by the data".

4.4.2. Absence of business sense or value for money

Most supply chain members agreed that using TMTs for every produce is not feasible given the small margins in vegetables. Market requirements, produce value, and the final customer determine the investment that can be made for temperature monitoring. For instance, broccoli destined for export markets is a high-value product, so using temperature monitoring practices and technologies would have a financial impact at the end of the chain; however, in the domestic market, cold chain practices are not incentivised, as quoted by grower 2 in case study 2: "customers are not interested in temperature management. You know what they're interested in. It's in specifications".

Temperature data needs retrieval, download, analysis and interpretation before being used for decision-making. Supply chain members, especially growers, neither have the time nor the financial resources to dedicate to this task. In other words, to make business case for utilisation of temperature monitoring technologies, supply chain members need to invest a significant amount of time and resources before they will see the benefits.

4.4.3. Responsibility avoidance

Every member of the chain is trying to avoid the responsibility of handling fresh produce within the required parameters. Lack of coordination and communication has been observed among respondents at different levels of the supply chain. In terms of cold chain monitoring, members of the chain consider it to be the responsibility of transport companies. Growers and packers feel that their responsibility is to provide fresh produce that meets market specifications to the transporter and then expect that it will be delivered and accepted. On the other hand, transport companies are categorically claiming that cold chain monitoring is the responsibility of every member of the chain, as stated by the transport company 1 in case study 1: "the first thing every time there's a claim is that everyone wants to know what's wrong with the trailer here". To conclude, responsibility avoidance behaviour among chain members is a significant factor between theory and practice regarding cold chain monitoring.

4.5. Chapter conclusion

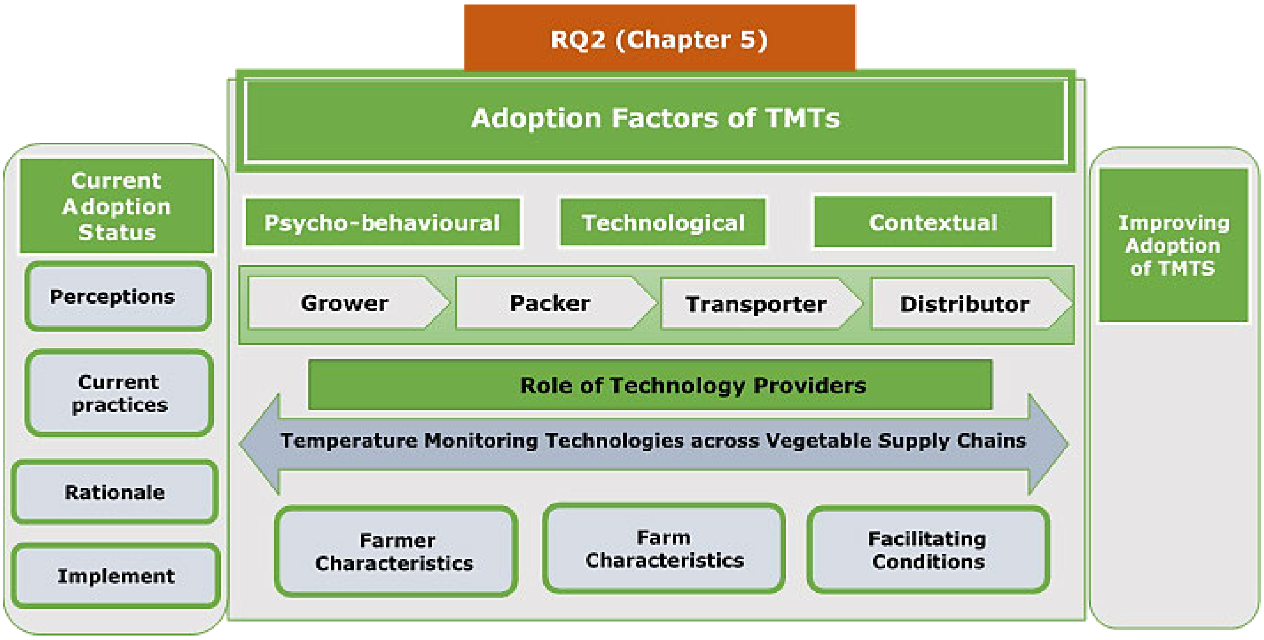
This chapter has addressed RQ1 by discussing the current adoption status of TMTs in the vegetable supply chain. This was achieved by first examining the perceived importance of the cold chain among the vegetable supply chain members and then identifying different methods and processes being performed by these actors for managing temperature across numerous stages of the chain, including farm to packing facility, during packing and grading processes and from farmgate to distribution centre. At the end of the chapter, rationalisation of perception about temperature monitoring and its practices was carried out to find emerging reasons for the discrepancy between chain members' perceived importance of temperature monitoring and their practices. In this context, Chapter 5 will explore the adoption factors of TMTs in vegetable supply chains and consider its current adoption status and barriers to its uptake.

CHAPTER 5: ADOPTION FACTORS OF TMTs IN VEGETABLE SUPPLY CHAINS

5.1. Introduction

The previous chapter presented findings about the current adoption status of temperature monitoring technologies (TMTs) in vegetable supply chains. It was clearly recognised that there exists a low level of uptake of TMTs. Therefore, this chapter aims to discuss the factors which inhibit the adoption of TMTs in vegetable supply chains. The chapter answers Research Question 2 (RQ2) which is *"What are the current practical and behavioural perspectives influencing the adoption of temperature monitoring technologies across vegetable supply chains?"*

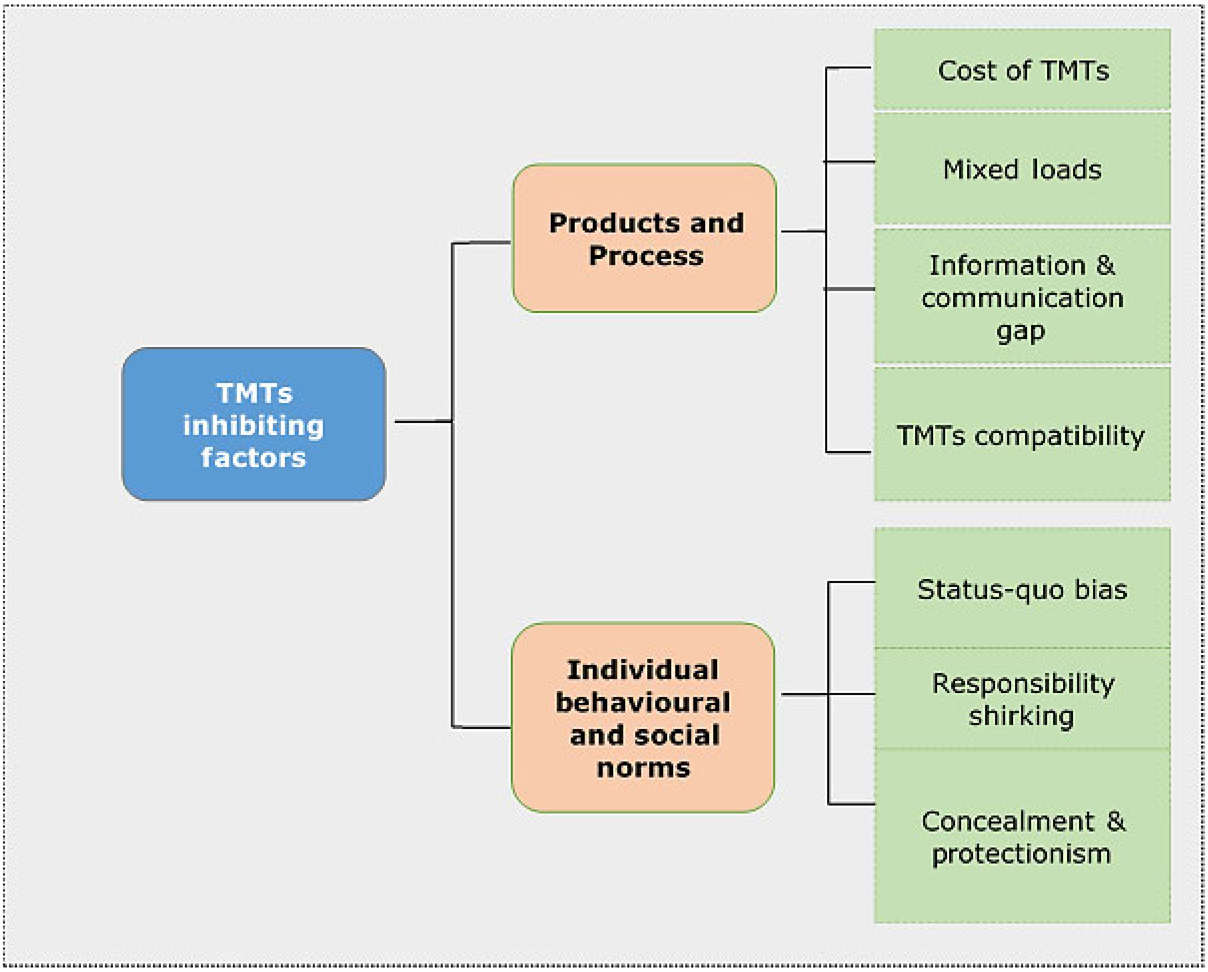
Figure 21
Research Question addressed by Chapter 5 - adoption factors of TMTs in vegetable supply chains



Factors concerning the adoption of TMTs in vegetable supply chains can be classified into two types, which are: 1) products and process-based adoption factors and 2) individual behavioural and social norms adoption factors.

Products and process-based adoption factors are predominantly related to the current practices of temperature monitoring and adoption of TMTs across vegetable supply chains, while individual behavioural and social norms adoption factors are providing insights into the psycho-behavioural perspectives of the supply chain members about TMTs applications. Themes identified from these two key deterring factors are presented below in Figure 22.

Figure 22
An overview of inhibiting factors of TMTs adoption in vegetables supply chains



5.2. Product and process-based inhibitors

Four main factors were identified that related to the current practices of temperature monitoring in vegetable supply chains. These are cost of TMTs and the uncertainty of return on investment, the practice of product mixing in existing supply chain practices, TMTs' technical understanding and information gap, and compatibility of TMTs. Each of these factors are explained below, along with observations from interview transcripts.

5.2.1. Cost of TMTs and uncertain return on investment

All members of the vegetable supply chain interviewed as part of this study argued that the cost of TMTs is an inhibiting factor in its uptake. The findings show two key underlying reasons that relate to the viability of TMTs in vegetable supply chains.

Firstly, the upfront and associated cost of TMTs is mentioned as the primary reason for their low adoption in vegetable supply chains. The average price of a disposable data logger is around AUD30 to AUD80 depending on its monitoring capabilities including features like live temperature tracking and location information (details of different types of data loggers are presented in Table 3 in Section 2.7.1). Growers argue that marginal profits in the vegetable industry make the present TMTs unjustifiable from a business standpoint, before the data is used for decision making, it must be retrieved and analysed, which incurs cost. Grower 1 in case study 2 argued: "it is not only the cost of [the] data logger but other costs to get something out from the technology which I [grower] can understand and use". Effectively utilising TMTs requires more labour as well as more units of TMTs in each shipment which requires additional things to worry about, such as the retrieval and analysis of collected data. Interviews were conducted at the time when agricultural supply chains were experiencing a tight workforce market and struggling to recruit and retain staff. Although labour inputs are sometimes reduced by TMTs and other technologies, their usage has resulted in increased workloads for vegetable farmers at the expense of minimal financial benefit.

Secondly, it was captured from the interviews of the supply chain members that they perceive the expenditure on TMTs as a cost rather than an investment. The primary reason they shared for this behaviour is that they are not entitled to gain extra monetary benefits or potential market preference for continuously maintaining the temperature of their product across different stages of the chain. Fresh produce at the distribution centre is not necessarily inspected for the remainder of its shelf life, let alone the history of temperature's readings from the paddock to consumer as argued by the grower 2 in case study 1: "as long as you deliver it within 5 °C [centigrade][11] and the broccoli is green, then no problem, you will get your money, and no one ever wants to know what happened before". This acceptance criteria of vegetables at the

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[11] 5 °C is the current market specification for fresh vegetables to be accepted at the distribution centre as stated in the FSANZ Food Standards Australia New Zealand FSANZ. (2016). Food standards code. In: Food Standards Australia New Zealand.

distribution centre renders a challenge to justify a return on investment from TMTs for growers.

TMTs technology providers and experts also emphasised that the cost of the data logger and its associated expenses, including labour and data handling is one of the principal inhibiting factors for its adoption. Experts interviewed as part of this research mentioned that farmers are rational decision-makers, and they want to ensure and invest in a technology that has a clear return on investment, as quoted by expert 3 in case study 3: "farmers are not stupid and they are very pragmatic […] and very focused around the dollars that they are going to make". Utilisation of TMTs was found to be based on the market value of produce and the potential target market including domestic high-value product or export markets. Some vegetable growers interviewed as part of this research had previously exported internationally to Singapore and Hong Kong. These growers were of the view that due to a high return on investment along with the challenge of product recalling[12] in case the produce is rejected in an overseas market, makes us more sensitive and compels us to use TMTs in our shipments – as stated by grower 2 in case study 1: “That is why the export market is so tricky [due to the above reasons], you need to make sure to stick with the proper protocols of temperature monitoring”.

In summary, not only the initial cost of TMTs but also its overheads are considered to be one of the key obstacles to their adoption across the domestic vegetable supply chains. Every member of the chain, including technology providers and experts, perceived that the cost of TMTs was a key challenge to their wider acceptance. However, in the export market, vegetable growers were found to justify the business case for the adoption of TMTs due to expected higher profit margins and logistical challenges related to product recalls. Table 16 below provides some excerpts related to the cost of TMTs from the interviews of vegetable supply chain members.

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[12] The risk of product recalling is high in export markets as horticulture produce has a very low level of insurance

Table 16
Interview excerpts highlighting cost of TMTs as an inhibiting factor

Supply chain member	Cost of TMTs and uncertain return on investment
Grower 1 **Case study 2**	If there is a cost, then there has to be value in it.
Transport 1 **Case study 1**	I think the perceived cost, whether it's right or wrong and it's like everything. It may have long term benefit, but people want to see their money back in three or four years.
Distribution centre 1 **Case study 1**	It comes down to cost. I understand its value in high priced products, but it is hard for a grower to put two data loggers in a container in capsicums.
Expert 1 **Case study 2**	It's cost, profit margins are very tight, and they will say that you want me to put a hundred-dollar logger in two hundred dollars consignment – there is no sense in it.
Technology provider 1 Case study 2	In my opinion, it’s not only the one-time cost but repetitive cost of this when they are repeating it again and again.

5.2.2. Practice of produce mixing (mixed loads)

Produce mixing refers to the practice of combining different types of produce through various stages of the vegetable supply chain. While this practice offers certain benefits such as reducing logistic cost and ensuring consistent supply to different markets, it emerged as another important inhibiting factor in the adoption of TMTs. Findings suggest that the issue of mixed loads during transport, storage and logistics parts of the vegetable supply chain is attributed to low level of uptake of TMTs.

Two critical practices related to mixed loads were identified in this study. First, combining a variety of multiple products in one container or cold room requires different transit or storage temperatures, which makes it difficult to establish accurate temperature traceability. Second, loading vegetables into a trailer that is not adequately cooled down results in an overall temperature spike[13] in the container. A combination of these practices posed a challenge to the adoption of TMTs in vegetable supply chains.

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[13] Spike is characterized with a recurrent and abrupt rise in the temperature monitoring log.

Transport companies in the chain explained that they have to load different types of vegetables into one trailer. A dedicated trailer for a single product is not feasible for several reasons, including cost, volume of market demand, product's delivery within a suitable timeframe, and utilisation of maximum trailer space. They found that these reasons are very challenging to overcome and thus it is quite often that a diverse variety of vegetables ends up in a single container with varied temperatures. Consequently, some vegetables are bound to be over-chilled while others will be exposed to a higher than desired temperature. For example, interviewee from distribution centre 1 in case study 1 quoted that: "very seldom you have dedicated trucks, you might have potatoes, avocados, capsicums on one truck which require different temperatures".

It was also found that even within the same product category, vegetables having different temperature readings are normally being loaded into the same trailer. This mixing of produce in a trailer disturbs the air temperature in the container and exposes all the produce to a higher temperature spike. The interviews from the transport companies also highlighted misalignment of motivation due to the need to satisfy different customers in the chain. For instance, a transport company is looking to satisfy growers while the primary concern of growers is the distribution centre that they are selling their produce to on an almost weekly basis. Therefore, transport companies are accepting overheated products from the farms due to the presence of tough competition among stakeholders in the industry, as quoted by transport company 1 in case study 1, "unfortunately in this industry [transport], the opposition is always there to grab opportunities and if we don't accept hot produce from a grower, then we lose business". Moreover, growers mistakenly view trailers as a replacement for cooling devices, however, these transport methods (containers) are only installed with enough air conditioning capacity to maintain temperature of the produce during transit i.e. they do not bring temperature down rather they maintain temperature, as stated by the transport company 1 in case study 2, "growers are thinking that our trailers can bring down the temperature however these things are designed to keep the temperature stable [but] not cool it down".

In summary, mixing diverse products and its provenance along different stages of the supply chain including post-harvest and logistics makes it difficult for the members to adopt best temperature monitoring practices. As a result of this, some of the more progressive and larger corporate growers are looking to invest in their own transport capabilities. As stated by packer 1 in case study 2: "so that is why we are trying to have our own transport […] to deliver our produce directly from our cold room to the distribution centre". Table 17 below presents some excerpts from the interviews of vegetable supply chain members related to existing practices of product mixing along the chain.

Table 17
Interview excerpts about product mixing as an inhibiting factor

Supply chain member	Product mixing/mixed loads
Grower 1 **Case study 1**	It comes hard [to use data logger] when you have different products in one container which happens all the time.
Distribution centre 1 **Case study 2**	Challenge is monitoring core temperature of produce as there is always breaks in the cold chain due to handling and mixing of produce
Expert 1 **Case study 1**	So, because of the existence of mixed loads, there's reduced incentive to try to fix that because it can't be fixed.
Grower 1 **Case study 2**	Cross stock over is another challenge for us as it is completing making sense for the transport companies but not for us.
Packer 1 **Case study 2**	Load mixing is another issue with transport companies as they put down our stuff, which is cold, but they put another stuff next to it, that's sitting at 20 °C , obviously it heats up and so it's hard to sort of control that.
Transporter 1 **Case study 2**	The issue is that farmers are thinking that our trailers can bring down the temperature. It is very hard for these trailers to bring down the temperature, these things are designed to keep the temperature stable but not cool it down.

5.2.3. Information and communication gap

Findings show that technology providers and vegetable supply chain members have different perceptions about the utilities of TMTs in fresh produce chains. Information asymmetry and communication gaps exist between technology providers and vegetable supply chain members. Technology providers are more focused on improving the existing capabilities of TMTs rather than understanding the specific challenges and complexities involved in fresh produce supply chains. This results in the development of technological solutions that do not align with the actual needs of the vegetable supply chain members. In addition, technology providers also struggle to make an argument and provide clear understanding about the financial benefits of the uptake of TMTs to potential adopters.

Most vegetable growers recognised that technology providers are predominantly investing in the hardware side of existing TMTs, such as improving their sensory qualities and data reliability. However, there is a limited focus on understanding the complex nature of fresh produce supply chains, which results in developing technological solutions that do not cater to the diverse needs of the members of contemporary fresh produce supply chains. Some vegetable growers even maintained that the technology providers are working in silos and are not usually open to integrate their perspectives into the product development process of TMTs, as stated by grower 1 in case study 2: "technology providers [of TMTs] do not know what we are doing and what they are trying to resolve".

Growers were found to be unaware of potential TMTs solutions and reluctant to consider their uptake which highlights the lack of information sharing between technology providers and vegetable supply chain members. Interviews captured that some supply chain members suspected that technology providers are more focused on pursuing their sales target by pitching their products to be one of the best available technological solutions for temperature monitoring. For instance, transport company 1 in case study 1 highlighted that: "there are a lot of snake oil salesmen having mostly a monetary interest. All they want is to sell you a data logger that we do not need". Similarly, experts interviewed for this research agreed with the growers' views and cited that most technology providers do not endeavour to comprehend the underlying dynamics and unique requirements of the sector, which impacts the uptake of TMTs in fresh produce chains.

On the other hand, TMTs providers mentioned that vegetable supply chain members are not generally receptive to information, and their approach to temperature monitoring is for the most part a reactive response. Technology providers also believed that the availability of different types of TMTs, combined with the growers' scepticism about technologies, makes it difficult for them to demonstrate the potential value that their technologies can provide. For example, technology provider 1 in case study 3 stated that, "growers are very cynical about us. If I go and explain to them […], they always have this sort of expression on their face that I am here with a hidden agenda which is to sell a logger".

In summary, there is an information and trust gap between technology providers and potential users of TMTs which leads to its low level of adoption in vegetable supply chains. This can be attributed to the impression of growers that technology providers lack deep understanding of the specific challenges and requirements of the fresh produce sector. Table 18 below provides some excerpts from the interviews of vegetable supply chain members, experts, and technology providers.

Table 18
Interview excerpts highlighting information and communication gap

Supply chain member	Information and communication gap
Grower 2 **Case study 1**	We do not have any relation with [the]technology providers.
Packer 2 **Case study 2**	No one came to me to explain it [TMTs] like we have fertiliser companies coming in and explaining their products, but I haven't seen anyone coming and explaining about these gadgets.
Distribution centre 1 **Case study 1**	I've got a few people [sales agents] trying to sell us but it all looks snake oil sort of stuff.
Expert 1 **Case study 3**	There are a lot of people who go in saying, you know, I've got drones, and I can do this, and I can do that. Whether it is actually what the producer is prepared for which is always a question mark.
Technology provider 1 **Case study 1**	I think there's a gap where the technology providers may be just pushing the technology, focusing on that and not focusing on the business solution for a lot of different parties in the supply chain.

5.2.4. Compatibility of TMTs

Interview findings also indicated that one of the other major obstacles towards TMTs adoption is that the existing technologies are not suitable for the perishable and complex nature of vegetable supply chains. For instance, existing TMTs involve a tedious process of analysing and interpreting temperature data before it can be effectively utilised during the post-harvest decision-making process. In addition, this task of analysing and interpreting collected data is perceived to be a highly labour-intensive process for fresh produce growers.

TMTs providers interviewed in this study acknowledged that existing TMTs for the fresh produce supply chains were not explicitly developed for the sector, as stated by technology provider 1 in case study 2: "a lot of technologies [TMTs] out there which are fantastic from a technology perspective, but it has probably been developed for mining or some other sector". As a result of this, one of the significant drawbacks pointed out by the various supply chain members was that the current TMTs are designed to measure the air temperature of the cold room or container rather than the core temperature of the product. Ideally, these technologies should be able to measure and provide core temperatures of each product or pallet in a cold room or container (as different types of vegetables are stored or transited in the same cold room or container simultaneously). Transport company 1 illustrates this in case study 1: "current technology only monitors return air. This won't identify if a hot pallet is there but will only identify if a hot freight is in there".

Supply chain members also exhibited that existing TMTs are disposable and passive[14]. Most data loggers are suitable for one-time use which means that it needs to be purchased separately for each shipment. In terms of the passive nature of these data loggers, temperature data is only available to the supply chain members after the delivery of produce to a distribution centre. Therefore, it requires a person at the end of the supply chain to reclaim and send it back to the point of origin for data retrieval. Thus, this data can be only useful in developing a best practice for the future, but has no value in controlling any potential damage to the ongoing shipment, as illustrated by packer 1 in case study 1 : "alright if we use a data logger to monitor our produce and if something is wrong and we found out once it reaches to the customer, then it is too late to fix, so there is no point of using a technology". In other words, the disposable and passive nature of existing data loggers makes it difficult for the supply chain members to ensure temperature control at every stage of the chain.

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[14] Temperature monitoring technologies usually come in active and passive formats. Active data loggers continuously collect data and convey it in real time while passive ones do not convey data in real time and require an action to be performed to retrieve data.

Additionally, findings show that current TMTs are highly reliant on human interventions and are labour intensive. For instance, probing[15] is involved at each stage of the supply chain which makes it more laborious and dependent on humans, as explained by grower 2 in case study 2: "probing on and off is the most challenging thing for us and for the upstream members as resources like the staff are tight up to this". This results in two major issues. Firstly, staff involved in this process require proper training and handling knowledge which may not be easily achievable given their low level of education and exposure. Secondly, and more importantly, it becomes very labour intensive and costly for the supply chain members to effectively acquire value from utilising existing TMTs in their operations. This factor is highly relevant to the growers in these chains who are simultaneously dealing with numerous other challenges, such as labour shortages and timely delivery of their products to markets.

In summary, the interviews identified four main challenges of existing TMTs in vegetable supply chains.

- Currently available TMTs are not designed for the perishable nature of fresh produce chains
- TMTs are passive which means that data is available ex-poste.
- Existing TMTs are disposable which entails repetitive purchase.
- Characteristics of existing TMTs make it hard for the supply chain members to apply them effectively in their operations.

Table 19 below presents some quotes from the interviews of supply chain members about the compatibility challenge of TMTs.

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[15] Probing is a process of placing a temperature probe on the surface of a product or inserted into a pallet of fresh produce to measure its temperature at different stages of the vegetable supply chain.

Table 19
Interview excerpts highlighting TMTs compatibility as an inhibiting factor

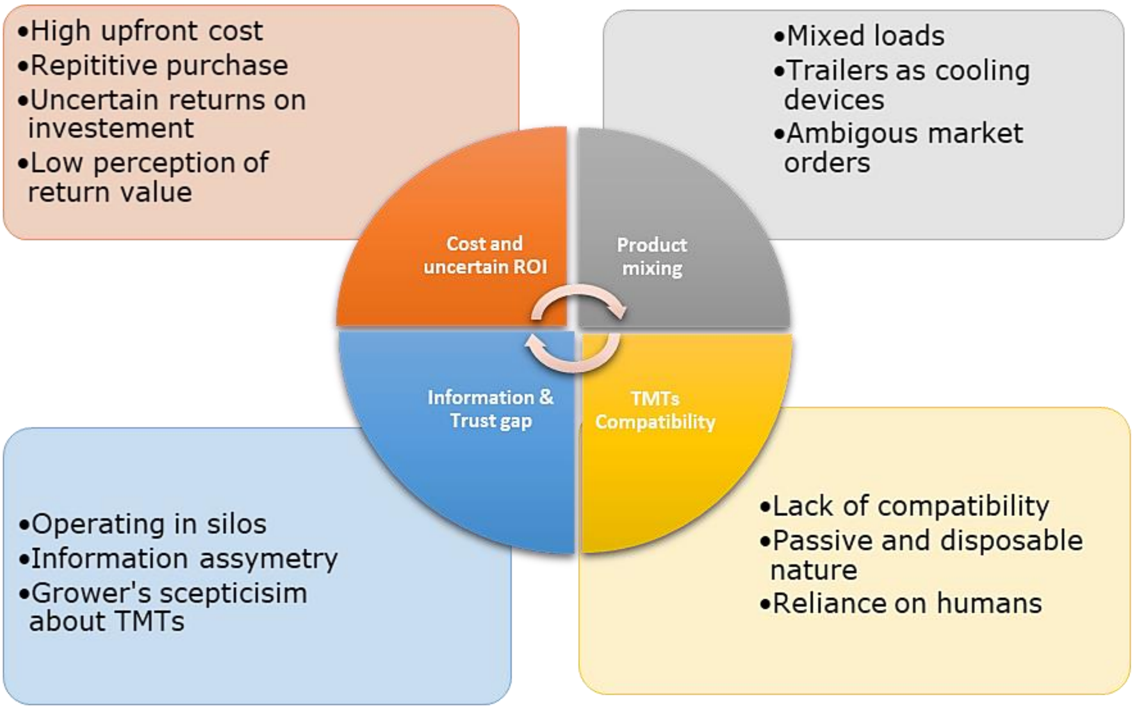
Supply chain member	Existing TMTs compatibility
Grower 1 **Case study 1**	I don't see any benefit unless you put a data logger on each piece of fruit or vegetable which is not making sense to me.
Grower 2 **Case study 1**	Data loggers are disposable things and last year we loaded almost 200 to 300 trailers, so it is not viable for us.
Expert 1 **Case study 1**	There is very limited [TMTs] options for horticulture supply chains which is typified as open chains where there is no regular movement of product.
Grower 2 **Case study 2**	Human factor in current technology is a big challenge for us. Farmers don't really want to interact with the technology. The current one is very labour intensive.
Distribution centre 1 **Case study 2**	Another barrier is that currently trailers have temperature monitoring capability that is the air around the produce not the temperature of the actual produce.
Packer 2 **Case study 2**	The loggers [TMTs] are not friendly to our business and in general to the fresh produce industry.

5.3. Review of product and process-based inhibiting factors

Four key product and process-based factors were identified from the interviews of vegetable supply chain members. The first factor is that vegetable supply chain members perceive the expenditure on TMTs as a cost rather than an investment and there is a lack of guaranteed return from the uptake of these technologies.

The second adoption factor identified from the interviews was that multiple types of vegetables having different temperature requirements are stored or transited simultaneously throughout the chain, which deters the uptake of TMTs. Lack of information sharing and ineffective coordination between TMTs technology providers and vegetable supply chain members was recognised as the third adoption factor affecting the utilisation of TMTs. Growers were found be sceptical about TMTs technology providers and argued that they do not endeavour to understand the complex nature of modern fresh produce supply chains. Finally, the compatibility of existing TMTs with the fresh produce chains was acknowledged as another critical inhibiting factor in its adoption. Figure 23 provides a summary of product and process-based inhibiting factors affecting the adoption of TMTs in vegetable supply chains.

Figure 23
Summary of product and process-based inhibiting factors of TMTs



5.4. Individual behavioural and social norms-based inhibiting factors

The previous section discussed the product and process-based factors related to the adoption of TMTs in vegetable supply chains. This section examines the individual behavioural and social norms of the vegetable supply chain members including growers, packers, transport companies, distribution centre staff, technology providers and experts in relation to the adoption of TMTs. Three main individual behaviours and social norms factors were identified. These behavioural factors include complacency, responsibility shirking, and concealment and protectionism. These are discussed in detail below along with extracts from interview transcripts of supply chain members.

5.4.1. Status quo bias behaviour

Complacency emerged as one of the dominant behaviours among the vegetable supply chain members interviewed in this study. Numerous members of the chain demonstrated this behaviour and were found to be satisfied with their current established practices of temperature management and monitoring. As a result, they were resistant to the uptake of TMTs in their existing supply chain operations.

Interviewees indicated that growers were found to be more complacent as compared to other members of the chain. This is due to their assumption that temperature is adequately maintained during storage, transportation, and handling of produce along the chain. They believe that their product will hold its post-harvest form and quality throughout the supply chain activities. As a result, growers, who are supposed to be the predominant users of TMTs, do not perceive potential risks associated with temperature variations of vegetables along the chain. This was evident from the interview of grower 1 in case study 1: “Oh, I know that broccoli will be alright, and it will be fine […] at the other end”.

In addition to growers, findings also revealed that staff members working in different parts of the chain also exhibit similar behaviour regarding temperature management of fresh produce. For instance, drivers in the logistics part of vegetable supply chain were described as usually more careless and lacking due diligence while handling fresh products during the transit stage. As distributor 1 in case study 1 quoted about the behaviour of a truck driver: “the truck driver will come here to pick up my two pallets, shoot from here with the fridge running and doors of the trailer wide open, and will go to another place to pick up some more pallets”.

Vegetable supply chain experts and technology providers interviewed as part of this research also mentioned that generally growers and staff members along the fresh produce supply chains also demonstrate negligent behaviour about temperature monitoring. They explained that this behaviour of growers is typically a result of their experiential knowledge that they had acquired over generations. Technology provider 1 in case study 2 highlighted that, “the biggest challenge that we face with the growers is that they do not see temperature as a big thing due to [sticking to] their practices [growing and selling to market] as they are engaged for the last 30 or 40 years”. Table 20 below presents excerpts from the interviews of supply chain members regarding status quo bias behaviour of vegetable supply chain members:

Table 20
Interview excerpts highlighting status quo bias behaviour of supply chain members

Supply chain member	Status quo bias behaviour
Packer 1 **Case study 1**	We are just using experience that it [fresh produce] is alright, so we make decisions on the basis of our experience. We do not make decisions by data.
Transporter 1 **Case study 1**	We have got some of the best equipment available to us, but our problem is the people who are working on the floor don't understand the importance of temperature. You will realise that common sense is not that common anymore.
Transporter 1 **Case study 2**	This is the nature of the farmers that they are more complacent about their produce.
Expert 1 **Case study 3**	There is a culture among growers that does not support adoption of new technologies in fresh produce chains generally.

5.4.2. *The ingrained culture of "responsibilities shirking"*

Responsibilities diffusion[16] by the supply chain members including blame-shifting[17] and shirking[18] across different parts of the chain was emerged as a prominent behaviour exhibited by the interviewed participants. Presence of unclear accountability and ineffective integration at each stage of the chain were considered to be critical challenges that lead to the behaviour of responsibility shirking among the members of the chain. For instance, growers were found to be blaming transport companies for temperature related issues and similarly, transport company's interviewees were blaming growers or distribution centres for their negligence.

Findings suggested that there was an active presence of an accountability gap at each stage of the vegetable supply chain. As a result of this, behaviour of responsibility diffusion among different actors of the chain was commonly found. Consequently, supply chain members are reluctant to utilise TMTs in their business

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[16] The diffusion of responsibility defined as a sociopsychological phenomenon of an individual to feel decreased responsibility in a group while being part of the group. Darley, J. M. (1970). The unresponsive bystander: Why doesn't he help?

[17] Blaming other members of the chain for not adequately handling produce with the aim of making them responsible for the losses in case the product is rejected at the end of the supply chain

[18] Shirking is intentionally underperforming one's agreed upon duties (Clemons et al., 1993; Wathne & Heide, 2000)

operations as this will make everyone accountable for their actions at each step of the chain. This behaviour is demonstrated from the interview of distribution centre 1 in case study 1: “I think everyone thinks it is everyone else problem, [the] grower thinks [that] once it leaves my gate, my job is done. But he [she] still owns that product until it is received by the customer”.

Experts and technology providers interviewed in this study explained that a lack of vertical integration and information asymmetry at each stage of the vegetable supply chain are also inhibiting the uptake of TMTs. This leads to a behaviour of animosity between chain members, and they start blaming each other for not adequately handling their produce. This friction was best exemplified from the interview of technology provider 1 in case study 1: “the main reason for [non-adoption of TMTs] is that everyone has their own data and does not want to share. The practice of growers blaming the transport companies for mishandling their produce or the transport company blaming the grower is prevalent. So, they have this animosity that grew up among them”.

In summary, an accountability gap and lack of vertical integration makes it difficult for the existing supply chains to utilise TMTs in their business operations. Table 21 below provides some excerpts from the interviews of supply chain members about this behaviour.

Table 21
Interview excerpts highlighting responsibilities shirking behaviour

Supply chain member	Responsibilities shirking
Transport company 1 **Case study 1**	They [growers] are thinking that our business is done when we put our product on the trailer. It is now your problem. Pass the parcel when the music is stopped.
Distribution centre 1 **Case study 1**	They [growers] just want to get away with something so that their produce is sold without having issues.
Expert 1 **Case study 2**	Growers do not have a really good relationship with most people in the supply chain, so they do not want to share information that makes it difficult for this technology to be used to its full potential.
Technology provider 1 **Case study 2**	They [growers] don't insist on using [TMTs] because they are not necessarily held accountable for it.
Distribution centre 1 **Case study 2**	It is the nature of the farmer to get away with something that is not making issue for them.

5.4.3. Culture of concealment and protectionism

The intent of supply chain members to use TMTs in their business operations was also found to be affected by their behaviour of concealment and protectionism. Information asymmetry led to this behaviour that was deeply entrenched across the supply chain. For example, variation in the interpretation and application of required standard operating practices existed among the members of the chain. Protectionist behaviour was also exhibited by some supply chain members and were concerned that TMTs might disclose non-compliance temperature management standards practices.

As mentioned in Section 5.4.2 above, responsibility avoidance and blame-shifting were found as a prominent social norm across the supply chain. However, due to the use of TMTs, vegetable supply chains will become more transparent which is considered to be a challenge for some members of the chain due to the presence of bad practices and supply chain opacity[19]. This was evident from the interview of grower 1 in case study 2 who stated that: “transparency is considered as a challenge as certain customers do not necessarily want it because they felt transparency is alike opening a can of worms”.

Technology providers interviewed as part of this study were more sceptical about the shirking behaviour of certain members of the vegetable supply chains, especially growers. They believed that vegetable growers are not adopting TMTs due to their motivation to hide non-compliant practices. For example, technology provider 1 in case study 1 explained that: “one of the growers actually told me that you are selling “devil tools” [TMTs] as some of the farmers and even other supply chain members see this as a real threat to their business”.

Vegetable supply chain experts interviewed in this study also revealed that TMTs adoption is also impacted by the secretive nature of vegetable supply chain members. Every participant across the chain feels that due to the use of TMTs, other members of the chain will have access to their business secrets and proprietary practices. As a result of this, enhancing the use of TMTs in vegetable supply chains is considered to be a challenge. This is evident from the view of expert 1 in case study 2, “In the domestic market and export market, they [growers] are very secretive of their

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[19] This refers to the lack of transparency and non-disclosure of information across different stages of the supply chain. Chaoyong, Z., & Aiqiang, D. (2018). The coordination mechanism of supply chain finance based on block chain. IOP Conference Series: Earth and Environmental Science.

growing practices and also maybe some of the ways that they treat their produce in the supply chain which they don't want to share it with the guy who's going to be on the farm just across the road".

In summary, the social norm of concealing information about non-standard practices of the supply chain members is impacting their TMTs adoption. In addition, supply chain members also resist the uptake of TMTs to protect their proprietary practices. Table 22 below provides some excerpts from the interviews of vegetable supply chain members regarding this behaviour.

Table 22
Interview excerpts about concealment and protectionism behaviour

Supply chain member	Concealment and protectionism behaviour
Grower 2 **Case study 1**	Because of the nature of the beast, nobody really wants to know what is happening in the supply chain.
Grower 1 **Case study 3**	Because it may expose a lot of things here and there that maybe we've been doing incorrectly or anything like that. Yeah, it could be a possible barrier as well that maybe I do not want to be monitored.
Technology provider 1 **Case study 1**	What we found is that people may be scared of unearthing some of their bad practices.
Expert 2 **Case study 2**	Growers do not have a really good relationship with most people in the supply chain, so they do not want to share information that makes it difficult for this technology to be used to its full potential.

5.5. Review of individual behavioural and social norms-based adoption factors of TMTs

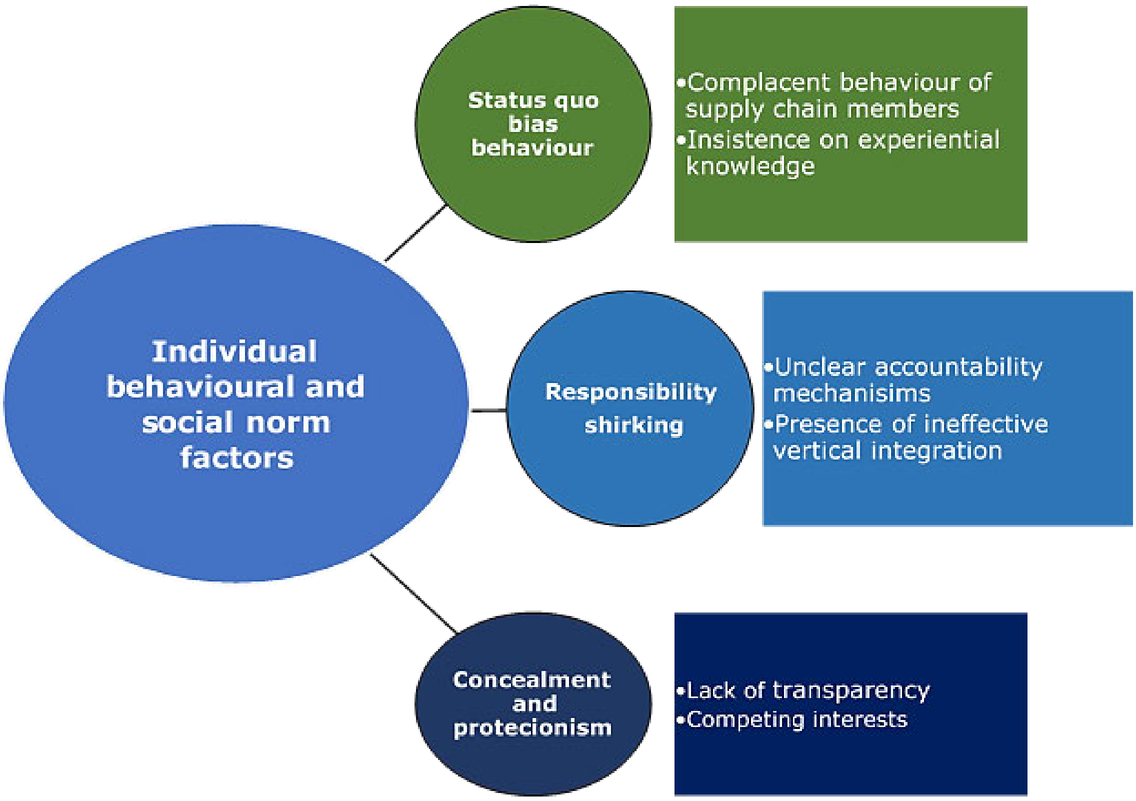
From the interviews of vegetable supply chain members, including technology providers and experts, three major individual behaviours and social norms were identified that impede the adoption of TMTs.

- Firstly, status-quo bias behaviour was exhibited as a prominent individual behaviour among the supply chain members. Growers were found to be more complacent as compared to other members of the supply chain.

- Secondly, averting and diffusion of responsibility and sense of accountability was also found to be a social norm across the vegetable supply chains. Findings suggest that due to lack of accountability, the chain members are able to avoid their responsibilities. Absence of integration and ineffective sharing of information was also considered to be a social norm which affects the adoption of TMTs in vegetable supply chains.
- Thirdly, the behaviour of concealing information about non-compliance practices across the vegetable supply chains was also found to be one of the main deterrents to the adoption of TMTs.

Figure 24 below provides an overview of the individual behavioural and social norms adoption factors of TMTs.

Figure 24
Summary of individual behaviour and social norm-based factors



5.6. Chapter conclusion

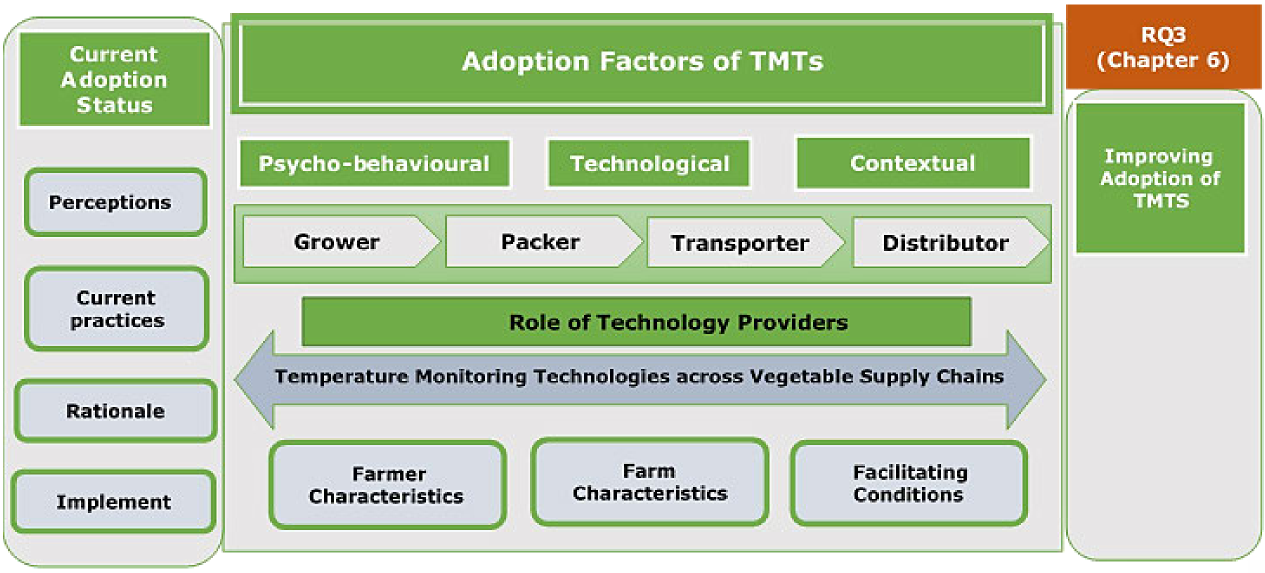
This chapter provided an overview of the findings of Research Question 2 (RQ2). The study identified two types of inhibiting factors affecting the adoption of TMTs in fresh produce supply chains. The first type of inhibiting factors was found to be related to existing practices of temperature monitoring in vegetable supply chains. Upfront and associated costs of TMTs were considered to be some of the central inhibiting factors. Lack of information sharing between TMTs providers and potential adopters was also found to be an inhibiting factor. It was also revealed that existing TMTs were not compatible with the complex nature of fresh produce supply chains which affected its uptake. The second type of inhibiting factors were related to individual behaviour and social norms. Status quo bias, diffusion of responsibilities and concealing behaviour of supply chain members were found to impact the uptake of TMTs. Therefore, these two challenges need to be comprehended and addressed which are discussed in next chapter.

CHAPTER 6: ENHANCING THE ADOPTION OF TMTs IN VEGETABLE SUPPLY CHAINS

6.1. Introduction

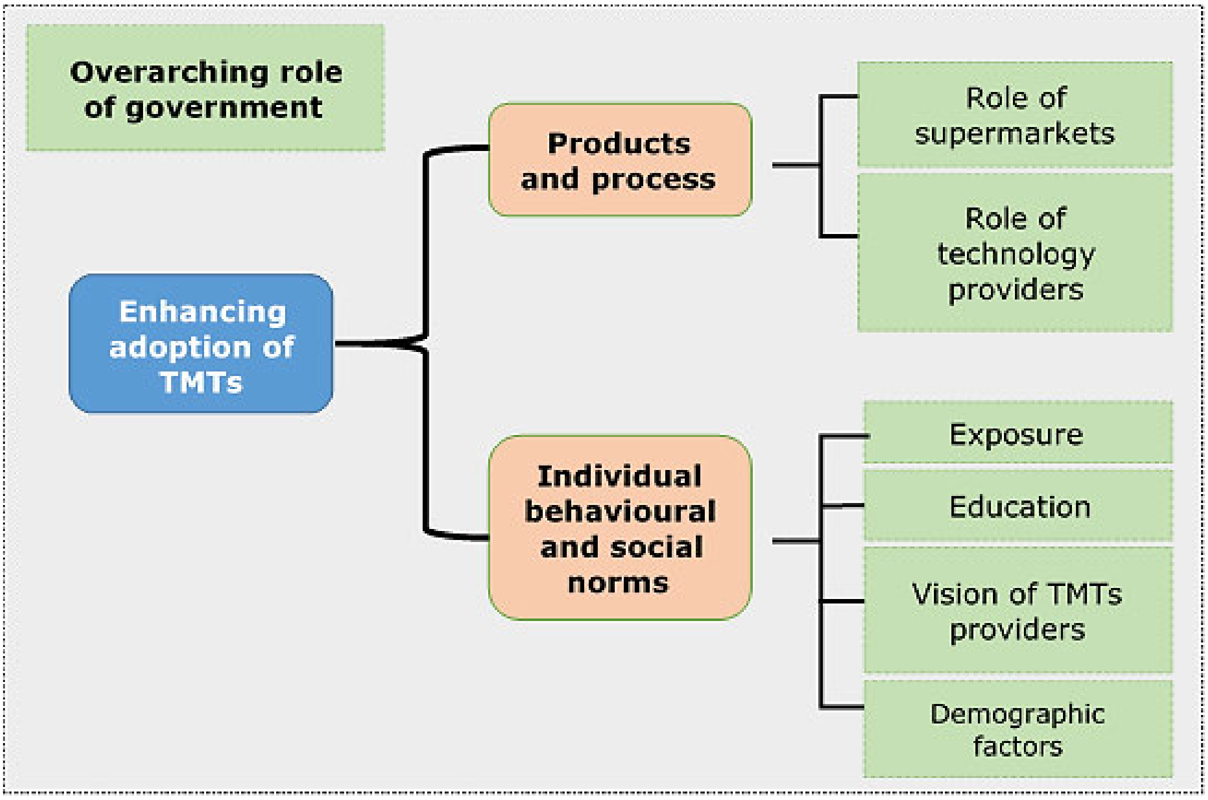
The previous chapter presented findings about the inhibiting factors affecting the adoption of TMTs in vegetable supply chains. This chapter discusses enhancing factors which would improve the uptake of TMTs by vegetable supply chain members. The chapter answers Research Question 3 (RQ3), *“How to enhance the adoption of temperature monitoring technologies practices across vegetable supply chains?”*

Figure 25
Research question addressed by Chapter 6 - enhancing the adoption of TMTs in vegetable supply chains



The enhancing factors of TMTs adoption in vegetable supply chains were mainly centred around two key elements, including products and processes, individual behavioural and social norms. Government plays an overarching role to improve the uptake of TMTs as shown in Figure 26 below.

Figure 26
Overview of enhancing factors of TMTs adoption in vegetable supply chains



6.2. Products and process-based enablers

The products or process-based suggestions for enhancing the use of TMTs are centred around the role of supermarket(s) or retailers and technology providers of TMTs. These are discussed in detail below along with quotes from the interviews of vegetable supply chain members.

6.2.1. Role of supermarket(s) or retailers

In Australia, supermarkets/retailers are key members of fresh produce chains driving whole industry (Davey & Richards, 2013). Therefore, they can play critical role in enhancing the uptake of TMTs. Two key roles of supermarkets were identified from the analysis of data. Firstly, pushing the use of TMTs across downstream operations of vegetable supply chains by including it in their private quality standards. The second strategy could be incentivisation, either financially or providing market preference for those suppliers who can demonstrate temperature compliance throughout supply chain operations.

Supply chain members agreed that the role of supermarkets is integral in improving adoption of TMTs. They highlighted that currently supermarkets do not necessarily require temperature tracking records of fresh produce. As a result, growers including other supply chain members do not feel a need for utilising TMTs in their current operations, as highlighted by grower 2 in case study 1: “as long as you deliver it within 5 °C […] no one ever wants to know what happened before". Due to this, temperature monitoring throughout the chain is not a high priority for the growers as quoted by grower 1 in case study 3: “if you put your body into a farmer's body […] [then] giving supermarket temperature data is not [a] high priority while you are delivering it within [the] specifications”. On the other hand, it has been categorically mentioned that if these supermarkets include this in the specifications and a push factor is involved, then the use of TMTs will be a high priority for them, as quoted by grower 1 in case study 2: “I guess the only way to convince [to use TMTs], is that the supermarkets want us to do it”. Distribution centres were also found to have similar opinion. For instance, distribution centre 1 stated in case study 1: “I can see the adoption of these technologies [TMTs] if it is a requirement of the market chains or customers. There must be a push from supermarkets”.

Lack of a clear cost and benefit analysis has been mentioned as another factor hindering the adoption of TMTs, as mentioned in Section 5.2.1. Most of the vegetable growers were either not orientated about the cost of TMTs or were found to be sceptical about the benefits of it in terms of dollars. In addition to this, growers do not see any economic value by using TMTs in their operations. For instance, grower 2 in case study 2 highlighted that: “[TMTs] is like a token thing where you put 40-50 [AUD] dollars tracker and want to know where it went and that’s it, actually reward versus risk is quite low”. To increase the use of TMTs, experts and technology providers believed that the dollar value of using these technologies is playing a central role. Growers emphasised that financial benefits from the supermarket for providing temperature records throughout the supply chain will enhance its adoption, as stated by the grower 2 in case study 1: “if Woolworth come to me and say we are going to give you another 10 cents a kilo […] if you can prove that your temperatures has been maintained from post-harvest to delivery [then] we will do it so where there is no financial gain, you tend not to do [as] it is in the human nature”. Table 23 below present quotes from the interviews of supply chain members about the role of supermarkets:

Table 23
Interview excerpts about role of supermarket(s)

Supply chain member	Role of supermarket(s)
Distribution centre 1 **Case study 2**	It is all about [the] cost margins and unfortunately in this industry the margins are very tight. Cost and benefit analysis and ROI is one of the best tools to display the importance of these technologies to the user and business.
Expert 1 **Case study 1**	Nature of industry is very reactive, unless there is a major failure in the cold chain and thousands of dollars are at stake, then they will not do it.
Packer 1 **Case study 2**	Another factor is the force from big supermarkets like Coles, Woolworth or Aldi. They want us to provide produce in a certain quality and temperature and they want us to do what can be done to deliver it in that specification. They are not concerned about history of the produce.
Packer 2 **Case study 2**	The other barrier is there is no technology push from the industry. We farmers are doing everything by stick. Like if there is a regulation or market requirement, we will do anything to meet it. There is no technology push either from the industry and not from the supermarket chains.
Technology provider 1 **Case study 2**	I think the best way to get uptake is to actually show them [farmers] what they don't know and give them data and prove them that they are making losses because they don't have good supply chain practices
Technology provider 1 **Case study 3**	Cost and benefit analysis should be carried out.

6.2.2. Role of technology provider(s)

Technology providers also have a key role to play in enhancing the adoption of TMTs in vegetable supply chains. Two critical roles of technology providers were identified from the interviews of supply chain members. The first one is that technology providers need to comprehend the complexity of fresh produce chains and the second one is that the customisation of current technologies for these chains is imperative for its adoption.

Integration of TMTs can be primarily facilitated by the technology providers if they can clearly understand the overall structure and complexity of fresh produce supply chains, especially at the production stage. As mentioned above in Section 5.2.3, there exists an information gap between technology providers and growers, which blocks the uptake of TMTs. Vegetable supply chain experts believed that active participation from technology providers through information sharing and engagement with the growers can enhance its adoption, as stated by expert 1 in case study 3: “technology providers have to understand […] about the production. They [TMTs technology providers] can then know that their technology can do that. They've got to be able to explain that to the producer”. Additionally, it is also emphasised that TMTs adoption can be enhanced if technology providers practically demonstrate the business viability of these technologies to growers, as stated by grower 2 in case study 1: “like we have fertiliser companies coming in and explaining their products, but I haven’t seen anyone coming and explaining about these gadgets [TMTs]”. To this end, experts also identified that technology providers are not keen on engaging with the growers rather they rely on the opinions of neutrals, as stated by the expert 1 in case study 2: “they prefer to work with people like me rather than at the ground level with growers, because I don't think they've got the resources to do that or understanding of [actual needs]”.

Customisable TMTs solutions can enhance their uptake and integration in the operations of vegetable supply chains. Current TMTs are not compatible with the complex nature of fresh produce, as mentioned in Section 5.2.4. Growers articulated that in case of fresh produce, bin-based[20] technologies need to be developed in which reliance on human intervention is limited, as observed by the grower 1 in case study 1, “unless it's [TMTs] already built onto the crate [bin] and then use like kind of RFID tags tied to a scanner, […] that could be a way where they go through your scanning equipment”. A transport company identified the barcode technology attached to each pallet and providing tracking information at the end of the chain as mentioned by

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[20] Bin-based is in which a temperature logger can be fixed with the bin at the farm including smart bins which provides information about the status of produce including temperature.

transporter 1 in case study 1, “my own method would be to have […] barcode identification of each pallet as it's loaded, position wise and everything else including temperature data, customer information and other attributes’.

In summary, two key roles were found to be attributed to the technology providers of TMTs. They need to understand the needs of vegetable growers and provide customised technologies to cater to the complex nature of fresh produce chains. Table 24 provides some quotes from the interviews of supply chain members about the role of technology providers in enhancing the adoption of TMTs.

Table 24
Interview excerpts about role of technology provider(s)

Supply chain member	Role of technology provider(s)
Packer 1 **Case study 2**	I think that if there were more people out there sort of going around to farms and just made them [growers] aware of technology, or even if they send out emails of interest can increase use of these technologies.
Technology provider 1 **case study 2**	I think the best way to get uptake is to actually show them [growers] what they don’t know and give them data and prove to them that they are making losses because they don't have good supply chain practices.
Expert 1 **Case study 3**	Its [TMTs] can be enhanced if providers provide that underpinning knowledge, not only of the technology that they're going to sell, but of the needs of the growers.
Technology provider 1 **Case study 1**	We need to provide a technology which reduces risk of the farmers and automate certain operations for them.
Packer 1 **Case study 3**	[TMTs] should be less laborious, friendly and easily understandable.

6.2.3. *Overarching role of government*

The role of government in enhancing the uptake of TMTs by the vegetable supply chain members was considered to be a critical factor. Two important aspects were suggested from the interviews of supply chain members. The first was about enacting a regulatory framework focusing on products’ traceability in fresh produce supply chains and the second was centred around support from government.

Findings suggest that there is a lack of an active regulatory framework enforcing the traceability of fresh produce from farm to fork. Supply chain members envisaged that the current provenance of fresh produce is based on the industry and commercial traceability systems in which product specifications other than temperature are highly relevant. Therefore, enacting a traceability regulatory framework regarding temperature will enhance utilisation of TMTs from a quality management perspective. For instance, packer 1 in case study 2 highlighted that, “I think there should be some sort of regulations to have make sure that it [temperature] is controlled. But I don't believe that there's anything […] which forcing it on us to implement”.

In addition, supply chain experts and technology providers interviewed in this study also mentioned that TMTs adoption can be enhanced if there is an obligatory regulatory compliance of temperature monitoring across the chain. They elaborated that unless temperature monitoring is a legal requirement, their adoption is not considered integral by the members of the chain. This is also referenced by packer 2 in case study 2, “We [growers] are actually doing everything by stick. Like if there is a regulation or market requirement, we will do anything to meet it”.

Government support was also mentioned as a key factor in increasing the uptake of TMTs. Different provisions of government support were presented by the participants of supply chain members. Financial government support in terms of contribution in upfront or associated cost of TMTs was considered to be a key enhancing factor. Infrastructure development for the effective utilisation of TMTs and updated information providers were suggested to increase the uptake of these technologies. Table 25 below contains some excerpts from the interviews about the role of government.

Table 25
Interview excerpts about the overarching role of government

Supply chain member	Role of government
Packer 1 **Case study 2**	I guess if it [TMTs] are expensive, whether the government sort of helps out a little bit a lot of the farmers can't just afford to just throw out all this money just to have the technology
Expert 1 **Case study 1**	I think there is a role in what are viewed as independent service providers in this area just to sort of give advice or to give comment or to convey case studies of what others have been doing without it being seen as a sales approach yet.

6.3. Individual behavioural and social norms-based enhancing factors

Findings suggest that behavioural factors are considered to be an important aspect that effect the intended uptake of technologies in agri-food supply chains. Certain elements of behavioural interventions captured from the interviews of vegetable supply chain members including technology providers and experts are presented below. These elements primarily centred around open communication and information sharing among the members of vegetable supply chains and technology providers.

6.3.1. Supply chain exposure

Exposing growers to technologies was identified to enhance the adoption of TMTs across vegetable supply chains. As discussed in Section 4.2, growers perceive temperature management as an important element, however, due to insistence on experiential knowledge, they hold myopic views about TMTs. Generally, vegetable growers are not exposed to the existing TMTs, as grower 2 in case study 1 categorically revealed that, “except from cold rooms, there is nothing that I know about it. We have never been introduced to anything that would allow us to monitor our temperature”. Therefore, exposing growers to TMTs can enhance their uptake. Grower 2 in case study 2 highlighted that, “exposure, as I said, makes people aware of what technology is because without understanding it or seeing it or knowing it exists, it's never going to expand”.

Changing growers and supply chain members orientation to a positive intent towards the use of TMTs will enable them to realise potential benefits for their businesses. From the perspective of potential adopters, growers were found to be keen to get more information about TMTs. They perceived that like other suppliers of inputs (fertilisers, chemicals), TMTs providers also need to display their products and expose producers to use it in their business operations, as stated by grower 2 in case study 2: “displaying of [TMTs] technologies will also improve its adoption”.

6.3.2. Growers’ education

Another critical enabling factor, after exposing supply chain members and growers to TMTs, was educating them about TMTs and their usage. Educating supply chain members about the real value of TMTs in their business operations can enhance their adoption, as cited by the technology provider 1 in case study 2, “I think the best way to get uptake is to actually show them [growers] what they don't know and give them data and prove to them that they are making losses because they don't have good supply chain practices”.

As mentioned in Section 5.2.1, growers are very sceptical about technologies and are not aware of their financial benefits from adoption. Therefore, providing information and educating them about the financial outcomes of these technologies will also enhance their uptake. This is highlighted by distribution centre 1 in case study 2, “chain members have to understand what the cost is to monitor temperature of their produce to their business as compared to not monitoring it. If they don’t see the value of monitoring, then they won’t invest in it”.

Supply chain experts interviewed as part of this study also believed that educating producers about TMTs would enhance its adoption. Vegetable growers need to be educated about the challenges of temperature monitoring right from the start of the chain and how it impacts the quality of produce and financial gains at the end. As pointed out by grower 1 in case study 1: “In my view educate farmers about it [TMTs] right from the start to the end. I think we don’t quite understand how it works”. On the other hand, supply chain members hold myopic views of education and training. This is due to ineffective ways of sharing complex information. As stated by expert 1 in case study 3, “they [growers] are not interested in tertiary education at all, […], all they want is someone that could go and work in the fields and pull out the crops”.

One-to-one interaction was considered to be an important strategy to improve the adoption of TMTs in vegetable supply chains. Supply chain experts believed that this type of interaction enhances open communication and the level of trust among supply chain members. However, due to efficiency and financial constraints, this method of education has been discarded, as stated by expert 1 in case study 1: “I think improving adoption is sort of the reverse of what a lot of people were saying […] one-on-one interaction is really important […], just spending time with each other. And then it went away from that. That's too inefficient’.

6.3.3. Improved vision of technology providers

To enhance the adoption of TMTs in vegetable supply chains, technology providers need to understand the complexity of production processes as well as the potential value of their technology in a strategic way for the grower’s business operations. . However, interviews from the technology providers suggested that they are focusing on utilising data loggers as a means to claim insurance in case something goes wrong at the end of the chain. This was also evidenced from the interview of expert 1 in case study 3: “vision of technology providers [TMTs] is not adding value to the product but asserting to claim the insurance which I think is the wrong way around to think about it”. They emphasise the utility of TMTs as a short-term tool or evidence to use against the distribution centre or a chain store in case of product rejection. Although, it may be a successful strategy for TMTs adoption in the short term, but in the long term, it reduces the scope for utilising data loggers for effective post-harvest decision-making processes. To improve the use of these technologies, TMTs providers must highlight its evolving scope as a sustainable solution to improve profitability and reduce existing food waste in fresh produce supply chains.

6.3.4. Role of demographic factors

Findings from the interviews suggested that two demographic factors were playing a prominent role in enhancing the use of TMTs. These factors included the age of the farmer, and their business succession plans.

Older growers typically behave suspiciously and are sceptical about new technologies. However, the younger generation have a positive perception of technology and seek to adopt it to improve their productivity. It was clearly mentioned that the younger generations are more ambitious and are looking forward to using technologies to get a competitive edge and enhance their profitability. Generally, the older generations do not have the drive to know about technologies that can be useful in their business operations, but the involvement of younger generations can change this. According to expert 1 in case study 3: “the other thing is that the overlay of all of this is the age of farmer. I mean, you've got farmers that are in their 60s and some of them are still in their 70s and for them to look at change and using new technology is not something that they are looking forward to”.

Succession planning was also found to be an important instrumental factor for enhancing the use of TMTs. The planning horizon becomes longer for the vegetable firms that have a successor which leads the farmer to invest more in modern technologies. Technology provider 1 in case study 1 highlighted that, “some of them [growers] do not have the will or desire to adopt new technologies unless they have got children coming into the business”.

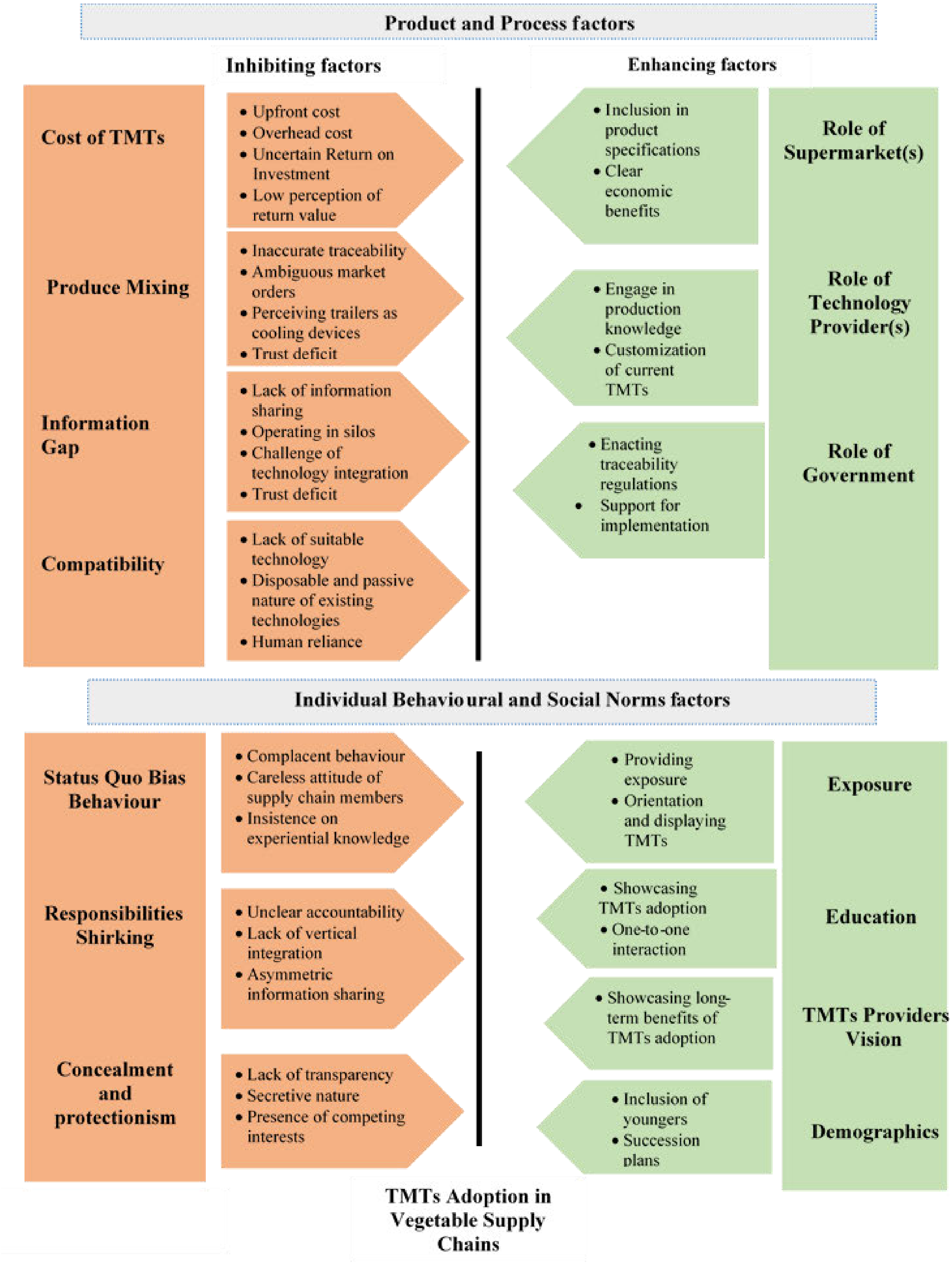
6.4. Review of TMTs adoption inhibiting and enhancing factors

Several inhibiting and enhancing factors regarding the adoption of TMTs in vegetable supply chains were identified from the analysis of supply chain members' interviews. Inhibiting and enhancing factors were classified into two main types depending on their nature and presence in vegetable supply chains.

- Product and process-based factors related to the current practice of temperature monitoring in vegetable supply chains.
- Individual behaviour and social norms related to overall behavioural and existing norms of supply chain participants. Figure 27 below summarises these factors and provide an overview of related items discussed in each factor.

Figure 27

Review of inhibiting and enhancing factors of TMTs in vegetable supply chains



6.5. Cross case analysis

Cross case analyses were undertaken to identify differences and similarities between the vegetable supply chains studied in this research. The focus of this analysis was to present similarities and differences identified through focusing on the nature of each chain, its market orientation, participants' perception of temperature monitoring and existing practices of cold chain management.

As discussed in Section 3.7.2, all three cases selected for this study were vegetable supply chains. However, in terms of market orientation, the supply chain in case study 1 was providing broccoli to domestic as well as export markets, case study 2 primarily supplied their produce to domestic markets and case study 3's target market was central markets only.

There were no major differences identified in terms of the supply chain participants' perception about the importance of temperature management and monitoring across selected vegetable chains. Every member across the chain in each case study highlighted that temperature monitoring is integral to improving product quality, enhancing shelf life of fresh produce and increasing any economic benefits. However, in the majority of cases, their practical approach to temperature monitoring was found to be reactive. They monitor temperature in case of any challenge to the supply chain, such as rejection at the distribution centre.

In terms of cold chain management practices, some differences were identified among the supply chains studied. It was observed that temperature monitoring practices depend primarily on two main elements, including the nature of fresh produce and target market requirements. For instance, in case study 2, at the farm to packing facility stage, shallots are not treated with hydro-cooling due to their endurance to high temperature. Similarly, in case study 3, participants were found unaware of hydro-cooling or vacuum-cooling technologies as they were not supplying their produce to supermarkets. Table 26 below provides an overview of existed similarities and differences across selected case studies.

Table 26
Cross case analysis

	Case study 1	Case study 2	Case study 3
Market orientation	Export and domestic	Domestic	Central Markets
Products	Broccoli	Broccolini and shallots	Asian vegetables
Family business	Yes	Yes	Yes
Perceived importance of temperature			
Importance of temperature management			
Reactive approach			
Cold chain management practices			
Farm to packing			
Lack of temperature monitoring on farm			
Lack of proper produce handling on farm			
Shifting produce through open trucks		Occasional	
Occasional pre-cooling			×
During packing and grading			
Controlled packing environment			×
Utilising cold rooms			
Farm gate to distribution centre			
Temperature-controlled transport			
Manual recording of temperature data			
Practice of product mixing			
Temperature feedback mechanism	×	×	×

Blank Cells= Yes Cross in Cells= No

There were numerous similarities among the cases about inhibiting and enhancing factors of TMTs adoption across the chain. Cost and non-guaranteed return on investments were specifically articulated as one of the critical inhibiting factors. Similarly, from the perspective of supply chain participants' behaviour, lack of accountability, ineffective vertical integration, lack of trust and collaboration and responsibilities shirking were identified as prominent inhibiting factors. It was also observed that the role of supermarkets and technology providers were considered integral in enhancing the adoption of TMTs in vegetable supply chains.

6.6. Unintended findings

The study attempts to explore a little-known phenomenon of TMTs adoption in vegetable supply chains. Some unexpected findings were observed and captured from the interviews of supply chain members.

The first unintended finding was that seasonality has a central impact on technology adoption in the horticulture sector. Findings suggested that vegetable growers are different from fruit growers due to seasonality. For instance, vegetable growers tend to work all year around and grow different types of vegetables whereas fruit growers have a specific season each year. As a result of this, fruit growers have the time to explore different technologies and decide on the suitable ones, while, on the other hand, vegetable growers do not have the opportunity to do so due to their hectic routine. Therefore, technology providers have to understand this context for better adoption, as stated by the technology provider 1 in case study 2, "I do understand that fruit growers are different to the vegetable growers in a way that vegetable growers sort of tend to work 24/7, 365 days a year and so they're always very busy whereas fruit growers tend to have periods where they're not quite as busy due to seasonality of the product. Therefore, fruit growers get more time to do planning and that sort of thing, which I think sometimes makes a little bit easier for them to adopt any technology".

A second unintended finding was the collaborative nature of some TMTs providers with certain vegetable growers and government entities. Technology providers tend to work with growers and other supply chain members who are more oriented towards export markets. They believe that there is scope for the existing technologies to be adopted for export markets rather than for use in domestic markets.

6.7. Chapter conclusion

This chapter provided an overview of the findings of Research Question 3 (RQ3). To enhance the adoption of TMTs, the role of supermarkets, technology providers and government is integral. They can drive the industry by showcasing real value of these technologies to potential adopters through exposure and educating supply chain members. Overall, this chapter has made significant contributions by explaining factors affecting the adoption of TMTs and various ways of enhancing its use in vegetable supply chains. The next chapter discuss these findings in the light of prior literature.

CHAPTER 7: DISCUSSION

7.1. Introduction

Previous chapters outlined literature and findings about the adoption of TMTs in the context of vegetable supply chains in Queensland, Australia. The current adoption status of TMTs was presented and numerous inhibiting and enabling factors were examined. Perspectives of the members of vegetable supply chains and technology providers were unified to identify challenges in the uptake of TMTs.

Chapter 7 discusses the findings of each research question presented in Chapter 4, Chapter 5 and Chapter 6 respectively. Each research question is discussed in turn in Sections 7.2, 7.3 and 7.4. The research questions for the study are:

RQ1: *To what extent temperature monitoring technologies have been adopted across vegetable supply chains?*

RQ2: *What are the current practical and behavioural perspectives influencing the adoption of TMTs across vegetable supply chains?*

RQ3: *How to enhance the adoption of temperature monitoring technologies across vegetable supply chains?*

7.2. Current adoption status of TMTs in vegetable supply chains (RQ1)

The purpose of RQ1 was to explore the current adoption status of TMTs across different stages of vegetable supply chains. Refrigerated cold chains maintain perishable food within a desired temperature range to preserve its quality, extend and ensure its shelf life, which leads to financial gains for the stakeholders across the chain (Mercier et al., 2017; Shashi et al., 2021).

Two factors need to be considered to understand the current adoption status of TMTs in vegetable supply chains. The first factor is to comprehend the perceptions of vegetable supply chain members about temperature monitoring and its relevant technologies. This is due to the fact that perceptions play a critical role in the decision-making process of farmers (Edwards-Jones, 2006). The second one is to discuss the current practices of temperature monitoring across different stages of vegetable supply chains. Combining perceptions and practices of supply chain actors can illustrate the current status of TMTs adoption.

The study found that growers and vegetable supply chain members considered temperature monitoring to be important across all stages from production to retail. Three key perceptions about temperature monitoring highlighted from the interviews of supply chain members were enhancing the shelf life and quality of vegetables, improving visibility of the supply chain, and achieving financial gains. A lack of proactivity about temperature monitoring was also found among all vegetable supply chain members. Perceptions about the importance of cold chain management in fresh produce are also highlighted in the literature as presented in Table 27 below.

Table 27
Prior literature on the importance of TMTs highlighting perceptions of vegetable supply chain members

Perceptions about TMTs	References
Enhancing shelf life and quality of fresh produce	(M. Göransson et al., 2018; Ruiz-Garcia et al., 2010; Tsironi et al., 2017)
Financial gain	(Badia-Melis et al., 2018; Lim et al., 2021; Wang & Zhao, 2021)
Improving visibility of the chain	(Bastian & Zentes, 2013; Gao et al., 2020)
Reactive approach	(J. P. Chavas & C. Nauges, 2020)

Members of the vegetable supply chain interviewed in this study perceived that temperature management and monitoring can play a critical role in enhancing the shelf life and preserving the quality of their produce. This perception agrees with the previous literature on the importance of temperature and its relationship with shelf life and quality of fresh produce (Mercier et al., 2017; Ndraha et al., 2018; Shashi et al., 2021). Similarly, Torres-Sánchez et al. (2020) experimentally estimated the quality and shelf life of lettuce throughout the supply chain under a different controlled temperature environment.

Actors of the vegetable supply chain also perceived that TMTs could improve the visibility and provenance of produce. Vegetable growers believed that it could allow them to check on real-time changes across the upstream operations of the chain. These findings are consistent with the literature on traceability and its importance along the chain (Costa et al., 2013; Óskarsdóttir & Oddsson, 2019).

Financial gain was also perceived as a significant outcome from the adoption of TMTs. Maintaining integrity of the cold chain from farm to fork was seen to lead to higher profits by improving chain efficiency and product pricing. The perceptions of supply chain members in this study agree with the previous research in terms of achieving financial benefits from adopting TMTs (Lim et al., 2021; Shashi et al., 2021). Similar evidence has also been found in the literature on cold chains in agri-food (Shashi et al., 2021; Vrat et al., 2018).

Vegetable supply chain members interviewed were unable to translate the above-mentioned perceived benefits from TMTs into financial gains. This led them to exhibit a reactive behaviour towards the utilisation of modern temperature monitoring and controlling technologies in their business operations. Recent studies are more focused on the sustainability challenges of food waste through reducing emissions (Bhatia et al., 2023) and enhancing shelf life and preserving quality of the fresh produce (Ramanathan et al., 2023). However, vegetable supply chain members (especially growers) who bear the cost of TMTs consider shelf life and preservation of quality as drivers of financial gains. This aligns with the findings of Cook et al. (2022) who confirmed that clear financial benefits from the adoption of digital technologies in the Australian agri-food industry can enhance its uptake. Future research needs to be conducted on carrying out cost and benefit analyses of TMTs by taking into account the perceptions of growers and current market scenarios.

Vegetable supply chains focused on export markets reflected greater proactivity in the utilisation of TMTs. Growers who were engaged in dealing with export markets were of the opinion that their produce is strictly checked for temperature at arrival. Temperature abuse along the chain leads to produce/consignment rejection at the distribution centre. Therefore, they perceived that the use of TMTs can reduce their financial loss and can be used as evidence in the case of rejection at arrival (Walsh, 2022).

To understand the practices of temperature monitoring, operations of vegetable supply chains were classified into three main activities, as discussed in Section 4.3, which are: farm to packing, during packing, and farm gate to distribution centre. Details of practices at each stage are presented in Table 28 below.

Table 28

Temperature management practices across vegetable supply chains

Stages	Farm to packing	During packing	Farmgate to distribution
Description of activities	Harvesting and transporting to pack house	Cleaning, grading and packing	Transporting and handing over
Temperature monitoring status	No temperature monitoring	Occasional temperature monitoring	Continuous temperature monitoring
Temperature monitoring practices	• No-monitoring on farm • produce setting in open environment • Shifting produce through open trucks • Occasional Hydro-cooling and vacuum-cooling depending on weather and market demand	• Controlled packing environment in some instances • Temperature control equipped cold rooms	• Temperature-controlled transport • Manual recording of temperature data • Product mixing on trailer as a challenge • Small window for order affect temperature practices • Temperature historical data is not considered at DC • Different tools for temperature monitoring at DC • Ineffective feedback mechanism

The farm to packing stage of vegetable supply chain exhibited no temperature monitoring largely because of the shorter distances between farms and packing facilities. Growers use open trucks to transport their produce without any temperature monitoring. This finding agrees with the study of Sanad Alsbu et al. (2023) who conclude that there is a minimum level of temperature monitoring at the farm to packing stage which leads to a higher amount of fresh produce loss. It was also observed that some growers were using hydro-cooling or vacuum-cooling techniques for higher market value vegetables (such as broccoli or lettuce) which were destined to supermarkets. Literature recommends end to end temperature monitoring right from the time they are harvested till its delivery for preserving its quality (Ashok et al., 2017; Centobelli et al., 2020; Mercier et al., 2017).

Intermittent temperature monitoring practices were observed during the packing stage which consists of cleaning, grading and packing activities. Packing was carried out in temperature-controlled rooms for heat sensitive products like broccolini, broccoli, whereas other produces were packed in non-controlled temperature areas (such as shallots and cucumbers). The focus of temperature monitoring at this stage was on bringing down surface temperature of produce rather than its core temperature. Literature on agri-food supply chains has found similar evidence of using cool environments to reduce the impact of higher temperature without measuring the core temperature of the produce (Sanad Alsbu et al., 2023).

Optimal arrangements for continuous temperature monitoring were observed in the third and final portion of vegetable supply chains that consists of transportation to the distribution centre. The produce is loaded onto a transport trailer that is equipped with temperature record tools. Temperature record is maintained in this part of the supply chain to prevent any loss (including insurance claims) in case the produce is rejected at the distribution centre due to temperature abuse. The key challenge in this part of the supply chain is that a diverse variety of products are loaded onto each truck which have different temperature requirements. Thus, mixing different types of produce in each load negatively impacts the overall quality of the consignment. These findings are consistent with the existing literature on agri-food supply chains which shows that product mixing is a common practice in logistic operations to increase transport efficiency (Surucu-Balci & Tuna, 2021).

Temperature monitoring data is not utilised properly in the current practices of temperature monitoring in vegetable supply chains. There is a lack of effective feedback mechanisms between growers and the staff in distribution centres. Temperature data is only shared in case of product rejection due to temperature abuse. Furthermore, the variation in temperature monitoring and logging tools at the distribution centre and supermarkets results in a cumbersome process of data retrieval and communication. Literature on cold chain monitoring in agri-food has found similar evidence of referring to data only in the case of complications and complaints (Anand & Barua, 2022). However, this study found that incompatible temperature monitoring tools at each stage of the chain blocks effective information sharing along the chain.

In a nutshell, temperature monitoring practices of vegetable supply chain members did not correspond to their perceptions. This perception-practice chasm shows that low adoption of TMTs in these chains is not due to lack of awareness about the importance of temperature monitoring, but the challenge is translating its perceived benefits into financial gains. Growers are expected to bear the cost of TMTs while extracting low level of economic gains from its use. This deters them form proactively seeking information and improving their temperature monitoring practices. Previous research in the context of agriculture has shown that different factors are responsible for a perception-practice chasm, such as dependence on experiential knowledge of farmers, lack of trust and coordination among the members of the chain (Dania et al., 2018). However, this study has also raised an opportunity for future research in the context of vegetable supply chains to undertake cost and benefit analyses of TMTs. This will provide a clear picture to the growers about the feasibility of TMTs, its value as an investment and its impact on long term sustainability of their business operations.

7.3. Adoption factors of TMTs in vegetable supply chains (RQ2)

The purpose of RQ2 was to identify specific factors affecting the adoption of TMTs in vegetable supply chains and to address the gaps identified in the literature for understanding the underlying aspects (behavioural, psychological and social norm) of technologies adoption in fresh produce chains (Aamer et al., 2021; Giua et al., 2022). Chapter 5 identified two main factors, namely product or process based, and individual behavioural or social norms based. These two factors are then classified into further categories as presented in Figure 22.

Prior research has broadly examined the factors affecting the adoption of different technologies in agriculture (Ugochukwu & Phillips, 2018). These technologies include precision agriculture technologies (Hort Innovation, 2020; Tey & Brindal, 2012; Vecchio, Agnusdei, et al., 2020), blockchain technologies (Zhao et al., 2019), IoT (Kodan et al., 2022; Pillai & Sivathanu, 2020) and digital twins (Purcell & Neubauer, 2023). Studies on cold chain management in the fresh produce industry are getting momentum due to their inherent complexities, combined with the increasing interest of consumers in eating fresh fruits and vegetables (Bremer, 2018; Shashi et al., 2021).

This study is unique in a way that the focus of this research is only on TMTs in vegetable supply chains. The study provides a holistic view about the perceptions, practices and experiences of supply chain actors along with the insights from TMTs providers and experts. From the findings of this study and in the light of the prior literature, five observations were extracted from the interviews of the participants which are discussed below.

7.3.1. Existence of low compatibility of current TMTs with the existing vegetable supply chain operations

Currently available TMTs exhibit low compatibility with the complex nature of vegetable supply chains. The members of the chain interviewed in this study considered it to be an overarching challenge. They reported that existing TMTs are not built for purpose to effectively integrate the complex needs and requirements of these chains. Four key issues were identified including design problems, the disposable and passive nature of present TMTs, heavy reliance on human interventions and the use of different temperature monitoring tools along the cold chain processes. These are discussed in detail below in the light of prior literature.

Existing TMTs in vegetable supply chains are designed to record the ambient temperature of the environment without providing any precise reading about the core temperature of the produce (Weston et al., 2021). As such, quality and the remaining shelf life of a produce depend on the management of its core temperature (Zhao et al., 2022). The challenge in existing TMTs is that it is installed either at pallet or container level which provides a general overview of overall surface temperature (Mosadegh Sedghy, 2018). To effectively monitor the temperature, readings from different parts of the pallet or container are vital. Thus, current TMTs fail to deliver precise data about the core temperature of the produce, which diminishes its utility for vegetable supply chain members. Mosadegh Sedghy (2018) also highlighted these challenges in their review article on RFID tags in the context of agricultural cold chain monitoring. Currently research is focusing on the development of smart pallets and containers to achieve full environmental sensing solutions by integrating IoT into fresh produce supply chain operations (Saffari et al., 2022).

The passive[21] nature of existing data loggers (TMTs) reduces their utility in the current processes of vegetable supply chains and increases its reliance on human interventions at each stage (Kumar et al., 2009). Data loggers record temperature throughout logistic operations which are usually available for retrieval at the end of the chain – typically at the distribution centre. Additionally, most of the existing TMTs are for one-time use only and therefore require repeated purchase of new data loggers (Roberts, 2006). They are usually thrown away at the end of supply chain operations. It is a difficult activity for the actors along the chain especially growers to retake possession of these data loggers from the end destination (Kapoor et al., 2009). They have to make special arrangements for retrieval and further analysis of collected data which act as a deterrent for them to actively track the temperature of their produce. The cost repercussions of the disposable nature of TMTs are discussed later in Section 7.3.2.

These findings align with the prior research on the challenges of utilising RFID tags or data loggers in cold chain monitoring for fresh produce (Angeles, 2005; Kapoor et al., 2009). Further research is suggested to build on the recent literature on active data collection such as integrating IoT with RFID tags to enhance its competitiveness and compatibility with the complex nature of perishable food supply chains (Tan & Sidhu, 2022).

Findings of the study indicate that the use of diverse temperature monitoring and recording tools at different stages of the supply chain act as a deterrent for the uptake of TMTs. For instance, growers embed RFID tags with their produce which records its surface temperature while the staff at distribution centres use infra-red laser guns Gowen et al. (2010) to monitor temperature of pallets as it often proves to be more commercially viable approach (Badia-Melis et al., 2018). The challenge is that

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[21] Temperature monitoring technologies are usually coming in active and passive formats. Active data loggers continuously collect data and convey it in real time while passive ones do not convey data in real time and requires an action to be performed to retrieve data. Details about different types of TMTs are available in chapter 2.

variation in TMTs produce different results which acts as a major limiting factor in their implementation. Similar results for temperature monitoring of vegetables (cucumber and chard) were also found by (Badia-Melis et al., 2017, p. 211) who confirmed that "temperature measured by thermal imaging showed a differential between 1.9 and 6 °C compared to temperature measured by thermal sensors".

This study also suggests that one of the key reasons for low compatibility of existing TMTs is the presence of information asymmetry among potential users and its providers (Lamberty & Kreyenschmidt, 2022). Vegetable growers reported that a "silo" mentality is present among the technology providers as they are currently driven by technological advancements rather than understanding ground realities of the overall ecosystem of fresh produce supply chains (Mahdad et al., 2022). As a result of this, there is a lack of coordination and trust among the technology providers and potential users (growers) which leads to developing TMTs in which users demands are not embedded. Prior literature has raised similar issue of limited coordination between technology suppliers and users in the uptake of technologies in agriculture (Jayashankar et al., 2020).

In summary, presently available TMTs are not technologically fit for purpose and do not have the perceived value for its uptake. Similar findings in prior literature have been suggested that compatibility of technologies with the complex nature of perishable supply chains is a challenge for its effective adoption (Sinha & Dhanalakshmi, 2022; Yadav et al., 2020).

7.3.2. TMTs cost is considered to be an expense rather than an investment

Members of the vegetable supply chains perceived the purchase of TMTs as an additional expense rather than an investment. There are two reasons for this behaviour:

- TMTs does not make a viable business case as retailer is not paying extra for temperature-controlled produce.
- Existing TMTs comes with a variety of repetitive and continuing costs including the time to cater for data collection and analysis.

These two factors explained below in the light of relevant literature.

Vegetable producers argued that TMTs do not yield any additional financial benefit to them from wholesalers (distribution centres). Use of TMTs is considered to be a supplementary quality attribute as it is neither financially incentivised nor given any specific preference by supermarkets. Currently, temperature requirements for fresh produce at the distribution centre is 5 °C or below, as specified by the Food Safety and Australia New Zealand Standards[22] (FSANZ, 2016). There is no requirement by any supply chain actors interviewed in this study for checking the temperature history of fresh produce across different stages of the chain. Consequently, vegetable growers are reluctant to adopt TMTs as its cost is not justified in their business operations. This attitude was also highlighted in the study of Aamer et al. (2021) who concluded that financial leverage plays a central role in the adoption of IoT in agriculture. Prior literature also suggests that there is a lack of specific guidelines to consider the economic risks and business viability of cold chains in agriculture (Mercier et al., 2017). Further awareness is needed to understand and showcase the business viability of TMTs along fresh produce supply chains.

The second issue faced by growers is the ongoing and continuous cost of utilising TMTs (data loggers) for their supply chain operations. Repetitive costs arise due to the disposable nature of existing data loggers, as discussed above in Section 7.3.1. Currently, growers have to purchase new data logger(s) for each shipment which are disposed of at the end of the chain. Thus, growers incur repeating expenditure of at least AUD 50 for each data logger (usually each shipment requires more than one data logger). This constitutes a significant proportion of the overall shipment of the supplied vegetable (as it is a low-cost product). This acts as a deterrent for the grower to take up TMTs. For decision-making, growers or other members of the chain need to retrieve the data logger for data extraction and analysis. The challenge is that these data loggers are usually lost due to presence of multiple handlers across the chain. These findings are consistent with the study of Mosadegh Sedghy (2018) who studied RFID tags in cold chain monitoring and presented the above-mentioned limitations of it in fresh produce chains.

7.3.3. Striving to achieve storing and logistic efficiency at the cost of produce quality

Mixing different types of produce in cold rooms and in trailers during storage and transit operations was also found to be a key challenge towards the uptake of TMTs in vegetable supply chains. Unlike fruit growers, vegetable producers are

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[22] Food Standards Australia New Zealand (FSANZ) is an independent statutory agency established by the Food Standards Australia New Zealand Act 1991 (FSANZ Act). Safe temperatures are 5°C or colder, or 60°C or hotter.

growing a diverse range of fresh produce at the same time. Vegetable growers temporarily store different types of freshly harvested produce with varying storage temperature requirements in a cold room having a common ambient temperature (normally 5 °C). It is neither financially feasible nor administratively viable to arrange a separate cold room for each type or variety of produce. Similarly, during logistic operations, a variety of produce is combined together in a trailer to reduce transportation costs. This practice of produce mixing during transit can lead to a higher or lower than desired temperature in the container (Derens-Bertheau et al., 2015; Newton et al., 2020). Adjusting temperature for one product cannot be achieved without negatively impacting other product(s). Although recent literature on fresh produce supply chains has confirmed the problem of product mixing and its negative impacts on the quality and shelf life of produce (Sanad Alsbu et al., 2023), it does not indicate it as a barrier to TMTs adoption. There has been a focus of prior research on designing intelligent transport containers in which different temperature zones are maintained for a variety of produce (Lütjen et al., 2013), however, its feasibility in the case of vegetable supply chains is still questionable. Further studies may need to be conducted to align the needs of vegetable supply chains to design and develop intelligent cold rooms and containers.

7.3.4. Preference for status quo and insistence on traditional practices

Status quo bias behaviour was observed among the members of vegetable supply chains. In the case of TMTs adoption, growers were found to be satisfied with their current practices of cold chain monitoring. Due to the complacent behaviour among vegetable growers, they believe that their produce will hold its original form and shape till the end of the chain without precise temperature management and control. Although vegetable growers realise that temperature cannot be strictly regulated and monitored without TMTs, they believe that their informal methods and experiential knowledge about cold chain practices are adequate to keep the vegetables fresh during supply chain operations (Šūmane et al., 2018).

The trajectory of farmer’s resistance to change and its relationship with the uptake of technologies in agri-food supply chains is well represented in prior literature (Conti et al., 2021; Newton et al., 2020). Insistence on experiential knowledge and old age practices transferred through generations among farmers is considered to be one of the factors for resistance to new developments or processes (Conti et al., 2021;

Šūmane et al., 2018). The findings of this study suggest that numerous underlying factors are responsible for the complacent behaviour of actors along the vegetable supply chain. These factors are a lack of trust on TMTs and its providers (Canavari et al., 2010), ineffective information sharing among supply chain actors (Teese et al., 2022), uncertain returns on investment (Long et al., 2016) and lack of strict regulatory requirements on temperature monitoring (FSANZ, 2016). Complacent behaviour was common among the older growers as compared to younger ones. This aligns with the previous research of Zuo et al. (2021) and Vecchio, Agnusdei, et al. (2020) who confirmed that younger age farmers are more agile and have a positive attitude towards the adoption of new technologies, practices and processes to achieve a competitive advantage.

Complacent behaviour of logistic staff, especially truck drivers along the vegetable supply chain operations was also cited as one of the inhibiting factors for the uptake of TMTs. Truck drivers were not generally well trained or informed about the sensitivity of vegetables towards temperature abuse. The study of Rendon-Benavides et al. (2023) on the berry supply chains in Australia revealed the same attitude of truck drivers during logistic operations.

In summary, status quo bias behaviour of growers and complacency of chain members towards the importance of temperature and its monitoring in vegetable supply chains inhibit TMTs adoption. These findings are consistent with the prior literature on resistance to change in agri-food chains (Conti et al., 2021).

7.3.5. Presence of responsibility diffusion behaviour

Responsibility diffusion[23] by the actors of the vegetable supply chains was observed as one of the deterrents to the uptake of TMTs. Presence of blame-shifting[24] and responsibility shirking[25] was exhibited as a prominent behaviour among the members of the chain. Findings suggest that a lack of accountability and ineffective integration along the chain are key precursors of the above behaviours.

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[23] The diffusion of responsibility defined as a sociopsychological phenomenon of an individual to feel decreased responsibility in a group while being part of the group. Darley, J. M. (1970). The unresponsive bystander: Why doesn't he help?

[24] Blaming other members of the chain for not adequately handling produce with the aim of making them responsible for the losses in case the product is rejected at the end of the supply chain

[25] Shirking is intentionally underperforming one's agreed upon duties (Clemons et al., 1993; Wathne & Heide, 2000)

The study found that due to the prevalent culture of blame-shifting, growers blame transporters while they in turn put the responsibility on growers and in some cases on distribution centres and supermarkets when a shipment is not accepted at the downstream operations. The underlying reason for this kind of behaviour among the vegetable supply chain actors is due to absence or lack of accountability at each stage of the chain. Prior literature has reflected the challenge of accountability in the agri-food chains. For example, Frankish et al. (2021) studied the food safety culture in Australia. The authors found that due to the presence of weak accountability mechanisms in horticulture supply chains, blaming each other for ineffective food quality is a dominant behaviour. In the same context, FLW among fresh produce chains is also commonly attributed to a lack of responsibility mechanism which leads to the behaviour of blaming others in the chain (Jacob-John & Veerapa, 2015; Richards et al., 2021).

Concealment and protectionism behaviour was also observed among the members of vegetable supply chains. They were found to be reluctant to share data with other stakeholders for effective integration and collaboration. Previous research suggests that due to the complex nature of perishable food supply chains (Panetto et al., 2020), sharing of information is imperative for the enhancement of collaboration among stakeholders (Lee, 2000; Taylor & Fearne, 2006). However, in the case of Australian fresh produce supply chains, actors are not usually open to information sharing (Teese et al., 2022).

Vegetable supply chain members, especially growers were feeling vulnerable to the uptake of TMTs. They believed that due to use of TMTs, some of their practices (which are not up to mark) will be exposed to the other members of the chain and hence they will lose business with them. For instance, if the produce is not cooled down properly during harvesting and packing stage, TMTs will expose it throughout the transit and distribution centre operations. Prior research has studied the issue of information transparency in cold chains through the lens of the power and business strategy of stakeholders (Hsiao & Huang, 2016). However, the behaviour of stakeholders towards the adoption of technologies in fresh produce cold chains is an extension of this study.

In summary, discussion on RQ2 suggests that low compatibility of existing TMTs with the current nature of the vegetable supply chain is an overarching adoption factor. Slim profit margins in vegetable supply chains act as a deterrent to the uptake of TMTs as they do not make a viable business case. Along with the tangible barriers, numerous behavioural factors such as status quo bias and responsibility diffusion by the supply chain stakeholders also play critical role. Enhancing the adoption of TMTs in vegetable supply chains requires a holistic approach by addressing the product/process based and behavioural based factors. The actions to improve the adoption of TMTs in vegetable supply chains is discussed below in RQ3. An overview of adoption factors found in this study along with references in previous literature are presented below in Table 29.

Table 29
Overview of TMTs adoption factors and prior literature

Adoption factors	Sub-categories	References
Product and process-based adoption factors		
Low compatibility of existing TMTs	Existing TMTs recording ambient/surface temperature rather than core	(Angeles, 2005; Lamberty & Kreyenschmidt, 2022; Ruiz-Garcia & Lunadei, 2011; Weston et al., 2021)
	Passive nature of currently available TMTs	(Kumar et al., 2009; Singh et al., 2010)
	Incompatibility with the current cold chain operations of vegetable supply chains	(Badia-Melis et al., 2018; Mercier et al., 2017; Mosadegh Sedghy, 2018)
	Utilisation of different temperature monitoring tools at different stages of vegetable supply chain	(Badia-Melis et al., 2017; Badia-Melis et al., 2023)
	Lack of coordination between technology providers and potential adopters	(Ali & Kumar, 2011; Kosior, 2018; Anil Kumar et al., 2020; Mahdad et al., 2022)
TMTs expense as	Uncertain return on investment	(Aamer et al., 2021; Hort Innovation, 2020; Kapoor et al., 2009; Long et al., 2016)

Adoption factors	Sub-categories	References
cost rather than investment	Repetitive cost of TMTs	(Aamer et al., 2021; Kapoor et al., 2009; Ugochukwu & Phillips, 2018)
Produce mixing	Mixing different varieties of produce during storage and logistics	(Derens-Bertheau et al., 2015; Kapoor et al., 2009; Lütjen et al., 2013)
Individual behavioural and social norms adoption factors		
Status quo behaviour	Insistence on experiential methods and knowledge	(Conti et al., 2021; Newton et al., 2020; Šūmane et al., 2018)
	Presence of complacent behaviour among staff	(Rendon-Benavides et al., 2023)
Responsibility shirking behaviour	Blame-shifting behaviour among actors of the chain due to a lack of clear accountability mechanism	(Frankish et al., 2021; Jacob-John & Veerapa, 2015; Richards et al., 2021)
	Concealment and protectionism behaviour	(Hsiao & Huang, 2016; Xing et al., 2020)

7.4. Enhancing the adoption of TMTs in vegetable supply chains (RQ3)

RQ3 focused on understanding the factors that can enhance the adoption of TMTs in vegetable supply chains. These factors were divided into two categories: firstly, the macro level, institutional factors which relate to products and processes and secondly, the micro-level individual behavioural factors and social norms. Four actions were identified from the findings which are discussed below in the light of prior literature.

7.4.1. Private quality standards of supermarkets/retailers and government regulations can enhance the uptake of TMTs

Interviewees from different parts of the vegetable supply chains agreed that supermarkets/retailers in the context of the Australian fresh produce industry can play a dominant role in improving adoption of TMTs. In addition to this, enacting a government regulation on traceability and tracking temperature of fresh produce can also act as a catalyst for TMTs adoption.

The current private quality standards (Rindt & Mouzas, 2015) of supermarkets/retailers are mainly focusing on tangible and visible quality attributes of a fresh produce such as colour, form and shape. These standards do not compel supply chain members, including growers and logistic providers to record temperature tracking history of the produce from production to distribution. A minimum standard of delivering the product within the specified temperature of 5 °C or below is sufficient for acceptability at the distribution centre. Previous literature suggests that maintaining adequate temperature of a produce right from harvesting to distribution stage has positive impacts on its shelf life and quality (Tsironi et al., 2017; Zhou et al., 2022). TMTs can be utilised in collecting the temperature history of a produce (Kumari et al., 2015; Zhou, 2021). This information can be used for a variety of continuous improvement strategies by the supermarkets. For instance, data obtained from TMTs can be used to predict the shelf life of fresh produce (Torres-Sánchez et al., 2020; Zhou et al., 2022), improve efficiency through implementing the first-to-expire first out policy (FEFO) policy instead of traditional first-in first out (FIFO) policy, identify and track food safety issues and enhance replenishment decisions (Ketzenberg et al., 2015). These improvements have the potential to make reasonable impact on the bottom line and can lead to a higher goodwill for supermarkets through socially responsible behaviour of lowering FLW (Forsman-Hugg et al., 2013).

Supermarkets/retailers can play a key role in enhancing the uptake of TMTs by demanding the temperature tracking record from downstream supply chain members. They can use their coercive power to redefine their private quality standards (Davey & Richards, 2013). In addition, supermarkets/retailers can incentivise temperature tracking through different measures such as offering higher prices for compliance. This will encourage the supply chain members to invest in TMTs to achieve additional profit. Prior literature has suggested that suitable prices, along with favourable market conditions, is one of the dominant factors driving farmers’ decisions. In case of a harvesting decision, Johnson et al. (2019) outlined numerous factors in which retailer’s financial incentivisation played a key role in modifying the behaviour of farmers.

Interview respondents also suggested that enacting a government regulation can enhance the uptake of TMTs in vegetable supply chains. They suggested that due to a lack of regulatory compliance, actors of vegetable supply chains are not required to track temperature of their produce along the chain. Similar evidence has been reflected in the study of Wiseman et al. (2019), who pointed out that due to a lack of clear regulations about collecting, sharing and using agricultural data, Australian farmers are reluctant to effectively engage in the adoption of modern technologies in their business operations. Compliance to a government regulation is an enforcing mechanism to modify behaviour of farmers (Herzfeld & Jongeneel, 2012). So, enacting a traceability regulation by the government can act as a catalyst to enhance the uptake of TMTs in vegetable supply chains.

7.4.2. Call for enhancing collaboration with technology providers and focus on providing services rather than technologies

Technology providers have a critical role in enhancing the uptake of TMTs in vegetable supply chains. Two key actions were suggested by the interview respondents. These include enhanced collaboration of technology providers with the stakeholders of vegetable supply chains and developing tailor-made solutions for the complex nature of the agri-food sector.

Findings in this study suggest that enhanced interactions of technology providers with vegetable supply chain members (especially growers) can play a key role in increasing the adoption of TMTs. These interactions will provide a platform to the technology providers to get insights into the changing dynamics of fresh produce supply chains. These findings align with the previous research of Mahdad et al. (2022) on enhancing the uptake of IoT in agri-food supply chains. Extant literature has suggested various ways of enhanced cooperation between technology providers and supply chain members. These include open innovation (Medeiros et al., 2016), co-creation (Handayati et al., 2015), collaboration-based business models (Ammirato et al., 2021) and interconnected business models (Jocevski et al., 2020). While farmer-centeredness has been considered important, further research is needed on how to align the competing interests of technology providers and farmers in the context of fresh produce supply chains (Ingram et al., 2022).

The current vision of TMTs suppliers in fresh produce chains is driven by sales-orientation rather than developing strategic partnerships with the supply chain actors. In other words, they are focusing on achieving efficiency through meeting their sales targets rather than being meaningful to the industry. This behaviour of technology providers acts as a barrier to the uptake of TMTs in vegetable supply chains as growers perceive them to be deceptive. This situation can be remedied if technology providers can change their vision and develop strategic and symbiotic relationships with the supply chain actors. This action is also recommended by Mahdad et al. (2022), who suggest that the focus of IoT-enabled firms in the context of agri-food chains should shift from efficiency and one-time sale activity to long term sustainable relationship building.

Tailor-made TMTs solutions can be developed by altering the existing business models of the technology providers. Mahdad et al. (2022, p. 1866) suggested that “customers’ needs are transitioning from purely technology-based issues toward servitization and the identification of different demands in the use of IoT applications for agri-food production”. Keeping this in mind, Escavox[26], a technology company providing temperature monitoring and tracking services to fresh produce supply chains in Australia, has modified its business model from a technology-based enterprise to a service-based company. They are working with the distribution centres to collect data loggers at the end of the chain and provide information for decision-making to the downstream members of the chain. Further research is suggested to develop the entrepreneurial capacity of technology providers in the context of the changing and complex nature of fresh produce supply chains (Mahdad et al., 2022).

7.4.3. Exposing, orienting and educating supply chain members about TMTs can enhance their adoption

Interviewees described that growers’ propensity to adopt TMTs mainly relies on their behavioural cues. Exposing, orienting and educating farmers can positively impact their intent towards the adoption of technologies (Mackrell et al., 2009). Findings from this study suggest that members of the vegetable supply chain , especially growers – the primary potential adopters – hold a myopic view about TMTs and their utilisation in their operations. The primary reason behind this behaviour is a lack of familiarity and acquaintance with TMTs. Growers were found to be least aware of technological innovations in TMTs. On the one hand, there was an absence of proactive communication from technology providers and research institutions that could deliver the crucial exposure to growers (Mahdad et al., 2022). On the other hand, farmers are mostly short of time to perform their day-to-day activities and are unable

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[26] An Australian fresh produce tracking technology provider. Further details can be found on https://www.escavox.com/

to dedicate time and effort to keep abreast of any cutting-edge developments. Previous literature has found that lack of exposure and awareness are the main reasons behind non-adoption of technological innovations in agriculture (Yigezu et al., 2018).

To address this situation, technology providers and research institutions should proactively advocate the benefits of TMTs by establishing interactive communication channels including conferences, forums and seminars as these have the highest positive correlation with adoption of technologies in agriculture (Colussi et al., 2022). Previous literature has also suggested that one-to-one meetings of technology suppliers with vegetable growers and peer farmers have higher positive impact on farmer attitudes towards a new technology. BenYishay and Mobarak (2019) found that incorporating peer farmers into the traditional system of communication created a positive intent towards the uptake of new technologies and innovations in agriculture.

Effective information provision about the benefits of TMTs can also affect farmer's behaviour towards its adoption. Previous research has cited the provision of clear information as a key to enhance perceived behavioural control[27] (i.e., feeling like they could do it) of farmers towards agricultural innovations (Pino et al., 2017; Zamasiya et al., 2017). Further, showing practical demonstrations to growers of using TMTs in vegetable supply chains and emphasising the benefits that they can acquire from tracking of produce in terms of meeting supermarket requirements and compliance can enhance its uptake. Prior literature has suggested that market compliance through technologies can develop a positive intent from farmers towards its use in agriculture (Richards et al., 2013).

Demographic factors of vegetable growers were also found to have an impact on their intention to engage with technology providers and seek information for improving their temperature monitoring practices. In demographic factors, the age of the farmer and succession plans of the business were found to be highly relevant for the uptake of TMTs in vegetable supply chains. Older aged farmers were found to be resistant to innovations while younger farmers proactively pursued temperature monitoring practices and were utilising modern technologies such as cold rooms, hydro-cooling and vacuum-cooling. These findings align with previous research on

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[27] Perceived behavioral control is an individual's perception of how easy or difficult it is to perform a behaviour. Ajzen, I., & Fishbein, M. (1980). Understanding attitudes and predicting social behaviours.

understanding the decision-making behaviour of farmers in which age was found to be one of the key determinants of technology adoption (O'Shea et al., 2018; Vecchio, De Rosa, et al., 2020). In addition, farm businesses which has clear succession plans were also actively looking for information to enhance their temperature monitoring practices, as evidenced in prior research (Sottomayor et al., 2011). Thus, it can be concluded that technology providers should focus at the start on interacting with younger growers and those family farm businesses which have clear succession plans for enhancing the adoption of TMTs.

7.4.4. Enhancing collaborative behaviour among actors in the vegetable supply chains

Findings from this study suggest that a lack of collaboration exists among vegetable supply chain members. The reasons for this lack include status quo bias, responsibility shirking and concealment and protectionism behaviour of the members of the vegetable supply chains, as discussed in Section 5.4. Literature on agri-food indicates that competitive advantage can be achieved through collaboration among heterogenous actors in the chain, which leads to an enhancement of market share, better profit margins, and continuous growth for all (Fearne et al., 2001). Collaboration can also help in fostering relationships among supply chain members that can reduce conflicts between them. Small-farm growers can overcome various inherent deficiencies through enhanced collaboration. For instance, in this study, vegetable growers were found to be overwhelmed with their daily tasks and unable to take a holistic view of the supply chain. Literature suggests that collaborative behaviour can empower farmers to relate their daily tasks to the overarching outcome of the chain (Gutiérrez & Macken-Walsh, 2022).

The actions recommended for enhancing collaboration behaviour among vegetable supply chain members can be classified into two broad categories. Firstly, creating a robust framework for information sharing aimed at enhancing productivity and operational efficiency along the chain. It has been found in prior literature that information sharing can lead to achieving mutual benefits (between information seeker and provider) and strengthening of relationships among the actors of the chain (Bao & Bouthillier, 2007). Secondly, setting up institutional arrangements[28] along the supply

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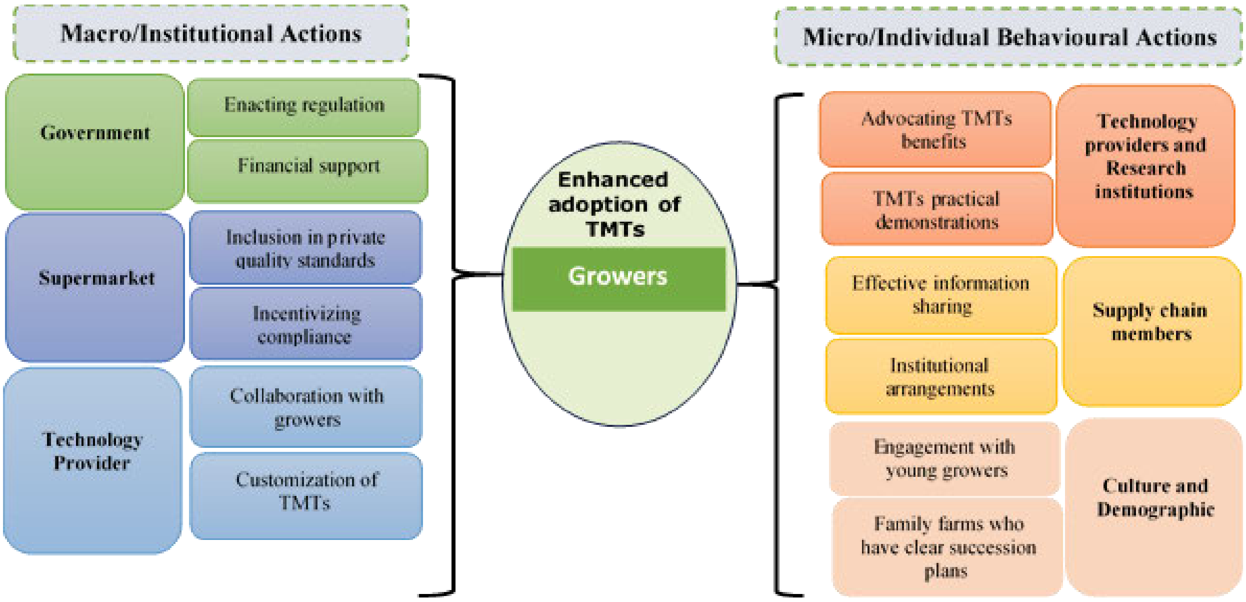
[28] Refers to integration across the supply chain with the aim to achieve efficient and effective flow of products and services. It also includes effective coordination among the members of the chain. Zhuo, N., Ji, C., & Yin, N.

chain can lead to resolution of conflicts among stakeholders and enhance collaborative behaviour (Ton, 2008).

7.5. Summary of actions to enhance uptake of TMTs

Figure 28 below summarises the actions recommended for enhancing the uptake of TMTs through macro level institutional and micro-level individual interventions. Macro level interventions could be taken by government, supermarket and technology providers while micro-level intervention would be additionally supported by the providers of TMTs, along with research institutions and vegetable supply chain members. The nature of actions recommended by these actors is long term, continuous and context specific. Thus, it is recommended that all these actions must be taken to a reasonable extent due to their complimentary nature.

Figure 28
Summary of actions to enhance the uptake of TMTs in vegetable chains



7.6. A consolidated conceptual model and chapter summary

This chapter discussed the findings of the study in the light of relevant literature on agri-food supply chains and technology adoption. Figure 29 below presents a summarised form of this chapter by revealing the relationships between insights

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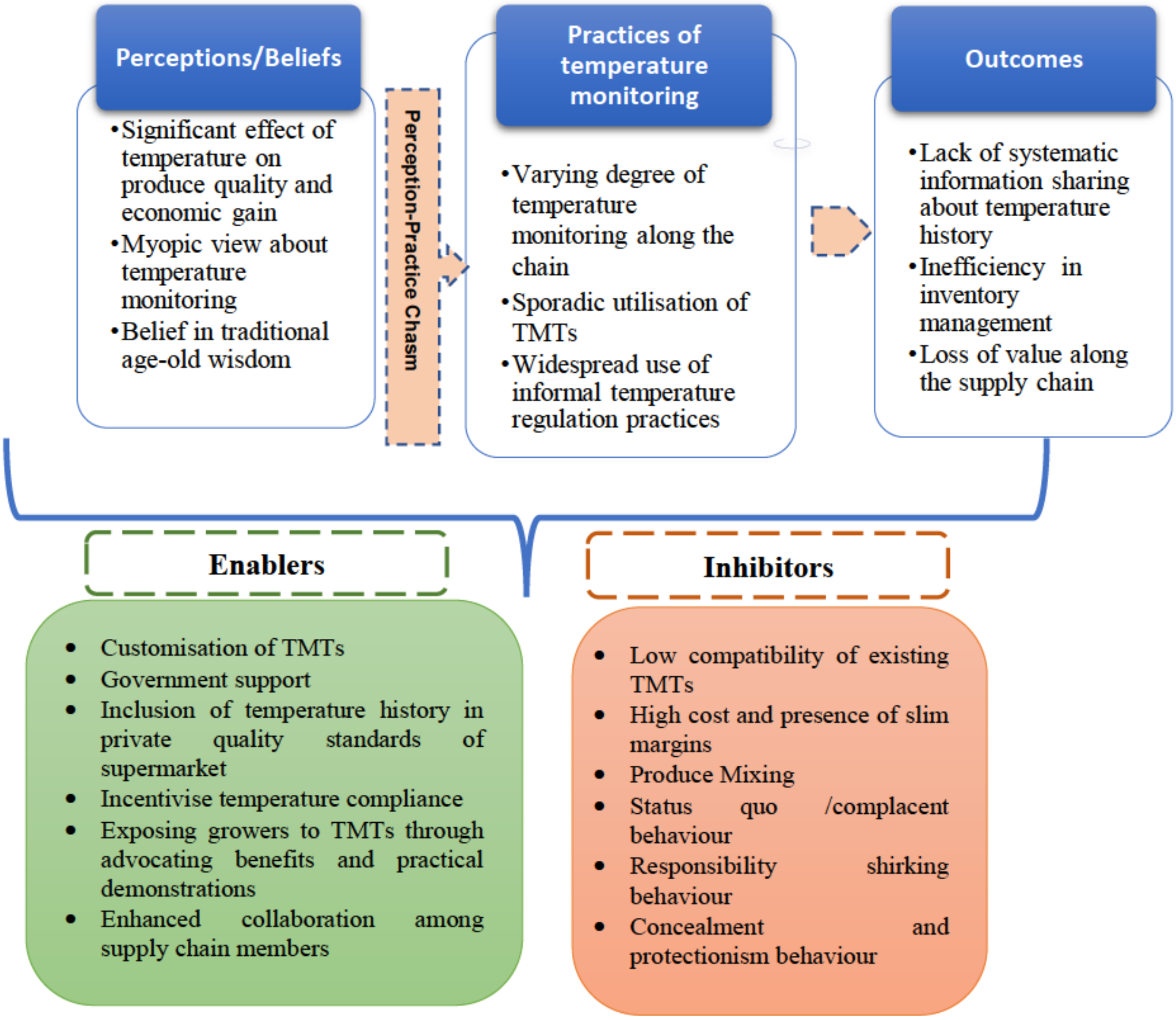
(2021). Supply chain integration and resilience in China's pig sector: case study evidences from emerging institutional arrangements. *Environmental Science and Pollution Research*, *28*(7), 8310-8322.

gained from the discussion undertaken on the findings of the three research questions in this study. The model shows three interrelated domains including perceptions and beliefs, practices of temperature monitoring, and outcomes. Enablers and inhibitors of TMTs adoption is also presented.

The first domain is related to the perceptions and beliefs of vegetable supply chain members about temperature monitoring. It clearly indicates that supply chain members, especially vegetable growers consider temperature maintenance to be an essential component for maintaining produce quality, extending shelf life and achieving financial gains. However, they hold myopic views about TMTs and rely mainly on their experiential knowledge and age-old beliefs.

Figure 29
Consolidated conceptual model of the study



The second domain represents the consequent practices of temperature monitoring that are currently in vogue among supply chain members. It shows that vegetable supply chains sporadically utilise TMTs as well as informal practices to varying degrees in controlling and monitoring temperature. There is a clear presence of a perception-practice chasm among the supply chain members about temperature monitoring.

The final domain shows the outcomes of deeply held beliefs and the consequent practices. There is a clear lack of integrated use of TMTs in vegetable supply chains. This causes various forms of inefficiencies such as inventory management and loss of produce during supply chain operations. The model also shows the most significant enablers and inhibitors that can enhance or diminish the use of TMTs, respectively. Current TMTs suffer from various compatibility issues while vegetable supply chain members are not able to undertake risky investments as they suffer from slim profit margins. Keeping a diverse range of produce with varying temperature requirements leads to the issue of product mixing in cold rooms and transport containers. Various behaviours including status quo and complacency, responsibility shirking, and concealment and protectionism further reinforce the substantial roadblock towards higher adoption of TMTs.

The model also shows that the current state of low uptake of TMTs in vegetable supply chains can be improved by working on high potential enablers. These efforts can be started with technology firms customizing their TMTs to match the complex needs of supply chain members while government can provide financial and non-financial support. However, these efforts must be complemented by the actions from supermarkets. They should push the use of TMTs by including its utilization in their private quality standards and motivating the vegetable supply chain members through providing incentives for end-to-end temperature monitoring and control.

CHAPTER 8: CONCLUSION

8.1. Introduction

Cold chains are becoming a significant part of modern global perishable food industries. Management and control of temperature along the chain is indispensable in maintaining the quality of fresh produce and reducing food loss and waste (Joshi et al., 2019; Shashi et al., 2021). Numerous technologies are available for cold chain tracking (Badia-Melis et al., 2018; Onwude et al., 2020); however, their widespread uptake by supply chain members is still considered a challenge (Ndraha et al., 2020). Thus, this research addressed a knowledge gap by considering the adoption of TMTs in vegetable supply chains, focusing on understanding the underlying reasons, including psycho-behavioural aspects of supply chain members and existing practices and technologies. The study also suggested numerous interventions to enhance the uptake of TMTs in vegetable supply chains.

Due to the complex nature of fresh produce supply chains (Romsdal et al., 2011), theories utilised in studying the adoption of technologies in these chains are not capable of fully explaining the phenomena. An integrated theoretical framework has been employed in this study as utilised by Mohr and Kühl (2021) and Laksono et al. (2022). On one hand, seminal and classical theories such as the diffusion of innovation theory by Rogers (2003), the theory of reasoned actions by Ajzen and Fishbein (1975), the theory of planned behaviour by Ajzen and Fishbein (1980), and the technology acceptance model by Davis and Venkatesh (1996) were consulted. On the other hand, overarching theories such as the unified theory of acceptance and technology adopted by Venkatesh et al. (2003) and the technology-organisation-environment framework by Tornatzky and Fleischer (1990) were used.

After undertaking qualitative thematic analysis of the data collected, it was identified that temperature monitoring is considered essential for preserving quality and enhancing the shelf life of fresh produce; however, its uptake by the members of the vegetable supply chain is low due to their insistence on their experiential knowledge and age-old practices. The factors affecting the adoption of TMTs in vegetable supply chains were found to be mainly related to the existing cold chain practices, currently available technologies, and ingrained individual behavioural and social norms in the industry. Supermarkets and technology providers along with the overarching support from government entities and research institutions can play a key role in enhancing the uptake of TMTs across the chain.

This chapter concludes the study by enumerating the significance of this research, its contribution to theory, practice and policy, limitations, and recommendations for future research.

8.2. Significance of research

The findings of this study provide insights into understanding the current adoption status of TMTs in Australian vegetable supply chains. Perceptions of various actors across the chain regarding the importance of temperature monitoring are presented in Section 4.2. Cold chain practices in different stages of vegetable supply chains are elaborated in Section 4.3, which extends existing theoretical and empirical research on cold chain adoption in fresh produce chains.

Adoption factors of TMTs in the context of Australian vegetable supply chains were discussed. Findings suggest that two types of adoption factors of TMTs exist in the current operations of vegetable supply chains. These factors are related to the current cold chain management operations in vegetable supply chains (see Section 5.2) and the individual behavioural and social norms of the stakeholders across the chain (see Section 5.4). These insights have implications for theory, policy makers and practitioners.

This study has also implications for individuals and firms interested in improving the cold chain management practices in vegetable supply chains. It provides suggestions and actions to enhance the uptake of TMTs across the chain (in Chapter 6), which provide insights for various stakeholders who are striving to improve inefficiencies in the current operations of vegetable supply chains in the Australian context.

The study has also implications for technology providers of TMTs and other supply chain stakeholders such as supermarkets and government entities. At a broader level, this study has provided interventions that can guide companies providing technologies to agri-food to devise effective marketing strategies for understanding the current context and improving their sales.

8.3. Contributions

The study contributes broadly to the understanding of the adoption of technologies in fresh produce supply chains. It has been argued that effective adoption of modern technologies in agri-food chains can be affected by numerous challenges, ranging from technological complexities to the behavioural tendencies of supply chain members (Han et al., 2021; Yan et al., 2018). Nevertheless, it has been recognised that behavioural aspects of individuals in adoption of technologies in agriculture is one of the least researched areas (Foguesatto et al., 2020). Further, Aamer et al. (2021) suggest that understanding applications of IoT and its adoption in cold chain practices across fresh produce chains need more attention from researchers. Thus, this study contributes to the prior knowledge of understanding the uptake of TMTs and its challenges in the context of Australian vegetable supply chains. Theoretical, practical and policy level contributions of the study are described below.

8.3.1. Theoretical contributions

Insights from the study clearly show a contribution to knowledge where limited use of TMTs across vegetable supply chains can be explained by adoption factors belonging to three categories, including individual psycho-behavioural, technological, and contextual.

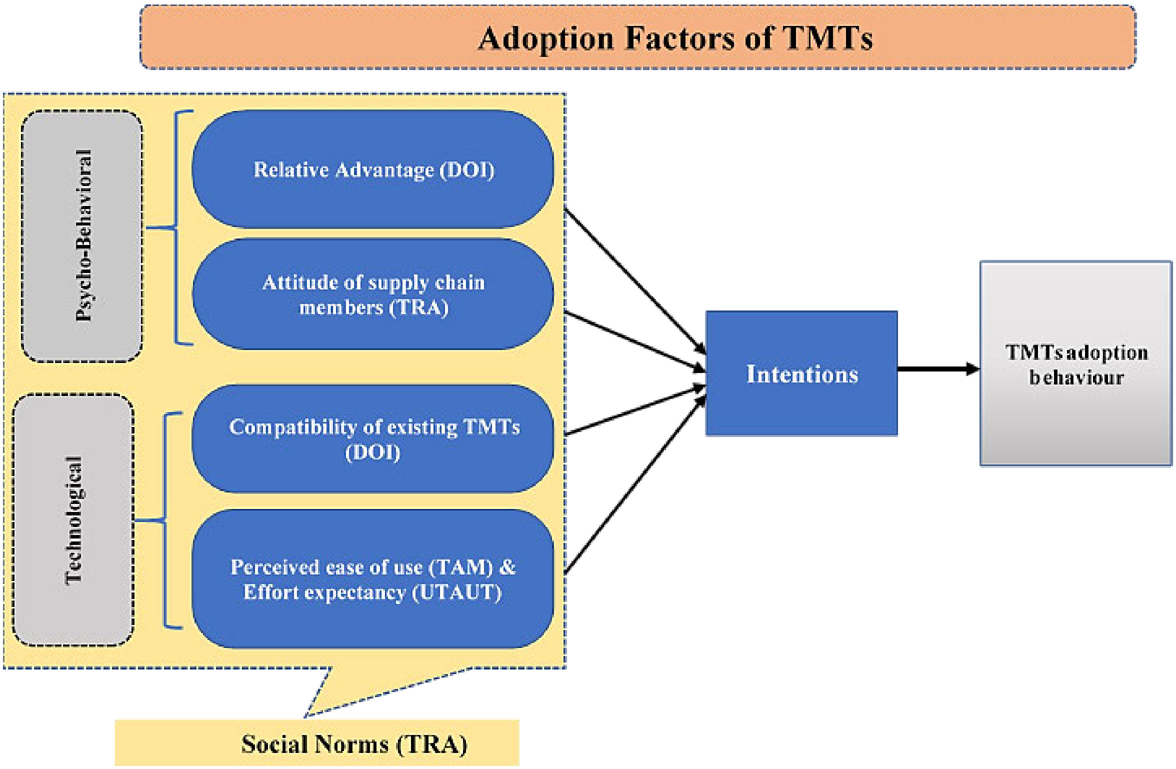
The first category is the psycho-behavioural factors of the members of vegetable supply chains. The most influential factor among them is the perceived absence of relative advantage as explained in DOI theory of (Rogers, 2003). Vegetable growers do not perceive a clear reward in terms of cost and benefit analysis from the uptake of TMTs. They are sceptical about its relative advantage while comparing it to their existing practices of cold chain management. Further, stakeholders across the vegetable supply chains exhibit a salient behavioural belief of keeping secrets and do not disclose and share information with each other. This secretive attitude is predominantly influenced by their convictions of using various non-standardised temperature management practices which may become questionable if revealed. Therefore, attitude as outlined in the theory of reasoned actions of Ajzen and Fishbein (1975) explains the TMTs adoption intentions of the members of vegetable supply chains.

The second category includes two technology related factors that influence the adoption of TMTs in vegetable supply chains. The first factor relates to the compatibility of existing TMTs that has been pointed as one of the primary issues for technology adoption in DOI theory (Rogers, 2003). Current TMTs have been adopted from other sectors (such as mining and pharmaceutical) and have limited functionalities in vegetable supply chains. Furthermore, they are not made for long term use and are disposable in nature (Roberts, 2006). Secondly, currently available TMTs are passive, which requires further resources for retrieval and decision-making (Badia-Melis et al., 2018). This phenomenon leads to a lack of perceived ease of use as presented in TAM by Davis and Venkatesh (1996) because of the inherently cumbersome process in current TMTs. Further, with regards to the effort expectancy of the UTAUT by Venkatesh et al. (2003), members of vegetable supply chains associate limited ease of use and high levels of effort with the utilisation of currently available TMTs, thus further diminishing their intent towards its adoption.

The third category includes the single but overarching factor of social norms that can be seen as encompassing the previous categories. Members of vegetable supply chains generally believe that their peers would approve the use of current temperature management practices rather than utilising TMTs. Thus, an individual grower's behaviour of using current temperature management practices and avoiding TMTs is a subjective norm, as suggested in TRA by Ajzen and Fishbein (1975) that is rooted in the social pressure they perceive from other stakeholders.

It can be concluded that the factors explained in the three categories above are the key determinants of TMTs adoption in vegetable supply chains. The factors address the knowledge gap by utilising extant theories of technology adoption and provide insights into the behavioural perspectives of the members of vegetable supply chains regarding the adoption of TMTs. These findings also contribute to the growing body of knowledge concerning challenges related to the adoption of technologies in fresh produce chains. More specifically, it explores the unaddressed issue of behavioural perspectives on the adoption cold chain monitoring technologies in fresh produce chains (Foguesatto et al., 2020). Figure 30 below presents the theoretical contributions of this study by explaining factors affecting the adoption of TMTs in vegetable supply chains

Figure 30
Theoretical contributions of the study



8.3.2. Practical contributions

Insights provided by this research can benefit managers, directors, and business owners of technology providers, along with other firms engaged directly or indirectly with fresh produce supply chains in Australia. This study highlights certain recommendations that can enhance the uptake of TMTs in the context of Australian vegetable supply chains.

Firstly, supermarkets are the most influential member of the chain as they act as an interface to the consumer. Currently, they do not provide any incentive for growers to keep records of temperature from the farm until the delivery of vegetable produce to a distribution centre. Nevertheless, they understand that if the temperature of the produce is properly maintained throughout the chain, it will sustain its visible qualities as well as nutrition contents for a longer period. Produce that is exposed to temperature abuse has significantly shorter shelf life (Malin Göransson et al., 2018). Thus, this study recommends that supermarket should include the provision of complete temperature history in their private quality standards and incentivise supply chain members, especially vegetable growers, to prove end-to-end temperature monitoring. This will not only motivate members of the chain to adopt TMTs, but also create a positive environment across the industry for its implementation at different stages of the chain.

Secondly, technology providers of TMTs are solely responsible for promoting and positioning their products as a favourable and viable proposition to the members of the chain, especially growers. As found in this study, it is recommended that technology providers should shift their business model by focusing on developing long term relationships with vegetable producers. Focusing on services rather than product-based selling outlook, technology providers can understand needs and requirements of the members of vegetable supply chains and customise their products accordingly.

8.3.3. Policy level contributions

The findings of this research also provide inputs for policy development for enhancing the utilisation of cold chain monitoring technologies in vegetable supply chains in Australia. These recommendations are theoretically grounded and pinpoint the specific barriers which can be resolved through policy measures.

Firstly, the absence of any government regulation renders any adoption of TMTs to be a voluntary act. Currently, cold chain guidelines such as the Australian Food and Grocery Council[29] AFGC (2017) and the Australian Food Cold Chain Council[30] are available. The guidelines are voluntary to enhance existing handling standards at different levels across the chain. Adoption of TMTs by the members of vegetable supply chains without any government regulation may be possible if it makes a strong business case. However, enacting government regulation regarding the mandatory use of TMTs and traceability can lead to their enhanced adoption. Prior research has suggested that government regulations can play a prominent role in enhancing the adoption of technologies in agriculture (Giua et al., 2022).

Secondly, the study found that there is a lack of effective formal and regular communication channels between vegetable supply chain members and relevant stakeholders, including government bodies and private technology providers regarding TMTs. Acting in silos has become a pervasive social norm along the chain,

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[29] AFGC is an industry association founded in 1995 with the aim to represent food and grocery supply industry in Australia

[30] Advocacy group devoted to improving compliance and handling standards of food across different levels of cold chains

resulting in a lack of awareness about technological development in temperature management and its benefits. Governments can enhance the existing communication channels, such as forums available under agriculture extension to provide up-to-date information and success stories on the utilisation of TMTs. Table 30 below provides a summary of recommendations which can increase the adoption of TMTs in vegetable supply chains in Australia.

Table 30
Summary of recommendations of the study

No.	Recommendations	Actor(s)	Potential impact
1	Inclusion of temperature monitoring record in private quality standards	Supermarkets	• Pervasive adoption of TMTs in vegetable supply chains
2	Incentivising use of TMTs across the chain	Supermarkets, government entities and technology providers	• Positive reinforcement of TMTs in vegetable supply chains • Determining business viability of utilising TMTs
3	Diversifying business models of technology suppliers	Technology providers	• Enhanced cooperation with technology providers of TMTs • Customisation of TMTs according to vegetable supply chain needs
4	Creating communication channels for dispersing benefits of TMTs and/or technological advancements	Government entities, research institutions and technology providers	• Enhanced awareness of TMTs and its benefits for numerous stakeholders • Changing existing social norms
5	Enacting government regulations regarding traceability of supply chains	Government entities with inputs from research institutions	• Mandatory minimum uptake of TMTs in agri-food sector • Acquaintance with the use of technologies

8.4. Limitations and opportunities for further research

There are some limitations of this study which can be opportunities for further research. Firstly, the study was limited to the Australian vegetable supply chains in which fresh produce was sold in domestic markets through numerous distribution channels such as central markets and agents for supermarkets. Vegetable supply chains focusing on exporting produce was not part of the study due to additional challenges such as time and access to overseas distribution channels. Therefore, findings of this study have limited implications for export-oriented vegetable supply chains. Future research may be needed to understand the context, factors, and motivations for the uptake of TMTs in export-oriented vegetable supply chains.

The second limitation of the study is related to the sample selection process of the study. The study was carried out in one regional council (Lockyer Valley Regional Council) of Queensland, Australia. Two types of limitations were pertinent to the sample selection which includes size of the sample and strategy for its selection. At the initial stage of data collection, efforts were made to collect data from at least five vegetable supply chains (denoted as cases in this study), however, due to unavailability of respondents along with the secretive nature of some supply chain members, only three chains were deeply studied in this research. Therefore, the generalisability of the findings in this study is limited. However, it is possible to conclude that the findings are representative of the vegetable supply chains studied as cases in this research (Maxwell & Chmiel, 2014). Additionally, interview respondents from the upstream operations of the chain were selected through referral from downstream members who may not be involved in cold chain activities. Efforts were made to get to the most relevant person to get deep insights about cold chain operations. Future study may be required to undertake research across multiple supply chains with additional respondents.

The third limitation of the study is that vegetable supply chains were regarded as a linear interaction of stakeholders in which fresh produce flows from grower to packer to transporter and to distribution centre as presented in Figure 13. However, in reality, firms within the fresh produce chains operate within supply chain networks (Bokelmann & Lentz, 2000). In this study, to understand the aspect of TMTs adoption across whole chain, efforts were made to understand the phenomena through the lens of technology providers as well experts. Further research may be conducted to incorporate actors across vegetable supply chains through implementing supply chain networks.

The study found that a limited collaboration exists between vegetable supply chain members and technology providers of TMTs, due to a lack of effective information sharing and the secretive nature of stakeholders. Generalisations of these findings are limited due to a low level of engagement from TMTs suppliers in this study. Therefore, further research is required to dig out these challenges in detail by engaging with a large number of technology providers and growers of fresh produce.

8.5. Concluding remarks

The study has contributed to the knowledge and practice by providing significant insights into a little understood and limited investigated phenomena, adoption of TMTs in vegetable supply chains in Australia. Utilising an integrated theoretical framework and employing qualitative thematic analysis of the data collected from numerous stakeholders across the chain, the study identified the current status and adoption factors of temperature monitoring technologies in vegetable supply chains. The study also provided a list of policy level inputs to enhance the uptake of these technologies to reduce waste and provide healthy fresh products to Australian consumers.

The findings and recommendations identified in this study are highly relevant given the current challenges of vegetable supply chains including a significant amount of food loss and waste, supply chain disruptions and increasing awareness of consumers about food quality. Improving the uptake of cold chain monitoring technologies from farm to distribution centre have direct impact on reducing food waste and improving competitive advantage of existing vegetable supply chains.

REFERENCES

Aamer, A. M., Al-Awlaqi, M. A., Affia, I., Arumsari, S., & Mandahawi, N. (2021). The internet of things in the food supply chain: adoption challenges. *Benchmarking: An International Journal*.

Accorsi, R., Bortolini, M., Baruffaldi, G., Pilati, F., & Ferrari, E. (2017). Internet-of-things paradigm in food supply chains control and management. *Procedia Manufacturing*, *11*, 889-895.

Adnan, N., Nordin, S. M., & Ali, M. (2018). A solution for the sunset industry: Adoption of Green Fertiliser Technology amongst Malaysian paddy farmers. *Land use policy*, *79*, 575-584. https://doi.org/https://doi.org/10.1016/j.landusepol.2018.08.033

Adnan, N., Nordin, S. M., Bahruddin, M. A., & Tareq, A. H. (2019). A state-of-the-art review on facilitating sustainable agriculture through green fertilizer technology adoption: Assessing farmers behavior. *Trends in Food Science & Technology*, *86*, 439-452. https://doi.org/https://doi.org/10.1016/j.tifs.2019.02.040

AFGC. (2017). *Australian Cold Chain Guidelines*. https://www.afgc.org.au/industry-resources/cold-chain-guidelines

Ahmed, Z., Asghar, M. M., Malik, M. N., & Nawaz, K. (2020). Moving towards a sustainable environment: the dynamic linkage between natural resources, human capital, urbanization, economic growth, and ecological footprint in China. *Resources Policy*, *67*, 101677.

Ajzen, I. (2002). Perceived behavioral control, self-efficacy, locus of control, and the Theory of Planned Behavior. *Journal of Applied Social Psychology*, *32*(4), 665-683. https://doi.org/10.1111/j.1559-1816.2002.tb00236.x

Ajzen, I., & Fishbein, M. (1975). A Bayesian analysis of attribution processes. *Psychological Bulletin*, *82*(2), 261.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour.* Prentice Hall.

Akerma, M., Hoang, H.-M., Leducq, D., & Delahaye, A. (2020). Experimental characterization of demand response in a refrigerated cold room. *International Journal of Refrigeration*, *113*, 256-265.

Akman, I., & Turhan, C. (2017). User acceptance of social learning systems in higher education: an application of the extended Technology Acceptance Model. *Innovations in Education and Teaching International*, *54*(3), 229-237. https://doi.org/10.1080/14703297.2015.1093426

Al-Dairi, M., Pathare, P. B., Al-Yahyai, R., & Opara, U. L. (2022). Mechanical damage of fresh produce in postharvest transportation: Current status and future prospects. *Trends in Food Science & Technology*, *124*, 195-207. https://doi.org/https://doi.org/10.1016/j.tifs.2022.04.018

Alfian, G., Rhee, J., Ahn, H., Lee, J., Farooq, U., Ijaz, M. F., & Syaekhoni, M. A. (2017). Integration of RFID, wireless sensor networks, and data mining in an e-pedigree food traceability system. *Journal of Food Engineering*, *212*, 65-75.

Ali, I., & Govindan, K. (2021). Extenuating operational risks through digital transformation of agri-food supply chains. *Production Planning & Control*, 1-13. https://doi.org/10.1080/09537287.2021.1988177

Ali, J., & Kumar, S. (2011). Information and communication technologies (ICTs) and farmers’ decision-making across the agricultural supply chain. *International Journal of Information Management*, *31*(2), 149-159.

Ammirato, S., Felicetti, A. M., Ferrara, M., Raso, C., & Violi, A. (2021). Collaborative organization models for sustainable development in the agri-food sector. *Sustainability*, *13*(4), 2301.

Anand, S., & Barua, M. K. (2022). Modeling the key factors leading to post-harvest loss and waste of fruits and vegetables in the agri-fresh produce supply chain. *Computers and Electronics in Agriculture*, *198*, 106936. https://doi.org/https://doi.org/10.1016/j.compag.2022.106936

Anderson, J. R., Dillon, J. L., & Hardaker, B. (1977). Agricultural decision analysis. *Monographs: Applied Economics*.

Andreopoulou, Z. (2017). Internet of Things and food circular economy: A new tool for Sustainable Development Goals. RIVISTA DI STUDI SULLA SOSTENIBILITA', *FrancoAngeli Editore*, *2017*(2), pp. 43-49. 43-49.

Angeles, R. (2005). RFID technologies: supply-chain applications and implementation issues. *Information Systems Management*, *22*(1), 51-65.

Annosi, M. C., Brunetta, F., Bimbo, F., & Kostoula, M. (2021). Digitalization within food supply chains to prevent food waste. Drivers, barriers and collaboration practices. *Industrial Marketing Management*, *93*, 208-220. https://doi.org/https://doi.org/10.1016/j.indmarman.2021.01.005

Annosi, M. C., Brunetta, F., Capo, F., & Heideveld, L. (2020). Digitalization in the agri-food industry: the relationship between technology and sustainable development. *Management Decision*. *58*(8).

Aryal, A., Liao, Y., Nattuthurai, P., & Li, B. (2018). The emerging big data analytics and IoT in supply chain management: a systematic review. *Supply Chain Management: An International Journal*.

Ashok, A., Brison, M., & LeTallec, Y. (2017). Improving cold chain systems: Challenges and solutions. *Vaccine*, *35*(17), 2217-2223.

Astill, J., Dara, R. A., Campbell, M., Farber, J. M., Fraser, E. D., Sharif, S., & Yada, R. Y. (2019). Transparency in food supply chains: A review of enabling technology solutions. *Trends in Food Science & Technology*, *91*, 240-247.

Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as enabler of sustainable farming: An empirical analysis of farmers' adoption decision of precision agriculture technology. *Decision Support Systems*, *54*(1), 510-520.

Aung, M. M., & Chang, Y. S. (2014). Temperature management for the quality assurance of a perishable food supply chain. *Food Control*, *40*, 198-207.

Aung, M. M., Liang, F. W., Chang, Y. S., Makatsoris, C., & Chang, J. (2011). RFID- and WSN-based intelligent cold chain management. *International Journal of Manufacturing Research*, *6*(2), 91-109.

Babbie, E. R. (2011). *Introduction to social research*. Wadsworth Cengage Learning.

Badarinath, R., & Prabhu, V. V. (2017). Advances in internet of things (IoT) in manufacturing. Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing: IFIP WG 5.7 International Conference, APMS 2017, Hamburg, Germany, September 3-7, 2017, Proceedings, Part I,

Badia-Melis, R., Emond, J., Ruiz-García, L., Garcia-Hierro, J., & Villalba, J. R. (2017). Explorative study of using infrared imaging for temperature measurement of pallet of fresh produce. *Food Control*, *75*, 211-219.

Badia-Melis, R., Mc Carthy, U., Ruiz-Garcia, L., Garcia-Hierro, J., & Robla Villalba, J. I. (2018). New trends in cold chain monitoring applications - A review. *Food Control*, *86*, 170-182. https://doi.org/https://doi.org/10.1016/j.foodcont.2017.11.022

Badia-Melis, R., Ruiz-Garcia, L., Garcia-Hierro, J., & Villalba, J. I. R. (2015). Refrigerated fruit storage monitoring combining two different wireless sensing technologies: RFID and WSN. *Sensors*, *15*(3), 4781-4795.

Badia-Melis, R., Ruiz-Garcia, L., Robla-Villalba, J. I., & Hoyos-Echevarria, P. (2023). Evaluation of Pallet Covers Performance for Produce Protection in Cold Chain Logistics for Chard, Cucumbers and Carrots. *Foods*, *12*(15), 2961.

Balamurugan, S., Ayyasamy, A., & Joseph, K. (2020). Iot based supply chain traceability using enhanced naive bayes approach for scheming the food safety issues. *Int. J. Sci. Technol. Res*, *9*(3), 1184-1192.

Bao, X., & Bouthillier, F. (2007). Information sharing: As a type of information behavior. Proceedings of the Annual Conference of CAIS/Actes du congrès annuel de l'ACSI, Barbosa, M. W. (2021). Uncovering research streams on agri-food supply chain management: A bibliometric study. *Global Food Security*, *28*, 100517. https://doi.org/https://doi.org/10.1016/j.gfs.2021.100517

Barnes, A. P., Soto, I., Eory, V., Beck, B., Balafoutis, A., Sánchez, B., Vangeyte, J., Fountas, S., van der Wal, T., & Gómez-Barbero, M. (2019). Exploring the adoption of precision agricultural technologies: A cross regional study of EU farmers. *Land Use Policy*, *80*, 163-174.

Bastian, J., & Zentes, J. (2013). Supply chain transparency as a key prerequisite for sustainable agri-food supply chain management. *The International Review of Retail, Distribution and Consumer Research*, *23*(5), 553-570.

Beker, I., Delić, M., Milisavljević, S., Gosnik, D., Ostojić, G., & Stankovski, S. (2016). Can IoT be used to mitigate food supply chain risk? *International Journal of Industrial Engineering and Management*, *7*(1), 43.

Ben-Daya, M., Hassini, E., & Bahroun, Z. (2019). Internet of things and supply chain management: a literature review. *International Journal of Production Research*, *57*(15-16), 4719-4742. https://doi.org/10.1080/00207543.2017.1402140

Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I. D., de Haan, S., Prager, S. D., Talsma, E. F., & Khoury, C. K. (2019). When food systems meet sustainability–Current narratives and implications for actions. *World Development*, *113*, 116-130.

Benyam, A., Soma, T., & Fraser, E. (2021). Digital agricultural technologies for food loss and waste prevention and reduction: Global trends, adoption opportunities and barriers. *Journal of Cleaner Production*, *323*, 129099. https://doi.org/https://doi.org/10.1016/j.jclepro.2021.129099

BenYishay, A., & Mobarak, A. M. (2019). Social learning and incentives for experimentation and communication. *The Review of Economic Studies*, *86*(3), 976-1009.

Bhatia, L., Jha, H., Sarkar, T., & Sarangi, P. K. (2023). Food waste utilization for reducing carbon footprints towards sustainable and cleaner environment: a review. *International Journal of Environmental Research and Public Health*, *20*(3), 2318.

Blackburn, S., & Gartner, D. (2017). Digital Australia: Seizing the opportunity from the fourth industrial revolution. https://www.mckinsey.com/featured-insights/asia-pacific/digital-australia-seizing-opportunity-from-the-fourth-industrial-revolution

Blaikie, N., & Priest, J. (2019). *Designing social research: The logic of anticipation*. John Wiley & Sons.

Blasch, J., van der Kroon, B., van Beukering, P., Munster, R., Fabiani, S., Nino, P., & Vanino, S. (2022). Farmer preferences for adopting precision farming technologies: a case study from Italy. *European Review of Agricultural Economics*, *49*(1), 33-81.

Bogner, A., & Menz, W. (2009). The theory-generating expert interview: epistemological interest, forms of knowledge, interaction. In *Interviewing experts* (pp. 43-80). Springer.

Bokelmann, W., & Lentz, W. (2000). Prerequisites for value adding partnerships between trade and producers in the vegetable-growing sector. *XIVth International Symposium on Horticultural Economics* 536,

Borges, J. A. R., & Oude Lansink, A. G. J. M. (2016). Identifying psychological factors that determine cattle farmers' intention to use improved natural grassland. *Journal of Environmental Psychology*, *45*, 89-96. https://doi.org/https://doi.org/10.1016/j.jenvp.2015.12.001

Bouzembrak, Y., Klüche, M., Gavai, A., & Marvin, H. J. (2019). Internet of Things in food safety: Literature review and a bibliometric analysis. *Trends in Food Science & Technology*, *94*, 54-64.

Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Sage.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Braun, V., & Clarke, V. (2020). One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology*, *18*(3), 328-352. https://doi.org/10.1080/14780887.2020.1769238

Bree, R. T., & Gallagher, G. (2016). Using Microsoft Excel to code and thematically analyse qualitative data: a simple, cost-effective approach. *All Ireland Journal of Higher Education*, *8*(2).

Bremer, P. (2018). Towards a reference model for the cold chain. *The International Journal of Logistics Management*.

Brosnan, T., & Sun, D.-W. (2001). Precooling techniques and applications for horticultural products—a review. *International Journal of Refrigeration*, *24*(2), 154-170.

Brown, T., Hipps, N., Easteal, S., Parry, A., & Evans, J. (2014). Reducing domestic food waste by lowering home refrigerator temperatures. *International Journal of Refrigeration*, *40*, 246-253.

Burli, P. H., Nguyen, R. T., Hartley, D. S., Griffel, L. M., Vazhnik, V., & Lin, Y. (2021). Farmer characteristics and decision-making: A model for bioenergy crop adoption. *Energy*, *234*, 121235.

Caffaro, F., & Cavallo, E. (2019). The Effects of Individual Variables, Farming System Characteristics and Perceived Barriers on Actual Use of Smart Farming Technologies: Evidence from the Piedmont Region, Northwestern Italy. *Agriculture*, *9*(5), 111. https://www.mdpi.com/2077-0472/9/5/111

Canavari, M., Fritz, M., Hofstede, G. J., Matopoulos, A., & Vlachopoulou, M. (2010). The role of trust in the transition from traditional to electronic B2B relationships in agri-food chains. *Computers and Electronics in Agriculture*, *70*(2), 321-327.

Centobelli, P., Cerchione, R., & Ertz, M. (2020). Food cold chain management: what we know and what we deserve. *Supply Chain Management: An International Journal*.

Chaoyong, Z., & Aiqiang, D. (2018). The coordination mechanism of supply chain finance based on block chain. IOP Conference Series: Earth and Environmental Science,

Charatsari, C., D. Lioutas, E., De Rosa, M., & Papadaki-Klavdianou, A. (2020). Extension and advisory organizations on the road to the digitalization of animal farming: An organizational learning perspective. *Animals*, *10*(11), 2056.

Chavas, J.-P., & Nauges, C. (2020). Uncertainty, Learning, and Technology Adoption in Agriculture. *Applied Economic Perspectives and Policy*, *42*(1), 42-53. https://doi.org/https://doi.org/10.1002/aepp.13003

Chavas, J. P., & Nauges, C. (2020). Uncertainty, learning, and technology adoption in agriculture. *Applied Economic Perspectives and Policy*, *42*(1), 42-53.

Chen, J., Gui, P., Ding, T., Na, S., & Zhou, Y. (2019). Optimization of transportation routing problem for fresh food by improved ant colony algorithm based on tabu search. *Sustainability*, *11*(23), 6584.

Chen, Q., Zhang, C., Zhao, J., & Ouyang, Q. (2013). Recent advances in emerging imaging techniques for non-destructive detection of food quality and safety. *TrAC Trends in Analytical Chemistry*, *52*, 261-274. https://doi.org/https://doi.org/10.1016/j.trac.2013.09.007

Cho, H.-W., Jo, G.-H., & Song, Y. J. (2017). New IoT Technology for Food Shelf Life Management. *Advanced Science Letters*, *23*(10), 10346-10348.

Chouinard, H. H., Paterson, T., Wandschneider, P. R., & Ohler, A. M. (2008). Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection. *Land Economics*, *84*(1), 66-82.

Collis, J., & Hussey, R. (2013). *Business research: A practical guide for undergraduate and postgraduate students*. Macmillan International Higher Education.

Colussi, J., Morgan, E. L., Schnitkey, G. D., & Padula, A. D. (2022). How communication affects the adoption of digital technologies in soybean production: a survey in Brazil. *Agriculture*, *12*(5), 611.

Conti, C., Zanello, G., & Hall, A. (2021). Why are agri-food systems resistant to new directions of change? A systematic review. *Global Food Security*, *31*, 100576.

Cook, S., Jackson, E. L., Fisher, M. J., Baker, D., & Diepeveen, D. (2022). Embedding digital agriculture into sustainable Australian food systems: pathways and pitfalls to value creation. *International Journal of Agricultural Sustainability*, *20*(3), 346-367.

Cooksey, R., & McDonald, G. (2019). *Surviving and thriving in postgraduate research*. Springer.

Corallo, A., Latino, M. E., & Menegoli, M. (2018). From industry 4.0 to agriculture 4.0: a framework to manage product data in agri-food supply chain for voluntary traceability. *International Journal of Nutrition and Food Engineering*, *12*(5), 146-150.

Corbin, J. M. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Sage.

Costa, C., Antonucci, F., Pallottino, F., Aguzzi, J., Sarriá, D., & Menesatti, P. (2013). A review on agri-food supply chain traceability by means of RFID technology. *Food and Bioprocess Technology*, *6*(2), 353-366.

Crabtree, B. F., & Miller, W. F. (1992). A template approach to text analysis: developing and using codebooks. In B. F. Crabtree & W. L. Miller (Eds.), *Doing qualitative research* (pp. 93–109). Sage Publications, Inc.

Creswell, J. (2013). *Qualitative inquiry and research design: Choosing among five approaches*. Sage Publications Inc.

Creswell, J. W. (2002). *Educational research: Planning, conducting, and evaluating quantitative.* Prentice Hall Upper Saddle River, NJ.

Creswell, J. W. (2009). Research design: Qualitative and mixed methods approaches. *London and Thousand Oaks: Sage Publications*.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.

Curtis, P. A., Anderson, K. E., & Jones, F. T. (1995). Cryogenic gas for rapid cooling of commercially processed shell eggs before packaging. *Journal of Food Protection*, *58*(4), 389-394.

da Silveira, F., Lermen, F. H., & Amaral, F. G. (2021). An overview of agriculture 4.0 development: Systematic review of descriptions, technologies, barriers, advantages, and disadvantages. *Computers and Electronics in Agriculture*, *189*, 106405. https://doi.org/https://doi.org/10.1016/j.compag.2021.106405

Daberkow, S. G., & McBride, W. D. (2003). Farm and operator characteristics affecting the awareness and adoption of precision agriculture technologies in the US. *Precision Agriculture*, *4*(2), 163-177.

DAF. (2020). *Choosing a consignment monitoring technology*. Retrieved from https://www.publications.qld.gov.au/ckan-publications-attachments-prod/resources/a78afbff-da1c-425e-ae99-0544edf85b0c/daf-hort-supply-factsheets-loggertech20200519-2.pdf?ETag=d6de32aa30eea46d4c229eaa900c4189

Dai, J., Che, W., Lim, J. J., & Shou, Y. (2020). Service innovation of cold chain logistics service providers: A multiple-case study in China. *Industrial Marketing Management*, *89*, 143-156.

Dania, W. A. P., Xing, K., & Amer, Y. (2018). Collaboration behavioural factors for sustainable agri-food supply chains: A systematic review. *Journal of Cleaner Production*, *186*, 851-864.

Darley, J. M., Latane, B. (1970). *The unresponsive bystander: Why doesn't he help?* Century Psychology Series. Prentice Hall.

Das, N. K., & Roy, A. (2022). COVID-19 and agri-food value chain: a systematic review and bibliometric mapping. *Journal of Agribusiness in Developing and Emerging Economies*, *12*(3), 442-462.

Davey, S. S., & Richards, C. (2013). Supermarkets and private standards: Unintended consequences of the audit ritual. *Agriculture and Human Values*, *30*, 271-281.

Davis, F. D. (1985). *A technology acceptance model for empirically testing new end-user information systems: Theory and results* .Massachusetts Institute of Technology].

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 319-340.

Davis, F. D., & Venkatesh, V. (1996). A critical assessment of potential measurement biases in the technology acceptance model: three experiments. *International Journal of Human-Computer Studies*, *45*(1), 19-45.

De Vries, H., Bekkers, V., & Tummers, L. (2016). Innovation in the public sector: A systematic review and future research agenda. *Public Administration*, *94*(1), 146-166.

Denzin, N. K., & Lincoln, Y. S. (2011). *The Sage handbook of qualitative research* (4 ed.). Sage Publications..

Derens-Bertheau, E., Osswald, V., Laguerre, O., & Alvarez, G. (2015). Cold chain of chilled food in France. *International Journal of Refrigeration*, *52*, 161-167.

Devin, B., & Richards, C. (2018). Food waste, power, and corporate social responsibility in the Australian food supply chain. *Journal of Business Ethics*, *150*(1), 199-210.

Diederen, P., Van Meijl, H., Wolters, A., & Bijak, K. (2002). Innovation adoption in agriculture: innovators, early adopters and laggards. *Cahiers d'Economie et de Sociologie Rurales*, *67*, 29-50.

Diwanji, M. M., Hisvankar, S. M., & Khandelwal, C. S. (2020). Temperature Measurement using Infrared Contactless Thermal Gun. 2020 International Conference on Smart Innovations in Design, Environment, Management, Planning and Computing (ICSIDEMPC),

Dou, Z., Ferguson, J. D., Galligan, D. T., Kelly, A. M., Finn, S. M., & Giegengack, R. (2016). Assessing U.S. food wastage and opportunities for reduction. *Global Food Security*, *8*, 19-26. https://doi.org/https://doi.org/10.1016/j.gfs.2016.02.001

Duan, Y., Wang, G.-B., Fawole, O. A., Verboven, P., Zhang, X.-R., Wu, D., Opara, U. L., Nicolai, B., & Chen, K. (2020). Postharvest precooling of fruit and vegetables: A review. *Trends in Food Science & Technology*, *100*, 278-291.

Dusoruth, V., & Peterson, H. H. (2020). Food waste tendencies: behavioral response to cosmetic deterioration of food. *PloS one*, *15*(5), e0233287.

Eagly, A., & Chaiken, S. (1998). Attitude structure. *Handbook of Social Psychology*, *1*, 269-322.

Edwards-Jones, G. (2006). Modelling farmer decision-making: concepts, progress and challenges. *Animal Science*, *82*(6), 783-790.

Eli-Chukwu, N. C. (2019). Applications of artificial intelligence in agriculture: A review. *Engineering, Technology & Applied Science Research*, *9*(4).

Engotoit, B., Moya, M. B., Mayoka, K. G., & Bonface, A. (2016). A Mobile-Based Communication Adoption Model for agricultural market information dissemination in Uganda. *Global Journal of Computers & Technology*, *5*(1).

Eraut, M. (2000). Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology*, *70*(1), 113-136.

Fadhel, K. (2002). Positivist and hermeneutic paradigm: A critical evaluation under their structure of scientific practice. *The Sosland Journal*, *21*, 28.

FAO. (2009). *Global agriculture towards 2050*. https://www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf

FAO. (2014). Agriculture Organization of the United Nations (2014b) Food wastage footprint. Impact on natural resources. https://www.fao.org/3/i3347e/i3347e.pdf

FAO. (2019). *The state of food and agriculture 2019. Moving forward on food loss and waste reduction*. https://www.fao.org/3/ca6030en/ca6030en.pdf

FAO (2019). *The state of food security and nutrition in the world 2019. Safeguarding against economic slowdowns and downturns. FAO, Rome, pp. 1-239.* https://www.fao.org/3/ca5162en/ca5162en.pdf

Far, S. T., & Rezaei-Moghaddam, K. (2017). Determinants of Iranian agricultural consultants’ intentions toward precision agriculture: Integrating innovativeness to the technology acceptance model. *Journal of the Saudi Society of Agricultural Sciences*, *16*(3), 280-286.

Fearne, A., Hughes, D., & Duffy, R. (2001). Chapter 4 - Concepts of collaboration: supply chain management in a global food industry J. F. Eastham, L. Sharples, & S. D. Ball (Eds.), *Food Supply Chain Management* (pp. 55-89). Butterworth-Heinemann. https://doi.org/https://doi.org/10.1016/B978-0-7506-4762-5.50008-0

Feng, H., Wang, X., Duan, Y., Zhang, J., & Zhang, X. (2020). Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. *Journal of Cleaner Production*, *260*, 121031.

Fielding, N. G., & Thomas, H. (2008). Qualitative interviewing. N. Gilbert (Ed.), *Researching Social Life* (3rd ed., pp. 123-144). SAGE Publications.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research*. Addison-Wesley.

Foguesatto, C. R., Borges, J. A. R., & Machado, J. A. D. (2020). A review and some reflections on farmers' adoption of sustainable agricultural practices worldwide. *Science of The Total Environment*, *729*, 138831. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.138831

Fontana, A., & Frey, J. (1994). The art of science. *The handbook of qualitative research*, *361376*.

Forrest-Lawrence, P. (2018). Case Study Research. P. Liamputtong (Ed.), *Handbook of Research Methods in Health Social Sciences* (pp. 1-16). Springer Singapore. https://doi.org/10.1007/978-981-10-2779-6_67-1

Forsman-Hugg, S., Katajajuuri, J. M., Riipi, I., Mäkelä, J., Järvelä, K., & Timonen, P. (2013). Key CSR dimensions for the food chain. *British Food Journal*, *115*(1), 30-47.

Fracarolli, G. S. (2021). Global Markets, Local Issues: The Hegemonic Process of Agri-Food Construction to Present Challenges. *Land*, *10*(11), 1182.

Frankish, E. J., McAlpine, G., Mahoney, D., Oladele, B., Luning, P. A., Ross, T., Bowman, J. P., & Bozkurt, H. (2021). Food safety culture from the perspective of the Australian horticulture industry. *Trends in Food Science & Technology*, *116*, 63-74.

Fróna, D., Szenderák, J., & Harangi-Rákos, M. (2019). The challenge of feeding the world. *Sustainability*, *11*(20), 5816.

FSANZ. (2016). Food standards code. In: Food Standards Australia New Zealand. https://www.foodstandards.gov.au/code/Pages/default.aspx

Gao, T., Tian, Y., Zhu, Z., & Sun, D.-W. (2020). Modelling, responses and applications of time-temperature indicators (TTIs) in monitoring fresh food quality. *Trends in Food Science & Technology*, *99*, 311-322. https://doi.org/https://doi.org/10.1016/j.tifs.2020.02.019

Gao, Y., Liu, B., Yu, L., Yang, H., & Yin, S. (2019). Social capital, land tenure and the adoption of green control techniques by family farms: Evidence from Shandong and Henan Provinces of China. *Land Use Policy*, *89*, 104250. https://doi.org/https://doi.org/10.1016/j.landusepol.2019.104250

Gerli, P., Clement, J., Esposito, G., Mora, L., & Crutzen, N. (2022). The hidden power of emotions: How psychological factors influence skill development in smart technology adoption. *Technological Forecasting and Social Change*, *180*, 121721. https://doi.org/https://doi.org/10.1016/j.techfore.2022.121721

Gibson, W., & Brown, A. (2009). *Working with qualitative data*. Sage.

Giua, C., Materia, V. C., & Camanzi, L. (2022). Smart farming technologies adoption: Which factors play a role in the digital transition? *Technology in Society*, *68*, 101869. https://doi.org/https://doi.org/10.1016/j.techsoc.2022.101869

Giusto, D., Iera, A., Morabito, G., & Atzori, L. (2010). *The internet of things: 20th Tyrrhenian workshop on digital communications*. Springer Science & Business Media.

Gloy, B. A., & Akridge, J. T. (2000). Computer and internet adoption on large US farms. *The International Food and Agribusiness Management Review*, *3*(3), 323-338.

Gómez-Chabla, R., Real-Avilés, K., Morán, C., Grijalva, P., & Recalde, T. (2019). *IoT applications in agriculture: A systematic literature review.* 2nd International conference on ICTs in agronomy and environment, DOI:10.1007/978-3-030-10728-4_8

Göransson, M., Nilsson, F., & Jevinger, Å. (2018). Temperature performance and food shelf-life accuracy in cold food supply chains – Insights from multiple field studies. *Food Control*, *86*, 332-341. https://doi.org/https://doi.org/10.1016/j.foodcont.2017.10.029

Gowen, A., Tiwari, B., Cullen, P., McDonnell, K., & O'Donnell, C. (2010). Applications of thermal imaging in food quality and safety assessment. *Trends in Food Science & Technology*, *21*(4), 190-200.

Grecuccio, J., Giusto, E., Fiori, F., & Rebaudengo, M. (2020). Combining blockchain and iot: Food-chain traceability and beyond. *Energies*, *13*(15), 3820.

Griliches, Z. (1957). Hybrid corn: An exploration in the economics of technological change. *Econometrica, Journal of the Econometric Society*, 501-522.

Guba, E. G., & Lincoln, Y. S. (1994). *Competing paradigms in qualitative research* (Vol. 2).

Guirado-Clavijo, R., Sanchez-Molina, J. A., Wang, H., & Bienvenido, F. (2018). Conceptual data model for IoT in a chain-integrated greenhouse production: Case of the tomato production in Almeria (Spain). *IFAC-PapersOnLine*, *51*(17), 102-107.

Gunders, D., & Bloom, J. (2017). *Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill*. Natural Resources Defense Council New York.

Gupta, V. K., Chaudhuri, A., & Tiwari, M. K. (2019). Modeling for deployment of digital technologies in the cold chain. *IFAC-PapersOnLine*, *52*(13), 1192-1197. https://doi.org/https://doi.org/10.1016/j.ifacol.2019.11.360

Gutiérrez, J. A., & Macken-Walsh, Á. (2022). Ecosystems of collaboration for sustainability-oriented innovation: the importance of values in the agri-food value-chain. *Sustainability*, *14*(18), 11205.

Han, J.-W., Zhao, C.-J., Qian, J.-P., Ruiz-Garcia, L., & Zhang, X. (2018). Numerical modeling of forced-air cooling of palletized apple: Integral evaluation of cooling efficiency. *International Journal of Refrigeration*, *89*, 131-141.

Han, J.-W., Zuo, M., Zhu, W.-Y., Zuo, J.-H., Lü, E.-L., & Yang, X.-T. (2021). A comprehensive review of cold chain logistics for fresh agricultural products: Current status, challenges, and future trends. *Trends in Food Science & Technology*, *109*, 536-551. https://doi.org/https://doi.org/10.1016/j.tifs.2021.01.066

Handayati, Y., Simatupang, T. M., & Perdana, T. (2015). Value co-creation in agri-chains network: an Agent-Based Simulation. *Procedia Manufacturing*, *4*, 419-428.

Hansen, B. D., Leonard, E., Mitchell, M. C., Easton, J., Shariati, N., Mortlock, M. Y., Schaefer, M., & Lamb, D. W. (2022). Current status of and future opportunities for digital agriculture in Australia. *Crop and Pasture Science*. https://doi.org/10.1071/CP21594

Hanson, C., Lipinski, B., Robertson, K., Dias, D., Gavilan, I., Gréverath, P., Ritter, S., Fonseca, J., VanOtterdijk, R., & Timmermans, T. (2016). *Food loss and waste accounting and reporting standard.* https://flwprotocol.org/wp-content/uploads/2017/05/FLW_Standard_final_2016.pdf

Hansson, H., Ferguson, R., & Olofsson, C. (2012). Psychological constructs underlying farmers' decisions to diversify or specialise their businesses–An application of Theory of Planned Behaviour. *Journal of Agricultural Economics*, *63*(2), 465-482.

Hardaker, J. B., & Lien, G. (2010). Probabilities for decision analysis in agriculture and rural resource economics: The need for a paradigm change. *Agricultural Systems*, *103*(6), 345-350.

Hayden, M. T., Mattimoe, R., & Jack, L. (2021). Sensemaking and the influencing factors on farmer decision-making. *Journal of Rural Studies*, *84*, 31-44.

Herzfeld, T., & Jongeneel, R. (2012). Why do farmers behave as they do? Understanding compliance with rural, agricultural, and food attribute standards. *Land Use Policy*, *29*(1), 250-260.

Himesh, S., Rao, E. P., Gouda, K., Ramesh, K., Rakesh, V., Mohapatra, G., Rao, B. K., Sahoo, S. K., & Ajilesh, P. (2018). Digital revolution and Big Data: a new revolution in agriculture. *CABI Reviews*(2018), 1-7.

Hobbs, J. E. (2003). *Incentives for the adoption of good agricultural practices (GAPs).* Background paper for the FAO Expert Consultationbon a Good Agricultural Practice approach Rome, Italy, 10-12 November 2003.

Hodgson, G. M. (2006). What are institutions? *Journal of Economic Issues*, *40*(1), 1-25.

Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. *Educational Psychology Review*, *13*(4), 353-383.

Hogarth, R. M. (2010). Intuition: A challenge for psychological research on decision making. *Psychological Inquiry*, *21*(4), 338-353.

Hort Innovation. (2020). *Adoption of precision systems technology in vegetable production (VG16009)*. H. Innovation.

Hort Innovation. (2022). *Australian Horticulture Statistics Handbook 2021/22*.

Hsiao, H.-I., & Huang, K.-L. (2016). Time-temperature transparency in the cold chain. *Food Control*, *64*, 181-188. https://doi.org/https://doi.org/10.1016/j.foodcont.2015.12.020

Hsu, L.-L., Lai, R. S. Q., & Weng, Y.-T. (2008). Understanding the critical factors effect user satisfaction and impact of ERP through innovation of diffusion theory. *International Journal of Technology Management*, *43*(1-3), 30-47. https://doi.org/10.1504/ijtm.2008.019405

Huberty, M. (2015). Awaiting the second big data revolution: from digital noise to value creation. *Journal of Industry, Competition and Trade*, *15*(1), 35-47.

Hüttel, S., Leuchten, M.-T., & Leyer, M. (2022). The Importance of Social Norm on Adopting Sustainable Digital Fertilisation Methods. *Organization & Environment*, *35*(1), 79-102. https://doi.org/10.1177/1086026620929074

Hwang, Y., Al-Arabiat, M., & Shin, D.-H. (2016). Understanding technology acceptance in a mandatory environment: A literature review. *Information Development*, *32*(4), 1266-1283.

Iakovou, E., Vlachos, D., Achillas, C., & Anastasiadis, F. (2012*). A methodological framework for the design of green supply chains for the agrifood sector*. de 2nd International Conference on Supply Chains, Greece.

ID. (2023). *Lockyer Valley Regional Council*. https://economy.id.com.au/lockyer-valley/

Ingram, J. (2011). A food systems approach to researching food security and its interactions with global environmental change. *Food security*, *3*(4), 417-431.

Ingram, J., Maye, D., Bailye, C., Barnes, A., Bear, C., Bell, M., Cutress, D., Davies, L., de Boon, A., Dinnie, L., Gairdner, J., Hafferty, C., Holloway, L., Kindred, D., Kirby, D., Leake, B., Manning, L., Marchant, B., Morse, A., . . . Wilson, L. (2022). What are the priority research questions for digital agriculture? *Land Use Policy*, *114*, 105962. https://doi.org/https://doi.org/10.1016/j.landusepol.2021.105962

Irani, Z., Sharif, A. M., Lee, H., Aktas, E., Topaloğlu, Z., van't Wout, T., & Huda, S. (2018). Managing food security through food waste and loss: Small data to big data. *Computers & Operations Research*, *98*, 367-383.

Ishimwe, R., Abutaleb, K., & Ahmed, F. (2014). Applications of thermal imaging in agriculture—A review. *Advances in Remote Sensing*, *3*(03), 128.

Jacob-John, J., & Veerapa, N. (2015). *Integrating responsibility within food supply chains-A conceptual model.* XVIII International Symposium on Horticultural Economics and Management 1132,

Jacob, S. A., & Furgerson, S. P. (2012). Writing interview protocols and conducting interviews: tips for students new to the field of qualitative research. *Qualitative Report*, *17*, 6.

Jagtap, S., Bhatt, C., Thik, J., & Rahimifard, S. (2019). Monitoring potato waste in food manufacturing using image processing and internet of things approach. *Sustainability*, *11*(11), 3173.

James, S., & James, C. (2010). The food cold-chain and climate change. *Food Research International*, *43*(7), 1944-1956.

Jayashankar, P., Johnston, W. J., Nilakanta, S., & Burres, R. (2020). Co-creation of value-in-use through big data technology-a B2B agricultural perspective. *Journal of Business & Industrial Marketing*, *35*(3), 508-523.

Jedermann, R., Nicometo, M., Uysal, I., & Lang, W. (2014). Reducing food losses by intelligent food logistics. The Royal Society Publishing. https://doi.org/10.1098/rsta.2013.0302

Jerhamre, E., Carlberg, C. J. C., & van Zoest, V. (2022). Exploring the susceptibility of smart farming: Identified opportunities and challenges. *Smart Agricultural Technology*, *2*, 100026. https://doi.org/https://doi.org/10.1016/j.atech.2021.100026

Jocevski, M., Arvidsson, N., & Ghezzi, A. (2020). Interconnected business models: present debates and future agenda. *Journal of Business & Industrial Marketing*, *35*(6), 1051-1067.

Jochinke, D. C., Noonon, B. J., Wachsmann, N. G., & Norton, R. M. (2007). The adoption of precision agriculture in an Australian broadacre cropping system—Challenges and opportunities. *Field Crops Research*, *104*(1), 68-76. https://doi.org/https://doi.org/10.1016/j.fcr.2007.05.016

Johnson, L. K., Bloom, J. D., Dunning, R. D., Gunter, C. C., Boyette, M. D., & Creamer, N. G. (2019). Farmer harvest decisions and vegetable loss in primary production. *Agricultural Systems*, *176*, 102672.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*(7), 14-26.

Jonker, J., & Pennink, B. W. (2010). *The Essence of Research Methodology*. Springer, Berlin, Heidelberg. https://doi.org/https://doi.org/10.1007/978-3-540-71659-4_2

Joshi, K., Tiwari, B., Cullen, P. J., & Frias, J. M. (2019). Predicting quality attributes of strawberry packed under modified atmosphere throughout the cold chain. *Food Packaging and Shelf Life*, *21*, 100354. https://doi.org/https://doi.org/10.1016/j.fpsl.2019.100354

Juliano, P., Sanguansri, P., Krause, D., Villaddra-Gamage, M., & Garcia-Flores, R. (2019). *Mapping of Australian fruit and vegetable losses pre-retail.* CSIRO: Melbourne, Australia.

Junior, C. H., Oliveira, T., & Yanaze, M. (2019). The adoption stages (Evaluation, Adoption, and Routinisation) of ERP systems with business analytics functionality in the context of farms. *Computers and Electronics in Agriculture*, *156*, 334-348.

Kache, F., & Seuring, S. (2017). Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management. *International Journal of Operations & Production Management*.

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, *72*(12), 2954-2965.

Kamble, S. S., Gunasekaran, A., & Gawankar, S. A. (2020). Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics*, *219*, 179-194. https://doi.org/https://doi.org/10.1016/j.ijpe.2019.05.022

Kang, Y.-S., Jin, H., Ryou, O., & Lee, Y.-H. (2012). A simulation approach for optimal design of RFID sensor tag-based cold chain systems. *Journal of Food Engineering*, *113*(1), 1-10.

Kapoor, G., Zhou, W., & Piramuthu, S. (2009). Challenges associated with RFID tag implementations in supply chains. *European Journal of Information Systems*, *18*(6), 526-533.

Ketzenberg, M., Bloemhof, J., & Gaukler, G. (2015). Managing Perishables with Time and Temperature History. *Production and Operations Management*, *24*(1), 54-70. https://doi.org/https://doi.org/10.1111/poms.12209

Kim, Y. G., & Woo, E. (2016). Consumer acceptance of a quick response (QR) code for the food traceability system: Application of an extended technology acceptance model (TAM). *Food Research International*, *85*, 266-272.

Kivunja, C., & Kuyini, A. B. (2017). Understanding and applying research paradigms in educational contexts. *International Journal of Higher Education*, *6*(5), 26-41.

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS - Wageningen Journal of Life Sciences*, *90-91*, 100315. https://doi.org/https://doi.org/10.1016/j.njas.2019.100315

Knierim, A., Borges, F., Kernecker, M., Kraus, T., & Wurbs, A. (2018). *What drives adoption of smart farming technologies? Evidence from a cross-country study.* Proceedings of the European International Farm Systems Association Symposium, Chania, Greece,

Kodan, R., Rashed, M. S., Pandit, M. K., Parmar, P., & Pathania, S. (2022). Internet of things in food industry. *Innovation Strategies in the Food Industry* (pp. 287-303). Elsevier.

Kosior, K. (2018). Digital transformation in the agri-food sector–opportunities and challenges. *Roczniki (Annals)*, *2018*(1230-2019-3703).

Krauss, S. E. (2005). Research paradigms and meaning making: A primer. *The qualitative report*, *10*(4), 758-770.

Krishnan, P., & Patnam, M. (2014). Neighbors and extension agents in Ethiopia: Who matters more for technology adoption? *American Journal of Agricultural Economics*, *96*(1), 308-327.

Kroft, B., Gu, G., Bolten, S., Micallef, S. A., Luo, Y., Millner, P., & Nou, X. (2022). Effects of temperature abuse on the growth and survival of Listeria monocytogenes on a wide variety of whole and fresh-cut fruits and vegetables during storage. *Food Control*, *137*, 108919.

Kuan, K. K. Y., & Chau, P. Y. K. (2001). A perception-based model for EDI adoption in small businesses using a technology–organization–environment framework. *Information & Management*, *38*(8), 507-521. https://doi.org/https://doi.org/10.1016/S0378-7206(01)00073-8

Kumar, A., Jain, S., & Yadav, D. (2020). A novel simulation-annealing enabled ranking and scaling statistical simulation constrained optimization algorithm for internet-of-things (IoTs). *Smart and Sustainable Built Environment*, *9*(4), 675-693.

Kumar, A., Mangla, S. K., Kumar, P., & Karamperidis, S. (2020). Challenges in perishable food supply chains for sustainability management: A developing economy perspective. *Business Strategy and the Environment*, *29*(5), 1809-1831.

Kumar, A., Singh, R. K., & Modgil, S. (2020). Exploring the relationship between ICT, SCM practices and organizational performance in agri-food supply chain. *Benchmarking: An International Journal*, *27*(3), 1003-1041. https://doi.org/10.1108/BIJ-11-2019-0500

Kumar, P., Reinitz, H., Simunovic, J., Sandeep, K., & Franzon, P. (2009). Overview of RFID technology and its applications in the food industry. *Journal of Food Science*, *74*(8), R101-R106.

Kumari, L., Narsaiah, K., Grewal, M. K., & Anurag, R. K. (2015). Application of RFID in agri-food sector. *Trends in Food Science & Technology*, *43*(2), 144-161. https://doi.org/https://doi.org/10.1016/j.tifs.2015.02.005

Kurosh, R.-M., & Saeid, S. (2010). Agricultural specialistsâ€™ intention toward precision agriculture technologies: integrating innovation characteristics to technology acceptance model. *African Journal of Agricultural Research*, *5*(11), 1191-1199.

Lai, P. (2017). The literature review of technology adoption models and theories for the novelty technology. *JISTEM-Journal of Information Systems and Technology Management*, *14*(1), 21-38.

Laksono, P., Irham, Mulyo, J. H., & Suryantini, A. (2022). Farmers’ willingness to adopt geographical indication practice in Indonesia: A psycho behavioral analysis. *Heliyon*, *8*(8), e10178. https://doi.org/https://doi.org/10.1016/j.heliyon.2022.e10178

Lamb, D. W., Frazier, P., & Adams, P. (2008). Improving pathways to adoption: Putting the right P's in precision agriculture. *Computers and Electronics in Agriculture*, *61*(1), 4-9.

Lamberty, A., & Kreyenschmidt, J. (2022). Ambient parameter monitoring in fresh fruit and vegetable supply chains using internet of things-enabled sensor and communication technology. *Foods*, *11*(12), 1777.

Lankester, A. J. (2013). Conceptual and operational understanding of learning for sustainability: A case study of the beef industry in north-eastern Australia. *Journal of Environmental Management*, *119*, 182-193.

Lawson-Body, A., Willoughby, L., Lawson-Body, L., & Tamandja, E. M. (2018). Students' acceptance of E-books: An application of UTAUT. *Journal of Computer Information Systems*, 1-12.

Lee, H. L. (2000). Creating value through supply chain integration. *Supply Chain Management Review*, *4*(4), 30-36.

Lee, I., & Lee, K. (2015). The Internet of Things (IoT): Applications, investments, and challenges for enterprises. *Business Horizons*, *58*(4), 431-440.

Lee, S., Yang, A., Jeon, B.-H., & Park, H. (2019). A structure of scalable and configurable interface for sensor and actuator devices in smart farming system. *Int. J. Inn. Tech. Exp. Eng*, *8*, 2779-2786.

Lezoche, M., Hernandez, J. E., Alemany Díaz, M. d. M. E., Panetto, H., & Kacprzyk, J. (2020). Agri-food 4.0: A survey of the supply chains and technologies for the future agriculture. *Computers in Industry*, *117*, 103187. https://doi.org/https://doi.org/10.1016/j.compind.2020.103187

Lim, M. K., Li, Y., & Song, X. (2021). Exploring customer satisfaction in cold chain logistics using a text mining approach. Industrial Management & Data Systems *121*(12), pp. 2426-2449. https://dx.doi.org/10.1108/IMDS-05-2021-0283

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage Publications.

Liu, T., Bruins, R. J., & Heberling, M. T. (2018). Factors influencing farmers' adoption of best management practices: A review and synthesis. *Sustainability*, *10*(2), 432.

Liu, W., Shao, X.-F., Wu, C.-H., & Qiao, P. (2021). A systematic literature review on applications of information and communication technologies and blockchain technologies for precision agriculture development. *Journal of Cleaner Production*, *298*, 126763.

Long, T. B., Blok, V., & Coninx, I. (2016). Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. *Journal of Cleaner Production*, *112*, 9-21. https://doi.org/https://doi.org/10.1016/j.jclepro.2015.06.044

Iori, E., Masotti, M., Falasconi, L., Risso, E., Segrè, A., & Vittuari, M. (2023). Tell Me What You Waste and I’ll Tell You Who You Are: An Eight-Country Comparison of Consumers’ Food Waste Habits. *Sustainability*, *15*(1), 430. https://www.mdpi.com/2071-1050/15/1/430

Lowenberg-DeBoer, J., & Erickson, B. (2019). Setting the record straight on precision agriculture adoption. *Agronomy Journal*, *111*(4), 1552-1569.

Luo, J., Ji, C., Qiu, C., & Jia, F. (2018). Agri-food supply chain management: Bibliometric and content analyses. *Sustainability*, *10*(5), 1573.

Lütjen, M., Dittmer, P., & Veigt, M. (2013). Quality driven distribution of intelligent containers in cold chain logistics networks. *Production Engineering*, *7*, 291-297.

Mack, M., Dittmer, P., Veigt, M., Kus, M., Nehmiz, U., & Kreyenschmidt, J. (2014). Quality tracing in meat supply chains. *Philosophical Transactions of the Royal Society A: Mathematical, Physical Engineering Sciences*, *372*(2017), Article 20130308. https://doi.org/10.1098/rsta.2013.0308

Mackenzie, N., & Knipe, S. (2006). Research dilemmas: Paradigms, methods and methodology. *Issues in Educational Research*, *16*(2), 193-205.

Mackrell, D., Kerr, D., & von Hellens, L. (2009). A qualitative case study of the adoption and use of an agricultural decision support system in the Australian cotton industry: The socio-technical view. *Decision Support Systems*, *47*(2), 143-153. https://doi.org/https://doi.org/10.1016/j.dss.2009.02.004

Maclntosh, R., & O'Gorman, K. (2015). Mapping Reserach Methods. *Research Methods for Business and Management*, 1-74.

Maertens, A., & Barrett, C. B. (2013). Measuring social networks' effects on agricultural technology adoption. *American Journal of Agricultural Economics*, *95*(2), 353-359.

Mahajan, P. V., Caleb, O. J., Singh, Z., Watkins, C. B., & Geyer, M. (2014). Postharvest treatments of fresh produce. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *372*(2017), 20130309.

Mahdad, M., Hasanov, M., Isakhanyan, G., & Dolfsma, W. (2022). A smart web of firms, farms and internet of things (IOT): enabling collaboration-based business models in the agri-food industry. *British Food Journal*, *124*(6), 1857-1874.

Maksimović, M., Vujović, V., & Omanović-Miklić anin, E. (2015). Application of internet of things in food packaging and transportation. *International Journal of Sustainable Agricultural Management and Informatics*, *1*(4), 333-350.

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability*, *13*(3), 1318.

Managa, M. G., Tinyani, P. P., Senyolo, G. M., Soundy, P., Sultanbawa, Y., & Sivakumar, D. (2018). Impact of transportation, storage, and retail shelf conditions on lettuce quality and phytonutrients losses in the supply chain. *Food Science & Nutrition*, *6*(6), 1527-1536.

Mankad, A. (2016). Psychological influences on biosecurity control and farmer decision-making. A review. *Agronomy for Sustainable Development*, *36*(2), 40. https://doi.org/10.1007/s13593-016-0375-9

Manski, C. F. (2000). Economic analysis of social interactions. *Journal of Economic Perspectives*, *14*(3), 115-136.

Marsden, T., Banks, J., & Bristow, G. (2000). Food Supply Chain Approaches: Exploring their Role in Rural Development. *Sociologia Ruralis*, *40*(4), 424-438. https://doi.org/https://doi.org/10.1111/1467-9523.00158

Marshall, A., Turner, K., Richards, C., Foth, M., & Dezuanni, M. (2022). Critical factors of digital AgTech adoption on Australian farms: from digital to data divide. *Information, Communication & Society*, *25*(6), 868-886. https://doi.org/10.1080/1369118X.2022.2056712

Marshall, C., & Rossman, G. B. (2014). *Designing qualitative research*. Sage Publications.

Marshall, B., Cardon, P., Poddar, A., & Fontenot, R. (2013). Does sample size matter in qualitative research?: A review of qualitative interviews in IS research. *Journal of Computer Information Systems*, *54*(1), 11-22.

Mastrangelo, M. E., Gavin, M. C., Laterra, P., Linklater, W. L., & Milfont, T. L. (2014). Psycho-social factors influencing forest conservation intentions on the agricultural frontier. *Conservation Letters*, *7*(2), 103-110.

Maxwell, J. A., & Chmiel, M. (2014). Generalization in and from qualitative analysis. *The SAGE handbook of qualitative data analysis*, *7*(37), 540-553.

McDonald, K., & Sun, D.-W. (2000). Vacuum cooling technology for the food processing industry: a review. *Journal of Food Engineering*, *45*(2), 55-65.

McEachan, R., Taylor, N., Harrison, R., Lawton, R., Gardner, P., & Conner, M. (2016). Meta-analysis of the reasoned action approach (RAA) to understanding health behaviors. *Annals of Behavioral Medicine*, *50*(4), 592-612.

McGrath, C., Palmgren, P. J., & Liljedahl, M. (2019). Twelve tips for conducting qualitative research interviews. *Medical Teacher*, *41*(9), 1002-1006. https://doi.org/10.1080/0142159X.2018.1497149

Mditshwa, A., Fawole, O. A., & Opara, U. L. (2018). Recent developments on dynamic controlled atmosphere storage of apples—A review. *Food Packaging and Shelf Life*, *16*, 59-68.

Medeiros, G., Binotto, E., Caleman, S., & Florindo, T. (2016). Open innovation in agrifood chain: A systematic review. *Journal of Technology Management & Innovation*, *11*(3), 108-116.

Mercier, S., Villeneuve, S., Mondor, M., & Uysal, I. (2017). Time–temperature management along the food cold chain: A review of recent developments. *Comprehensive reviews in food science food safety 16*(4), 647-667.

Mertens, D. M., & Ginsberg, P. E. (2009). *The handbook of social research ethics*. Sage.

Messner, R., Johnson, H., & Richards, C. (2021). From surplus-to-waste: A study of systemic overproduction, surplus and food waste in horticultural supply chains. *Journal of Cleaner Production*, *278*, 123952.

Meuser, M., & Nagel, U. (2009). The expert interview and changes in knowledge production. *Interviewing experts* (pp. 17-42). Springer.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2018). *Qualitative data analysis: A methods sourcebook*. Sage Publications.

Miller, C. (1995). In-depth interviewing by telephone: Some practical considerations. *Evaluation & Research in Education*, *9*(1), 29-38.

Miranda, J., Ponce, P., Molina, A., & Wright, P. (2019). Sensing, smart and sustainable technologies for Agri-Food 4.0. *Computers in Industry*, *108*, 21-36.

Mishra, D., Akman, I., & Mishra, A. (2014). Theory of Reasoned Action application for Green Information Technology acceptance. *Computers in Human Behavior*, *36*, 29-40. https://doi.org/https://doi.org/10.1016/j.chb.2014.03.030

Moazzam, M., Akhtar, P., Garnevska, E., & Marr, N. E. (2018). Measuring agri-food supply chain performance and risk through a new analytical framework: a case study of New Zealand dairy. *Production Planning & Control*, *29*(15), 1258-1274.

Mohr, S., & Kühl, R. (2021). Acceptance of artificial intelligence in German agriculture: an application of the technology acceptance model and the theory of planned behavior. *Precision Agriculture*, *22*(6), 1816-1844. https://doi.org/10.1007/s11119-021-09814-x

Morgan, D. L. (2007). Paradigms lost and pragmatism regained: Methodological implications of combining qualitative and quantitative methods. *Journal of Mixed Methods Research*, *1*(1), 48-76.

Mosadegh Sedghy, B. (2018). Evolution of Radio Frequency Identification (RFID) in Agricultural Cold Chain Monitoring: A Literature Review. *Journal of Agricultural Science; 11*(3); 2019. DOI:10.5539/jas.v11n3p43

Mugo, D. G., Njagi, K., Chemwei, B., & Motanya, J. O. (2017). The technology acceptance model (TAM) and its application to the utilization of mobile learning technologies. *Journal of Advances in Mathematics Computer Science*, 1-8.

Munesue, Y., Masui, T., & Fushima, T. (2015). The effects of reducing food losses and food waste on global food insecurity, natural resources, and greenhouse gas emissions. *Environmental Economics and Policy Studies*, *17*, 43-77.

Mustafa, F., & Andreescu, S. (2018). Chemical and biological sensors for food-quality monitoring and smart packaging. *Foods*, *7*(10), 168.

Naeem, H. (2019). Detection of malicious activities in internet of things environment based on binary visualization and machine intelligence. *Wireless Personal Communications*, *108*(4), 2609-2629.

Narwane, V. S., Gunasekaran, A., & Gardas, B. B. (2022). Unlocking adoption challenges of IoT in Indian Agricultural and Food Supply Chain. *Smart Agricultural Technology*, *2*, 100035. https://doi.org/https://doi.org/10.1016/j.atech.2022.100035

Nath, A., Meena, L., Kumar, V., & Panwar, A. (2018). Postharvest management of horticultural crops for doubling farmer’s income. *Journal of Pharmacognosy & Phytochemistry.*

Ndraha, N., Hsiao, H.-I., Vlajic, J., Yang, M.-F., & Lin, H.-T. V. (2018). Time-temperature abuse in the food cold chain: Review of issues, challenges, and recommendations. *Food Control*, *89*, 12-21.

Ndraha, N., Vlajic, J., Chang, C.-C., & Hsiao, H.-I. (2020). Challenges with food waste management in the food cold chains. *Food industry wastes* (pp. 467-483). Elsevier.

Newton, J. E., Nettle, R., & Pryce, J. E. (2020). Farming smarter with big data: Insights from the case of Australia's national dairy herd milk recording scheme. *Agricultural Systems*, *181*, 102811.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge University Press.

Nuthall, P. L., & Old, K. (2014). *Report on a succession and governance survey of a random stratified sample of NZ farmers*. Lincoln University. Agricultural Economics Research Unit.

Nuthall, P. L., & Old, K. M. (2018). Intuition, the farmers’ primary decision process. A review and analysis. *Journal of Rural Studies*, *58*, 28-38. https://doi.org/https://doi.org/10.1016/j.jrurstud.2017.12.012

Nysveen, H., & Pedersen, P. E. (2016). Consumer adoption of RFID-enabled services. Applying an extended UTAUT model. *Information Systems Frontiers*, *18*(2), 293-314.

O’Gorman, K., & MacIntosh, R. (2015). Mapping research methods. *Research methods for business and management: A guide to writing your dissertation*, 50-74.

O’Shea, R., O’Donoghue, C., Ryan, M., & Breen, J. (2018). *Understanding farmers: From adoption to attitudes*.

Onwude, D. I., Chen, G., Eke-Emezie, N., Kabutey, A., Khaled, A. Y., & Sturm, B. (2020). Recent advances in reducing food losses in the supply chain of fresh agricultural produce. *Processes*, *8*(11), 1431.

Onwuegbuzie, A. J., & Leech, N. L. (2007a). A call for qualitative power analyses. *Quality & Quantity*, *41*(1), 105-121.

Onwuegbuzie, A. J., & Leech, N. L. (2007b). Sampling designs in qualitative research: Making the sampling process more public. *Qualitative Report*, *12*(2), 238-254.

Oreszczyn, S., Lane, A., & Carr, S. (2010). The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations. *Journal of Rural Studies*, *26*(4), 404-417.

Óskarsdóttir, K., & Oddsson, G. V. (2019). Towards a decision support framework for technologies used in cold supply chain traceability. *Journal of Food Engineering*, *240*, 153-159. https://doi.org/https://doi.org/10.1016/j.jfoodeng.2018.07.013

Ostrom, E. (2009). *Understanding institutional diversity*. Princeton University Press.

Pan, C., & Liu, M. (2021). Optimization of intelligent logistics supply chain management system based on wireless sensor network and RFID technology. *Journal of Sensors*, *2021*.

Panetto, H., Lezoche, M., Hormazabal, J. E. H., Diaz, M. d. M. E. A., & Kacprzyk, J. (2020). Special issue on Agri-Food 4.0 and digitalization in agriculture supply chains-New directions, challenges and applications. *Computers in Industry*, *116*, 103188.

Pathak, H. S., Brown, P., & Best, T. (2019). A systematic literature review of the factors affecting the precision agriculture adoption process. *Precision Agriculture*, *20*(6), 1292-1316. https://doi.org/10.1007/s11119-019-09653-x

Patton, M. Q. (1990). *Qualitative evaluation and research methods*. SAGE Publications, inc.

Paul, J., Modi, A., & Patel, J. (2016). Predicting green product consumption using theory of planned behavior and reasoned action. *Journal of Retailing and Consumer Services*, *29*, 123-134.

Paustian, M., & Theuvsen, L. (2017). Adoption of precision agriculture technologies by German crop farmers. *Precision agriculture*, *18*(5), 701-716.

Pawson, R., & Tilley, N. (1997). *Realistic evaluation* (1 ed.). sage.

Peano, C., Tecco, N., Dansero, E., Girgenti, V., & Sottile, F. (2015). Evaluating the sustainability in complex agri-food systems: The SAEMETH framework. *Sustainability*, *7*(6), 6721-6741.

Perrett, E., Heath, R., Keogh, M., Laurie, A., & Darragh, L. (2017). *Accelerating precision agriculture to decision agriculture–analysis of the economic benefit and strategies for delivery of digital agriculture in Australia*, Australian Farm Institute,Sydney

Phillips, P. W., Relf-Eckstein, J.-A., Jobe, G., & Wixted, B. (2019). Configuring the new digital landscape in western Canadian agriculture. *NJAS-Wageningen Journal of Life Sciences*, *90*, 100295.

Pillai, R., & Sivathanu, B. (2020). Adoption of internet of things (IoT) in the agriculture industry deploying the BRT framework. *Benchmarking: An International Journal*.

Pino, G., Toma, P., Rizzo, C., Miglietta, P. P., Peluso, A. M., & Guido, G. (2017). Determinants of farmers' intention to adopt water saving measures: Evidence from Italy. *Sustainability*, *9*(1), 77.

Pivoto, D., Barham, B., Dabdab, P., Zhang, D., & Talamin, E. (2019). Factors influencing the adoption of smart farming by Brazilian grain farmers. *International Food and Agribusiness Management Review*, *22*(1030-2019-2946), 571-588.

Popa, A., Hnatiuc, M., Paun, M., Geman, O., Hemanth, D. J., Dorcea, D., Son, L. H., & Ghita, S. (2019). An intelligent IoT-based food quality monitoring approach using low-cost sensors. *Symmetry*, *11*(3), 374.

Prause, L., Hackfort, S., & Lindgren, M. (2021). Digitalization and the third food regime. *Agriculture and Human Values*, *38*(3), 641-655. https://doi.org/10.1007/s10460-020-10161-2

Prokopy, L. S., Towery, D., & Babin, N. (2014). Adoption of agricultural conservation practices: Insights from research and practice. *Purdue Extension: West Lafayette, IN, USA*.

Punch, K. F. (2013). *Introduction to social research: Quantitative and qualitative approaches*. sage.

Purcell, W., & Neubauer, T. (2023). Digital Twins in Agriculture: A State-of-the-art review. *Smart Agricultural Technology*, *3*, 100094.

Qian, C., Liu, Y., Barnett-Neefs, C., Salgia, S., Serbetci, O., Adalja, A., Acharya, J., Zhao, Q., Ivanek, R., & Wiedmann, M. (2022). A perspective on data sharing in digital food safety systems. *Critical Reviews in Food Science and Nutrition*, 1-17. https://doi.org/10.1080/10408398.2022.2103086

Qu, S. Q., & Dumay, J. (2011). The qualitative research interview. *Qualitative Research in Accounting & Management*, *8*(3),238-264. https://doi.org/10.1108/11766091111162070.

Raffo, A., Senatore, M., Moneta, E., Paoletti, F., Peparaio, M., & Saggia Civitelli, E. (2021). Impact of different temperature abuse scenarios on sensory quality and off-odour formation in ready-to-eat salad leaves. *International Journal of Food Science & Technology*, *56*(5), 2345-2356.

Ramanathan, R., Duan, Y., Ajmal, T., Pelc, K., Gillespie, J., Ahmadzadeh, S., Condell, J., Hermens, I., & Ramanathan, U. (2023). Motivations and challenges for food companies in using IoT sensors for reducing food waste: some insights and a road map for the future. *Sustainability*, *15*(2), 1665.

Ramirez, A. (2013). The influence of social networks on agricultural technology adoption. *Procedia-Social and Behavioral Sciences*, *79*, 101-116.

Rana, R. L., Tricase, C., & De Cesare, L. (2021). Blockchain technology for a sustainable agri-food supply chain. *British Food Journal*. DOI:10.1108/BFJ-09-2020-0832

Rattanakaran, J., Saengrayap, R., Aunsri, N., Padee, S., Prahsarn, C., Kitazawa, H., Bishop, C. F., & Chaiwong, S. (2021). Performance of Thermal Insulation Covering Materials to Reduce Postharvest Losses in Okra. *Horticulturae*, *7*(10), 392.

Raynard, M. (2017). Understanding Academic E-books through the diffusion of innovations theory as a basis for developing effective marketing and educational strategies. *The Journal of Academic Librarianship*, *43*(1), 82-86.

Reddy, K. H. K., Luhach, A. K., Pradhan, B., Dash, J. K., & Roy, D. S. (2020). A genetic algorithm for energy efficient fog layer resource management in context-aware smart cities. *Sustainable Cities and Society*, *63*, 102428.

Rehman, T., McKemey, K., Yates, C. M., Cooke, R. J., Garforth, C. J., Tranter, R. B., Park, J. R., & Dorward, P. T. (2007). Identifying and understanding factors influencing the uptake of new technologies on dairy farms in SW England using the theory of reasoned action. *Agricultural Systems*, *94*(2), 281-293. https://doi.org/https://doi.org/10.1016/j.agsy.2006.09.006

Reichardt, M., & Jürgens, C. (2009). Adoption and future perspective of precision farming in Germany: results of several surveys among different agricultural target groups. *Precision Agriculture*, *10*(1), 73-94.

Reimer, A., Thompson, A., Prokopy, L. S., Arbuckle, J. G., Genskow, K., Jackson-Smith, D., Lynne, G., McCann, L., Morton, L. W., & Nowak, P. (2014). People, place, behavior, and context: A research agenda for expanding our understanding of what motivates farmers' conservation behaviors. *Journal of Soil and Water Conservation*, *69*(2), 57A-61A.

Reina, L., Fleming, H., & Humphries, E. (1995). Microbiological control of cucumber hydrocooling water with chlorine dioxide. *Journal of Food Protection*, *58*(5), 541-546.

Rejeb, A., Rejeb, K., Abdollahi, A., Zailani, S., Iranmanesh, M., & Ghobakhloo, M. (2022). Digitalization in food supply chains: A bibliometric review and key-route main path analysis. *Sustainability*, *14*(1), 83. https://www.mdpi.com/2071-1050/14/1/83

Rendon-Benavides, R., Perez-Franco, R., Elphick-Darling, R., Plà-Aragonés, L. M., Gonzalez Aleu, F., Verduzco-Garza, T., & Rodriguez-Parral, A. V. (2023). In-transit interventions using real-time data in Australian berry supply chains. *The TQM Journal*, *35*(3), 759-777.

Richards, C., Bjørkhaug, H., Lawrence, G., & Hickman, E. (2013). Retailer-driven agricultural restructuring – Australia, the UK and Norway in comparison. *Agriculture and Human Values*, *30*, 235-245.

Richards, C., Hurst, B., Messner, R., & O'Connor, G. (2021). The paradoxes of food waste reduction in the horticultural supply chain. *Industrial Marketing Management*, *93*, 482-491. https://doi.org/https://doi.org/10.1016/j.indmarman.2020.12.002

Rindt, J., & Mouzas, S. (2015). Exercising power in asymmetric relationships: the use of private rules. *Industrial Marketing Management*, *48*, 202-213.

Roberts, C. M. (2006). Radio frequency identification (RFID). *Computers & security*, *25*(1), 18-26.

Robson, C. (2011). *Real world research: a resource for users of social research methods in applied settings*. John Wiley & Sons. Chichester.

Rogers, E. M. (2003). *The diffusion of innovation 5th edition*. New York: Free Press.

Rogers, E. M. (2010). *Diffusion of innovations*. Simon and Schuster.

Romsdal, A., Thomassen, M. K., Dreyer, H. C., & Strandhagen, J. O. (2011). *Fresh food supply chains; characteristics and supply chain requirements.* 18th international annual EurOMA conference,

Ronaghi, M. H., & Forouharfar, A. (2020). A contextualized study of the usage of the Internet of things (IoTs) in smart farming in a typical Middle Eastern country within the context of Unified Theory of Acceptance and Use of Technology model (UTAUT). *Technology in Society*, *63*, 101415. https://doi.org/https://doi.org/10.1016/j.techsoc.2020.101415

Rose, D. C., Keating, C., & Morris, C. (2018). *Understanding how to influence farmers' decision-making behaviour: A social science literature review.* Agriculture and Horticulture Development Board.

Rosenberg, J. P., & Yates, P. M. (2007). Schematic representation of case study research designs. *Journal of Advanced Nursing*, *60*(4), 447-452.

Rougoor, C. W., Trip, G., Huirnc, R. B., & Renkema, J. A. (1998). How to define and study farmers' management capacity: theory and use in agricultural economics. *Agricultural Economics*, *18*(3), 261-272.

Roulston, K., & Choi, M. (2018). Qualitative interviews. *The SAGE handbook of qualitative data collection*, 233-249.

Ruiz-Garcia, L., & Lunadei, L. (2011). The role of RFID in agriculture: Applications, limitations and challenges. *Computers and Electronics in Agriculture*, *79*(1), 42-50.

Ruiz-Garcia, L., Steinberger, G., & Rothmund, M. (2010). A model and prototype implementation for tracking and tracing agricultural batch products along the food chain. *Food Control*, *21*(2), 112-121.

Sabherwal, R., Jeyaraj, A., & Chowa, C. (2006). Information system success: individual and organizational determinants. *Management Science*, *52*(12), 1849-1864.

Saffari, A., Iyer, V., Kapetanovic, Z., & Ranganathan, V. (2022). Smart Pallets: Toward Self-Powered Pallet-Level Environmental Sensors for Food Supply Chains. Proceedings of the 20th ACM Conference on Embedded Networked Sensor Systems

Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *Turkish Online Journal of Educational Technology-TOJET*, *5*(2), 14-23.

Sakoda, G., Takayasu, H., & Takayasu, M. (2019). Data science solutions for retail strategy to reduce waste keeping high profit. *Sustainability*, *11*(13), 3589.

Sanad Alsbu, R. A., Yarlagadda, P., & Karim, A. (2023). Investigation of the factors that contribute to fresh fruit and vegetable losses in the Australian fresh food supply chain. *Processes*, *11*(4), 1154.

Sandelowski, M. (1995). Sample size in qualitative research. *Research in Nursing & Health*, *18*(2), 179-183.

Santos, S. F. d., Cardoso, R. d. C. V., Borges, Í. M. P., Almeida, A. C. e., Andrade, E. S., Ferreira, I. O., & Ramos, L. d. C. (2020). Post-harvest losses of fruits and vegetables in supply centers in Salvador, Brazil: Analysis of determinants, volumes and reduction strategies. *Waste Management*, *101*, 161-170. https://doi.org/https://doi.org/10.1016/j.wasman.2019.10.007

Searle, J. R. (2015). *Seeing things as they are: A theory of perception*. Oxford University Press.

Seuring, S. (2005). Case study research in supply chains—An outline and three examples. *Research Methodologies in Supply Chain Management: In Collaboration with Magnus Westhaus*, 235-250.

Shang, L., Heckelei, T., Gerullis, M. K., Börner, J., & Rasch, S. (2021). Adoption and diffusion of digital farming technologies - integrating farm-level evidence and system interaction. *Agricultural Systems*, *190*, 103074. https://doi.org/https://doi.org/10.1016/j.agsy.2021.103074

Shashi, Centobelli, P., Cerchione, R., & Ertz, M. (2021). Food cold chain management: what we know and what we deserve. *Supply Chain Management: An International Journal*, *26*(1), 102-135. https://doi.org/10.1108/SCM-12-2019-0452

She, X., Cong, L., Nie, B., Leng, G., Peng, H., Chen, Y., Zhang, X., Wen, T., Yang, H., & Luo, Y. (2018). Energy-efficient and-economic technologies for air conditioning with vapor compression refrigeration: A comprehensive review. *Applied Energy*, *232*, 157-186.

Shi, X., An, X., Zhao, Q., Liu, H., Xia, L., Sun, X., & Guo, Y. (2019). State-of-the-art internet of things in protected agriculture. *Sensors*, *19*(8), 1833.

Shoji, K., Schudel, S., Shrivastava, C., Onwude, D., & Defraeye, T. (2022). Optimizing the postharvest supply chain of imported fresh produce with physics-based digital twins. *Journal of Food Engineering*, *329*, 111077. https://doi.org/https://doi.org/10.1016/j.jfoodeng.2022.111077

Silverman, D. (2013). *Doing qualitative research: A practical handbook*. SAGE publications limited.

Singh, J., Singh, S., Desautels, K., Saha, K., & Olsen, E. (2010). An evaluation of the ability of RFID tags to withstand distribution of fresh produce in the RPC pooling system. *Packaging Technology and Science*, *23*(4), 217-226.

Singh, R. K., Gunasekaran, A., & Kumar, P. (2018). Third party logistics (3PL) selection for cold chain management: a fuzzy AHP and fuzzy TOPSIS approach. *Annals of Operations Research*, *267*(1), 531-553. https://doi.org/10.1007/s10479-017-2591-3

Sinha, B. B., & Dhanalakshmi, R. (2022). Recent advancements and challenges of Internet of Things in smart agriculture: A survey. *Future Generation Computer Systems*, *126*, 169-184.

Skaalsveen, K., Ingram, J., & Urquhart, J. (2020). The role of farmers' social networks in the implementation of no-till farming practices. *Agricultural Systems*, *181*, 102824. https://doi.org/https://doi.org/10.1016/j.agsy.2020.102824

Slife, B. D., Williams, R. N., & Williams, R. N. (1995). *What's behind the research?: Discovering hidden assumptions in the behavioral sciences*. Sage.

Smith, M. J. (2018). Getting value from artificial intelligence in agriculture. *Animal Production Science*, *60*(1), 46-54.

Sotiriadou, P., Brouwers, J., & Le, T.-A. (2014). Choosing a qualitative data analysis tool: a comparison of NVivo and Leximancer. *Annals of Leisure Research*, *17*(2), 218-234. https://doi.org/10.1080/11745398.2014.902292

Sottomayor, M., Tranter, R., & Costa, L. (2011). Likelihood of succession and farmers’ attitudes towards their future behaviour: evidence from a survey in Germany, the United Kingdom and Portugal. *The International Journal of Sociology of Agriculture and Food*, *18*(2), 121-133.

Spencer, S., & Kneebone, M. (2012). *FOODmap: An analysis of the Australian food supply chain*. Department of Agriculture, Fisheries and Forestry.

Stahl, B.-C. (2003). How we invent what we measure: A constructionist critique of the empiricist bias in IS research. *AMCIS 2003 Proceedings*, 376.

Stoneman, P., & Kwon, M. J. (1996). Technology adoption and firm profitability. *The Economic Journal*, *106*(437), 952-962.

Streletskaya, N. A., Bell, S. D., Kecinski, M., Li, T., Banerjee, S., Palm-Forster, L. H., & Pannell, D. (2020). Agricultural adoption and behavioral economics: Bridging the gap. *Applied Economic Perspectives and Policy*, *42*(1), 54-66.

Šūmane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., des los Rios, I., Rivera, M., Chebach, T., & Ashkenazy, A. (2018). Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. *Journal of Rural Studies*, *59*, 232-241.

Surucu-Balci, E., & Tuna, O. (2021). Investigating logistics-related food loss drivers: A study on fresh fruit and vegetable supply chain. *Journal of Cleaner Production*, *318*, 128561.

Tagliavini, G., Defraeye, T., & Carmeliet, J. (2019). Multiphysics modeling of convective cooling of non-spherical, multi-material fruit to unveil its quality evolution throughout the cold chain. *Food and Bioproducts Processing*, *117*, 310-320.

Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. *Procedia Manufacturing*, *22*, 960-967. https://doi.org/https://doi.org/10.1016/j.promfg.2018.03.137

Tamirat, T. W., Pedersen, S. M., & Lind, K. M. (2018a). Farm and operator characteristics affecting adoption of precision agriculture in Denmark and Germany. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science*, *68*(4), 349-357. https://doi.org/10.1080/09064710.2017.1402949

Tamirat, T. W., Pedersen, S. M., & Lind, K. M. (2018b). Farm and operator characteristics affecting adoption of precision agriculture in Denmark and Germany. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, *68*(4), 349-357.

Tan, W. C., & Sidhu, M. S. (2022). Review of RFID and IoT integration in supply chain management. *Operations Research Perspectives*, *9*, 100229.

Taylor, D. H., & Fearne, A. (2006). Towards a framework for improvement in the management of demand in agri-food supply chains. *Supply Chain Management: An International Journal*, *11*(5), 379-384.

Teese, J., Currey, P., & Somogyi, S. (2022). Influences on strategic information sharing in Australian fresh produce chains: The view from experts. *Journal of International Food & Agribusiness Marketing*, *34*(3), 235-245.

Tey, Y. S., & Brindal, M. (2012). Factors influencing the adoption of precision agricultural technologies: a review for policy implications. *Precision Agriculture*, *13*(6), 713-730.

Thomas, C. (2018). *2030 Industry roadmap. Australian agriculture's plan for a $100 billion Industry.* National Farmers' Federation. https://nff.org.au/wp-content/uploads/2020/02/NFF_Roadmap_2030_FINAL.pdf

Thompson, J. F. (2016). Precooling and Storage Facility In C. Y. W. Kenneth C. Gross, and Mikal Saltveit (Ed.), *The commercial storage of fruits, vegetables, and florist and nursery stocks* (Vol. Agriculture Research Service). United States Department of Agriculture

Ton, G. (2008). Challenges for smallholder market access: a review of literature on institutional arrangements in collective marketing. *Steward Postharvest Review*, *5*(1).

Tonkin, B. (2016). *IBISWorld industry report G4111: Supermarkets and grocery stores in Australia*. www.ibisworld.com.au

Tornatzky, L., & Fleischer, M. (1990). *The process of technology innovation.* Lexington Books. Lexington.

Torres-Sánchez, R., Martínez-Zafra, M. T., Castillejo, N., Guillamón-Frutos, A., & Artés-Hernández, F. (2020). Real-time monitoring system for shelf life estimation of fruit and vegetables. *Sensors*, *20*(7), 1860.

Tort, Ö. Ö., Vayvay, Ö., & Çobanoğlu, E. (2022). A Systematic Review of Sustainable Fresh Fruit and Vegetable Supply Chains. *Sustainability*, *14*(3), 1573. https://www.mdpi.com/2071-1050/14/3/1573

Trevisan, C., & Formentini, M. (2023). Digital Technologies for Food Loss and Waste Prevention and Reduction in Agri-Food Supply Chains: A Systematic Literature Review and Research Agenda. *IEEE Transactions on Engineering Management*.

Triandis, H. C. (1979). Values, attitudes, and interpersonal behavior. *Nebraska symposium on motivation, 27,* pp. 195-259.

Tripoli, M., & Schmidhuber, J. (2020). *Emerging opportunities for the application of blockchain in the agri-food industry.* Rome and Geneva, FAO and ICTSD.

Trivelli, L., Apicella, A., Chiarello, F., Rana, R., Fantoni, G., & Tarabella, A. (2019). From precision agriculture to Industry 4.0: Unveiling technological connections in the agrifood sector. *British Food Journal, 12*1(8), 1730-1743.

Tsang, Y. P., Choy, K. L., Wu, C.-H., Ho, G. T., Lam, C. H., & Koo, P. (2018). An Internet of Things (IoT)-based risk monitoring system for managing cold supply chain risks. *Industrial Management & Data Systems, 118*(7), 1432-1462.

Tsironi, T., Dermesonlouoglou, E., Giannoglou, M., Gogou, E., Katsaros, G., & Taoukis, P. (2017). Shelf-life prediction models for ready-to-eat fresh cut salads: Testing in real cold chain. *International Journal of Food Microbiology*, 240, 131-140. https://doi.org/https://doi.org/10.1016/j.ijfoodmicro.2016.09.032

Tsolakis, N. K., Keramydas, C. A., Toka, A. K., Aidonis, D. A., & Iakovou, E. T. (2014). Agrifood supply chain management: A comprehensive hierarchical decision-making framework and a critical taxonomy. *Biosystems Engineering, 120*, 47-64.

Tuck, M., & Riley, D. (2017). The theory of reasoned action: A decision theory of crime. *The reasoning criminal* (pp. 156-169). Routledge.

Tuckett, A. G. (2005). Applying thematic analysis theory to practice: A researcher’s experience. *Contemporary Nurse*, 19(1-2), 75-87.

Ugochukwu, A. I., & Phillips, P. W. (2018). Technology adoption by agricultural producers: A review of the literature. From agriscience to agribusiness: theories, policies and practices in technology transfer and commercialization, 361-377.

UN. (2015). Sustainable Development Goals.

UNDESA. (2019). World Population Prospects 2019. United Nations, Department of Economic and Social Affairs.

UNEP. (2022). *Refrigeration, Air conditioning and Heat Pumps Technical Options Committee:* . https://ozone.unep.org/system/files/documents/RTOC-assessment%20-report-2022.pdf

UNICEF. (2020). The state of food security and nutrition in the world 2020.

Van den Berg, A., & Struwig, M. (2017). Guidelines for Researchers Using an Adapted Consensual Qualitative Research Approach in Management Research. *Electronic Journal of Business Research Methods, 15*(2).

Van Der Vorst, J. G., & Beulens, A. J. (2002). Identifying sources of uncertainty to generate supply chain redesign strategies. International *Journal of Physical Distribution & Logistics Management, 32 (6).*

Vecchio, Y., Agnusdei, G. P., Miglietta, P. P., & Capitanio, F. (2020). Adoption of Precision Farming Tools: The Case of Italian Farmers*. International Journal of Environmental Research and Public Health, 17*(3), 869. https://www.mdpi.com/1660-4601/17/3/869

Vecchio, Y., De Rosa, M., Adinolfi, F., Bartoli, L., & Masi, M. (2020). Adoption of precision farming tools: A context-related analysis. *Land use policy, 94,* 104481. https://doi.org/https://doi.org/10.1016/j.landusepol.2020.104481

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management science, 46*(2), 186-204.

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS quarterly*, 425-478.

Verdouw, C., Sundmaeker, H., Tekinerdogan, B., Conzon, D., & Montanaro, T. (2019). Architecture framework of IoT-based food and farm systems: A multiple case study. *Computers and Electronics in Agriculture, 165,* 104939. https://doi.org/https://doi.org/10.1016/j.compag.2019.104939

Vern, P., Miftah, N., & Panghal, A. (2022). Digital technology: Implementation challenges and strategies in agri-food supply chain. Agri-Food 4.0. Emerald Publishing Limited.

Verghese, K., & Lockrey, S. (2019). National food waste baseline-Final assessment report. Australian Government’s Department of Environment and Energy (funded through Australia Government's National Environmental Science Program).

Villalobos, J. R., Soto-Silva, W. E., González-Araya, M. C., & González–Ramirez, R. G. (2019). Research directions in technology development to support real-time decisions of fresh produce logistics: A review and research agenda. *Computers and Electronics in Agriculture, 167,* 105092. https://doi.org/https://doi.org/10.1016/j.compag.2019.105092

Vorst, V. d. (2006). *Quantifying the agri-food supply chain*. Amsterdam (NLD): Logistics and.

Vrat, P., Gupta, R., Bhatnagar, A., Pathak, D. K., & Fulzele, V. (2018). Literature review analytics (LRA) on sustainable cold-chain for perishable food products: research trends and future directions. *Opsearch, 55*(3-4), 601-627.

Walsh, K. (2022). Postharvest regulation and quality standards on fresh produce. *Postharvest Handling* (pp. 51-98). Elsevier.

Wang, M., & Zhao, L. (2021). Cold chain investment and pricing decisions in a fresh food supply chain. *International Transactions in Operational Research, 28*(2), 1074-1097. https://doi.org/https://doi.org/10.1111/itor.12564

Weersink, A., & Fulton, M. (2020). Limits to profit maximization as a guide to behavior change. *Applied Economic Perspectives and Policy, 42*(1), 67-79.

Wen, Z., Hu, S., De Clercq, D., Beck, M. B., Zhang, H., Zhang, H., Fei, F., & Liu, J. (2018). Design, implementation, and evaluation of an Internet of Things (IoT) network system for restaurant food waste management. *Waste Management, 73*, 26-38.

Weston, M., Geng, S., & Chandrawati, R. (2021). Food Sensors: Challenges and Opportunities. *Advanced Materials Technologies, 6*(5), 2001242. https://doi.org/https://doi.org/10.1002/admt.202001242

Wilkinson, R. (2011). The many meanings of adoption. In ‘Changing land management: adoption of new practices by rural landholders’. (Eds D Pannell, F Vanclay) pp. 39–49. CSIRO Publishing: Melbourne.

Wiseman, L., Sanderson, J., Zhang, A., & Jakku, E. (2019). Farmers and their data: An examination of farmers’ reluctance to share their data through the lens of the laws impacting smart farming. *NJAS: Wageningen Journal of Life Sciences, 90-91*(1), 1-10. https://doi.org/10.1016/j.njas.2019.04.007

Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M.-J. (2017). Big data in smart farming–a review. *Agricultural Systems, 153*, 69-80.

Wood, B. A., Blair, H. T., Gray, D. I., Kemp, P. D., Kenyon, P. R., Morris, S. T., & Sewell, A. M. (2014). Agricultural science in the wild: A social network analysis of farmer knowledge exchange. *PloS one, 9*(8), e105203.

Wu, W., Beretta, C., Cronje, P., Hellweg, S., & Defraeye, T. (2019). Environmental trade-offs in fresh-fruit cold chains by combining virtual cold chains with life cycle assessment. *Applied Energy, 254*, 113586.

Xing, X.-H., Hu, Z.-H., Wang, S.-W., & Luo, W.-P. (2020). An evolutionary game model to study manufacturers and logistics companies’ behavior strategies for information transparency in cold chains. *Mathematical Problems in Engineering, 19,* 1-18. DOI:10.1155/2020/7989386

Xue, L., Liu, G., Parfitt, J., Liu, X., Van Herpen, E., Stenmarck, Å., O'Connor, C., Östergren, K., & Cheng, S. (2017). Missing food, missing data? A critical review of global food losses and food waste data. *Environmental science & technology, 51*(12), 6618-6633.

Yadav, S., Garg, D., & Luthra, S. (2020). Analysing challenges for internet of things adoption in agriculture supply chain management. *International Journal of Industrial and Systems Engineering, 36*(1), 73-97.

Yahya, N. (2018). Agricultural 4.0: Its implementation toward future sustainability. *Green Urea* (pp. 125-145). Springer.

Yan, B., Jin, Z., Liu, L., & Liu, S. (2018). Factors influencing the adoption of the internet of things in supply chains. *Journal of Evolutionary Economics, 28*(3), 523-545. https://doi.org/10.1007/s00191-017-0527-3

Yang, Q., Zhu, Y., Liu, L., & Wang, F. (2022). Land tenure stability and adoption intensity of sustainable agricultural practices in banana production in China. *Journal of Cleaner Production, 338*, 130553. https://doi.org/https://doi.org/10.1016/j.jclepro.2022.130553

Yavas, V., & Ozkan-Ozen, Y. D. (2020). Logistics centers in the new industrial era: A proposed framework for logistics center 4.0. Transportation Research Part E: *Logistics and Transportation Review, 135*, 101864.

Yigezu, Y. A., Mugera, A., El-Shater, T., Aw-Hassan, A., Piggin, C., Haddad, A., Khalil, Y., & Loss, S. (2018). Enhancing adoption of agricultural technologies requiring high initial investment among smallholders. *Technological Forecasting and Social Change, 134,* 199-206. https://doi.org/https://doi.org/10.1016/j.techfore.2018.06.006

Yin, R. K. (2009). *Case study research: Design and methods*. Sage Publications. Thousand oaks.

Yin, R. K. (2018). *Case study research and applications*. Sage.

Zamasiya, B., Nyikahadzoi, K., & Mukamuri, B. B. (2017). Factors influencing smallholder farmers' behavioural intention towards adaptation to climate change in transitional climatic zones: A case study of Hwedza District in Zimbabwe. *Journal of Environmental Management, 198*, 233-239.

Zhang, A., Baker, I., Jakku, E., & Llewellyn, R. (2017). *Accelerating precision agriculture to decision agriculture: The needs and drivers for the present and future of digital agriculture in Australia*. A cross- industries producer survey for the Rural R&D for Profit ‘Precision to Decision’ (P2D) project. CSIRO and Cotton Research and Development Corporation, Australia

Zhao, G., Liu, S., Lopez, C., Lu, H., Elgueta, S., Chen, H., & Boshkoska, B. M. (2019). Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions. *Computers in Industry, 109*, 83-99.

Zhao, S., Han, X., Liu, B., Wang, S., Guan, W., Wu, Z., & Theodorakis, P. E. (2022). Shelf-life prediction model of fresh-cut potato at different storage temperatures. *Journal of Food Engineering, 317*, 110867.

Zhong, R. Y., Xu, C., Chen, C., & Huang, G. Q. (2017). Big data analytics for physical internet-based intelligent manufacturing shop floors. *International Journal of Production Research, 55*(9), 2610-2621.

Zhou, B., Luo, Y., Huang, L., Fonseca, J. M., Yan, H., & Huang, J. (2022). Determining effects of temperature abuse timing on shelf life of RTE baby spinach through microbial growth models and its association with sensory quality. *Food Control, 133*, 108639.

Zhou, H. (2021). Application of RFID information technology in fresh food cold chain logistics management. *Journal of Physics: Conference Series*

Zuo, A., Wheeler, S. A., & Sun, H. (2021). Flying over the farm: understanding drone adoption by Australian irrigators. *Precision Agriculture, 22*(6), 1973-1991. https://doi.org/10.1007/s11119-021-09821-y

APPENDIX A: CASE STUDY PROTOCOL

Overview of the study

Temperature management along the chain enhances quality and shelf life of fresh produce. Therefore, traceability of temperature during different stages of the chain is an integral component of supply chain operations. Numerous technologies are currently available to trace temperature monitoring in the chain; however, the adoption of these temperature monitoring gadgets along the chain is still an issue. Therefore, the purpose of this research is to investigate the process of adoption of temperature monitoring technologies across the vegetable supply chain.

Research participants

- Vegetable supply chain members – Growers, packers, transporters and staff of the distribution centre engaged in quality monitoring of vegetables
- Technology providers of temperature monitoring technologies
- Industry experts who are working on improving efficiencies of existing supply chains

Data collection procedure

Semi-structured interviews by following the interview guide of the study. Interviewing growers of the chain, then packers, transporters and staff of the distribution centre. Snowball sampling procedure will be followed. References of technology providers to be interviewed will be collected from members of vegetable supply chains. Industry experts will be shortlisted on the basis of their experiences with fresh produce supply chains and specifically developing capacity of growers on the adoption of agriculture technologies.

Expected outcome of the study for participants

A key outcome of the research is the design and development of a “tool box” which may, for example, include procedures or processes to identify key blocks to the adoption of temperature monitoring technologies in the vegetable value chain and to signpost approaches to overcome these and improve the use of these technologies.

APPENDIX B: ENGAGEMENT PLAN

Improving adoption of temperature monitoring technologies in the vegetable value chains: A case study of Southeast Queensland

The researcher will work in collaboration with the management of XXX Produce to work through the whole chain participants such as growers, logistic companies, and technology providers, service providers such as technical expertise as well as general and distribution centers. The researcher will work according to the management protocols of the compnay and all the information will be kept confidential and will be used only for this research purpose.

Selection of innovation and supply chain

The selection of value chain and temperature monitoring technology will be carried out by mutual understanding of the XXX Produce management and the researcher.

Activities in the research

This research is based on a case study approach in which the researcher will interview participants along a specific vegetable supply chain to understand dynamics in the cold chain management and adoption of cold chain management technologies.

Significance to firm

Cold chain management is critical to the maintenance of the quality of perishable horticultural commodities and minimizes deterioration after harvest. However, the adoption of cold management and temperature monitoring technologies is still an issue. Therefore, the main objective of this research project is to understand the behaviors and factors which cause less adoption and how businesses can develop procedures to increase its adoption. This project will study firm’s vegetable chain from harvesting till distribution center to understand cold chain management technology adoption issues and then recommend actions and procedures to improve the processes along the chain.

Overview of the activities and timeline

This is a tentative plan outlining the collaboration of RECoE-USQ with XXX throughout the project duration, however, it can be re-arranged upon the availability, access and at the disposal of the management.

Chain actors	Activity and # of activities	Nov-20	Dec-20
Grower, packing and quality control in XXX	Interview with growers (2 growers)	🟦	
	Interview with farm manager (1 farm manager)	🟦	
	Interview quality control staff (1)	🟦	
	Interview packing shed manager(1)	🟦	
Transport providers	Logistic company providers quality control staff (2)	🟦	🟦
Technology providers	Cold chain management technology providers (2)	🟦	🟦
End of chain	Distribution centre quality staff (2)	🟦	🟦

APPENDIX C: PARTICIPANT INFORMATION

University of Southern Queensland

Participant Information for USQ Research Project
Interview

Project Details

Title of Project:	An investigation into Australian Vegetable Value Chains: Enhancing adoption of temperature monitoring technologies
Human Research Ethics Approval Number:	H19REA097

Research Team Contact Details

Principal Investigator Details	**Other Investigator Details**
Mr. Moudassir Habib	Assoc Prof Ben Lyons
[redacted]	[redacted]

Description

The main purpose of this project is to explore and understand the behavioral aspects of adoption of temperature monitoring technologies along the vegetable value chain in Queensland, Australia.

While many technical and decision-making innovations in temperature monitoring are available in vegetable value chains, the adoption of these practices is still generally low. This project will investigate the current status of adoption of these practices in the vegetable value chain in Southern Queensland and will explore the factors for enhancing the adoption of it in the vegetable value chains.

Participation

Your participation will involve contributing your thoughts and ideas in an interview which will take no more than an hour and a half of your time. The interview will take place at a time and venue that is convenient for you.

Your participation is entirely voluntary and you are free to withdraw from the project at any stage. If you decide to take part and later change your mind, you are free to withdraw. If you wish to withdraw at any time, please contact the Research Team (contact details at the top of this form).You have the opportunity to know about the outcome of the research. If you wish to receive a summary report will be sent to your email. The report will also be available on the website: http://eprints.usq.edu.au/view/type/thesis.html.

Expected Benefits of Your Participation in this Project

The benefit from the research will be greater understanding of the barriers and incentives to the adoption of innovation. The outcome of the project will also include developing a "Tool Box" including procedures and practices to enhance adoption of innovation in vegetable value chains. The outcome may also provide inputs to the government entities in formulating policy decisions for effective uptake of new innovative practices.

Risks Involved in Your Participation in this Project

There are no anticipated risks beyond normal day-to-day living associated with your participation in this project.

Privacy and Confidentiality

All comments and responses will be treated absolutely confidential

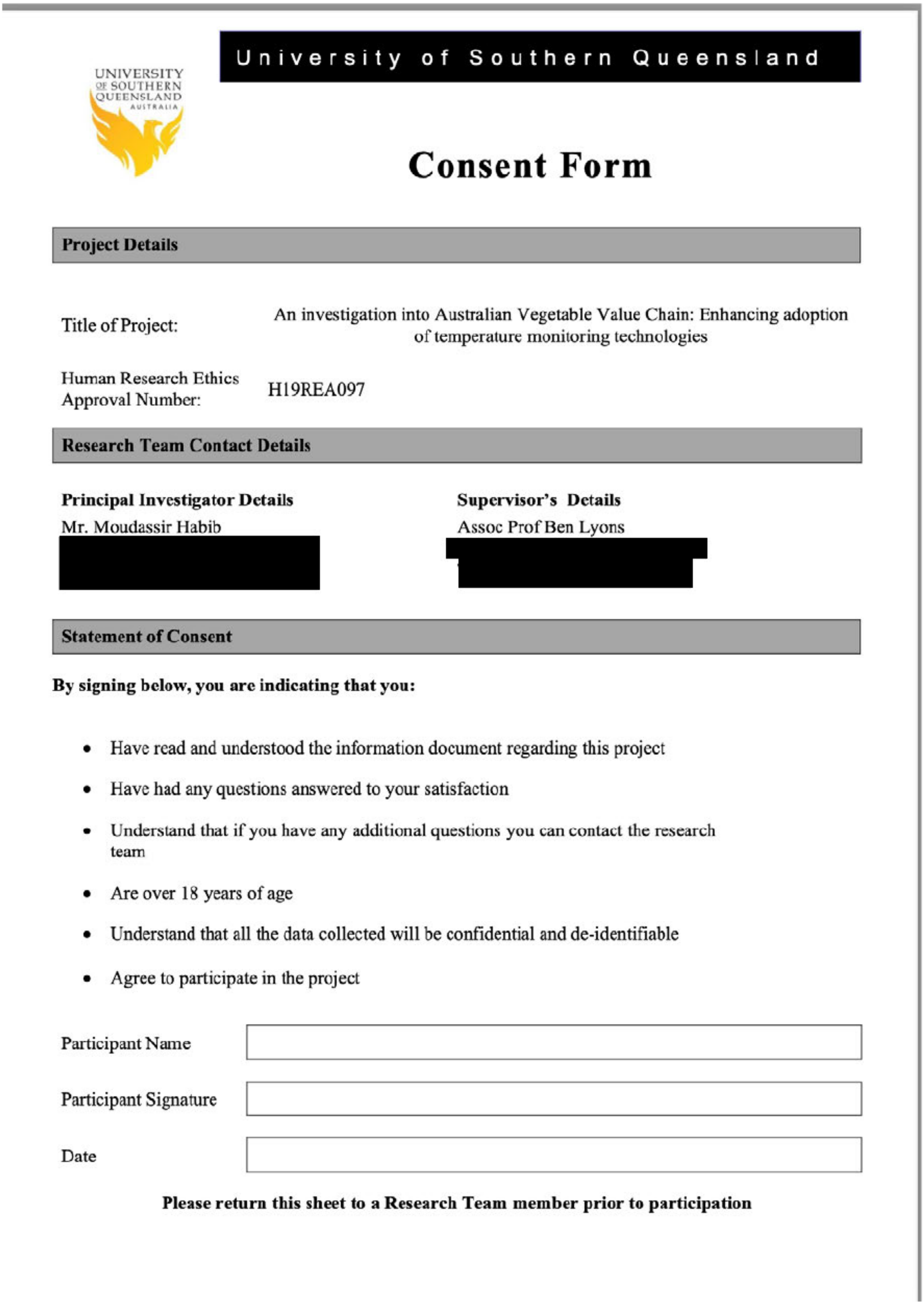
- ☐ Only the investigator will have access to the interview responses
- ☐ Please advise the investigator if you do not want the interview to be recorded. In this case, the interview may take longer as the researcher will need more time to take notes during the interview.
- ☐ Any data collected as a part of this project will be stored securely as per the University of Southern Queensland's Research Data Management policy.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project you may contact the University of Southern Queensland Manager of Research Integrity and Ethics on +61 7 4631 2214 or email researchintegrity@usq.edu.au. The Manager of Research Integrity and Ethics is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

Thank you for taking the time to help with this research project. Please keep this sheet for your information.

APPENDIX D: CONSENT FORM



University of Southern Queensland

Consent Form

Project Details

Title of Project: An investigation into Australian Vegetable Value Chain: Enhancing adoption of temperature monitoring technologies

Human Research Ethics Approval Number: H19REA097

Research Team Contact Details

Principal Investigator Details	Supervisor's Details
Mr. Moudassir Habib	Assoc Prof Ben Lyons
[redacted]	[redacted]

Statement of Consent

By signing below, you are indicating that you:

- Have read and understood the information document regarding this project
- Have had any questions answered to your satisfaction
- Understand that if you have any additional questions you can contact the research team
- Are over 18 years of age
- Understand that all the data collected will be confidential and de-identifiable
- Agree to participate in the project

Participant Name	
Participant Signature	
Date	

Please return this sheet to a Research Team member prior to participation

APPENDIX E: INVITATION TO PARTICIPATE

Hi XXX

This is Habib and I am a Ph.D. student at the University of Southern Queensland Toowoomba

I am currently conducting interviews of industry professionals, researchers and experts in the agriculture technologies field and I am wondering if I can interview you either on phone, zoom, or face to face depending on your availability. I am based in Toowoomba but can travel to UQ Gatton or St Lucia campus. Please find attached the Participant's information sheet and consent form as per USQ ethics approval. The interview can take 30 minutes to an hour.

The main focus of this research is to understand the social, psychological and organizational side of the adoption of temperature monitoring technologies in vegetable supply chains in South East Queensland.

The focus of this interview is to understand your perspectives on

What is the status of technology adoption in agriculture specifically in vegetable supply chains?

In your opinion what are the general and specific barriers to the adoption of technologies in agriculture and how can we improve the adoption?

Until now 2 vegetable chains have been studied including growers, packers, transporters, and distribution centres and this phase is aiming on understanding a bigger picture from industry professionals, researchers and experts about the challenges regarding technology adoption in agriculture. Please let me know about your availability.

Regards
Habib
University of Southern Queensland, Toowoomba
Contact No.[redacted]

APPENDIX F: GROWER INTERVIEW GUIDE

Interview Guide

Grower interview guide

The purpose of this guide is to keep the researcher in line with the theoretical framework of the study.

Estimated time:

<u>45 to 50 minutes for the entire duration of the interview session</u>

The interview session consists of five parts (A, B, C, D, E)

A. **Introduction to the interview (5 min)**
    - Greetings
    - Introducing the research/project
      In this part, the researcher introduces the research topic and explains the importance of the research in terms of reducing food wastage, increasing customer satisfaction, creating more value for the business, including how this research can enhance a positive image of their business in customer's mind (viz., goodwill). The researcher informs the grower that this process will be extended to the other stakeholders along the vegetable chain.
    - Describing the purpose of the interview
    - Expressing that the discussion will be completely confidential and will be used only for the research purpose
    - Asking for permission to record the interview
    - Obtaining consent (signing consent form) from the interviewee

B. **Background info: (5 min)**

Farmer information	Farm information
☐ Please tell me about yourself **Prompts:** • age • experience in growing vegetables • education level (Masters, Bachelor, Diploma, Certificate, etc.) • time commitment to the farm operations (part time or full time)	☐ Please tell me about your farming business **Prompts:** • Farm structure; e.g., family farm, how much is used for cropping? • Farm size • Main crops • Operational level of the business (growing, growing & harvesting, growing, harvesting& packing) Number of employees on the farm (Permanent and part-time/casual)

C. **Main/essential interview questions (30 min)**
   (The researcher will involve the participant in a casual discussion to understand the current practices the organization/grower is undertaking regarding temperature monitoring in their current process)

1. In your opinion, do you think that temperature monitoring along the supply chain of your produce is important?
   (This question investigates basic understanding of the participant about the importance of temperature monitoring in the supply chain of their product and realizes its importance in terms of the prompts below).
   The intention is to bring the researcher and participant on one page about the importance of temperature monitoring in the chain
   Prompts:
   - Less wastage
   - Retaining freshness of the produce
   - More value for the customers and happy customers at the end
   - More value for the business
   - Food quality and safety
   - More distant markets

2. Which temperature monitoring methods/procedures are you currently using in your farm operations like in the field before harvest, at the harvest and in the packing shed
   Prompts:
   - Recording temperature at the field, pack house
   - Reason behind it for keeping a record of it
   - Temperature monitoring devices at different stages
   - Communication process with the other chain member like transport company, distribution centre staff or any other
   - Motivation to use the current system
   - Challenges in the current method/procedure (Any complaint about the temperature monitoring issue from the customer)

3. Do you have any idea/information on what technologies can be used to monitor the temperature of the produce in your farm/business operations?
   Prompts:
   - Probing about the technologies to understand more about the level of information the participant has

4. Have you started / or do you think of initiating any technology in the improvement of temperature monitoring on your farm operations? (If yes, then subsequent questions. If no, then probing the reasons to understand the factors of not initiating it like cost, lack of skilled labor, attitude towards not using it)
5. Subsequent questions: What are that technology? How it has been initiated and why the selected ones?
   Prompts:
   - Information source (technology provider, field day, other growers, extension officer, internet etc)
   - Factors to evaluate the information
   - Procedural adjustments to make it more operationalized

6. What are the most important things that you will consider and want to initiate/adopt with regard to the temperature monitoring technology in your farm operations

   Prompts:
   - Less effort
   - Adding value to the business
   - Compatible with your business operations
   - Easy to understand
   - Level of risk
   - Quality monitoring
7. In your opinion, what are the main barriers that you can think of in adopting a temperature monitoring technology in your farm operations?

   Prompts:
   - Staff behaviour
   - Lack of organization commitment
   - Communication process along the chain members
   - Getting information sent back to me on farm

D. Other questions

If time allows and the participant is showing interest, I will also probe the following questions for more understanding

8. In your view, what role the other chain members can play to successfully adopt the temperature monitoring technologies?
9. What future role do you see technologies in temperature monitoring will play in your farming operations and industry in the next 5/10 years?
10. In your opinion, what actions can be taken to improve the acceptability of temperature monitoring technologies in your business and also across the chain?

E. Closing of interview (10 min)

- State what will happen next in the research; i.e. transcribing and analysing the interview data
- Ask from the participant to identify other colleague who could be potential participant in this research
- Thanks participant

APPENDIX G: LOGISTIC PROVIDER INTERVIEW GUIDE

Interview Guide

Logistic company interview guide

The purpose of this guide is to keep the researcher in line with the theoretical framework of the study.

Estimated time:

<u>45-50 minutes for the entire duration of the interview session</u>

The interview session consists of four parts (A, B, C, D, E)

A. **Introduction to the interview (5 min)**
    - Greetings
    - Brief introduction of the research
      In this part, the researcher introduces the research topic and explains the importance of the research in terms of food wastage, customer satisfaction, creating more value for the business and how this research can enhance positive image of their business in customer's mind (Goodwill).
    - Purpose of the interview
    - Expressing that the discussion will be completely confidential and will be only use for the research purpose
    - Ask for recording for the interview
    - Getting consent (signing consent form) from the interviewee

B. **Background info: (5 min)**

Participant information	Company information
• Please tell me about yourself **Prompts:** • age • experience in growing vegetables • education level (Masters, Bachelor, Diploma, Certificate etc) • time commitment to the farm operations (part time or Full time)	• Please tell me about your company **Prompts:** • What services the company provide? • Number of truck/units • Business structure i.e. Family business • Number of employees (Permanent, part time and casual)

C. **Main/essential interview questions (30 min)**
   (The researcher will involve the participant in a casual discussion to understand the current practices the organization/grower is undertaking regarding temperature monitoring in their current process)

    1. In your opinion, do you think that temperature monitoring along the supply chain of fresh produce like vegetable is important? (This question will be asked to investigate basic understanding of participant about the importance of temperature monitoring in the supply chain and realize the importance of it to bring the researcher and participant on one page)

Prompts:

- Less wastage
- Retaining freshness of the produce
- More value for the customers and happy customers at the end
- More value for the business
- Food Safety

2. What are the issues as a business you are facing in selling the temperature monitoring devices to the users
    - Farmers
    - Transporters
    - Other chain members
3. What are your marketing strategies in selling your products to the agriculture/fresh produce chain members?
    - Is it different from another business portfolio?
    - What other strategies are you implementing
4. Do you understand as a sales manager the needs of the farmers?
5. In your opinion, what are the main barriers that you can think of in adopting a temperature monitoring technology for the chain members?
   Prompts:
    - Lack of organization commitment
    - Communication process along the chain members

D. Other questions

If time allows and the participant showing interest; I will also probe the following questions for more understanding

6. Have you done any cost/benefit analysis?
7. In your view, what role the other chain members can play to successfully adopt the temperature monitoring technologies?
8. What future role do you see technologies in temperature monitoring will play in agriculture industry in the next 5/10 years?
9. In your opinion, what actions can be taken to improve the acceptability of temperature monitoring technologies across the chain?

E. Closing of interview (10 min)

- State what will happen next in the research i.e. Transcribing and analysing the interview data
- Will ask from the participant to identify other colleague who could be potential participant in this research
- Thanks participant

Prompts:

- Less effort
- Adding value to the business
- Compatible with your business operations
- Easy to understand
- Level of risk
- Quality monitoring

6. In your opinion, what are the main barriers that you can think of in adopting a temperature monitoring technology in your business operations?
   Prompts:
   - Staff behaviour
   - Lack of organization commitment
   - Communication process along the chain members

D. Other questions

If time allows and the participant showing interest; I will also probe the following questions for more understanding

7. In your view, what role the other chain members can play to successfully adopt the temperature monitoring technologies?
8. What future role do you see technologies in temperature monitoring will play in your business operations and industry in the next 5/10 years?
9. In your opinion, what actions can be taken to improve the acceptability of temperature monitoring technologies in your business and also across the chain?

E. Closing of interview (5 min)

- State what will happen next in the research i.e. Transcribing and analysing the interview data
- Will ask from the participant to identify other colleague who could be potential participant in this research
- Thanks participant

APPENDIX H: TECHNOLOGY PROVIDER INTERVIEW GUIDE

Interview guide

Technology provider interview guide

Estimated time:

<u>45- 50 minutes for the entire duration of the interview session</u>

The interview session consists of four parts (A, B, C, D, E)

A. **Introduction to the interview (5 min)**
    - Greetings
    - Brief introduction of the research
      In this part, the researcher introduces the research topic and explains the importance of the research in terms of food wastage, customer satisfaction, creating more value for the business and how this research can enhance positive image of their business in customer's mind (Goodwill).
    - Purpose of the interview
    - Expressing that the discussion will be completely confidential and will be only use for the research purpose
    - Ask for recording for the interview
    - Getting consent (signing consent form) from the interviewee

B. **Background info: (5 min)**

Participant information	Company information
Please tell me about yourself **Prompts:** age experience in selling temperature monitoring devices education level (Masters, Bachelor, Diploma, Certificate etc) (BBA) time commitment to the business operations (part time or **<u>Full time</u>**)	Please tell me about your company **Prompts:** What is the target market? Percentage of the value of the business in the agriculture sector? What services the company provide? Number of data loggers Business structure Number of employees (Permanent, part time and casual)

C. **Main/essential interview questions (30 min)**
   (The researcher will involve the participant in a casual discussion to understand the current practices the organization/grower is undertaking regarding temperature monitoring in their current process)

    1. In your opinion, do you think that temperature monitoring along the supply chain of fresh produce like vegetable is important? (This question will be asked to investigate basic understanding of participant about the importance of temperature monitoring in the supply chain and realize the importance of it to bring the researcher and participant on one page)

Prompts:

- Less wastage
- Retaining freshness of the produce
- More value for the customers and happy customers at the end
- More value for the business
- Food Safety

2. What are the issues as a business you are facing in selling the temperature monitoring devices to the users
   - Farmers
   - Transporters
   - Other chain members
3. What are your marketing strategies in selling your products to the agriculture/fresh produce chain members?
   - Is it different from another business portfolio?
   - What other strategies are you implementing
4. Do you understand as a sales manager the needs of the farmers?
5. In your opinion, what are the main barriers that you can think of in adopting a temperature monitoring technology for the chain members?
   Prompts:
   - Lack of organization commitment
   - Communication process along the chain members

D. Other questions

If time allows and the participant showing interest; I will also probe the following questions for more understanding

6. Have you done any cost/benefit analysis?
7. In your view, what role the other chain members can play to successfully adopt the temperature monitoring technologies?
8. What future role do you see technologies in temperature monitoring will play in agriculture industry in the next 5/10 years?
9. In your opinion, what actions can be taken to improve the acceptability of temperature monitoring technologies across the chain?

E. Closing of interview (10 min)

- State what will happen next in the research i.e. Transcribing and analysing the interview data
- Will ask from the participant to identify other colleague who could be potential participant in this research
- Thanks participant

APPENDIX I: ETHICS APPROVAL

Dear Habib

I am pleased to confirm your Human Research Ethics (HRE) application has now been reviewed by the University's Expedited Review process. As your research proposal has been deemed to meet the requirements of the National Statement on Ethical Conduct in Human Research (2007),
ethical approval is granted as follows:

USQ HREC ID: H19REA097
Project title: An investigation into Australian Vegetable Value Chains: Enhancing adoption of innovative practices
Approval date: 18/04/2019
Expiry date: 18/04/2022
USQ HREC status: Approved

The standard conditions of this approval are:

a)   responsibly conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal;.

(b)   advise the University (email:ResearchIntegrity@usq.edu.au) immediately of any complaint pertaining to the conduct of the research or any other issues in relation to the project which may warrant review of the ethical approval of the project;

(c)   promptly report any adverse events or unexpected outcomes to the University (email: ResearchIntegrity@usq.edu.au) and take prompt action to deal with any unexpected risks;

(d)   make submission for any amendments to the project and obtain approval prior to implementing such changes;

(e)   provide a progress 'milestone report' when requested and at least for every year of approval.

(f)   provide a final 'milestone report' when the project is complete;

(g)   promptly advise the University if the project has been discontinued, using a final 'milestone report'.

The additional conditionals of approval for this project are:

(a) Nil.

Please note that failure to comply with the conditions of this approval or requirements of the Australian Code for the Responsible Conduct of Research, 2018, and the National Statement on Ethical Conduct in Human Research, 2007 may result in withdrawal of approval for the project.
Congratulations on your ethical approval! Wishing you all the best for success!

If you have any questions or concerns, please don’t hesitate to make contact with an Ethics Officer.

Kind regards

Human Research Ethics

University of Southern Queensland
Toowoomba – Queensland – 4350 – Australia
Phone: (07) 4631 2690
Email: human.ethics@usq.edu.au

Appendix J: Market Specifications of Broccoli

GENERAL APPEARANCE CRITERIA	
COLOUR	***With blue-green to purple-green florets; olive green leaves; light green stalks; white to cream cut flesh at base. Nil with brownish or reddish florets***
VISUAL APPEARANCE	***Fresh, compact heads; 3-6 narrow outer leaves retained; stalks with even, clean fresh cuts; no leaves growing through or above the head; no foreign matter.***
SENSORY	***With firm, crisp heads; pleasant flavour; no persistent 'off' odours or tastes***
SHAPE	***With compact, domed heads; tightly grouped branchlets, not loose or spreading; floret size relatively even over the head.***
SIZE	***Preferred Head diameter is 100 - 140mm (small/medium). All other sizes only by request; 80 - 100mm (small), 140 - 180mm (medium), 180 - 200mm (large).*** ***Stalk length: trimmed, per requirements, eg. With distance from cut base to dome top being approximately equal to dome width; or cut not >20mm below the join (lower side) of bottom lateral to main stalk.***
MATURITY	***Full firm stalks, no evidence of bud opening (overmature).***
MAJOR DEFECTS	
INSECTS DISEASES	***With evidence of live insects, eg. insect larvae, slugs, snails.***
	With fungal or bacterial rots in the head, stem or attached leaves.
PHYSICAL / PEST DAMAGE	***With broken or crushed branchlets, or with cuts or splits in the stems which break the skin.***
PHYSIOLOGICAL DISORDER	***With limp, soft leaves or florets (dehydrated).***
	With yellowish, purplish or brown toned florets, or with yellowed or brown jacket leaves.
	With yellowing florets (age, ethylene damage).
TEMPERATURE INJURY	***With bleached or discoloured appearance (sunburn)***
	With soft, discoloured water-soaked florets, leaf or stalk tissues (freezing injury).
MINOR DEFECTS	
PHYSICAL / PEST DAMAGE	***With minor (<2mm deep) abrasion, scuffing, pest chewing, hail or rub damage/blemish to florets or stalks, affecting >1sq cm.***
	With minor breaks to florets around the head perimeter exposing >6 sq cm of damaged florets (white-green appearance in side-on-view).
PHYSIOLOGICAL DISORDERS	***With hollow stalk, ie. Discoloured cracks/hollow areas affecting >1 sq cm of the cut base of the stalk.***
CONSIGNMENT CRITERIA	
TOLERANCE PER CONSIGNMENT	***Total minor defects (within allowance limit) to be < 2 defects per item Total minor defects (outside allowance limit) must not exceed 10% of consignment. Total major defects must not exceed 2 % of consignment. Combined Total not to exceed 10%.***
PACKAGING & LABELLING	***Packaging manufactured from new food grade materials or sanitised returnable crates. All labelling must meet the current legislative requirements. Labelling to identify grower's name/brand (plus growers name/code if via a packhouse), address, contents, class, size and minimum net weight. Produce to identify 'Packed On' date (eg. Pkd DD/MM/YY) and Country of Origin (eg. Produce of Australia) on outer container. Produce delivered in styrofoam***
SHELF LIFE	***Produce must provide not less than 14 days clear shelf life from date of receival.***
RECEIVAL CONDITIONS	***Compliance with Quarantine Treatments (if required) for Interstate Consignment. Stacked onto a stabilised pallet as pre-ordered. Refrigerated van with air bag suspension, unless otherwise approved. Pulp Temperature 0 - 5 °C.***
CHEMICAL & CONTAMINANT RESIDUES	***All chemicals used pre/postharvest must be registered and approved for use in accordance with the requirements of the APVMA regulatory system. Residues, Contaminants and Heavy Metals to comply with the FSANZ Food Standards Code MRL's and ML's.***
FOOD SAFETY REQUIREMENTS	***Produce is to be grown and packed under a HACCP based food safety program that is subject to an annual third-party audit. A copy of current certification to be forwarded to receiver. Produce that meets the above specifications but is not grown under a HACCP based food safety program must not be labelled Class 1.***
Specifications reviewable: eg. to account for specific regional effects or adverse seasonal impacts on quality or early or late seasonal variances as agreed and communicated formally in writing.	