12-7-2022

Adoption of Digital Technologies and Decision Support Systems in Horticulture Supply Chains

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Full research paper

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Abstract

This paper presents key factors affecting the adoption of digital technologies and decision support technologies in horticulture supply chains. Using the case study method, in-depth interviews were conducted with decision-makers of three distinctive horticulture supply chains, complemented by site observations. The Technology Acceptance Model (TAM) is the theoretical foundation guiding this qualitative study. The findings indicate the constructs perceived ease of use, usefulness, attitudes, behavioural intentions, trust, social influence, and costs affecting adoption. The study contributes to the literature by presenting an integrated TAM model that can be used to understand adoption in horticulture supply chains. It strengthens TAM by providing evidence of its applicability to real-life industry settings and further creates a link to the unique adoption problems in industry. The practical contribution to ICT developers, industry peak bodies, and governments is that the inter-firms' interactions need to be considered when designing decision-support technologies and implementing improvement programs.

Keywords horticulture, cold chain, TAM, temperature, technology adoption

1 Introduction

Agriculture is currently facing many challenges, including diminishing land and water resources, soil degradation, contamination, and adverse climate change patterns (OECD/FAO 2021). Up to one-third of food produced for human consumption is lost or wasted due to poor post-harvest practices, with most of the losses occurring in horticulture industries (AWE 2019; Lamberty and Kreyenschmidt 2022). The emergence of the digital era provides agriculture with the tools to tackle productivity and post-harvest loss challenges. Technological advances in post-harvest practices, particularly in cold chains, can improve food security significantly by making more food available (Bhardwaj et al. 2021; Kader 2013; OECD/FAO 2021). Efficient cold chains or temperature-controlled supply chains (Hertog et al. 2014) are essential to maintaining horticulture product quality and safety and minimising losses between production and consumption (Bhardwaj et al. 2021; Kader 2013). Due to its perishability, fresh produce requires an uninterrupted cold chain from farm to consumer, to ensure that product shelf-life is extended, and food spoilage is avoided (Kader 2013; Lamberty and Kreyenschmidt 2022). Cold chain management is particularly important when exporting because exported fresh produce is usually of high value and sent to premium markets, which are dependent on maintaining a set temperature to guarantee quality (Brodribb et al. 2020). This involves the constant monitoring of the temperature while produce is stored or in-transit. Failure to control temperature may induce early ripening, colour and texture variations, and microbiological contamination (Kader 2013).

Technologies and decision support systems (DSS) for monitoring, maintaining, and managing cold chains in horticulture are being developed (DAF 2020; Villalobos et al. 2019; Visconti et al. 2020). These assist in detecting quality problems and inform when temperature ranges are not within optimum levels (Lamberty and Kreyenschmidt 2022). The data gathered as the fresh product moves along the cold chain, informs the DSS and allows businesses to take action (Villalobos et al. 2019). With the emergence of the internet of things (IoT), digital sensors such as wireless sensor networks and RFID that monitor real-time temperature, humidity, and other parameters, are being developed (Göransson et al. 2018; Lamberty and Kreyenschmidt 2022). These smart tools, also known as dataloggers, can measure conditions in real-time and communicate product conditions while the product is still in-transit (Lamberty and Kreyenschmidt 2022). The dataloggers capture large amounts of data that enables users to assess conditions over the life of the fresh produce, from farm to retailer (Visconti et al. 2020). The DSS that accompany the dataloggers provide the value of the technology to cold chain as the collated data can support individual businesses in to identify cold chain vulnerabilities (Aamer et al. 2021; Villalobos et al. 2019). The integration of DSS into the regular operations of the supply chains can assist in creating efficiencies and innovation in the growing, processing, distribution, and marketing of fresh produce (Griffith et al. 2013; Visconti et al. 2020). With these DSS, businesses can predict the remaining shelf life of horticulture produce and support inventory management (Pina et al. 2021). Supermarkets, for example, are starting to integrate these technologies into their purchasing systems (Boyd 2019; Jackson 2021). The dataloggers and their accompanying DSS can improve efficiencies, reduce waste, and improve profitability by delivering a better product to consumers. Horticulture supply chains that can manage the continuity of their cold chain can greatly improve the quality of their produce and compete more successfully in the marketplace (Visconti et al. 2020).

Although digital technologies are available, many in Australian agriculture have been hesitant to embrace them (Marshall et al. 2022; Nolet and Mao 2018). The National Farmers Federation indicates that Australia could increase yield production by AUD20.3 billion with the widespread adoption of digital agriculture (NFF 2021). Limited research has been undertaken to study the adoption of digital cold chain technologies and DSS in horticulture. Hence, this paper provides a deep insight into the factors influencing the adoption of cold chain monitoring and supporting DSS in horticulture industries. This paper used the Technology Acceptance Model (TAM) to guide the research because scarce literature exists using Information Systems (IS) behavioural models to study adoption in Australian agriculture. The research might assist Australian governments, industry associations, and technology developers to design and implement technologies that can be adopted by horticulture industries. Failing to design appropriate technologies might lessen widespread adoption and perpetuate food waste and losses in horticulture industries. The findings might be relevant to other perishable products such as dairy, meat, seafood and floriculture products.

2 Technology adoption in horticulture supply chains

Horticulture is the third largest agricultural industry in Australia with a gross value of production (GVP) of AUD 15.2 billion in 2020–21 (Hort Innovation 2022) and is the largest agricultural sector employer (ABARES 2022). Much of the production is sold in the domestic market, with exports in June 2021 valued at AUD 2.65 billion (Hort Innovation 2022). Most produce is sold fresh, straight from the farm, with little production transformation or processing taking place. Because Australia's horticulture industry covers a wide range of geographical areas, produce needs to be transported over long distances to markets and distribution centres (DCs). Additionally, horticulture produce varies greatly in terms of perishability, with some produce needing special treatment, such as ripening before retailing. For exports, produce must go through strict quarantine treatments as a condition for international market access. In addition, cold chain logistics vary according to the specific temperature conditions and market access requirements of each crop (Kader 2013).

Although cold chains are relatively efficient in Australian horticulture, disruptions in the chain still occur (Ambiel et al. 2019; AWE 2019; Brodribb et al. 2020). CSIRO research found that between 18% and 22% of all Australian vegetable and fruit production is lost even before reaching consumers, with mangoes reporting the greatest loss at 46% of production (Ambiel et al. 2019). Most of the losses are attributed to inadequate cold chain systems (AWE 2019; Brodribb et al. 2020). While the technologies and associated DSS are available to improve cold chain practices, the extent of such losses indicates that the adoption of such technologies in horticulture is limited. The high level of waste and loss across all horticulture industries indicates that technology uptake is low. Industry sources indicate that, in general, Australian horticulture has been slow to adopt ICT technologies (Growcom 2014). If technologies were adopted, GVP in horticulture could increase by 40% mostly due to improvements in cold chains (Heath 2018). This lack of technology adoption is not recent: One study of ICT adoption in Australian horticulture found that although basic systems have a relatively high level of adoption, uptake of more advanced tools was almost non-existent (Molla and Peszynzki 2008). Although research indicates that the use of digital technologies in horticulture can improve supply chain efficiencies (Ahearn et al. 2016), almost no uptake of digital technologies for monitoring, recording, forecasting, and supply chain collaboration has been reported (Molla and Peszynzki 2008). Research indicates that although there is great potential for horticulture to better utilise digital tools throughout the supply chain, most in the industry are not fully embracing the technologies (Growcom 2014). Industry research indicates that a major barrier for the implementation of innovations is the lack of trust and commitment along the supply chain (Marshall et al. 2022). Research of Australian food supply chains concluded that the horticulture sector, along with the seafood sector, is the lowest ranked in relation to data sharing and communication, particularly when referring to price and quality signals (RIRDC 2016).

3 Theoretical framework

This study was grounded in TAM, the most widely used model to predict adoption of technology (Davis 1989). Compared to the other models, TAM has advantages in parsimony, is ICT-specific, and has a sound theoretical framework and empirical support (Hu et al. 1999; King and He 2006). TAM assumes that an individual's intention to use a particular technology is determined by the person's attitude towards using such technology and proposes that a person's beliefs about perceived usefulness (PU) and perceived ease of use (PEOU) are the drivers of technology usage (Davis 1989) (Figure 1). TAM seeks to advance the understanding of user ICT acceptance processes and provide the theoretical framework for a practical methodology from the user's perspective (Davis et al. 1989). To our knowledge, this is the first time TAM is used to study technology adoption in Australian horticulture.

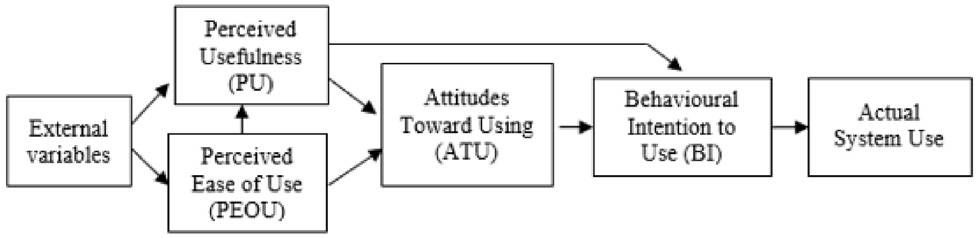

Figure 1: Technology Acceptance Model (Davis 1989)

4 Methodology

Because limited research has been conducted into the factors affecting the adoption of technologies and DSS in horticulture supply chains, a qualitative approach was selected. This approach is the most appropriate because the driving factors for adoption remain widely unknown. Specifically, a multiple case study design was used. This approach enabled analytic generalisation and model verification (Eisenhardt and Graebner 2007; Yin 2018). The population consisted of horticulture businesses that were active members of well-defined supply chains actively interacting with other sectors of the chain. Purposive sampling was used in this study because the cases were not randomly chosen but were selected to represent specific conditions aimed at gaining insight and understanding (Braun and Clarke 2013). Each of the three cases represents a unique horticulture supply chain with unique elements. Data were collected using in-depth interviews with open-ended questions. A field test was conducted to assess the validity of the in-depth interview questions and the data collection protocol. The instrument was pilot tested with officers from the Department of Agriculture and Fisheries (DAF) who provided feedback. In each business, key personnel was interviewed who were involved in the quality assurance programs, trade relationships, or ICT deployment. They also had to be engaged with members of the business supply chain. A qualitative approach using in-depth interviews was used because it allowed for a deeper understanding of the adoption experience and provide in-depth analysis beyond what can be found with purely survey research (Vogelsang et al. 2013).

A total of seven interviews with three different supply chains were conducted. The interviews were recorded with consent and transcribed verbatim. For data analysis, two stages of analysis were conducted, initially a within-case analysis and then a cross-case analysis was conducted. For the within-case analysis, each case was first treated as an individual comprehensive case. All data were carefully examined and organised into a comprehensive unique holistic description (Mills 2010). For the cross-case evaluation, each case was compared to the other cases to uncover cross-case patterns. Theoretical Thematic Analysis was used because this research was guided by TAM constructs (Braun and Clarke 2013). This approach assisted in assessing TAM's applicability to study the adoption of temperature monitoring technologies and DSS.

5 Findings

5.1 Within-case study

5.1.1 Case Study 1

Case 1 is a large wholesaling company trading in fruit and vegetables at the Brisbane Wholesale Markets, employing more than 100 staff, with an extensive supply base of growers. It sources fresh produce from every major growing region across Australia and imports fresh produce of key crops. It has access to more than 90 fruit, vegetable and herb produce lines. The company supplies major supermarkets, other wholesalers, independent retailers, and food service businesses. It has expanded its services to include logistics services such as cold storage, quality control, ripening, pre-packing, and customised third-party logistics. Case 1 is well regarded among its peers as a wholesaling company that is innovative, strategic, and a leader in fresh produce trading in Australia. Case 1 has invested in extensive logistics facilities, including ripening rooms, and quarantine disinfestation treatment rooms, as well as cold chain infrastructure and traceability ICT systems. There are two distinctive and separate units within the business. One unit specialises in logistics and offers packing, ripening and other services to growers, consolidators, and buyers. The other unit is a typical wholesaler trading on the floor of the wholesale market, buying and selling to different clients including the logistics unit of the organisation.

Case 1 has both merchant and agent relationships with its horticulture suppliers. Under the merchant arrangement, the company purchases the produce for resale, while under the agent arrangement, the company is engaged to provide logistics services and sell the produce on the grower's behalf for a fee. Business relationships with suppliers are governed by horticulture produce agreements that stipulate the wholesaler is acting as an agent only, thus ownership of the product resides with the grower. Case 1 does not monitor temperature as fruit moves from the farm to its market facilities. Likewise, it does not monitor temperature after it has been sold and moves from the wholesaler to the next customer. Case 1 relies on its in-house cold chain practices and processes, and trusts that its suppliers have similar cold chain systems in their businesses. As Case 1 does not take ownership of the product and offers only trading services, they feel that it is up to the grower to adopt the technologies. Case 1 feels that there is a limited need for the growers to monitor the chain because the cost of the devices does not justify the additional expense. The company considers that temperature mismanagement is not an extensive problem with its suppliers, as fruit can withstand minor temperature fluctuations given the relatively short distance the produce is in-transit, and the speed of trade.

5.1.2 Case Study 2

Case 2 is a medium-sized family-owned farming enterprise, growing up to 80% of one of the most popular Australian mango varieties. The company owns seven farms in Queensland and Northern Territory. Case 2 has a long-term supply contract with one of Australia's largest retailers and supplies premium independent retailers and is one of the leading mango exporters. The company and its management team have won many awards recognising their leadership and innovation in Australian horticulture. Case 2 prides itself on growing the best quality mangoes and fostering collaborative relationships across the value chain. The company proactively has sought to disengage with the wholesaler markets and avoid selling through the trading floor, instead developing direct strong linkages with retailers. Case 2 has invested in ICT systems to improve the process of information flow along their supply chain, particularly to improve communications and speed up information sharing. Due to this innovation, the company can track every carton and every batch through the supply chain, from the packing shed to the retail shelf. This has led to a marked fall in product rejection at their retailer, meaning less waste for the company and retailer. Case 2 are early technology adopters and have co-partnered with the Federal and State Governments to test new technologies and systems. It has received considerable support from agricultural departments to refine its export protocols. In terms of temperature management, the company has been active in testing and using commercial temperature management technologies and DSS. Currently, Case 2 does not regularly temperature monitor its domestic supply chain, rather it relies on its internal processes to ensure that temperature mismanagement is limited. The company does temperature monitor its export supply chain because there are more risks involved in moving produce from farms in Northern Australia to markets in Asia or the Americas. Traditionally, the company has used USB-enabled dataloggers to monitor the chain, but it has found problems because it has been difficult to retrieve the devices from overseas customers and access its data. The company has co-invested in government-backed projects intended to improve international supply chains by using novel temperature monitoring technologies and DSS. Although the company has found the novel technologies to be an improvement compared to the traditional USB-enabled dataloggers, there are still technological challenges that limit their commercial value.

5.1.3 Case Study 3

Case 3 is a medium-sized family-owned grower and consolidator enterprise marketing four fruit lines. It has the marketing rights to market and distributes fruit from its own farms and from a large base of independent growers located throughout Australia. They have packhouses in Far North Queensland, the Northern Territory, and a central packhouse in Southeast Queensland. The central packhouse handles the ripening and distribution of fruit, with the support of other ripening facilities. Case 3 supplies major supermarkets, independent retailers, and the processing sector, with small quantities exported. To manage quality, the company has strict supply arrangements with their growers that dictate how the fruit is grown, packing details, the quality parameters fruit must meet, how the fruit is graded, and where the fruit is sold. To support its growers, the company has production and grading guides, employs a grower liaison officer, and holds regular meetings and conferences. Case 3 has invested in packhouse operations to improve efficiencies and traceability in multiple sites across various stages. Its management team is perceived among its peers as an innovator and early adopter. Technology developers and sellers test new systems and devices in their facilities before promoting the technologies to the rest of the horticulture industry. Furthermore, Case 3 has co-invested research and development (R&D) funds with the Federal and State Governments to improve production and post-harvest practices. Case 3 does not regularly monitor the temperature along the supply chain and relies on its existing cold chain processes. However, it does monitor a small percentage of shipments that move from farms in the Northern Territory to ripening facilities in southern Australia. Case 3 has participated in research projects into cold chain monitoring of fresh produce supply chains, using RFIDs and Wi-Fi-based dataloggers. The company still prefers to rely on its own in-house cold chain management systems to manage the temperature. Case 3 is concerned about the cost imposition of new devices to its growers' base and how supermarkets are going to use the new information.

5.2 Cross-Case Analysis

The research found these three cases had a good understanding of the relationship between temperature and the quality of fresh produce and the businesses had appropriate cold chain management within their operations to manage fresh produce under their care. However, the level of temperature monitoring along the supply chain varies. All three cases have experienced different levels of adoption of temperature dataloggers and DSS. Table 1 shows the similarities and differences between the three cases.

Factors	**Case 1**	**Case 2**	**Case 3**
Adoption of temperature monitoring technologies and DSS			
Monitoring temperature in their supply chain	No	Yes, exports	Yes, ad-hoc
Uses dataloggers and DSS in supply chain – ad-hoc	No	Yes	Yes
Uses dataloggers and DSS in supply chain – regular	No	No	No
Cold chain management practices			
Understand importance of temperature management	Yes	Yes	Yes
Established cold chain processes in business	Yes	Yes	Yes
Participates in R&D temperature monitoring	No	Yes	Yes
Bears the risks due to temperature mismanagement	No	Yes	Yes
Management structure & ICT know-how			
Supportive management structure	Yes	Yes	Yes
Innovation culture within business	Yes	Yes	Yes
ICT skills and/or ICT personnel	No	Yes	Yes
Uses tools & DSS to track and trace produce	Yes	Yes	Yes
Participates in government or industry R&D projects	Yes	Yes	Yes
Business relationships			
Takes ownership of product	No	Yes	Yes
Long-term arrangements with supply chain partners	No	Yes	Yes
Governed by HPA arrangements	Yes	No	No
Supplies directly to supermarkets	No	Yes	Yes
Exporter of Australian fruit	No	Yes	Yes

Table 1: Cross-Case Analysis

5.3 Towards a TAM framework for technology adoption in horticulture

Adoption of the temperature monitoring technologies and associated DSS is considered using TAM.

5.3.1 Attitude Towards Using Temperature Monitoring Technology and DSS

Participants from all three cases were aware of the importance of maintaining cold chain processes and optimum temperature, to safeguard the quality of the produce. They had well-established processes and had invested in cold chain infrastructure, such as cold rooms and temperature probes. Furthermore, they took care to ensure that their partners maintain an unbroken cold chain, including the use of refrigerated trucks when transporting produce. However, consistent with TAM studies (Davis 1989; Pappa et al. 2018), their attitudes towards cold chain monitoring their own supply chain influence their intention to use temperature dataloggers. In Case 1, temperature monitoring dataloggers were not used because it was deemed unnecessary to monitor the cold chain. Participants have relatively little control or ownership of the product. Furthermore, they believe that the benefit for their growers was only marginal. Case 2 participants had extensive experience using temperature dataloggers, were participating in R&D trials, and were using the logger on an ongoing basis in most of their international shipments. They had a positive attitude towards monitoring their export chains.

Case 3 has participated in R&D trials to test monitoring temperature systems and was interested in the effects of temperature mismanagement during transport. They were occasionally using USB-enabled dataloggers to assess their transport routes.

5.3.2 Perceived Ease of Use

As per TAM research (Davis 1989; King and He 2006), each of the three cases mentioned ease of use as a prerequisite for adoption. The complexity refers to simple aspects such as turning on the device or placing the logger within the transport unit. More complex aspects include the analysis of the data from more than one datalogger and managing and integrating the data captured. The three case studies identified that ICT expertise to fully use the vast data collected is lacking and the existing DSS lack an easy-to-read dashboard to guide them in their decision-making. Another challenge identified by Case 2 and Case 3 is that the current dataloggers do not allow for integration with existing traceability systems. Because automation is not available, the temperature readings are often manually copied from the dataloggers to the traceability software. With the current DSS, a certain level of expertise is needed to interpret the temperature readings, and even to place the dataloggers in the shipments. For appropriate evaluation of the cold chain, more than one data logger needs to be placed in different areas of the shipment. For accurate analysis of the temperature, a good understanding of the product journey is needed to identify where temperature abuses occur. Even with relatively easy-to-use USB-enabled loggers, the three case studies reported difficulties, including staff making mistakes when manually activating the unit, restrictions on monitoring at retailers' DCs due to security policies, and difficulties in accessing the data. The most serious drawback of USB-enabled is how easy is for the loggers to get lost, misplaced, or damaged. The three cases could identify that RIFD-and Wi-Fi-based systems are a significant improvement because businesses are not solely dependent on the supply chain partners to collect the data. For Case 2 and Case 3, the government and consultants managing the trials provided advice on what type of loggers to use, because the businesses did not have the knowledge or the time to evaluate the loggers in the market. The three case studies agreed that for greater adoption the devices need to be made easier to activate and program and to collect and interpret the data.

5.3.3 Perceived Usefulness

All three cases could identify potential benefits of using temperature technologies and DSS, and this belief affected their attitude towards using the technologies in line with TAM studies (Davis 1989; Pappa et al. 2018). Specifically, the following benefits were noted: process improvements, evidence of cold chain practices, maintenance of quality and shelf life, greater traceability, better risk management, and compliance with health and safety protocols. However, given the limited commercial use of the technologies, respondents agreed that conveying these benefits to their supply chain was a challenge. Case Study 1 was of the notion that, for smaller producers supplying for only 6-8 weeks of the year, the benefits of using the technology were unclear. Case 2, with experience using the technology and access to R&D support to test the technologies, believed that the current monitoring systems needed to be improved before widespread acceptance by the industry. Case 3 found it hard to ask their growers to adopt the technology unless economic benefits can be identified.

5.3.4 Supply Chain and Technical Trust

Consistent with research in food supply chains, this research found that trust affects adoption (Aamer et al. 2021; Eden et al. 2011; Lezoche et al. 2020). There was a consensus that lack of trust has been a feature of trading relationships in horticulture. Case study 1 was particularly careful when dealing with other traders in the market because there had been some unpleasant exchanges, such as substituting produce after the sale was completed. Case study 2 and Case study 3 have opted for bypassing the wholesaler market and dealing directly with the retailers to avoid disagreements. All three cases concur that maintaining trusting relationships within their chains is vital for their success and take active steps to ensure the trust is maintained, including establishing legal arrangements with suppliers and customers. Case study 1 uses the Horticulture Produce Agreement (HPA) contract to set up all its trading arrangements with suppliers. Case study 2 seeks to have long-term contracts with buyers. Case study 3 has long-term contracts with its contract growers and with its buyers. In addition, the three cases have established communication channels and regularly interact with suppliers and customers to improve trust in their chain. Case 2 has spent time cultivating relationships with overseas suppliers, including providing training to the importer's QA team. Case 3 has annual business meetings where the previous season's problems and current production forecasts are discussed. As the three case studies have trusting relationships, they feel confident to use the dataloggers if needed. Case 1 uses RFID loggers with their overseas suppliers and was prepared to install the RFID hubs on their premises and maintain them. Case 2 uses USB-enabled dataloggers when using long-haul transporters for process improvement, rather than a punitive angle. Case 3 has enlisted the support of their overseas importers to improve logistics with the use of the RFID loggers, this included convincing importers to install the RFID hubs in their premises. Due to the existing trust in the chains, a positive attitude exists toward the use of the dataloggers. Furthermore, because the partners believe that there are efforts to improve logistics, there is also the belief that the technologies are useful.

Given that RIFDs and Wi-Fi-based dataloggers are relatively new, some level of technology mistrust was reported in the three case studies. Furthermore, as the technologies were untested for Australian conditions, the level of exposure to the technologies by most in the industry has been limited. Case study 1 had not had training with staff, suppliers, or buyers on the need for temperature monitoring. Case 2 and Case 3 had participated in industry and government-run trials where they had exposure to the proper use of the technologies, and how to use collected data for process improvements. For Wi-Fi-based devices, the mistrust was also about the lack of internet connection in remote farms in Northern Australia and rural roads, because the lack of adequate internet connection impacts the quality of the data and reduces the level of analysis that can be conducted. For USB-enabled devices, the lack of trust was due to businesses' previous experiences with the tampering of the units, which meant the data collected could not be trusted, because it may not reflect the cold chain conditions.

5.3.5 Social Influence

Technology adoption by the three case studies reflects the way that technologies are usually introduced in Australian horticulture, where most of the R&D activities are funded by the government or Peak Industry Bodies (PIBs) (NHRN 2019). This model of extension is consistent with DOI, which assumes that technologies are first trialled with innovators, and then the rest industry will follow (Rogers 2003). For example, Case 2 and Case 3 are participating in government- and industry-funded trials, where the datalogger devices are paid for from project funds, and the data analysis is conducted by consultants or government officials. Without the government and industry support, those large-scale trials would not have happened, and awareness, acceptance, and use of the technologies would be scant. Case 1 had no adoption of smart dataloggers in their supply chains, and were not participating in any trials, nor were their suppliers. However, all three cases indicated that the real catalyst driving widespread adoption is the retail customers, in particular large supermarket chains. Due to power asymmetries in the supply chain, the three case studies implied that if the supermarket chains mandate the use of temperature dataloggers, suppliers will have no option but to adopt this practice. Case 2 is preparing for that possibility and is testing RIFD dataloggers in their domestic supply chain. Case 3 also feels that they should be prepared, and this is the main reason for participating in the trials. The findings are consistent with IS research which has found that social influence affects attitudes to adoption, in particular in mandatory settings (Pappa et al. 2018; Venkatesh and Davis 2000).

5.3.6 Perceived Cost

All three case studies indicated that perceived cost was the main deterrent affecting adoption. Costs are even more important as the businesses paying for the technology (e.g., growers or wholesalers), do not feel that they benefit most from the adoption (e.g., retailers). This is in line with research into adoption in food supply chains (Aamer et al. 2021; Pappa et al. 2018), in particular when power asymmetries are prevalent (Lamberty and Kreyenschmidt 2022). The companies in the three case studies believed that the benefits of the technologies do not justify the costs. In addition, uncertainty remains regarding who in the supply chain should pay for the dataloggers. Case study 1 believes that because they are not taking ownership of the product, they should not be responsible for purchasing the dataloggers. Case studies 2 and 3, believe that given that retailers benefit the most from capturing the data, they should share the costs of adopting the dataloggers. The case studies also indicated that the costs of cold chain monitoring are more than just the price of the device. For example, with RFID technologies there is the cost of the tags, the hardware and software, integration into existing traceability systems, but most important are the costs associated with transforming business practices because of the monitoring. In addition, for a detailed analysis of the cold chain, more than one device is required, significantly increasing the costs of supplying produce. Case study 2 indicated that monitoring one chain in one market may cost up to AUD10,000 per season.

6 Discussion

The three case studies had different stages of adoption of dataloggers. Case 1 was not using dataloggers in their supply chain, because they believe that, due to the fast speed of trade in their chain, there was low transactional risk from temperature mismanagement. In addition, as the wholesaler does not take ownership of the product, it also does not take responsibility for the quality of the produce once it leaves its premises. Case 2 was involved in a government-funded research project testing the applicability of dataloggers to horticulture export chains. They were testing RIFDs and Wi-Fi-based dataloggers in their export supply chains. In the past, Case 2 used USB-enabled dataloggers to set up their cold chain processes and tested the use of RIFDs loggers in their domestic supply chains. Case 3 had participated in the trial of a Wi-Fi-based data logger in one of their fruit lines, and had used USB-enabled dataloggers to monitor produce transported in long-haulers from farms in Northern Australia to the ripening centres in capital cities. Case studies 1 and 2 were first introduced to novel temperature tools and data analytics by participating in government-funded projects.

Based on the analysis of the responses a new model is derived and presented in Figure 2. The research indicates that the classical constructs of TAM – attitudes, perceived ease of use, and perceived usefulness – do influence adoption. Additional constructs are added to TAM – supply chain trust, technological trust, social influence and perceived costs. This amended TAM enables us to understand adoption in complex supply chain settings, where there are power asymmetries, and trust and uncertainty in the allocation of costs might impede widespread technology uptake. The additional constructs have been independently used in IS research, but this is first time they have been used together to explain adoption in supply chains. The importance of the social influence construct was identified by Venkatesh and Davis (2000) and included in subsequent TAM extensions and UTAUT. Trust and perceived costs have also been used (Gefen et al 2004, Machogu & Okiko 2012). The amended model presented in Figure 2. provides government, industry, and ICT developers with an adoption framework that might increase adoption of post-harvest technologies and DSS, and, in turn, might assist reducing food loss and waste in horticulture. To the authors' knowledge, this is the first time TAM has been used to study adoption in Australian horticulture.

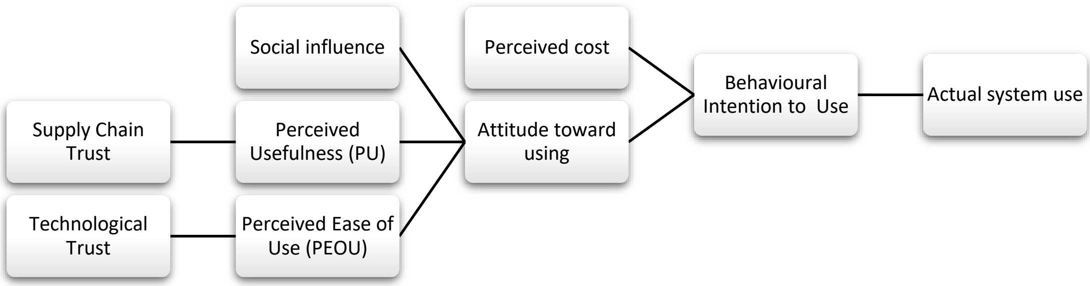

Figure 2: Amended Technology Acceptance Model

7 Conclusion

This research indicates that TAM is useful to understand the business practices of three mango supply chains and their experience with the adoption of temperature monitoring technologies and DSS. TAM as suggested by Davis (1989) partly explains the use of dataloggers and associated DSS in Australian horticulture supply chains. The research indicates that the classical constructs of TAM – attitudes, perceived ease of use, and perceived usefulness – do influence adoption. It is proposed that to examine adoption in horticulture, trust, social influence, and perceived costs should be included in TAM to increase its predictive power given the unique context of this environment. Our findings are consistent with other studies on supply chain adoption that highlight the need for supply trust, the importance of social influences, and the need to share costs to adoption equitable among the supply chain (Aamer et al. 2021; Eden et al. 2011; Lezoche et al. 2020; Pappa et al. 2018). This is the first time TAM has been used to study adoption of technologies in Australia. This is significant because TAM seeks to advance the understanding of user ICT acceptance processes from the user's perspective, in this case from horticulture supply chains, which has been missing in Australian agricultural adoption research. Importantly, TAM gives ICT developers, PIBs, and governments an opportunity to evaluate the technologies before their full implementation. This research verifies the applicability of the TAM framework to explain adoption studies and extends the model by adding a supply chain dimension. This makes the model more suitable for cold chain studies as the technology used to manage and monitor horticulture cold chain primarily needs the collaboration of all in the supply chain. The findings of this qualitative research are valid as the amended TAM model was verified against three horticulture distinct supply chains. The findings are significant, and the TAM framework can act as the basis for further studies by governments, industry groups, ICT developers, and other stakeholders, to provide guidance and recommendations when designing and implementing cold chain interventions.

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