Impact assessment of the investment:

Technology review for fruit traceability at every stage of the apple and pear fruit production and supply chain (AP19004)

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November 2023

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Disclaimer:

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Executive summary

What the report is about

Ag Econ conducted independent analysis to determine the economic, social, and environmental impact resulting from delivery the apple and pear project AP19004 *Technology review for fruit traceability at every stage of the Apple and Pear fruit production and supply chain*. Delivered by Agriculture Victoria over the period October 2020 to July 2021, the project was funded by Hort Innovation using the apple and pear research and development levy and contributions from the Australian Government.

The analysis applied a five-step analytical process to understand the impact pathway and collect supporting data.

Review documents	Engage stakeholders	Map logical framework	Cost-benefit analysis	Discuss implications
Contracts Milestones Final reports	Hort Innovation Researchers / delivery partners Growers	Activities Outputs Outcomes Impacts	RD&E costs Adoption curve Adoption benefits NPV, BCR, IRR, MIRR	So what?

Research background

The Hort Innovation Strategic Investment Plan (SIP) 2017-2021 highlighted the need for research into information technology (IT) and data systems to enable better collection and connectivity of orchard and business data at every level of the supply chain. This need led to the delivery of AP19004, which investigated next generation traceability technologies, including any potential opportunities and challenges for implementation in the apple and pear sector and broader application to Horticulture fruit and nut crops.

Key findings

The nominal investment cost of $0.30 million was adjusted for inflation (ABS, 2023) and discounted (using a 5% real discount rate) to a present value (PV) of costs equal to $0.38 million (2022-23 PV).

AP19004 resulted in improved information to support the strategic traceability objectives. As the project was a desktop study of potential traceability technology solutions for the apple and pear industry, AP19004 was found to sit in the early stages of the impact pathway, and did not directly generate social, economic, or environmental impacts. However, through its recommendations, the project had both direct and indirect linkages to further research into traceability systems for the apple and pear industry (through ongoing Agriculture Victoria research and collaborations towards the design of a product traceability system initiated in AP19004), as well as other industries (notably table grapes and citrus, also being conducted by Agriculture Victoria).

Through the successful delivery of this ongoing research, AP19004 has the potential to contribute to future impact in food safety risk reduction, improved market access, reduced supply chain costs, marketing benefits, and increased regional community wellbeing.

Sufficient data was available to quantify the benefit of reduced food safety risk, which was estimated at $0.71 million (2022-23 PV). When combined with the PV costs of $0.38 million, this generated an attributable RD&E impact with a net present value (NPV) of $0.33 million, an estimated benefit-cost ratio (BCR) of 1.86 to 1, an internal rate of return of 10% and a modified internal rate of return of 7%.

Detailed sensitivity testing showed a likely BCR range of between 0.31 to 1 (a negative impact with benefits below costs) and 5.93 to 1, with 76% of results having a BCR greater than 1 to 1.

The additional social and economic impacts identified through the logical framework were not able to be quantified due to data limitations that were highlighted in the analysis. These additional impacts have the potential to further increase the impact above that identified in this analysis.

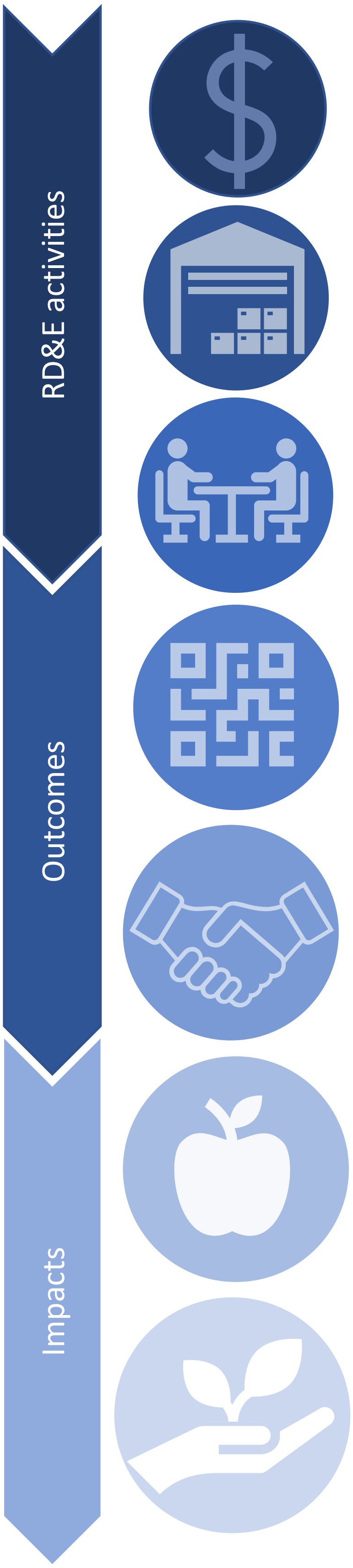
The key findings of the AP19004 impact assessment are summarized in Figure 1 below.

Keywords

Impact assessment, cost-benefit analysis, apple, pear, traceability

Figure 1. Summary of impact assessment findings

AP19004 Technology review for fruit traceability



Hort Innovation

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Total RD&E costs:

- $298,842 (nominal value)
- 58% R&D levy and Government matching, and 42% Ag Vic in-kind funding.

Research activities:

- Identified, evaluated and made recommendations on traceability technologies for the apple and pear industry.

Extension activities:

- Face-to-face interviews and system inspections with apple and pear industry stakeholders.
- Surveys to gauge industry need and potential for integration of the technology.

Outcomes:

- Increased industry understanding of traceability options available.
- Strategic framework and industry pathway to inform future research, including Agriculture Victoria research related to apple and pear, grape, and citrus traceability system design.

Industry adoption:

- Traceability platform not available in market at time of analysis
- Assessed potential adoption of 61% by 2037

Economic impacts:

- Reduced biosecurity & food safety risk
- Improved market access
- Marketing benefits
- Cost reductions

Environmental impacts:

- Accountability for environmental metrics, incentivising reduced resource use and environmental impact.

Social impacts:

- Accountability for social metrics, incentivising improved outcomes such as social initiatives related to labour or the community at large.

Quantified impact:

- PV investment costs of $0.38 million from October 2020 to July 2021.
- PV industry benefits of $0.71 million from 2025-26 to 2049-2050.
- Net present value (NPV) of $0.33 million.
- Benefit cost ratio (BCR) of 1.86:1.
- 76% probability of a BCR greater than 1:1.

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Introduction

Evaluating the impacts of levy investments is important to demonstrate the economic, social, and environmental benefits realised through investment to levy payers, Government, and other industry stakeholders. Understanding impact is also an important step to inform the ongoing investment agenda.

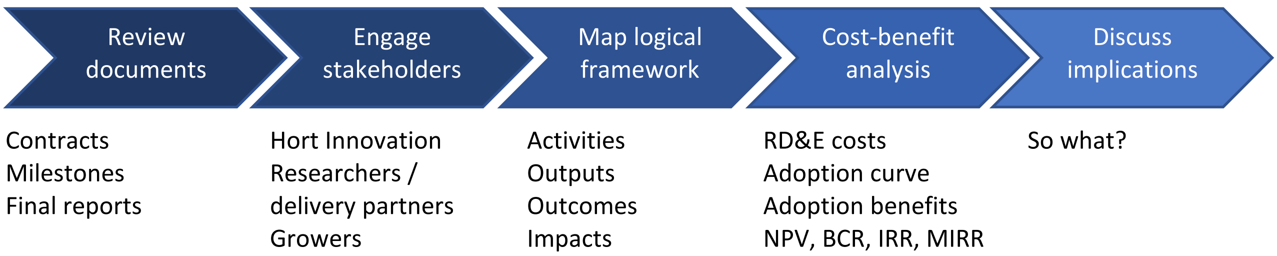
Reflecting its commitment to continuous improvement in the delivery of levy funded research, development, and extension (RD&E), Hort Innovation required a series of impact assessments to be carried out annually on a representative sample of investments of its RD&E portfolio. Commencing with MT18011 in 2017-18, the impact assessment program consisted of an annual impact assessment of 15 randomly selected Hort Innovation RD&E investments (projects) each year. In line with this ongoing program, Ag Econ was commissioned to deliver the *Horticulture Impact Assessment Program 2020-21 to 2022-23* (MT21015).

Project *AP19004 Technology review for fruit traceability at every stage of the Apple and Pear fruit production and supply chain* was randomly selected as one of the 15 investments in the 2021-22 sample. This report presents the analysis and findings of the project impact assessment. The report structure starts with the general method of analysis used, followed by the RD&E background and an outline of the impact pathway in a logical framework, then describes the approach used to quantify the identified costs and benefits including any data gaps and limitations to the analysis, presents the results including from the sensitivity analysis, and finally discusses any implications for stakeholders.

General method

The impact assessment method built on the impact assessment guidelines of the CRRDC (CRRDC, 2018) and included both qualitative and quantitative analysis. The general method that informed the impact assessment approach was as follows:

1. Review project documentation including project plan, milestone reports, outputs, and final report.
2. Discuss the project delivery, adoption, and benefits with the Hort Innovation project manager, project researcher/consultant, growers, and other stakeholders (see *Stakeholder Consultation*).
3. Through a logical framework, qualitatively map the project's impact pathway, including activities, outputs, outcomes to identify the principal economic, environmental, and social impacts realised through the project.
4. Collect available data to quantify the impact pathway and estimate the attributable impacts using cost-benefit analysis (over a maximum 30 years with a 5% discount rate), and then sensitivity test the results to changes in key parameters.
5. Discuss the implications for stakeholders.



The analysis identified and quantified (where possible) the direct and spillover impacts arising from the RD&E. The results did not incorporate the distributional effect of changes to economic equilibrium (supply and demand relationships) which was beyond the scope of the MT21015 impact assessment program. A more detailed discussion of the method can be found in the *MT21015 2021-22 Summary Report* on the Hort Innovation project page [Horticulture Impact Assessment Program 2020/21 to 2022/23 (MT21015)](#).

Project background

When project AP19004 was undertaken, there were a range of different traceability systems and technologies used in the apple and pear production and supply chain. Each system was developed to address specific needs and requirements at a given point in the supply chain, and the systems may have been augmented to address new traceability requirements as they arose. The various systems tended to be independent with limited integration. No whole of chain fruit product traceability system solutions existed at the time, and data relating to traceability was fragmented across systems. As such, an opportunity to improve access and efficiencies was identified for the industry by way of a purpose-built traceability system.

The Hort Innovation Strategic Investment Plan (SIP) 2017-2021 articulated four industry investment outcome areas. Project AP19004 aligned to strategy 5 of outcome area 1: Research information technology (IT) and data systems that enable better collection and connectivity of orchard and business data at every level of the supply chain. The Apple & Pear Australia Ltd (APAL) Apple and Pear Industry Strategy 2018-2023 is based on four interdependent pillars for industry transformation, and include market growth, supply chain management, industry sustainability and capability, and capacity building. Project AP19004, with its focus on traceability, sought to examine several key challenges and opportunities linked to these transformational pillars. On the challenges side, this included the lack of cohesion and integration, poor supply chain knowledge system and a complex biodiversity environment. On the opportunities side, this included advancing industry focus around expanding developing export markets, rapid technology advances and strong fresh fruit chain credentials.

As a result of the above drivers, Hort Innovation contracted Agriculture Victoria to undertake a review of food traceability in the apple and pear industry.

Project details

Agriculture Victoria was selected as the lead delivery partner, with the project running from October 2020 to July 2021 (Table 1).

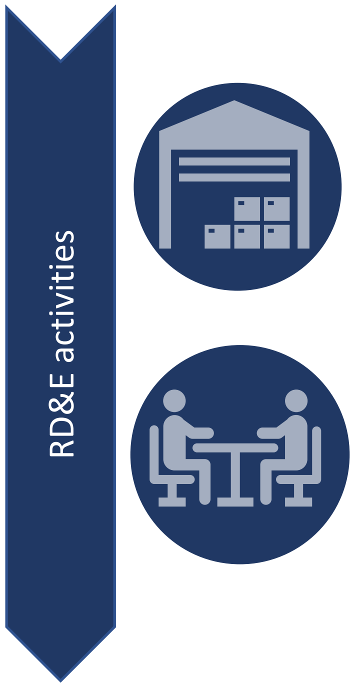
Table 1. Project details

Project code	AP19004
Title	Technology review for fruit traceability at every stage of the Apple and Pear fruit production and supply chain.
Research organization	Agriculture Victoria (Ag Vic) (Victorian Government)
Project leader	Kieran Murphy
Funding period	October 2020 to July 2021
Objective	To undertake a detailed review of next generation traceability technologies, including any potential opportunities and challenges in implementation in the apple and pear sector, with broader application to Horticulture fruit and nut crops.

Logical framework

The impact pathway linking the project's activities and outputs, and their assessed outcomes and impacts have been laid out in a logical framework (Table 2).

Table 2. Project logical framework detail



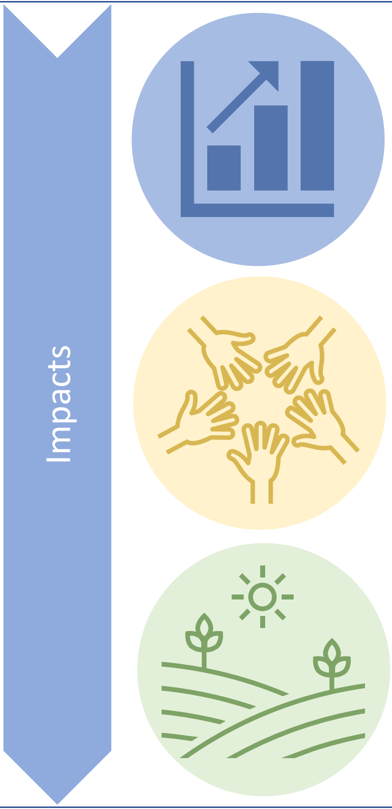
- Identified emerging technologies and trends for end-to-end production and supply chain monitoring, management, and traceability for apple and pears.
- Undertook detailed evaluation of technologies used in apple and pear traceability supply chains, and the preparedness of the industry to take on next generation technology developments.
- Summarised challenges, opportunities, and risks for industry in adopting the technologies, including any impacts on industry and government.
- Identified the possibilities and impacts of traceability technologies and data.
- Identified how technologies could be customised by the apple and pear industry to optimise the traceability systems in the supply chain by integrating multiple new technologies to achieve compliance for products and marketplace differentiation.
- Developed new conceptual models and frameworks to better describe and communicate traceability aspects of the industry, relevant technology, and current and potential traceability solutions.
- Due to the COVID 19 pandemic, the project team was largely unable to undertake face to face interviews and property and system inspections. To mitigate the limitations on engagement the project team developed a survey to understand the use of technologies in the industry and allow for virtual engagement. However, there were very few responses to the survey, which were followed up where possible.
- Significant effort during project AP19004 was focused on reviewing material published online, including published research, and conducting virtual meetings with technology groups and vendors across the globe.

RD&E outputs

- A report available on the Hort Innovation website called *"Technology review for fruit traceability at every stage of the apple and pear fruit production and supply chain"*.
- The report reviewed traceability in the apple and pear industry, including the existing use of technology at the time, and opportunities for improvement from the use of emerging technologies.
- The findings from the review are supported by information sourced from supply chain participants, industry, technology providers, and published research.

Outcomes

- Project AP19004 increased industry awareness and understanding of the latest traceability technology, including how it could be applied to apples and pears:
    - The project helped promote an understanding in the industry of the available traceability options. The report contained specific analysis on new technologies such as robotic harvesting highlighted potential business opportunities which can come from implementing different technologies.
    - The project helped promote an understanding in the industry of traceability system application in the context of the apple and pear industry. Traceability was identified as having the potential to increase the precision, responsiveness, and richness of information delivered to markets and stakeholders. This would help with quicker and easier traceback to manage and resolve issues related to for example biosecurity and food safety. This was described in the report as a point of difference from competitors, and as exceeding existing market requirements for traceability. Such improvements can protect markets, enhance the reputation of the industry, and increase consumer confidence both in Australian and export markets.
    - The project increased industry knowledge of approaches to further progress traceability RD&E and adoption. The project developed a strategic framework and industry pathway for traceability integration.
- The research also supported longer-term outcomes relating to the development and adoption of whole of supply chain traceability:
    - Project AP19004 resulted in the lead researcher (Ag Vic) investing further into developing traceability outcomes for the apple and pear and summer fruit industry. The findings from the review helped inform and secure funding (external to Hort Innovation) for additional research undertaken by Ag Vic (stakeholder pers. comms). In mid-2022, Ag Vic was publicly looking for growers to help test orchard measurement system to support a finer level of fruit traceability from tree to consumer (APAL, 2022); however, trials on commercial farms of traceability platform aspects were still in the planning stages (Stakeholder pers comms). Ag Vic aimed to create a development environment to use advances in fruit tracking and the establishment of Application Programming Interface (API) services to support information exchange to industry stakeholder through an exemplar API gateway. This would allow for testing and deployment for industry through an environment that mimics current industry settings.
    - The AP19004 final report noted that the engagement of the AP19004 project team with traceability and AgTech providers had resulted in new collaborations and initiated early work towards the design of a product
    - traceability system for the apple and pear industry, and potentially other industries. The AP19004 final report also noted that this opportunity would require further funding partnerships.
    - Other projects which may have potential indirect linkages to the recommendations made in AP19004 include a table grape traceability pilot and a citrus traceability pilot, and a research project with Monash University on integrating MARS (Monash Apple Retrieving System) robot technology onto an apple harvesting platform of Ag Vic.



While the research in AP19004 represents an early step in the RD&E impact pathway, through the end of project outcomes and the support for the longer term outcomes, AP19004 has the potential to support the following impacts:

- [Economic] Supply chain cost reductions. A whole of supply chain traceability platform has the potential to replace segmented data capture, supporting improved efficiency (cost) and effectiveness (outcomes) in data collection, and synthesis to inform improved decision making.
- [Socio-economic] Biosecurity and food safety. The ability to trace products back through the supply chain quickly and efficiently to minimise both reputational and financial costs to the industry and industry stakeholders and increase confidence among consumers.
- [Economic, social, and environmental] Marketing benefits. Providing consumers with increased information regarding the sustainability credentials of products, in turn supporting domestic apple consumption with associated health and wellbeing benefits as well as encouraging greater industry incentive and progress towards social and environmental goals to differentiate products based on sustainability credentials.
- [Economic] Market access. Helping the industry to meet increasingly regulated markets with traceability requirements (which are often based on food safety and sustainability information).
- [Socio-economic] Increased contribution to regional community wellbeing and resilience from more profitable apple growers.

These impact areas are discussed in more detail under "Project impacts".

Project costs

The project was funded by Hort Innovation, using the apple and pear research and development levy and contributions from the Australian Government, with additional in-kind contributions from research partners Ag Vic (Table 3). Where relevant, overhead and extension costs were added to the direct project cost to capture the full value of the RD&E investment.

Nominal investment

Table 3. Project nominal investment

Year end 30 June	Hort Innovation project costs ($)	Hort Innovation overheads[1] ($)	Ag Vic in-kind contributions[2] ($)	Total nominal ($)
2020	46,000	7,774	39,318	93,318
2021	102,000	16,568	87,182	205,751
Total	**148,000**	**24,342**	**126,500**	**298,842**

1. The overhead and administrative costs were calculated from the Apple and Pear Fund Annual Report, Financial Operating Statement, averaging 16.6% for the AP19004 funding period.
2. Other funds from Ag Vic were provided in the contract as a lump sum of in-kind salaries, so have been apportioned yearly based on Hort Innovation cash costs.

Present Value of investment

The total nominal investment of $0.30 million identified in Table 3 was adjusted for inflation (ABS, 2023) into a real investment of $0.34 million (2022-23 equivalent values). This was then further adjusted to reflect the time value of money using a real discount rate of 5% (CRRDC 2018), generating a present value (PV) of costs equal to $0.38 million (2022-23 PV). The results were sensitivity tested changes in the discount rate between 2.5% and 7.5%.

Project impacts

The impact pathways identified in Table 2 was evaluated against available data to determine if the impacts could be quantified and attributed with a suitable level of confidence. The final report for AP19004 had several important outcomes, including for example improving industry knowledge, informing the continued research on traceability by Agriculture

Victoria, facilitating new collaborations with traceability system providers, and early work toward the design of an apple and pear traceability system. However, a purpose-built whole of supply chain fruit product traceability system had not been developed at the time of publication.

A traceability system for the whole supply chain could be designed in different ways, which would result in different costs and benefits for an individual orchard and for the industry. As such, there are a range of possible future impacts that may be attributable (fully or in part) to project AP19004. Given the early stage of the R&D in the context of the broader impact pathway (i.e. a system design was not complete and the final delivery of a traceability system platform for the whole apple and pear industry was uncertain), and data limitations, only the reduction in potential gross margin value lost due to a major food safety issue was valued.

The impacts identified in Table 2 are discussed in a qualitative manner below, including suggestions for information or data that could be collected for a full quantitative assessment of impacts.

Biosecurity and food safety

The ability to trace back quickly and efficiently to address any issues relating to for example biosecurity and food safety enhances market access recovery and retention. This is a key driver of the development of traceability systems, according to the AP19004 final report. Facilitating traceability to quickly address any such issues can potentially help minimise both reputational and financial costs to the industry and industry stakeholders and increase confidence among consumers. AP19004 generally discussed biosecurity and food safety risks together, reflecting the ability to collect data and rapidly identify sources of food safety contamination or biosecurity outbreak. Given the complexity of biosecurity No external analyses or data were identified that quantified the marginal benefit of traceability in reducing biosecurity risk. Further, given the complexity of biosecurity outbreak, spread, and management, the ability to quantify the marginal benefit of traceability in the context of broader management options was deemed too complex for this analysis. In contrast, while there was also a lack of data on the marginal benefit of traceability in mitigating food safety incidents, discussions with stakeholders highlighted the central importance of traceability in this area, so there was greater confidence in estimating potential impact.

Although food recalls are not very common in Australia with on average 79 recalls per year from 2013 to 2022 (Food Standards Australia & New Zealand, 2023), they can result in significant reputational and financial risks for the industry, particularly if potentially unsafe food is sold to consumers. Recalls have occurred in the apple and pear industry, for example, a brand of Australian apple juice was recalled from Australian supermarkets as well as from Hong Kong and Singapore in 2020 when it was found to be contaminated with patulin (APAL, 2020).

The costs of a food safety issue and/or recall include direct costs (e.g., identifying source of the problem, logistics to remove product, alerting stakeholders, stopping production etc) and indirect costs (e.g., government penalties, increase insurance premiums, legal fees etc), as well as lost sales and/or brand damage (Eden Green Technology, 2022). If the food safety issue results in illness or worse, then this involves medical costs, lost wages and/or a decrease in health-adjusted life years. The resulting costs can be high. According to a 2012 study by Grocery Manufacturers of America (GMA) and Food Marketing Institute (FMI), the average direct costs for food companies during a recall was $US10 million (Tosca, 2023). In Australia, a well-known example of a food safety issue in the fresh fruit industry is the 2018 listeria contamination in muskmelons (FSANZ, 2018), which resulted in a 35% decline in farmgate value relative to 2017 (Hort Innovation, 2023).

Whilst improved traceability does not prevent biosecurity and food safety issues, it can be very helpful in minimising the associated reputational and financial costs. The extent to which a whole-of-supply chain traceability solution for the apple and pear industry decreases the costs associated with biosecurity and food safety issues depends on the design elements of the system (e.g., a track and trace system may deliver better traceability for food safety and biosecurity issues than a "point of origin" system), and how they compare to current traceability protocols. Once a design of a product traceability solution is more clearly defined, more detailed analysis will be possible in terms of cost/value savings relating to, for example, time spent identifying the source of the problem, production that needs to be stopped and/or thrown out, and/or lost sales.

This impact was quantified as a reduction in consequences in the event of a food safety incident. The total surplus accruing to apple and pear growers was calculated based on the total hectares of apple and pears grown and the estimated gross margin per hectare of a model orchard. The potential gross margin value lost due to a major food safety issue was estimated both with and without a finer level traceability system, together with the likelihood of a major food safety issue occurring. These results were scaled by estimating an adoption and diffusion curve of a traceability platform using stakeholder feedback and available data to inform inputs into CSIRO ADOPT analysis (Kuehne et al 2017). The attribution of the full results was considered in relation to other contributing R&D, and a suitable outcome attribution factor was applied. Finally, the potential for the research to have been conducted without levy investment was also considered, with results adjusted down by an estimated R&D counterfactual factor.

Supply chain cost reductions

There may be benefits in terms of efficiencies in the supply chain, including reduced costs, from improved traceability. The AP19004 final report noted that there were a multitude of systems and technologies utilised throughout the supply chain for apples and pears, and a purpose-built system may therefore result in improvements in efficiencies, including reductions in costs. For an individual orchard, some traceability solutions, such as robotic harvesting may enable fuller characterisation and grading of fruit at harvest which could reduce pack-out losses.

Improving the resolution of information capture at the orchard level so that production and other relevant information can be traced to an individual tree (or near) could enable a grower to better assess the success of certain orchard management practices and make any relevant changes to reduce costs and/or improve yield/quality. This could include for example crop thinning, chemical spraying, pest and disease monitoring, crop assessment, harvest planning, picking, labelling of bins etc. A more detailed investigation into linkages between the design of a finer level of traceability system for the apple and pear industry and orchard management practices would need to be conducted to quantify this impact, noting that some solutions may also come with an initial upfront cost and/or ongoing costs.

At the industry level, better traceability may improve quality management during transport, which may prevent for example food loss due to unsuitable temperatures.

Marketing benefits

Marketing benefits may accrue from a finer level of traceability in the apple and pear industry. Many consumers want to know more about for example the health, safety, and social and environmental credentials of their food. Research suggests that consumers increasingly want to know for example if a product is “locally sourced” or “organic” to make purchasing decisions, and that food fraud can be both prevalent and far reaching (in a global context) (World Economic Forum, 2019).

Whilst there are some surveys conducted on willingness to pay for traceability, there is doubt as to whether survey results are truly representative of a consumer’s willingness to pay. Some consumers may not trust traceability labels, an issue driven in part by a financial incentive to mislabel products to the highest possible price premium, for example “organic” (World Economic Forum, 2019). A US survey of 1,500 consumers found that 75 percent of respondents do not trust the accuracy of food labels (Label Insight, 2016). Further, it may be difficult to separate out the willingness to pay for (a finer level of) traceability from the attributes communicated through the traceability system such as “locally produced” and “organic” (Dessureault, 2019).

The willingness to pay for traceability may differ between consumer segments. Some apple and pear customers (in certain locations, or with certain demographics) may place higher value on a finer level of traceability than others. Research from China indicated that participants had a significant willingness to pay for apple products that had production information traceability, reduced pesticide use, and were grown with organic fertilisers (Qu et al., 2023). However, at the time of the AP19004 report, only 2% of apples and 9% of pears were exported overseas, and to other countries as well as China. No specific research on willingness to pay for a finer level of traceability has been identified for apple and pears in Australia. A pilot or other initiative may be required to fully understand apple and pear consumers’ willingness to pay for a finer level of traceability from individual tree (or near) to consumer. If there is a willingness among apple and pear consumers to pay for a finer level of traceability than what is currently available, then this increases the potential benefits generated from project AP19004, including potential health and wellbeing benefits from any increased demand and consumption (APAL, 2023; Hort Innovation, 2020). Better traceability may also increase brand value through increased consumer confidence in the brand (e.g. Australian apples or individual grower brands), knowledge of the brand, and/or loyalty to the brand, and increase brand protection from instances of food fraud and food substitution which lead to a poor consumer experience with the brand.

It is possible that improved traceability systems would also improve the ability to track environmental and social impacts of produce throughout the supply chain, for example the chemical, water and other resource use associated with the product. Traceability in and of itself will not necessarily improve environmental and social outcomes, but it is easier to measure and manage such impacts with improved traceability. There may be marketing benefits (price premiums) associated with for example sustainability or social initiatives if environmental and social impacts were captured and able to be validated as part of the traceability system. For example, with a trusted and well understood traceability system a grower may be incentivised (through market or regulatory mechanisms) to reduce pesticides and water resource use, increase organic fertiliser use, improve their emissions footprint, or demonstrate social initiatives related to labour or the community at large. Easier access for growers to marketing benefits and price premiums (or to meet current or future regulatory requirements) for environmental and/or social initiatives that they are already undertaking, or are considering undertaking, may also have a feedback impact in terms of facilitating higher adoption of the finer level traceability system. More detailed information is needed regarding what environmental/social marketing benefits may be facilitated through a finer level of traceability to quantify this impact.

Market access

Linked to the above benefits, traceability is also becoming increasingly important in market access. For example, market access regulations such as the digital product passports (DPP) in the European Union (EU), which seek to create transparency through the supply chain, will likely impact exporting industries in the coming years, although food is currently exempted (A&L Goodbody, 2023). At this stage, project AP19004 has not had any specific known impact on such market access (stakeholder pers. comms.), however market access negotiations typically take many years, so there could be impacts in the future. In the event of regulatory changes in existing markets, there may be impacts on market access if the industry is not ready to comply.

Community spillovers

The CIE (2023) highlighted the broader socio-economic effects of the apple industry for Australian production regions. The industry contributed over $0.5 billion in valued added (contribution to gross domestic product) and directly supported 1,818 full time employees primarily in regional economies. While this impact assessment is a first step in understanding and quantifying the direct effects of traceability on industry production and value, quantifying the additional flow-on effects requires analysis with economic models that capture regional and national linkages, which are beyond the scope of the R&D impact assessment program (CRRDC 2018). However, the analysis and results from this impact analysis will provide an important input into any future regional or national economic impact modelling.

Data assumptions

This analysis focuses on the contribution of a whole of supply chain traceability platform in reducing industry risk from a food safety issue. For this impact, the necessary data was collected from the project documents and other relevant resources. Where available, actual data was applied to the relevant years, with estimates applied for any data gaps and projections into the future based on analytical techniques (for example correlations and trend analysis), or stakeholder estimates, or both. Where estimates were used, a data range was considered to reflect underlying risk and uncertainty, which was further analysed through in sensitivity testing (see *Results*). A summary of the key data, assumptions and sources is provided in Table 4.

Table 4. Summary of data and assumptions for impact valuation

Variable	Assumption	Source / comment
Discount rate	5% (± 50%)[1]	CRRDC Guidelines (2018)
Hectares	12,601 ha	APAL (2020b), average of 2017 to 2020.
Gross margin	$12,601 / ha	AgFirst (2022), 2017-2021 average, adjusted for inflation.
Cost of traceability platform to growers	$0	The direct cost is assumed to be borne by other stakeholders in the supply chain. Agriculture Victoria (2021), in a traceability pilot for citrus, assumes this cost is borne by pack houses. Traceability solutions are not expected to be overly expensive for orchards (stakeholder pers. comms.).
Gross margin value lost due to a major food safety issue (%)	Current (no) traceability system: 50% With finer level traceability system: 25% (± 50%)	The actual value lost will depend on the nature of the food safety incident (what occurred, when it occurred, how serious the issue is in terms of health implications etc). Agriculture Victoria (2021), in a traceability pilot for citrus, estimated that the value lost from food fraud at 25%, and the value lost from perishable goods was 23%. Note that these numbers were estimates and that no real data was available for this study. The "with traceability system" numbers assume that the value lost decreases by half. This is an estimate, as the magnitude of decrease will depend on the design on the traceability system.
Likelihood of a major food	5% (± 50%)	Although food recalls are not very common in Australia with on

[1] The range relating to percentage assumptions are in relative terms, i.e., the discount rates sensitivity tested are 2.5%, 5% and 7.5%.

Variable	Assumption	Source / comment
safety incident per year		average 79 recalls per year from 2013 to 2022 (Food Standards Australia & New Zealand, 2023), they do happen. A lack of data on the likelihood or expected frequency of occurrence of a major (25% gross margin loss) food safety issue in the apple and pear industry meant an estimate had to be made. The estimated 5% likelihood is equal to a 1 in 20 year occurrence. Due to the uncertainty, this was tested at a wide range.
Outcome attribution (reduced risk through a supply chain traceability system)	20% (± 50%)	The final report of project AP19004 is a technology review of traceability options for the apple and pear industry, with recommendations for next steps. More investment and time will be required to develop a platform which is ready for use by industry stakeholders; however, gaining industry buy-in and support through levy funded research likely enhances research outcomes and likely adoption is likely improved and therefore a conservative estimate of 10% outcome attribution is used.
R&D counterfactual attribution	50% (-50%)	There are a number of externally funded traceability programs in Australian agriculture and horticulture, including the Agriculture Traceability Grants (DAFF 2023) and Ag Vic (2023).
Industry adoption of traceability systems	Start 2026, Reach 79% by 2051	Industry adoption of a traceability system (or systems) was estimated using the ADOPT model (Kuehne et al 2017). See Appendix A for details.
Market share of AP19004 attributable system	50% (± 50%)	The final AP19004 report proposes to initially build a cloud-based system that can harvest required data from traceability reporting with minimal impact on existing system investments. There may be other platforms that come to market to offer the same, or a similar, service.
Years before traceability platform available in market	4 years (± 1 years)	There was no whole-of-supply chain traceability platform for the apple and pear industry at the conclusion of project AP19004, and it is likely that the development of a pilot and then availability for market usage will take several years. The development will likely require additional funding or potentially be driven by regulatory requirements (stakeholder pers. comms).
Years before redundancy	10 years (± 5 years)	Traceability technologies were developing quickly at the time of the AP19004 report completion, and new solutions became available during the project. The analysis assumes that a traceability platform has a life of ten years before it starts to decline in usage towards 0% at the end of the 30-year analysis period.

Results

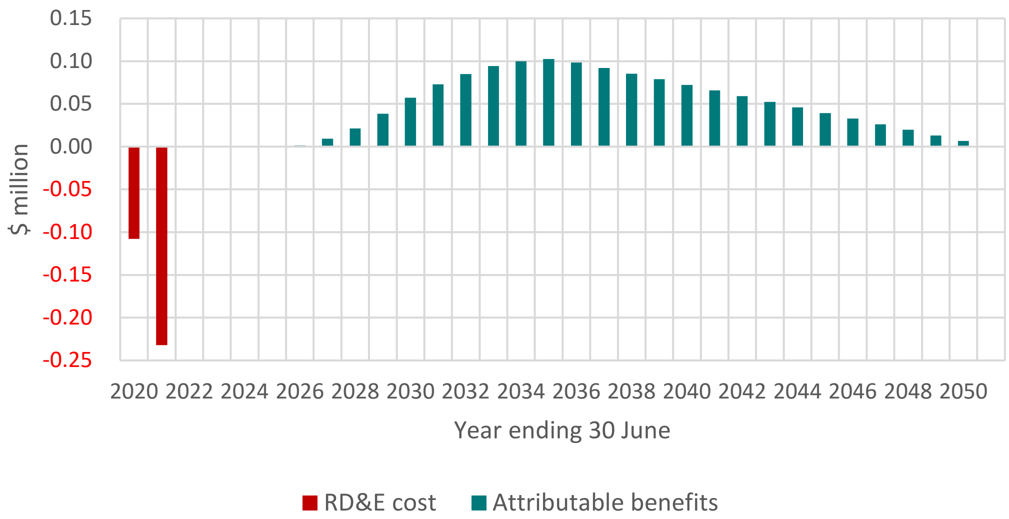
The analysis identified a PV costs (PVC) of $0.38 million (2022-23 PV) between 2020 and 2021 and estimated PV benefits (PVB) of $0.71 million (2022-23 PV) accruing between year 2025-26 and 2049-50 (Table 5). When combined, these costs and benefits generate an RD&E impact with a net present value (NPV) of $0.33 million, an estimated benefit-cost ratio (BCR) of 1.86 to 1, an internal rate of return (IRR) of 9.5% and a modified internal rate of return (MIRR) of 6.9%.

Table 5. Impact metrics for the total investment in project AP19004

Impact metric	Years after last year of investment						
	0	5	10	15	20	25	30
PVC ($m)	0.38	0.38	0.38	0.38	0.38	0.38	0.38
PVB ($m)	0.00	0.00	0.14	0.42	0.61	0.69	0.71
NPV ($m)	-0.38	-0.38	-0.24	0.04	0.23	0.31	0.33
BCR	0.00	0.00	0.38	1.11	1.59	1.81	1.86
IRR	Negative	Negative	Negative	6.0%	8.7%	9.4%	9.5%
MIRR	Negative	Negative	Negative	5.6%	7.0%	7.1%	6.9%

Figure 2 shows the annual undiscounted benefit and cost cash flows for the total investment of AP19004. Cash flows are shown for the duration of the investment plus 30 years from the last year of the investment.

Figure 2. Annual cash flow of undiscounted total benefits and total investment costs

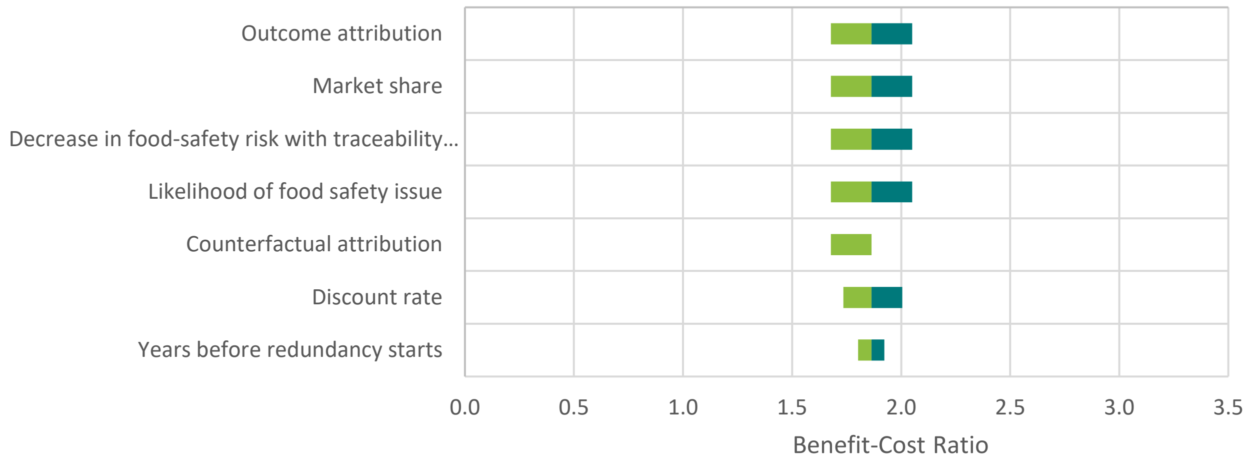


Sensitivity analysis

Given the risk and uncertainty associated with several underlying modelling inputs (particularly due to the forward projections inherent in the impact process), the results were tested to sensitivity to changes in the variable where a potential value range was identified (Table 4).

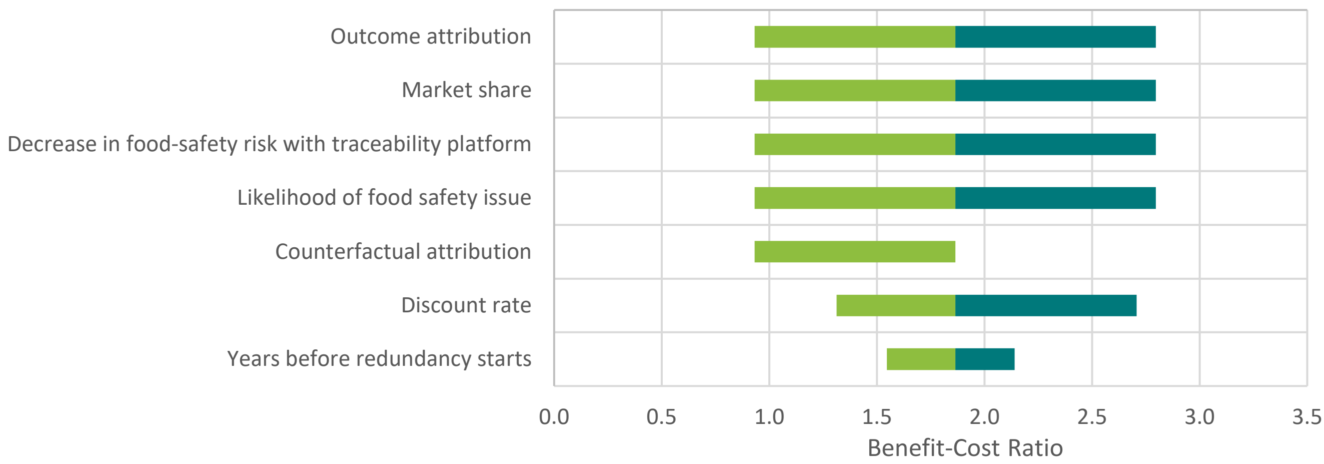
Results were first tested for sensitivity to uniform changes in underlying variables, in this case 10%. This highlighted that the results were most sensitive to the modelling variables: market share, outcome and counterfactual attribution, likelihood of a food safety issue and value lost due to a food safety issue with the traceability platform (Figure 3).

Figure 3. Hurricane graph showing the result sensitivity to a uniform 10% change in key variables).



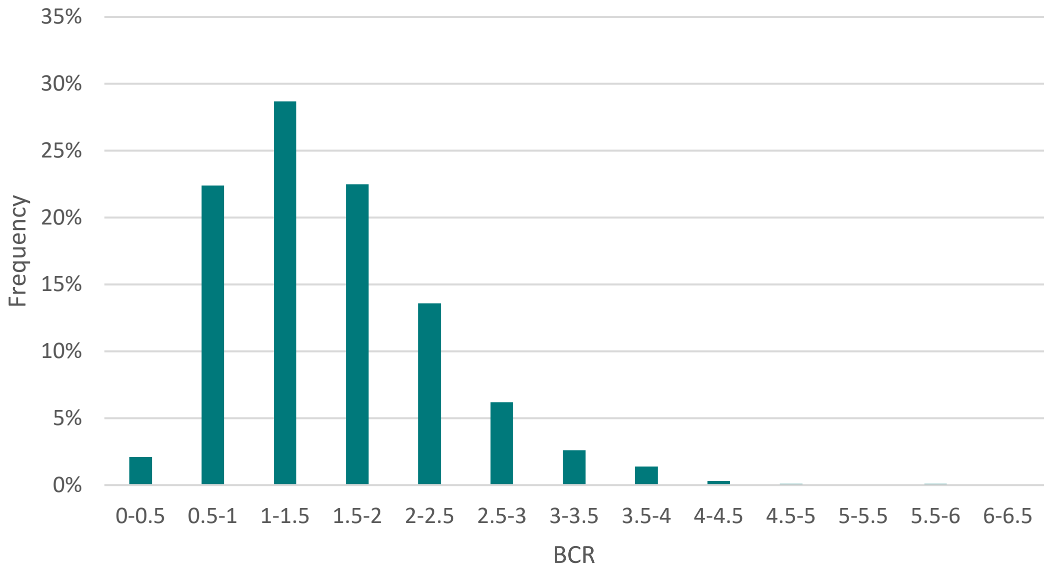
Results were then tested for sensitivity to the identified full range of potential variability for each data input to determine their potential impact on the results. This highlighted the same variables as identified for Figure 3 above reflecting the uncertainty across many of the modelling inputs (Figure 4).

Figure 4. Hurricane graph showing the result sensitivity to the identified full range of key variables



Finally, the full range of potential impact was estimated using @Risk stochastic modelling to incorporate the combined effect of changing all variables across their full ranges over 1,000 simulations. This process showed an impact (BCR) range of between 0.31:1 and 5.93:1, with 90% of the results falling between 0.60 and 2.92 (i.e., excluding the low probability tails), and a 76% probability of a BCR greater than 1:1 (Figure 5). This indicates a moderate to high confidence that the investment will generate a positive impact.

Figure 5. Impact histogram (1000 simulations)



Implications and learnings

AP19004 was a scoping study of potential traceability technology solutions for the apple and pear industry and was therefore found to sit in the early stages of the impact pathway. No direct industry impact could be attributed to AP19004 as a purpose-built whole of supply chain fruit product traceability system had not been developed at the time of publication and would require (unknown) additional investment (and time). However, AP19004 was found to have had several important outcomes, including improving industry knowledge, informing the continued research on traceability by Agriculture Victoria, facilitating new collaborations with traceability system providers, and early work toward the design of an apple and pear traceability system, as well as for other industries (notably table grapes and citrus, also being conducted by Agriculture Victoria).

Through these outcomes, AP19004 has the potential to contribute to future impact. However, given the early stage in the logical framework, there remains a high level of uncertainty relating to the remaining RD&E cost, timeline, and outcomes (including technology specifications and capability). As a result of this uncertainty and associated data limitations, only one of the four identified potential impacts could be quantified, namely a reduction of the reputational and financial costs of food safety issues for the industry.

For this area of impact, the estimated total expected benefits were $0.71 million(2022-23 equivalent value) compared to total funding from all sources of $0.38 million (2022-23 equivalent value), giving a baseline impact NPV of $0.33 million and BCR of 1.86:1. Sensitivity testing showed a potential impact (BCR) range of 0.31:1 to 5.93:1, with a 76% probability of a BCR greater than 1:1, giving a moderate to high confidence that the investment will generate a positive impact. The modelling variability was driven by changes in the likely market share of the technology, the attribution of the risk reduction to AP19004, the likelihood of a food safety incident, and the avoided farmgate losses resulting from the traceability system. More accurate estimates of these variables, as well as identified data gaps preventing the quantification of additional impacts, would support a more accurate and wholistic estimate of traceability RD&E impact.

Stakeholder consultation

Where possible, Ag Econ sought to engage multiple stakeholders across key areas of the logical framework and impact pathway to augment existing information and data sources, and reduce any uncertainty or bias from individual stakeholders. All stakeholders were engaged through telephone or online meetings, with follow up emails as necessary. Consultation followed a semi-structured approach in line with broad topics relating to the impact pathway and associated data requirements. Table 6 outlines the stakeholders consulted as part of this impact assessment and the topics on which they were consulted.

Table 6. Stakeholder consultation by theme

Stakeholder details		Consultation topics						
Stakeholder and organisation	**Stakeholder type**	**Related research**	**Research inputs**	**Research outputs**	**Research immediate outcomes**	**Follow on research**	**Stakeholder adoption**	**Impact areas and data**
Bianca Cairns, Hort Innovation Training and Leadership R&D manager	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Anthony Baker, Hort Innovation Market Access R&D Manager	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Kieran Murphy, Agriculture Victoria	RD&E practitioner	✓	✓	✓	✓	✓	✓	✓

Glossary of economic terms

Benefit-cost ratio (BCR)	The ratio of the present value of investment benefits to the present value of investment costs.
Cost-benefit analysis (CBA)	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Direct effects	Impacts generated for the funding industry as a result of adoption of the RD&E outputs and recommendations, typically farm level outcomes relating to productivity and risk.
Discounting (Present Values)	The process of relating the costs and benefits of an investment to a base year to reflect the time value of money or opportunity cost of RD&E investment. The analysis applies a real discount rate of 5% in line with CRRDC Guidelines (CRRDC 2018) with results sensitivity tested at discount rates of 2.5% and 7.5%.
Economic Equilibrium	Due to a market's underlying supply and demand curves, changes in supply will have an impact on price and vice-versa. The Economic Equilibrium is the point at which market supply and price are balanced. Estimating the magnitude of market response to changes in supply or demand is a complex and demanding task that is considered beyond the scope of most CRRDC Impact Assessments (CRRDC 2018).
Gross Margin (GM)	The difference between revenue and cost of goods sold, applied on a per hectare basis and excluding fixed or overhead costs such as labour and interest payments.
Internal rate of return (IRR)	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Modified internal rate of return (MIRR)	The internal rate of return of an investment that is modified so that the cash inflows generated from an investment are re-invested at the rate of the cost of capital (in this case the discount rate).
Net present value (NPV)	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Nominal and real values	Nominal values reflect the actual values in a given year (e.g. contracted RD&E expenses). These are converted to real (inflation adjusted) values to make them comparable across time.
Spillover effects	Impacts generated for stakeholders who did not fund the RD&E, including other agricultural industries, consumers, communities, and the environment.

Abbreviations

ADOPT Adoption and Diffusion Outcome Prediction Tool

Ag Vic Agriculture Victoria (Department of Energy, Environment and Climate Action)

APAL Apple & Pear Australia Ltd

API Application Programming Interface

COVID 19 Coronavirus pandemic starting in 2019

CRRDC Council of Rural Research and Development Corporations

CSIRO The Commonwealth Scientific and Industrial Research Organisation

DPP Digital Product Passports

EU European Union

MARS Monash Apple Retrieving System

RD&E Research, Development and Extension

SIP Strategic Investment Plan

References

A&L Goodbody (2023) The EU Digital Product Passport – The future of free movement of goods and a sustainable Europe. Retrieved from https://www.lexology.com/library/detail.aspx?g=50cd3745-08ed-43b8-8081-b2bcf55a2995. Accessed May 2023.

AgFirst (2016-2021). *Australian Pome Fruit Industry Orchard Business Analysis Reports 2014-2020.* Funded by Hort Innovation as part of AP15005, using the apple and pear research and development levy and contributions from the Australian Government. Received from Hort Innovation pers comm May 2022.

AgFirst (2022). *Australian Pome Fruit Industry Orchard Business Analysis Report 2020 Actual and 2021 Forecast.* Received from APAL pers comm July 2022.

Agriculture Victoria (2021) Citrus Traceability Pilot. Retrieved from https://agriculture.vic.gov.au/__data/assets/pdf_file/0010/629902/Citrus-Traceability-Pilot.pdf. Accessed May 2023.

Agriculture Victoria (2023) *Traceability Research Pilot Projects*. Available https://agriculture.vic.gov.au/export/traceability/traceability-research-and-development. Accessed September 2023.

Apple and Pear Australia Ltd (APAL) (2020a) Patulin in apple juice – what you need to know. Retrieved from https://apal.org.au/patulin-in-apple-juice-what-you-need-to-know/. Accessed May 2023.

Apple and Pear Australia Ltd (APAL) (2020b) Apple and Pear Crop Estimate 2020. Retrieved from https://apal.org.au/wp-content/uploads/2020/01/Apple-and-Pear-Crop-Estimate-2020-Final.pdf . Accessed May 2023.

Apple and Pear Australia Ltd (APAL) (2022) Growers sought to help support fruit traceability research. Retrieved from https://apal.org.au/growers-sought-to-help-support-fruit-traceability-research/. Accessed April 2023.

Apple and Pear Australia Limited (APAL) (2023) *Consumer Health Benefits*. Available https://apal.org.au/consumer/health-benefits/. Accessed September 2023.

Australian Bureau of Statistics (ABS) (2023). 5206.0 – Australian National Accounts: National Income, Expenditure and Product, December 2022. Table 5. Expenditure on Gross Domestic Product (GDP), Implicit price deflators. Retrieved from Australian Bureau of Statistics: https://www.abs.gov.au/statistics/economy/national-accounts/australian-national-accounts-national-income-expenditure-and-product/latest-release#data-download

Australian Government (2023) *Department of Agriculture, Fisheries and Forestry: National traceability*. Available https://www.agriculture.gov.au/biosecurity-trade/market-access-trade/national-traceability. Accessed September 2023.

Dessureault, S. (2019) Cost, Benefits and Business Value of Traceability: A Literature Review. Retrieved from https://www.researchgate.net/publication/338038880_Costs_Benefits_and_Business_Value_of_Traceability_A_Literature_Review. Accessed May 2023.

Eden Green Technology (2022) The true impact and cost of food recalls. Retrieved from https://www.edengreen.com/blog-collection/food-recall-costs. Accessed May 2023.

Food Standards Australia and New Zealand (2018) Trade recall of rockmelons linked to Listeria. Retrieved from https://www.foodstandards.gov.au/media/Pages/Trade-recall-of-rockmelon-linked-to-Listeria-.aspx#:~:text=Food%20Standards%20Australia%20New%20Zealand%20%28FSANZ%29%20is%20coordinating,can%20result%20in%20severe%20illness%20and%20even%20death.. Accessed June 2023.

Food Standards Australia and New Zealand (2023) Food recall statistics. Retrieved from https://www.foodstandards.gov.au/industry/foodrecalls/recallstats/pages/default.aspx. Accessed May 2023.

Hort Innovation (2017). *Apple and Pear Strategic Investment Plan 2017-2021*. Retrieved from https://www.horticulture.com.au/globalassets/hort-innovation/levy-fund-financial-and-management-documents/sip-pdfs-new/hortinnovation-sip-apple-pear-2017-2021.pdf. Accessed December 2022.

Hort Innovation (2020) *The Good Mood Food*, available https://www.thegoodmoodfood.com.au/en/food/yellow/banana/ Accessed September 2023.

Hort Innovation (2018 to 2021). *Apple and Pear Fund Annual Reports*. Retrieved from https://www.horticulture.com.au/hort-innovation/funding-consultation-and-investing/investment-documents/fund-annual-reports/. Accessed April 2023.

Hort Innovation (2023). *Horticulture Statistics Handbook* 2012-13 to 2021-22. Data available https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/grower-resources/ha18002-assets/australian-horticulture-statistics-handbook/. Accessed June 2023.

Kuehne G, Llewellyn R, Pannell D, Wilkinson R, Dolling P, Ouzman J, Ewing M (2017). Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy, *Agricultural Systems* 156:115-125 https://doi.org/10.1016/j.agsy.2017.06.007

Label Insight (2016) How Consumer Demand for Transparency is Shaping the Food Industry. Retrieved from https://davissciencesays.ucdavis.edu/sites/g/files/dgvnsk6006/files/inline-files/Label_Insight-Food-Revolution-Study.pdf%3FhsCtaTracking%3Dfc71fa82-7e0b-4b05-b2b4-de1ade992d33%257C95a8befc-d0cc-4b8b-8102-529d937eb427#:~:text=17%25-,Nearly%20all%20respondents%20(94%20percent)%20say%20it%20is%20important%20to,more%20in%2Ddepth%20product%20information. Accessed May 2023.

The Centre for International Economic (The CIE) (2023) *Economic contribution of Australian horticulture (MT21010)* Final report. Funded by Hort Innovation using a multi-industry strategic levy investment and contributions from the Australian Government. Retrieved from https://www.horticulture.com.au/growers/help-your-business-grow/research-reports-publications-fact-sheets-and-more/mt21010/. Accessed July 2023

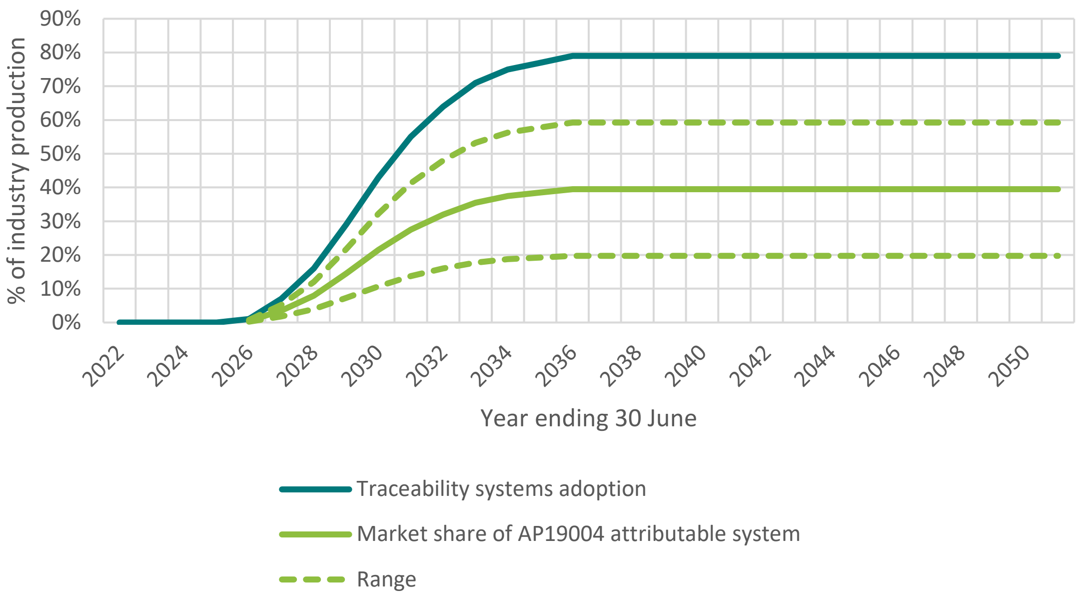
Tosca (2023) How to Create a Culture Focused on Food Safety. Retrieved from https://www.toscaltd.com/how-to-create-a-culture-focused-on-food-safety/. Accessed May 2023.

World Economic Forum (2019) Innovation with a Purpose: Improving Traceability in Food Value Chains through Technology Innovations. Retrieved from https://www3.weforum.org/docs/WEF_Traceability_in_food_value_chains_Digital.pdf. Accessed May 2023.

Qu et al (2023) Consumers' Preferences for Apple Production Attributes: Results of a Choice Experiment. In Foods 2023, 12 (9). Retrieved from https://www.mdpi.com/2304-8158/12/9/1917. Accessed May 2023.

Appendix A. Adoption and diffusion using the ADOPT framework

Appendix A includes the estimated adoption and diffusion curve for a whole of supply chain traceability system for the apple industry. The adoption and diffusion curve was estimated based on stakeholder consultation and available data which were incorporated into the CSIRO ADOPT framework (Kuehne et al 2017). The baseline adoption curve reflects industry use of a general traceability system. While a whole of industry system would have the best outcomes for traceability and data collection, there is a possibility other platforms may be developed to offer the same, or a similar, service. As a result, a market share of 25% to 75% was considered for any products attributed to AP19004.



ADOPT inputs for traceability platform for apple and pear industry

1. What proportion of farms have maximising profit as a strong motivation?

A majority all have maximising profit as a strong motivation.

2. What proportion of farms has protecting the natural environment as a strong motivation?

About half have protection of the environment as a strong motivation.

3. What proportion of farms has risk minimisation as a strong motivation?

About half have risk minimisation as a strong motivation.

4. On what proportion of farms is there a major enterprise that could benefit from the technology?

Almost all of the target farms have a major enterprise that could benefit.

5. What proportion of farms have a long-term (greater than 10 years) management horizon for their farm?

About half have a long-term management horizon.

6. What proportion of farms are under conditions of severe short-term financial constraints?

Almost none currently have a severe short-term financial constraint.

7. How easily can the innovation be trialled on a limited basis before a decision is made to adopt it on a larger scale?

Easy trailable.

8. Does the complexity of the innovation allow the effects of its use to be easily evaluated when it is used?

Difficult to evaluate effects of use due to complexity.

9. To what extent would the innovation be observable to farmers who are yet to adopt it when it is used in their district?

Difficult to observe.

10. What proportion of growers use paid advisors capable of providing advice relevant to the innovation?

About half use paid advisors.

11. What proportion of growers participate in groups that enable discussion relevant to the innovation?

About half of growers participate in relevant discussion groups.

12. What proportion of growers/advisors will need to develop substantial new skills and knowledge to use the innovation?

About half will need new skills and knowledge.

13. What proportion of growers would be aware of the use of trialling of this innovation in their district?

About half are aware that it has been used or trialled in their district.

14. What is the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?

No initial upfront cost.

15. To what extent is the adoption of the innovation able to be reversed?

Easily reversed.

16. To what extent is the use of the innovation likely to affect the profitability of the farm business in the years that it is used?

Small profit advantage due to factors listed in impacts section. In the case of supply chain issues, the advantage could be larger.

17 To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm business?

Small profit advantage in the future (due to reduced farm management costs)

18 How long after the innovation is first adopted would it take for effects on future profitability to be realised?

3-5 years, due to ongoing nature of reducing farm management costs.

19. To what extent would the use of the innovation have net environmental benefits or costs?

Small environmental gain if traceability system is used to be monitor, measure, and improve environmental outcomes.

20. How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realised?

3-5 years.

21. To what extent would the use of the innovation affect the net exposure of the farm business to risk?

Large reduction in risk. The ability to trace back quickly and efficiently to address any issues relating to food safety enhances market access recovery and retention and could result in large cost savings.

22. To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?

Small decrease in ease and convenience. An increase may arise from a higher resolution of picking and spraying and other activities should help improve farm management practices. However, implementation can be difficult depending on how much is invested in the user experience.

Ends.