Final report

Defining the overarching requirements for automated product verification and the development of key industry standards

Project code: V.RDA.2004

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Abstract

This project was one of four 'foundational' studies commissioned by ISC to help guide the implementation of its *Strategic Plan for the Integrity System 2025 and Beyond*. Building on an earlier ISC study led by CSIRO (V.RDA:2001), and including consultation with industry and MLA's regional in-market teams, the project identified the key product claim attributes of Australian red meat that require product verification and undertook a global scan of regtech (Regulatory Technology) and other digital solutions. Both industry and MLA's in-market teams underscored the need to complete the digitisation and interoperability of Australia's current red meat integrity system before embarking on a transition to new technologies, such as regtech and block chain, or seeking to fully automate data acquisition and verification across the supply chain. The sentiment was firmly that significant value can be obtained from optimising the existing system, and from communicating its strengths to trading partners and the global base of consumers. The report recommended that ISC define the key global standards and ontologies that facilitate integration and interoperability of verification within Australia's red meat integrity system and develop a more compelling and equitable value proposition for the existing system before incorporating new elements. It was also recommended that ISC identify and evaluate opportunities to adopt technologies or solutions that provide enhanced digitalisation and digital interoperability and, once other recommendations have been met, and a clear and compelling return on investment has been demonstrated, pursue new technologies that will support a whole-of-supply-chain traceability system.

Executive summary

Australia's red meat integrity system underpins the ability of Australian red meat supply chain participants to develop and maintain access to an array of global markets through the provision of assurances relating to food safety, product quality, and whole-of-life traceability. Notwithstanding the reputation that Australia has as a provider of clean, green and wholesome products to these markets, there are further opportunities to grow the industry's competitive advantage through enhancement of the integrity system. As part of its *Strategic Plan for the Integrity System 2025 and Beyond*, ISC have identified three strategic pillars which are aimed at ensuring the integrity system continues to deliver the impacts desired by the industry, explores new integrity approaches and technologies, and maximises the value of integrity data to all supply chain participants. This report, in conjunction with that of project V.RDA:2001 (Global scan of technologies and systems enabling data capture and transfer across red meat supply chains), describes the digital and biological concepts that may form the basis of a future integrity system.

The objectives of this project were to:

1. Identify the key product claim attributes of Australian red meat that require product verification across domestic and international markets now and into the future.
2. Complete a global scan for frameworks and technologies used in other industries and countries for verifying product requirements for market and legislative requirements.
3. Determine what frameworks and technologies are automated and effectively used to manage market compliance.
4. Determine the likelihood of existing frameworks and technologies to be applied to the red meat and livestock integrity system including risks to success and mitigation factors.
5. Provide a comprehensive final report, along with a power point presentation summarising the project findings.

The project had three key components:

1. Consultation with representatives of Australia's red meat supply chain and MLA's regional in-market team.
2. Global scan of regtech and digital solutions.
3. Evaluation of the applicability of identified verification technologies to Australia's red meat supply chain.

The project was informed by the (completed) ISC project V.RDA:2001, Global Scan of Technologies and Systems Enabling Data Capture and Transfer across Red Meat Supply Chains.

Results and key findings:

Product integrity across the Australian red meat supply chain is underpinned by the National Livestock Identification System (NLIS), the Livestock Production Assurance (LPA), the National Vendor Declarations (NVD), and by the AUSMEAT language and quality assurance system. In addition to these core integrity programs are brands or production systems, including the National Feedlot Accreditation Scheme (NFAS) and the Pasturefed Cattle Assurance System (PCAS), and a range of state- or territory-based systems, such as the requirement for Queensland feedlots to comply with the Environmental Protection Regulation 2019. Importantly, the number of cattle being presented for Meat Standards Australia (MSA) grading also continues to rise and is now approaching 50% of all adult cattle slaughtered.

Consultation with both industry and MLA's regional in-market teams about Australia's approach to product integrity across the red meat supply chain highlighted the message that whilst the

possibilities associated with an automated red meat integrity system are appealing, emphasis should first be placed on completing the digitisation of the existing system. This action will yield greater efficiencies, reduced errors and improved data management and transfer. Enhanced data transfer will then lead to improved regulatory efficiency and better information for sales agents, producers, feedlotters, processors, customers and consumers and other participants in the red meat supply chain. The sense across this spectrum of stakeholders was that opportunity exists to gain substantial value from optimising the existing platform and communicating its strengths to both trading partners and overseas consumers. It was recognised, however, that the benefits of this are not likely to be uniform throughout Australia's export markets, with some relatively more receptive to existing technologies, such as product inserts and QR codes, or relatively more attuned to particular product attributes, such as sustainable production, animal welfare and the ethical treatment of staff. Notably, there have been recent movements by large retail groups (e.g. AEON Co. Ltd) to assess the potential value associated with communicating and verifying these attributes.

Consultation with industry and MLA's regional in-market teams identified the interoperability of the components of the current red meat integrity system, both in Australia and globally, as a key opportunity to improve the existing system. Central to this is the need for standards and an effective data ontology. The current level of integration between existing systems (including the NLIS, LPA and NVD) was perceived to be insufficient, with substantial hurdles arising from inconsistencies around regulatory and other requirements and underscoring a need for standards and definitions. This aside, Australia has demonstrated leadership in the digital connectivity of supply chains through initiatives such as the Meat Messaging system. The system, which is based on GS1 standards for numbering and bar coding of meat products, and the GS1 EANCOM electronic message standards, has enabled the issuing of electronic health certificates for exported product and is now in use for trade between Australia and the US. The integration of digital systems, such as the case with Meat Messaging, or the linking of existing processes to a digital system (e.g. link animal health treatments to NLIS), are widely viewed as the next logical step in the development of global integrity systems for red meat and agricultural products more broadly.

Beyond the continued digitisation and integration of the red meat of integrity system, industry stakeholders acknowledged the importance of research and development aimed at the more ambitious goal of fully integrated digitisation and automation. The ongoing CSIRO Supply Chain Integrity Digital Initiative was discussed, including work packages focused on automated farm provenance, product traceability and the verification of biological origin. Although much of this technology is at, or approaching, the point of commercialisation, the possible integration within Australia's red meat supply chain is likely to be deferred to the later stages of ISC's *Strategic Plan for the Integrity System 2025 and Beyond*.

The potential application of regtech (Regulatory Technology) was also reviewed. Regtech can be useful in settings where the regulatory environment is particularly complex or otherwise difficult to navigate or monitor. Regtech can also improve both regulatory compliance and the systematisation and efficiency of supply chain audits. For these reasons, regtech has marked potential for application across the touchpoints for regulation and certification within the red meat integrity system. Regtech developments are not, however, simple to implement, and would require an improvement in the consistency, standardisation and interoperability of the red meat industry's data streams and data structures. Drivers for this level of change will include an escalating requirement for more efficient regulatory compliance, as well as the market pull likely to be associated with an increasingly sophisticated and informed global consumer base.

Future research and recommendations

The intent of these foundational investigations was to identify processes by which Australia's red meat integrity system can progress from its current whole-of-life traceability design to a complete whole-of-supply-chain traceability system. Consistent with this intent is a need to articulate an equitable value proposition and subsequently incentivise all supply chain participants. The following recommendations are proposed to enable the ongoing evolution of Australian red meat integrity system in accordance with ISC's S*trategic Plan for the Integrity System 2025 and Beyond*:

1. Define the key global standards and ontologies that facilitate integration and interoperability of the verification systems currently underpinning Australia's red meat integrity systems.
2. Develop a more compelling and equitable value proposition for the current verification systems before incorporating new elements.
3. Identify and evaluate opportunities to adopt technologies/solutions that provide enhanced digitalisation and digital interoperability.
4. Pursue and adopt new technologies that enable a whole-of-supply-chain traceability system but only after 1, 2 and 3 are achieved and there is clear and compelling return on investment.

In light of these recommendations, and others arising from the foundational projects, some reprioritisation of the objectives within the ISC S*trategic Plan for the Integrity System 2025 and Beyond* may be required.

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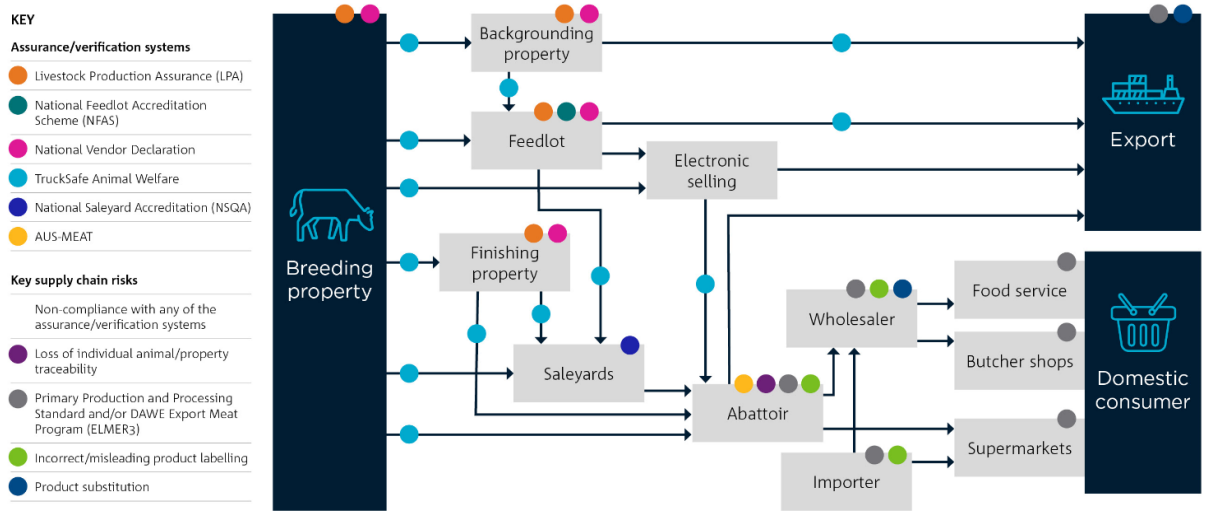
1. Background

Australia's red meat integrity system underpins the ability of Australian red meat supply chain participants to develop and maintain access to an array of global markets via the provision of assurances relating to food safety, product quality and whole-of-life traceability. Notwithstanding the reputation that Australia has as a provider of clean, green and wholesome products to these markets, there are further opportunities to grow the industry's competitive advantage through enhancement of the integrity system. As part of its S*trategic Plan for the Integrity System 2025 and Beyond*, ISC have identified three strategic pillars which are aimed at ensuring the integrity system continues to deliver the impacts desired by the industry, explores new integrity approaches and technologies, and maximises the value of integrity data to all supply chain participants. This report, in conjunction with that of project V.RDA.2001 (*Global Scan of Technologies and Systems Enabling Data Capture and Transfer across Red Meat Supply Chains*) describes the digital and biological concepts that may form the basis of a future integrity system. Whilst opportunities for integrity system advancement can be identified, it is imperative that the evolution of the system occurs within a process that is fully supported by all red meat supply chain participants and for which the value proposition is clear.

A schematic overview of the assurance and verification points in the red meat supply chain is given in Figure 1. This schematic also illustrates the risks associated with non-compliance.

Figure 1: Red meat supply chain risks and vulnerabilities



2. Objectives

The objectives of this project were to harness the relevant domain expertise within CSIRO Agriculture and Food, and Data 61, to:

1. Identify the key product claim attributes of Australian red meat that require product verification across domestic and international markets now and into the future.
2. Complete a global scan for frameworks and technologies used in other industries and countries for verifying product requirements for market and legislative requirements.

3. Determine what frameworks and technologies are automated and effectively used to manage market compliance.
4. Determine the likelihood of existing frameworks and technologies to be applied to the red meat and livestock integrity system including risks to success and mitigation factors.
5. Provide a comprehensive final report, along with a power point presentation summarising the project findings.

These objectives have been met.

3. Approach

The research component of this project had three key components:

1. Consultation with representatives of Australia's red meat supply chain and MLA's regional in-market team
2. Global scan of regtech and digital solutions
3. Evaluation of the applicability of identified verification technologies to Australia's red meat supply chain.

The project was informed by the (completed) ISC project V.RDA.2001, Global Scan of Technologies and Systems Enabling Data Capture and Transfer across Red Meat Supply Chains. ISC acknowledged that the outcomes of this completed work would satisfy Objective 2 (Section 2).

4. Results

4.1 Recap V.RDA:2001 – global scan of technologies and systems enabling data capture and transfer across red meat supply chains

4.1.1 Introduction

The overarching objectives of project V.RDA.2001 (**Global scan of technologies and systems enabling data capture and transfer across red meat supply chains**) were to:

- Describe and review relevant and best practice systems and technologies that enable traceability throughout red meat supply chains from both agricultural and non-agricultural sectors, and
- Provide recommendations and advice to ISC to inform future investment decisions relevant to data capture and traceability systems for the red meat sector in Australia.

To address these objectives, an evaluation framework that enabled a multi-factorial assessment of each technology cluster was developed. Table 1 details the six main factors (choice/control, convenience, community, completeness, compatibility, customer's cost) applied to evaluate the features, benefits and suitability of each technology cluster. A rating scale of 1-5 (1= least benefit; 5= greatest benefit) was used to assess each technology cluster for its potential benefit to the Australian red meat supply chain. An overall score is achieved by combining the ratings of each factor for each technology cluster.

Table 1: Technology evaluation framework applied in assessing tracking or tagging systems and technologies for use in the red meat supply chain in project V.RDA.2001

Factor	Feature	Benefit	Criteria
Choice/ control	Supply chain participants obtain greater choice or control from a new product or service.	Technology/innovation adoption rates increase across the supply chain.	• Added value • Traits being measured • Resolution/accuracy
Convenience	The technology/ innovation reduces the burden on the user whilst delivering equivalent or greater outputs.	Increased convenience facilitates the change process.	• Automation • Trust and security • Practicability • Data integrity
Community	The extent to which the technology/innovation addresses the breadth of supply chain correlates with the level of industry support.	Technology/innovation solutions that address greater portions of the supply chain will result in greater adoption levels.	• Whole or part of supply chain solution • Useability (traceability and management)
Completeness	Is the technology / innovation a new technical capability or a supply chain ready solution.	Technology/innovations that can be deployed into supply chains have increased industry appeal.	• Technology readiness level • Efficacy and broadness of applicability of tech
Compatibility	Can the technology / innovation operate in the existing integrity system.	Technology/innovations that are interoperable with existing systems yet scalable and futureproofed to emerging standards have higher adoption rates.	• Interoperability/ Scaleability • Futureproofing
Customer's Cost	The cost to acquire / implement the technology/innovation is derived from market pull considerations.	The value proposition for the technology/ innovation is understood.	• Cost-benefit • Who's paying?

The review identified that relevant technologies and systems fall into two key categories:

1. The digital architecture that tracks or traces products as they move along the supply chain, and
2. The technologies that verify the product is indeed what is claimed.

Technologies that verify a product can then be split into two sub-categories comprising:

a) Those that test the product to verify, and
b) Those that identify the product to enable verification.

Emphasis was placed on technology clusters that rate highly but are also less known to ISC and the sector and likely to bring an enhanced offering to multiple parts of the supply chain.

4.1.2 Digital platforms that track or trace product through the supply chain

Digital platforms for use in the red meat supply chain fall into two broad clusters: blockchain and cloud. The main difference between the platforms is that blockchain is typically characterised by a decentralised network of nodes aimed at recording agreed transactions between users in a supply chain. Cloud platforms, on the other hand, are typically centralised, controlled by a single company and designed to store data and information online. Cloud platforms can be further divided into cloud

platforms for business and cloud platforms for the whole supply chain with the platforms consisting of several modular traceability solutions that can be coupled together to provide the best supply chain solution.

Blockchain technology enables users to store information on a decentralised peer to peer network providing increased transparency, better user control and enhanced confidence around its ability to prevent fraudulent activities. Not surprisingly, examples of blockchain platforms in operation are more numerous than cloud-based systems for supply chain management. This is evident regardless of the supply chain being considered with many agricultural and non-agricultural examples available. Blockchain platforms rated highest when compared to the cloud-based platforms particularly for choice/control and convenience (Table 2).

Table 2: Tracking or tagging systems and technologies for use in the red meat supply chain

Digital platforms	Choice/control	Convenience	Community	Completeness	Compatibility	Customer cost	Overall Rating
Digital platforms							
Cloud platforms for whole supply chain	2	2	5	5	4	3.5	**21.5**
Blockchain platforms	4	3	5	4	4	3.5	**23.5**
Cloud platforms for businesses	3	2.5	2.5	5	4	3	**20**
Verifying the product through testing							
Hyphenated mass spectrometry	3	2	3	3	4	3	**18**
Elemental profiling (destructive)	2	2	2	2	3	3	**14**
Elemental profiling (non-destructive)	2	2	2	2	3	3	**14**
Ambient mass spectrometry	3	4	3	2	4	3	**19**
Federated spectroscopy and spectrometry	4	3	5	4	4	3	**23**
Spectroscopy (NMR)	4	2	2	2	3	2	**15**
Omics	5	3	4	2	3	3	**20**
Genotyping	4	4	5	4	4	5	**26**
Tracking or tagging the product							
RFID and GPS	4	3	5	5	4	3	**24**
Molecular tagging	4	4	3	5	4	5	**25**
Tagging	4	4	3	5	4	5	**25**
Anti-counterfeit/ tracking labels	4	3	3	4	3	4	**21**
Computer vision	4	4	3	3	2	2	**18**
GS1 product code applications	4	4	3	5	4	4	**24**

4.1.3 Technologies that test product for verification

Red meat products are often traded as a commodity with an expectation that the receiving market or customer is likely to transform the product into more retail ready formats. This process routinely separates the meat product from all its packaging and provides opportunity for food fraud activities to occur. In view of this, there is a need for technologies and systems that verify that a product

matches the digital record associated with it and furthermore, it complies to the provenance, safety and quality specifications being requested by the market or consumers.

Eight technology clusters associated with product verification were identified and rated, as shown in Table 2. Whilst there are some established technology clusters, such as genotyping and federated spectroscopy and spectrometry, the notable feature of the remaining clusters are the relatively low ratings for completeness. The low ratings stem from most technologies requiring yet to be developed databases for red meat supply chain applicability and the lack of field-ready or processing-ready solutions. These limitations are, to some degree, being addressed through industry-led initiatives for database development and via the miniaturisation of the test systems.

4.1.4 Technologies that track or tag product for verification

Being able to track food through all stages of the red meat supply chain, including production, processing and distribution is necessary to ensure that products entering markets meet expected quality specifications and safety standards. Additionally, it ensures unexpected events or outcomes can be adequately investigated and rectified. In Australia, traceability through to slaughter is achieved via the National Livestock Identification System (NLIS) where all livestock are identified by a visual or electronic eartag or device. The NLIS enables whole-of-life traceability of an animal that assists in ensuring access to global markets, maintaining consumer confidence and reducing the impact of livestock disease. Whilst this is readily achievable, the traceability of products from individual animals through processing remains highly problematic due to batch or lot-based identification strategies typically used by processing plants, distribution and retail.

Six technology clusters associated with the tracking and tagging of animals or meat products through the red meat supply chain were identified and evaluated (Table 2). The technology clusters are well known and at first glance it may appear that little has changed in recent times. However, there are improvements in several technology clusters that provide additional value to the supply chain or potentially enable the technology to overcome barriers to adoption.

4.1.5 Conclusions and recommendations from V.RDA.2001

An overview of the evaluations described in Sections 4.1.2 to 4.1.4 was given in Table 2 above.

Whilst high-rating opportunities for the Australia red meat sector were identified, and warrant further investigation, the project also found that a single supply chain solution does not exist currently and instead several solutions exist at each of the major supply chain stages. Furthermore, the choice of solution for a supply chain participant will be influenced by their relative position in the supply chain, the trust level between participants, and the value proposition attached to each solution. Thus, any complete whole-of-supply-chain traceability system will require multiple types of technologies and consequently, interoperability will be paramount.

In order to systematically progress the red meat integrity system from its current whole-of-life-traceability design to a complete whole-of-supply-chain traceability system, a set of preliminary recommendations for future action were given.

Recommendation 1: Define the overarching architecture of a complete whole-of-supply-chain traceability system for 2025 and beyond.

It was not anticipated that ISC would attempt to develop a ‘complete’ traceability solution by prescribing the traceability technologies or systems for the Australian red meat sector and supply chains. Rather, the recommendation was that ISC should continue to oversee the management of an

expanded traceability system by prioritising the development of the overarching digital infrastructure supporting a national traceability system and defining the standards and specifications for inclusion of identification/verification technologies and systems into this architecture. It was acknowledged that this recommendation correlated with ISC Foundation Project 1 (*Defining overarching requirements for the future state traceability systems in terms of objectives, data points, collection, storage and analysis*). This recommendation called for specific emphasis on standards that are central to the interoperability of traceability technologies/systems. It was considered critical that these standards undergo periodic revision commensurate with the evolution of new and potentially disruptive technologies. This will enable more rapid introduction and implementation of new traceability technologies.

Recommendation 2: Facilitate the extension of the red meat integrity system from whole-of-life to whole-of-supply-chain through evaluation of technologies that facilitate the traceability of the individual animal and its products through to the consumer.

Whilst individual animal traceability from birth to the end of the slaughter process is achieved via the existing red meat integrity system, it rarely continues through the remainder of the supply chain. Batch or lot identification beyond the point of slaughter is the limit of the current traceability system. Project V.RDA.2001 identified candidate technologies that would:

- deliver unequivocal traceability (e.g. genotyping)
- or may provide real-time, in-line traceability (e.g. ambient mass spectrometry)
- or generates tagged product that can be identified for the remainder of the supply chain (e.g. molecular tagging).

It was recommended that a more detailed evaluation of the applicability and value of the higher rating candidate technologies should be undertaken. Ideally, design-led principles should be applied in this further evaluation so that solutions address the needs of the red meat sector and the market.

Recommendation 3: Assess the potential for advances in key foundational technologies to alter the technological landscape by changing what is possible in supply chain traceability.

Developments in the areas of AI, IoT, blockchain, global payments and 5G provide opportunities for the evolution of existing supply chain solutions that ultimately broaden their scope of applicability. For example, the evolution of smart eartags has enabled additional functionality around animal management, biosecurity monitoring and provenance. There is an expectation that as traceability technologies evolve through the uptake of disruptive technologies, they will, as has been observed with the ear tag example, generate solutions with much broader supply chain scope. As necessary, candidate technologies with broadened supply chain scope or multiple functions should be assessed for value and practical applicability in the Australian context.

4.2 Consultation with industry and MLA's in-market team

4.2.1 Consultation with industry

The project team sought to gain the views of red meat supply chain participants by inviting producers, processors, retailers, government and industry bodies to participate in a stakeholder consultation process. The following invitation was sent to over 20 industry participants and interviews with positive respondents occurred between 19th August and 8th September.

> "*We are undertaking a project with the Integrity Systems Company of MLA to explore opportunities and overarching requirements for automated red-meat product verification*

and the development of key industry standards. Further details of the background and objectives for this and other foundational projects is outlined in the provided document (see PDF from Alex Ball)[1].

In the first stage of the project we are conducting stakeholder consultation to develop a clear view of the key product claims of Australian red meat that require product verification across domestic and international markets now and into the future. We also want to differentiate between those attributes that are generic and/or non-negotiable and those that may be more brand or market specific.

If you are willing to participate in the consultation process could you indicate a date and time over the next two weeks (19th Aug to 2nd Sept) where one of the project team could contact you to gain your insights and views. We anticipate that this will only take 15 – 30 minutes."

The participants that agreed to participate in the stakeholder discussions are listed in Table 3.

Table 3: List of participating companies

Company / Organisation
JBS Northern
JBS Southern
Teys
Stockyard
Australia Country Choice
Northern Cooperative Meat Company
Angus Australia
Coles Supermarkets
SALRC
Cattle Council of Australia
Sandalwood Feedlot
Greenhams

Each participating company was asked to respond to the following list of questions:

- What are the verification systems that apply (directly or indirectly) to your company or organisation?
- Given your knowledge of the current verification systems, what do you believe they convey in terms of the key product attributes of Australian beef and lamb to markets and consumers?
- What are the critical product attributes of Australian red meat that we must demonstrate?
- What are the key attributes that provide a competitive edge or differentiated value in our markets - now and into the future?
- Given your response, will the current verifications systems require additional elements and refinement?
- Are the relevant verification systems to your business effective? If not, what are the current shortcomings and opportunities for improvement?
- Are the existing verification systems, or components thereof, amenable to automation?
- What challenges do you foresee with the automation of these systems?

[1] Please contact ISC for a copy of this introductory letter

A summary of the stakeholder interviews is provided below.

Verification systems

The Australian red meat supply chain is underpinned by the NLIS, the Livestock Production Assurance (LPA), the National Vendor Declarations (NVD), and by the AUSMEAT language and quality assurance system. Away from the core group of integrity programs there were other systems highlighted that related to brands or production system certification. These included the National Feedlot Accreditation Scheme (NFAS) and Pasturefed Cattle Assurance System (PCAS). It was also noted that branded beef programs may have systems in place that align to the standards of NFAS or PCAS though they do not seek accreditation under the specific scheme. The number of cattle being presented for Meat Standards Australia (MSA) grading continues to rise and is approaching 50% of all adult cattle slaughtered with all supply chain participants aware of the value that the MSA brand generates thereby making it a must for all branded beef programs. State based systems such as the requirement for feedlots in Queensland to have an environmental management plan which ensures all methods used in those feedlots are approved under the Environmental Protection Regulation 2019.

Importance to markets and consumers

The overriding belief from all supply chain participants was that consumers are aware that the industry has in place a range of verification systems that ensures the safety and quality of red meat products nationally and globally, however they have very little knowledge or line of sight of the systems themselves and their impact on the end product. Indeed, a number of participants believed the systems were of greater benefit to the industry than consumers, but they did create trust for the consumer. Consumers are beginning to seek out additional information from supply chains and this is particularly evident in branded beef programs. To date though, this level of information is focused on telling the story of the product rather than conveying messages on the compliance of the supply chain to various systems.

The importance of verification systems to markets is more tangible to supply chain participants, although it is not a 'one size fits all' approach with markets having differing requirements which are typically linked to value. That is, low value markets place a lower emphasis on verification systems whereas higher value markets often have requirements for a set of systems that verify additional emerging product attributes. This inherent market variation presents a challenge to the design and refinement of generic verification systems. There is also a perception within the industry that whilst Australia trades on the premise of being a provider of clean, green and wholesome foods, there is an emerging need to ensure these claims are evidence based.

Critical product attributes of red meat that must be demonstrated

Safety remains the number one attribute that must be demonstrated for all products, although it is not the main driver of repeat purchasing by consumers with quality and the sensory experience being of greater importance. Compliance with the LPA and MSA is expected to deliver product of acceptable standard to consumers and is viewed as the baseline production standard for the industry to aspire to. Provenance, animal welfare and sustainability are viewed as emerging attributes. Whilst there was some support for the inclusion of metrics associated with these emerging attributes in existing verification systems, it was more broadly accepted that brand owners will drive development of standards that support these product claims. This is particularly the case where aspects of the animal production system are not considered as critical to all animals or all markets. Importantly, there was a consistent view from respondents that there needs to be greater emphasis on promoting the value proposition of the existing verification systems before pursuing

the incorporation of additional product attributes. Finally, in addition to verifying critical and emerging product attributes, end to end traceability has the potential to provide a competitive edge in global markets.

Are the relevant verification systems effective?

There is general acceptance that current verification systems have enhanced the industry's offering and assist in supporting Australia's image as a clean, green producer of wholesome foods. That said, all participants were able to demonstrate shortcomings and opportunities for improvement with many commenting that the industry should master the current systems before embarking on their evolution. The largest area of concern for industry participants is around the use of NVDs, with all processors reporting they employ 0.5-1 FTE at each plant to address concerns about the quality and/or completeness of NVDs. The roll-out of eNVD was expected to resolve some of these issues, however take-up has been slow with version control, connectivity, and age of producers/farmers seen as adoption barriers. It is widely accepted that the value proposition associated with compliant use of NVDs is not being conveyed to producers. Others in the supply chain must take additional steps to educate producers of the value of conveying accurate information to the entire supply chain.

Most supply chain participants noted a lost opportunity associated with current verification systems and their inability to provide additional value across the supply chain. Those that generate products for less mature and lower value markets view adherence to existing systems as a compliance exercise and not one that provides a level of assurance for the entire industry. The current level of integration between existing systems (e.g. the NLIS, LPA and NVD) is perceived as insufficient with substantial hurdles associated with the intertwining of Commonwealth and state or territory jurisdictions. Inconsistencies around standards and definitions were also noted with certified and non-certified standards in operation for pasture fed animals, for example. The language used to convey grading outcomes and critical attributes through the supply chain and particularly to the consumer is inconsistent and efforts to harmonise and standardise descriptors should be considered a priority exercise before evolving current verification systems.

Are existing verification systems amenable to automation?

A general message from all participants interviewed was that it is first necessary to complete work to make the language used in standards (i.e. AUS-MEAT, SAFEMEAT) consistent and harmonised as this will underpin future automated solutions. This feedback was most pronounced from producer respondents and did tail off as you move through the supply chain with processors believing automation of traceability (beyond the slaughter floor), some meat inspection services (offal inspection) and optimisation of shelf life specifications in export markets are feasible. Some processor respondents discussed technologies and systems they were currently evaluating in this context. There is, however, strong appetite for the development of integrated, interoperable and cost-effective digital solutions that provide enhanced data transfer across the supply chain and provide additional efficiencies, value and opportunities for continual improvement across the supply chain. The industry can identify activities (e.g. production of health certificates) that cost in excess of $100M per annum that could directly benefit from the development of cost-effective digital certification systems. There is also a sense that automation could provide opportunity for trading governments to move to a systems-based audit process thereby allowing the Commonwealth government to provide consistency within plant inspections which would enable uniformity for the industry.

What are the challenges associated with automation of these systems?

Two main areas were identified that create the greatest challenges to adoption of automation. The first of these relates to the role of producers in accurately recording and transferring information at the start of the supply chain. Whilst the rationale for automated or at least digitised verification systems on-farm is clear, there are clear barriers associated with digital connectivity and the typical age of many producers – with the latter only solved by generational change. The other challenge is to develop and implement systems that are cost-effective. The value proposition that creating more robust systems that communicate a greater range of product attributes to markets and consumers always results in greater product value is not accepted and therefore further development of verification systems must result in a reduction of compliance costs across the supply chain. However, it may also be the case that the creation of advanced verification systems may not provide immediate benefits but instead futureproofs the industry.

4.2.2 Consultation with MLA regional in-market team

Previous discussions with supply chain participants within Australia identified the critical product attributes that must be demonstrated to markets and consumers, the verification systems being utilised to achieve this, the effectiveness of those systems, and the opportunities and challenges for the red meat integrity system now and into the future. MLA have an international markets team that operates to improve and maintain market access and grow demand for Australian red meat products. MLA achieves these objectives by having sub-team offices in priority export markets including Japan and Korea, China, USA, UK and Europe, and the Middle East and North Africa. In order to gain the perspectives of the in-market teams invites were sent to each regional team to participate in the in-market consultation process.

The participants that agreed to participate in the stakeholder discussion are listed in Table 4.

Table 4: MLA regional teams

Regional team
Japan/Korea
China
USA
UK and Europe
Middle East/North Africa

Each regional team was asked to respond to the following questions:

1. Within your region/market, what do you believe the current product verification systems convey in terms of the key product attributes of Australian beef and lamb to markets and consumers?
2. What are the critical product attributes of Australian red meat that we must demonstrate?
    - What are the key attributes that provide a competitive edge or differentiated value in our markets - now and into the future?
    - Given your response, will the current verifications systems require additional elements and refinement?
3. Are the relevant verifications systems effective? If not, what are the current shortcomings and opportunities for improvement?
4. Have you observed emerging trends, technologies or systems relating to product traceability and/or verification that warrant closer evaluation from an Australian red meat perspective?

What do the product verification systems convey to the market?

It was broadly acknowledged across all regions that consumers do not understand the individual systems that underpin Australia's red meat integrity system. Similarly, the regional markets and their associated supply chain participants are also generally unaware of the specific systems in place. Whilst individually the systems are not recognised or well understood, they do achieve a clear and recognised aggregated impact in terms of integrity, traceability, and safety. Significantly, this view persists regardless of the relative value of Australian products compared with local or competitors' offerings. The acceptance of what Australia's integrity system delivers to global markets does drive premiumisation in Asian markets but not in less advanced markets such as the Middle East and North Africa, or in markets such as the UK, Europe and USA where there is strong emphasis on buying local product.

Critical product attributes of red meat that must be demonstrated

Demonstrating country of origin is a key focus in all markets and reinforces the underlying reputation-based credentials that consumers associate with product from particular countries. In Asian markets, the presence of Australian red meat is indicative of product that is clean, green and safe, and consumers subsequently concern themselves with the quality of the product as the primary driver of purchasing decisions. Product entering Middle Eastern and North African markets must contain an insert in each vacuum packaged item detailing the country of origin and other traceability attributes. The Middle Eastern and North African markets are complex, with product being received from almost all red meat exporting countries. This results in the receival of product produced under highly variable levels of integrity and modernisation. Consequently, there is substantial focus on shelf-life of products with country-specific regulations on the length of time fresh product can be sold at retail. The use of product inserts therefore provides an enhanced level of traceability whilst also ensuring Australian products generate prices that reflect the integrity system and the quality of product it produces. In the UK, Europe and USA, the emphasis is on meeting customer requirements and demonstrating compliance. Australian products often occupy niche sectors and the ability to demonstrate attributes such as antibiotic or hormone free, organic and certified grass-fed are essential and efforts to automate or streamline these compliance processes are essential for the ongoing competitiveness of Australian product.

Looking forward, the extent to which markets will require additional attribute verification appears to be specific to regions. There is an increasing profile for attributes such as sustainable production, animal welfare and ethical treatment of staff in the UK, European and USA markets although these attributes remain mostly attached to the marketing of a product rather than as a component of a verification system *per se*. Whilst Asian consumers view sustainability and animal welfare as important there is an absence of market demand for products demonstrating these attributes. That said, there have been recent movements by large retail groups (e.g. AEON Co. Ltd) to assess the potential value associated with communicating and verifying these attributes. As the Middle Eastern and North African markets continue to develop, it is unclear if these will place emphasis on the demonstration of product attributes over and above other markets. However, these markets do contain a large young, well-educated and well-travelled population and therefore changes in these markets may occur rapidly and will likely reflect all other markets.

Are the relevant systems effective?

The systems are effective in that they have paved the way for Australia to trade globally with an enviable reputation. However, a clear message from all markets was that Australia should attempt to better communicate what systems are in place for verification and traceability and what do they

achieve. For example, products entering the Chinese market have requirements around traceability which are clearly met by Australia's integrity system. Products from competing regions (e.g. North and South America) also meet these traceability requirements by focusing on their post-processing traceability systems. The resulting consumer assumption is that the traceability systems of products being imported into China have equivalent traceability which means Australian producers do not achieve additional value for the whole-of-life traceability system in place. The focus of the Middle East and North Africa on the shelf-life of red meat products is perhaps one area where the effectiveness of Australia's integrity system does create additional value. In these markets, Australian product can be sold fresh for longer durations than product from some competing regions. This outcome is crucial as it offsets the shorter supply chain times that the other regions benefit from and ensures reasonable timeframes are available for Australian product to move through commerce.

When considering shortcomings and opportunities, there was strong consistency with the feedback from the domestic consultation process in terms of a need for better integration of existing systems rather than a desire for a completely updated approach. The UK, European and North American regions noted opportunities and risks around ensuring the Australian integrity system can demonstrate equivalency with local systems. Emphasis should therefore be placed on the harmonisation of systems and language to ensure that the interface between trading regions is as seamless as possible. Similarly, China's announcement of plans to develop a unified agricultural food traceability platform, and to develop standards and procedures for the traceability of agricultural products and foods, highlights the need to ensure any attempt to evolve Australia's current integrity system prioritises integration with global systems.

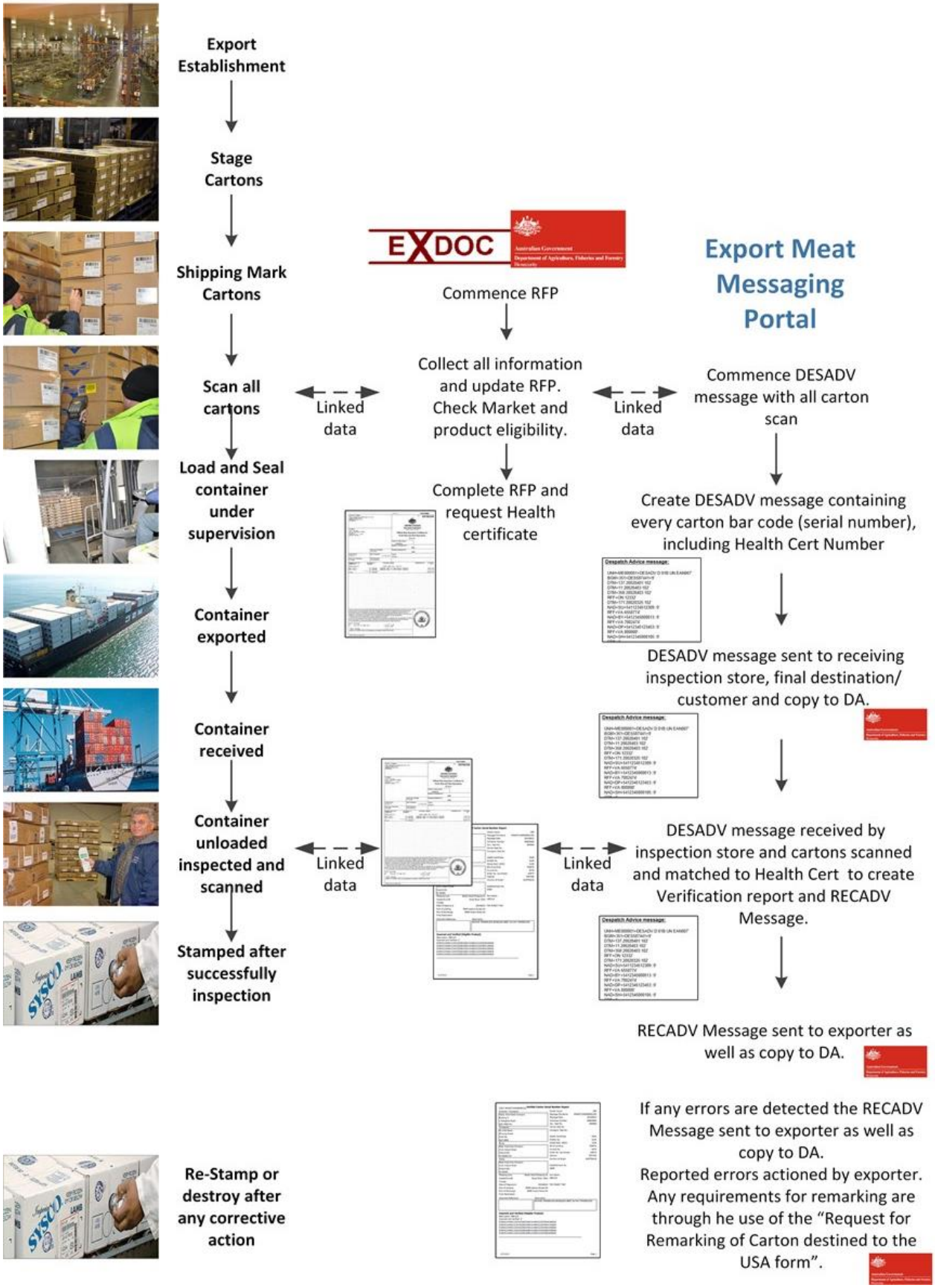
Emerging trends, technologies or systems relating to traceability and/or verification

Australia's position as a world leader in red meat integrity systems means that other regions are more likely to be investigating technologies or systems that enable equivalency with Australia as opposed to superseding our systems. Consequently, specific technologies and systems warranting further evaluation by Australia were not easily identifiable. Traceability through to consumer, and sustainability, have emerged as key focus areas in many regions although consumers are presently concerned with the story of the product and not the absolute ability to verify either attribute. Interestingly, this shift may be more pronounced in the less advanced Middle Eastern and North African markets where supply chain participants are taking advantage of the product inserts and using more advanced labelling technologies (e.g. QR codes) to communicate the story of the product as far into the supply chain as possible. Conversely, traceability systems in markets such as Japan and China result in a substantial portion of Australian product entering retail as 'true Aussie beef' or 'brand Australia' which lessens the ability of specific Australian brands to convey messages of product attributes to consumers.

Digital systems and connectivity are viewed as the next areas of development in global markets. Perhaps unsurprisingly, Australia has demonstrated leadership in this space through the development of the Meat Messaging system (Figure 2). The system, which is based on GS1 standards for numbering and bar coding of meat products, and the GS1 EANCOM electronic message standards, has enabled the issuing of electronic health certificates for exported product and is now in use for trade between Australia and USA. The benefits to the Australian red meat industry are estimated at >$AU18 million per annum through the elimination of ineligible products due to unreadable shipping marks. The integration of digital systems, such as occurs with Meat Messaging, or the linking of existing processes to a digital system (e.g. link animal health treatments to the NLIS), are widely viewed as the next logical step in the development of global integrity systems for red

meat and agricultural products more broadly. Furthermore, they remain consistent with the views of Australian supply chain participants which believe there is opportunity to move to a systems-based auditing process that is driven by the integration and automation of verification systems.

Figure 2: Shipping mark verification model using Meat Messaging



Source: https://meatmessaging.info/iots/menu2_4.asp

4.3 Global scan

4.3.1 Introduction

This section provides a global scan of how other industries are engaged in the task of establishing whole-of-supply-chain traceability for their supply chains in the context of demonstrating compliance with regulatory and market requirements. This section also discusses the impact of the general compliance burden on business operations, outlining the emergence of a category of technology called 'regtech' in response. A distinction is drawn between regtech products, and how existing systems manage compliance and are integrated into the task of managing traceability.

Although each industry faces a different set of conditions and challenges, and each has approached the task differently, some common lessons/themes across industries can be discerned that are relevant in the evolution of traceability systems within the red meat sector. These include:

- Drivers of traceability are typically regulation, consumer expectations and business process efficiency
- Collective effort/representation through industry groups is highly-effective in generating progress
- The need for interoperability and standardisation is required to deal with complexities of integrated supply chain traceability and meeting compliance objectives
- GS1 is widely deployed as a means of standardisation across industries to facilitate interoperability for traceability and compliance
- Understanding the benefits of interoperability, and limitations in evaluating interoperability, are barriers to technology adoption and therefore highlights the significant work required to enable the 'buy-in' of supply chain participants.

A further case study for automated farm provenance illustrates how the latest technologies can be combined to provide new capacity for traceability and verification in aid of meeting regulatory obligations and market requirements. The combination of this case study; the industry analyses, themes and lessons; and an understanding of current versus emerging methods of compliance management with technology, gives an holistic perspective of how the red meat integrity system can progress from its current whole-of-life-traceability design, to a complete whole-of-supply-chain system.

4.3.2 The cost of compliance to business and growth

The accumulation, complexity and pace of change of regulation is creating a significant compliance burden on the economy. Some estimates put the annual cost of compliance on the Australian economy at $250 billion, with organisations diverting ever increasing amounts of resource to managing it (Deloitte, 2020).

It is important to acknowledge that this burden affects small to medium sized businesses more disproportionately than it does large business. A recent survey of 709 businesses, mostly of small-medium size (1-49 employees), by the Australian Chamber of Commerce and Industry found the following (ACCI, 2015):

- Nearly half (47%) of businesses reported the impact of regulation had prevented them from making changes to grow their business
- 25% of respondents spent 11 hours per week on compliance tasks (more than 1 day)
- 30% of businesses put the cost of complying with regulation at $10,000 to $50,000 per year
- 50% were unable to pass the cost onto consumers

- Record keeping, completing forms, implementing and practicing regulatory obligations were deemed the top three most expensive compliance activities.
- The top three areas of most complexity of compliance were;
    - Workplace health and safety
    - Workers compensation, employee wages, conditions and superannuation
    - Industry specific regulations (e.g. food safety standards)
- The most prominent methods of finding information were via:
    - Professional advisers/external consultants (costs money)
    - Chambers of commerce (costs time)
    - Self-led searching (costs time and money)
    - Enquires with relevant departments or agencies (costs time).

For participants in the red-meat industry, the value proposition associated with compliance can vary significantly depending on the market focus of a business. Consequently, a lack of benefits versus cost is typically cited as a barrier to technology adoption. A deeper understanding of the above dynamics as applied to the red meat supply chain for players of differing sizes and resourcing capabilities would be useful to frame future work particularly in relation to delivering against the objectives of the ISC 2025 Strategy.

4.3.3 Application of regtech

The Productivity Commission's recent information paper on regulatory technology provides a useful starting point for understanding this category of technology. The following are relevant excerpts from the paper (Productivity Commission, 2020).

Regulatory technology ('regtech') is the use of technology to better achieve regulatory objectives. Used well, it can support the improved targeting of regulation and reduce the costs of administration and compliance. The regulatory compliance costs potentially incurred by individuals and businesses are related to:

- Assessments, approvals, authorisations or accreditation for products, processes, occupations, business operations or activities (for example, permits, certifications, development approvals, registrations, licensing or other permissions)
- Reporting and conduct obligations, including to a regulator and to the public or customers
- Industry code of conduct requirements
- Inspections, audits and investigations.

Leading-edge regtech involves the use of data for predictive analytics and real time monitoring, enabling better regulatory outcomes and potentially fewer compliance burdens for businesses. But advanced regtech can require specialised resources and long development times.

Even in low-tech applications, widespread implementation of regtech can take some years. It can require substantial investment by regulators and businesses in capacity and cultural change while (as with technology solutions generally) enumeration of the scale and timing of the benefits can be difficult.

When is regtech useful?

There are four key areas where regtech solutions may be particularly beneficial:

1. Where regulatory environments are particularly complex to navigate and monitor
2. Where there is scope to improve risk-based regulatory approaches, thereby targeting the compliance burden and regulator efforts

3. Where technology can enable better monitoring, including overcoming constraints related to physical presence
4. Where technology can safely unlock more uses of data for regulatory compliance.

Creating and maintaining a regulatory environment that supports the realisation of regtech benefits would mean:

- Improving the consistency and structure of data and the interoperability of, and standards for, technology — these are precursors to wider regtech adoption investing in the technical skills and capabilities of regulators to enable measured steps in regtech adoption;
- Determining accountability for outcomes associated with regtech solutions, including privacy, data security, and responsibility for resolving disputed outcomes;
- Reviewing regulation to remove technology-specific requirements that could prevent the take-up of beneficial regtech solutions;
- Creating familiarity with the possibilities of regtech (for example, through liaison forums and trials), facilitating collaboration between regulators, regulated entities and regtech developers, and establishing safe environments to develop and test regtech solutions.

What are the benefits of regtech?

For businesses, regtech may free up resources for more productive uses. Specifically, it may:

- Reduce the time needed to identify and understand regulatory requirements, with an associated reduction in the risks and costs of non-compliance
- Reduce the time and financial costs (including lost business opportunities) associated with gathering information, form filling or record keeping, and the provision of information and data to demonstrate compliance or enable the regulator to deliver a desired regulatory outcome
- Generate a range of additional benefits for the business.

Use of technology to reduce the administrative costs for, and improve the efficiency of, regulators are equally important to consider, as regulators are often able to facilitate and drive change. Technology, particularly when combined with data collection and analysis, can help regulators to increase their internal efficiency and improve regulatory effectiveness. The increased use of technology by regulated businesses and individuals adds pressure for regulators to also operate in faster and more sophisticated ways. In some areas, traditional regulatory approaches may no longer be effective in a more digital environment. As is the case with regulated entities, the capacity of regulators to adopt technology will depend on their initial capabilities and the time and money they are able to invest in new approaches that support regtech.

For regulators, regtech can enable:

- More timely and useful communication between regulators and regulated individuals/businesses to enable a better understanding of individual/business needs and activities, and facilitate avenues for compliance and non-compliance recourse
- Increased volume, variety, speed and accuracy of data available to monitor marketplaces and compliance with regulatory requirements, enable near real-time decision making, undertake more targeted risk assessments (including development of predictive models of non-compliance and harm), identify systemic risks, and be a catalyst for innovation
- Standardised regulatory processes and tools to make it easier to coordinate cross-jurisdiction and cross-sector regulatory supervision, and to help bring about regulatory redesign when necessary.

How can the red meat sector benefit from regtech?

The above benefits to regtech adoption are generic and the red meat sector can be expected to reap similar returns in terms of efficiency and accuracy of information collection and distribution in aid of regulatory outcomes. The key benefit of applying better technology to regulatory pursuits is a saving in time and cost on this area of the business, that although crucial, is one that is not geared toward growth. Business can subsequently re-direct resources to more pressing business needs.

4.3.4 Managing regulatory obligations and market requirements

Core elements for traceability and verification systems and frameworks

A holistic operating framework that would systematically capture traceability and verification requirements for an industry supply chain should contain the following four pillars (Frost and Sullivan Global, 2018). The lessons of the global scan below show the need for these elements of the architecture to interrelate and interoperate is paramount in achieving effective traceability and compliance.

1. **'Critical Tracking Event' technology (CTE)**: Data capture or data carriers such as bar codes, Radio Frequency Identification (RFID) tags and scanners, Global Positioning Systems (GPS) and other Internet-of-Things (IoT) devices.
2. **'Key Data Event' Information Systems (KDE)**: Software encompassing a data capture interface, data repository and data query interfaces. Systems that can utilise common frameworks like GS-1 Electronic Product Code Information Service (EPCIS) standards enabled greatly enhanced traceability capabilities. For example, Enterprise Resources Planning (ERP) systems can meet these needs well (see below). Emerging technologies like blockchain are providing next generation data capture and sharing between supply chain participants.
3. **Authentication Technology**: Profiling/fingerprinting forensic technology including DNA sequencing and qPCR analysis; infrared (IR) and near IR spectrometry; nuclear magnetic resonance (NMR) spectroscopy; mass spectrometry (MS), fluorescence, spectrometry, terahertz spectroscopy, etc.
4. **Certification Services**: Certifying agencies for geographical origin labelling, species analysis, direct equipment sales, other profiling services such as ethical sourcing, sustainability, unique ingredients, religious codes and anti-fraud services.

Technological base case

Technology deployed by participants in supply chains is commensurate with their size and available resources (people and technology). Smaller players typically deploy less sophisticated systems, whereas larger players can afford more resources in terms of people, processes and technology. Regardless of size and resources, many organisations still deploy manual and paper-based processes which are typically supported by generic technology tools like spreadsheets.

More sophisticated compliance management practices see the deployment of Governance, Risk and Compliance systems (GRC). GRC functionality maps regulatory/market requirements to business risks and then maps control processes against these. Control processes are designed to collect evidence/data to substantiate compliance. Specialist compliance staff administer these systems and processes. In order to ensure compliance, firms must also develop and maintain systems that produce reliable data and that facilitate self-audit and testing on a continual basis. Automation is common in order to minimise errors and therefore improve the timeliness of internal control processes.

GRC products can be standalone software products, or form part of an organisation's installed IT systems, such as their Enterprise Resourcing Planning (ERP) systems. ERP software offers a set of tools that share a common process and data model, covering end-to-end operational processes within a business, such as accounting, analytics, inventory management, customer relationship management (CRM), and human resources (HR) management. ERP software unites otherwise segregated processes into a central data network, helping businesses track information while gathering insights from across the business.[2]

Appendix 1 sets out in more detail the features, functions and benefits of deploying systems like these and the competitive advantages that can result. Also, the current trends suggest that this technology is becoming more affordable and accessible.

Applications of ERP/GRC to traceability and verification management

ERP systems can enhance visibility and transparency of business processes. From acquiring materials or products for production through final delivery to customers, organisations must be able to track material flow to meet compliance guidelines. Features can include, but are not limited to the following:

- Trace a product's life cycle
- Record retention
- Inspection controls – store and track evidence of tests performed to ensure materials meet quality standards operator maintenance facilities
- Control numbers – assign a unique identification number to raw material receipts and production batches
- Equipment controls – documented proof of calibration and testing equipment used in the production process that can affect product quality
- Document controls – manage and track documents such as engineering specifications, material specifications and operating procedure
- Segregation of duties
- Data encryption
- Audit trails – records of data changes and the users responsible
- Electronic signatures – secure transactions by authenticating the operator who is performing the transaction.

The functionality of ERP/GRC systems place them in the KDE category of technology described above. As more sophisticated CTE technologies are deployed across the supply chain (those which generate data in the field like IoT devices), the ability to collect this data for analysis and business decision making will become important, especially regarding the verification of compliance obligations and market requirements standards.

4.3.5 Case study: beef industry

The CSIRO Supply Chain Integrity Digital Initiative is developing and validating technologies for future supply chain integrity that can enhance brand trust, privacy and efficiency for red meat producers. The second phase of the project has three work packages focusing on automated farm provenance, product traceability, and biological origins.[3] This use case is a good example of what is possible in the future within the red meat sector.

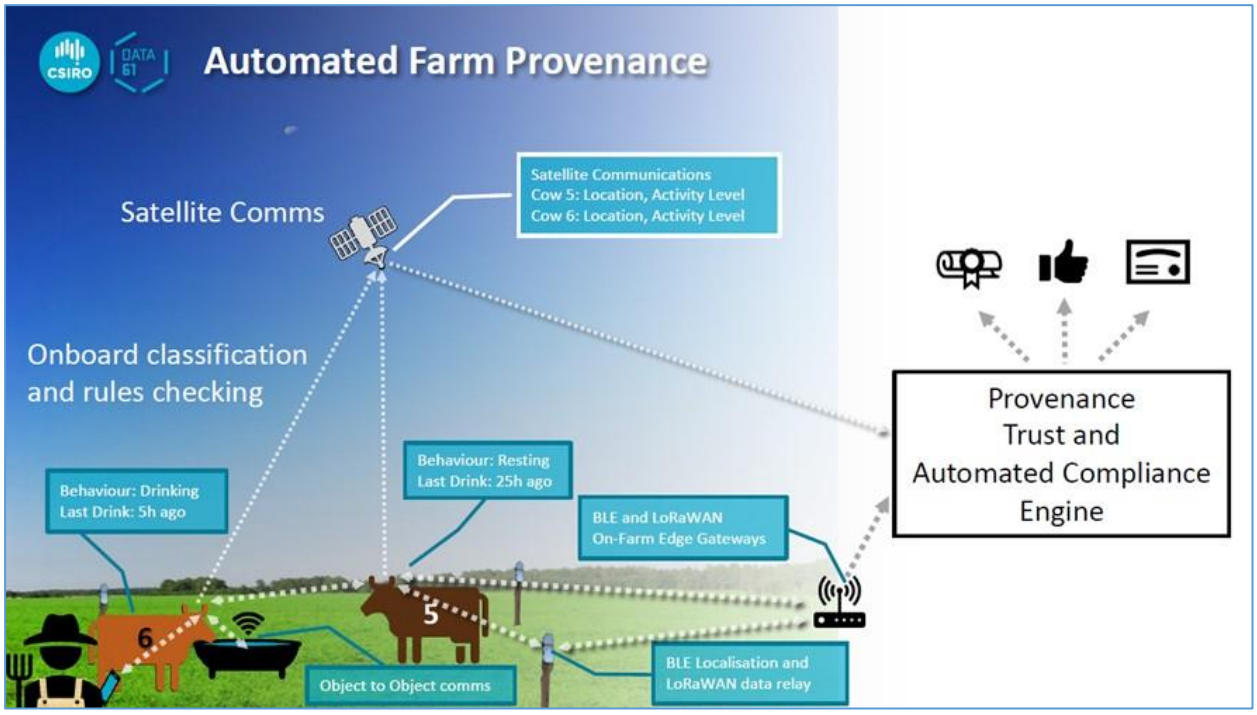
[2] https://www.softwareadvice.com/erp/#buyers-guide

[3] This research is supported by the Science and Industry Endowment Fund

Automated Farm Provenance

The aim of the automated farm provenance work package is to develop novel solutions for future on-farm data provenance, data trust and automated compliance to increase price premiums through improved efficiency and consumer trust and decrease compliance costs for producers. To validate the developed solutions, an automated farm provenance demonstrator has been designed (Figure 3). This demonstrator enables automated collection and communication of data from multiple interconnected devices and sources (e.g. smart devices on animals, devices on farms and data in the cloud) in a reliable and secure manner. For the development of the provenance, trust and compliance algorithms, on-farm livestock trials were conducted to produce annotated data of animal location, movement, behaviour, welfare state and herd dynamics.

Figure 3: Components of the automated farm provenance demonstrator



Data provenance: To achieve data provenance, an immutable record trail of data has been generated that accounts for the collection and processing of the data using blockchain technology. A private blockchain and distributed database are employed by the edge gateways deployed on the farm to store distributed, immutable records that are also replicated to the sensor data cloud platform. The authenticity of the data sources has been achieved through data encryption and authentication.

Data trust: Although automating data collection improves data trust, it does not guarantee that the collected data is accurate. Additional trust and reputation mechanisms that corroborate direct and indirect evidence that support the data source and the collected data are required to underpin trust in the data. For improving the security of the data stored on the private blockchain, block hashes are pushed to a public blockchain.

Automated compliance: Currently, regulatory compliance is a laborious task mostly relying on manual data gathering, inspection and audits, and reporting. Non-compliance can have significant impacts on the supply chain resulting in fines, reputation damage, and market loss. Automated compliance can reduce the regulatory burden for producers by employing new technologies for automating the compliance process. By employing logic and rules to automatically determine

compliance against standards and guidelines, automated compliance promises to reduce the dependency on manual reporting and inspections and reduce the risks of non-compliance by improving the correct determination of compliance. As part of the demonstrator, a sample set of welfare standards/guidelines from The Australian Animal Welfare Standards and Guidelines for Cattle, and Meat Standards Australia™ Standards Manual Section 5: Livestock Supply have been digitally codified into a set of compliance rules focused on animal handling, water access, feeding and animal transport.

The integration of the automated farm provenance components has been validated on a multi-agent simulator that is developed for generating novel representative farm data and enabling the flow of data similar to the communication paths that would be achieved in a real-world demonstrator.

Product Traceability

The aim of the product traceability work package is to enhance traceability in the red meat supply chain with a focus on transport and processing of products.

Traceability during processing products: In a red meat processing facility, individual meat pieces from different animals are aggregated and disaggregated, and tracing individual pieces is a challenging task. A novel computer vision algorithm has been developed for enabling the traceability of individual meat pieces back to the source animal during processing. A machine learning algorithm developed using video images captured in a mock facility setting tracks individual pieces of meat through the production process to the source animal.

Traceability during transportation: During the transportation of products in the supply chain, anomalies, data errors, and fraudulent events can be detected based on the status of the products and analytics. As part of the product traceability work package, low cost and low environmental footprint vibration energy harvesting sensors have been developed to provide real-time status updates. These sensors do not require batteries and generate the required energy from the physical movement of products during transportation. To improve the visibility of the status of the transported products, vibration energy harvesting sensors have been used to collect data from frozen meat transport routes in south-east Queensland, working with the Australian company BeefLedger. The collected data is processed to characterise normal transport routes, and to detect anomalies and potentially fraudulent events. Furthermore, a situational awareness model has been developed to identify anomalies, missing data, and fraud based on the supply chain traceability data and the rules on how products are transported in the supply chain.

Biological Origin

The aim of the biological origin work package is to identify unique biogeochemical signatures or markers that can be used with confidence to validate biological origin and determine geographic origin of food products for provenance traceability and authenticity assessments.

Identification of markers or signatures: As part of the work package, unique biogeochemical signatures or markers (e.g. geochemical, biochemical, isotopic, lipidomic or genomic) for Australian cherries and beef have been explored. The cherry samples have been analysed for biogeochemical signatures using conventional laboratory methods (ICP-MS/OES and GC-MS) and portable sensing devices (vis-NIR and pXRF), while the beef samples have been analysed for their biogeochemical signature using portable sensing devices (vis-NIR and pXRF) and for their genomic markers. The datasets generated by the analysis of Australian cherry and beef samples have been used to develop a model to predict the biological signature or marker of a product grown in a distinct region.

Privacy-preserving distributed learning model for biological origin: Initially, a distributed learning model for predicting the regional provenance of Australian cherries has been developed. Since, the data used by the model is the private data of producers, it is important to preserve the data privacy. The developed model preserves the privacy of producers by ensuring that the data regarding the individual farms cannot be deduced from the model and the producers have full control of their data. The learning model will be adapted to beef use case.

4.3.6 Case studies: other industries

Table 5 shows that most industries find it difficult to grapple with the component parts of traceability frameworks. What is clear is that for most industries, interoperability of systems and data, centralisation, data integrity and security are all particularly hard to implement. The following industry-specific analysis helps contextualise some of these challenges and highlight what these industries are doing to achieve better traceability and compliance outcomes.

Appendix 2 contains a further summary of industry capabilities mapped to specific traceability framework components. An indicative appraisal of the beef industry has been added to enable a comparison of the industry's strengths and weaknesses. Appendix 3 contains a list of example technology companies in traceability and verifications.

Table 5: Headwinds driving traceability market growth

Headwinds	Auto	Aerospace and Defence	Food and Beverage	Consumer Packaged Goods	High Tech	Pharma-ceuticals	Medical Devices
Integration of diverse data sources and conversion of data into insights	High	Med	High	High	High	High	High
Blurred returns on capital employed (ROCE) restrains adoption	Med	Low	Med	Med	Low	Med	Med
Supply chain integration onto one common platform requires investment, IT expertise, etc.	High	Low	High	High	Med	High	Med
Business process automation (local and global) mandates change management policies	Med	Low	Med	Med	Low	Med	Med
Event integrity, reliability, and security issues continue to question investment rationale	High	High	High	High	Med	High	High
Lack of open systems and heavy competition ring-fences marketplace	Med	Low	High	High	Med	Med	Med

Source: Frost and Sullivan (2013). Finding Value Beyond Compliance: The New Dimension of Traceability. Critical Business Imperatives that Drive Incremental Changes in traceability Markets.

Automotive industry

Industry characteristics: The global automotive industry is dominated by large corporations with subsidiaries, business units, and divisions operating world-wide.

Production trends have shifted to outsourcing production of individual components to suppliers around the world. This has resulted in complicated supply chains where information about a vehicle's componentry is dispersed across many businesses. The global parts manufacturing capacity is estimated to be 2 trillion parts, with approximately 20% of components being traced (or 400 billion). To manage this volume requires strong data platform strategies for cost-effective recalls and operational cost control. As such, firms in this supply chain require information sharing as a prerequisite to conducting business (Bhatt et al., 2016).

Drivers of traceability: The main drivers of traceability in the automotive industry stem from regulatory requirements and business process efficiency, and include the following;

- The need to adhere to mandatory safety recalls of defective parts
    - The financial cost of safety recalls in the automobile industry grows exponentially the farther down the value chain inputs travel toward the consumer. For example, the cost of recalling a faulty part early in the supply chain can be hundreds to thousands of times less than if it were to be recalled as part of the finished vehicle
    - On average, 20-30 million vehicles per year are recalled for defects. Some recalls per brand can be as high as 1 million vehicles and regularly top 90,000. The follow-on reputational and financial consequences are significant to the brand[4]
- The complexity of the production process. A single vehicle is made up of thousands of components sourced from hundreds of different suppliers around the world
- The need to prevent the widespread counterfeiting of replacement parts
- The need to observe multi-jurisdictional regulatory requirements.

As more companies move to modular designs and common product platforms and supply chain partners, it becomes more likely that a defect on a single module or component can affect multiple vehicle platforms. The overall effect is that the complexity and reach of quality issues have increased. Half of all recalls today affect more than one model, and 14% more than one brand.

Systems in response: The main goal of traceability in the automotive industry is to trace each component of a vehicle to its source, and throughout the entire life cycle of the vehicle. To achieve this, firms deploy all the following categories of systems:

- Sophisticated ERP systems in order to link subcomponents to components, sub-assemblies, assemblies, and finally to the completed vehicles
- Enterprise Quality Management Software (EQMS) systems are employed to facilitate the integration of a firm's ERP with its business processes. This type of software facilitates quality management across a firm's complex operations and allows disjointed modules of an overall ERP system to communicate effectively
- Advanced traceability systems then deploy machine-readable product identifiers/codes in the form of Direct Part Marking (DPM)
- Each component of a vehicle is given a unique identification (e.g. 1D or 2D barcodes)
- The marking technologies are integrated with the assembly/production line itself. Full traceability can be achieved only by marking the single unit to the accumulation of the

[4] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/return-to-sender-resolving-the-automotive-recall-resurgence

main assembled parts ('kitting') while collecting all information and storing it for future purposes.

Industry groups facilitating change: The Automotive Industry Action Group (AIAG) has played a central role in establishing interoperable traceability across the global automotive industry. AIAG is a not-for-profit association of stakeholders (retailers, suppliers, automakers, manufacturers, service providers, academia, and government) who collaborate to streamline industry processes via global standards development and harmonised business practices. Through engagement with automotive and component manufacturers, AIAG developed and manages AIAG Supply Safe, a suite of tools designed to ease challenges associated with transparency and compliance reporting in the global automotive supply chain. The Supply Safe portal is a gateway for tracking origination and flow of raw materials, parts, and finished goods through the supply chain. The portal allows suppliers to create free security and reporting profiles through the Supplier Security Assessment link on the Supplysafe.org homepage.

Specific achievements cited by AIAG that have enabled interoperability to occur across the automotive and component manufacturing industry include:

- Bar code standards: Development in 1984 of a single alphanumeric bar code symbology and standard for the industry and pioneering of the concept of data identifiers (alphanumeric strings indicating part number, purchase order number, quantity), which was benchmarked by other industries (e.g. aerospace)
- Electronic data interchange (EDI) standardisation: Adoption of the American National Standards Institute's ASC X12 protocol; global harmonisation of the standard; and publication of the industry's first EDI Implementation Guideline
- Trade collaboration system: Development of a computing cloud allowing authorised tracking of shipments and document access, and complete interoperability and supply chain operation visibility
- Data specification: Development of a simple, flexible, and generic non-proprietary standard ('QMD specification') that allows variable, attribute, and binary quality measurement data from any source in any format to be seamlessly translated; eliminating the need for multiple systems and data integrators.

Pharmaceuticals industry

Industry characteristics: The global pharmaceuticals industry deals with thousands of different products and is extremely high value, generating over $300 billion in revenue annually. Demand for pharmaceuticals of all types is global, but the supply side of the industry is consolidated. The ten largest firms, which account for over 30% of the global market and are all based in North America and Europe. The industry is also highly regulated, with more than 50 countries having enacted pharmaceutical product serialisation laws (Bhatt et al., 2016).

Drivers of traceability: The main driver of traceability in the pharmaceuticals industry is government regulation designed to protect consumer/patient safety by reducing drug counterfeiting. However, legal frameworks around the world differ significantly creating obstacles for the global supply chain. Some laws also require independent, and often competing, organisations to work together and share information to ensure life cycle traceability, which creates added friction.

Pharmaceuticals pass through long and complex supply chains being bought, stored, and resold several times before making it to the point of sale. This can increase the difficulties faced in implementing traceability in the absence of global standards.

Compared to the automotive and horticulture sectors, the pharmaceutical industry is not as advanced in the development of global traceability solutions and most approaches remain national. Global solutions currently being explored centre on GS1's identification systems. This is useful given that the most fundamental concern for effective global traceability in the healthcare industry is the use of a unique product identification/serialisation. The centrality of an organisation like GS1 to assign and record these identifiers would greatly reduce complexity.

There are several models for traceability, and the choice of which depends on market specific and country-specific characteristics:

- The 'one-up, one-down' model in the pharma industry is like that used for food products. The absence of a single repository for tracing information in this model means that the speed of tracing is not as fast as in the following alternative models.
- The 'pedigree' model for traceability requires that a record containing information on product identification, characteristics, and change of ownership accompanies the product (either physically or electronically) throughout the supply chain.
    - For example, the California e-Pedigree Law requires an electronic pedigree to accompany all prescription drug distributions in California starting from the manufacturer until the point of sale.
    - The law requires that these records be maintained using an interoperable, electronic system that ensures compatibility at all stages of the supply chain.
- The 'point of dispense authentication' model is a process that determines whether a product is what it purports to be at the point of sale. For example, Turkish law requires drug manufacturers to uniquely identify their products using GTINs (GS1) and lot/batch numbers, and to upload a list of these numbers to a central government database. The drugs are then authenticated at the point of sale by checking human- and machine-readable identifications on product packaging against the central database.
- The 'distributed network track and trace' model requires that all firms who produce, buy, sell, store, or otherwise impact a product in the supply chain publish key data that are accessible to other authorised parties in the supply chain as well as government regulators. Information is published on a 'cloud' and permissions are granted by the owners of the data as to who can access it. This model is perhaps the most advanced traceability architecture but also is the most complex to implement.

Systems in response: The models above require unique identification that is affixed to each package. The most common method of identifying products is by using 1D barcodes or 2D data matrix codes, with the latter capable of storing a significant amount of product information. RFID is also growing in use, although there are significant cost and technology barriers to implementation.

A system that is widely used in the pharmaceutical industry is the electronic product code information services (EPCIS) system, maintained by GS1. The service contains information, provided by the manufacturer, on every product in the industry. Based on the use of this service, GS1 proposes the use of the electronic product code (EPC) global network architecture which is effectively a set of standards for unique product identification, hardware devices, software, network services, and data interfaces in the healthcare industry. This architecture was designed to create a universal, yet distributed, database that can be queried to obtain any information required, with the necessary permissions, and is like the "distributed network track and trace" model for traceability.

Financial services

Industry characteristics: Financial transactions range widely in size and location. Financial transactions are regularly aggregated or disaggregated at multiple points along the value chain. These factors, along with finance being the world's most global, digitised and intertwined industry,

make the tracing and monitoring of transactions highly complex and challenging. The global financial industry ranges significantly in the size, geographic footprint, commercial interactions and relationships, along with marked differences in the power and authority of individual organisations. Consequently, generalisations are difficult to make (Bhatt et al., 2016).

Drivers of traceability and compliance: These drivers include:

- Digital transformation of traditional banking services driven by regulatory changes and consumer preferences for innovation
    - For example, The Consumer Data Right legislation was recently passed in Australia to give consumers control of their data, enabling them to share it with third parties. In response, the 'Open Banking' initiative gives consumers the power to securely share their selected banking data with accredited third parties. Open Banking lays the foundation to improve consumer experience and create new products and services and change the competitive landscape.[5]
- New products and target markets
- Global growth of, and regulatory response to, financial crime and fraud
- Widening demand for government and institutional oversight of the financial industry.

Systems in response: The response by the industry to its traceability and compliance challenges falls into three broad categories.

1. Industry-wide structural responses
2. Internal operating systems inside companies providing financial services (e.g. ERP/GRC systems)
3. Specific products that focus on specific regulatory pain points for companies, the subject of the regulatory environment.

Some of the structural solutions that contribute to the globalised interoperability of the industry include the following:

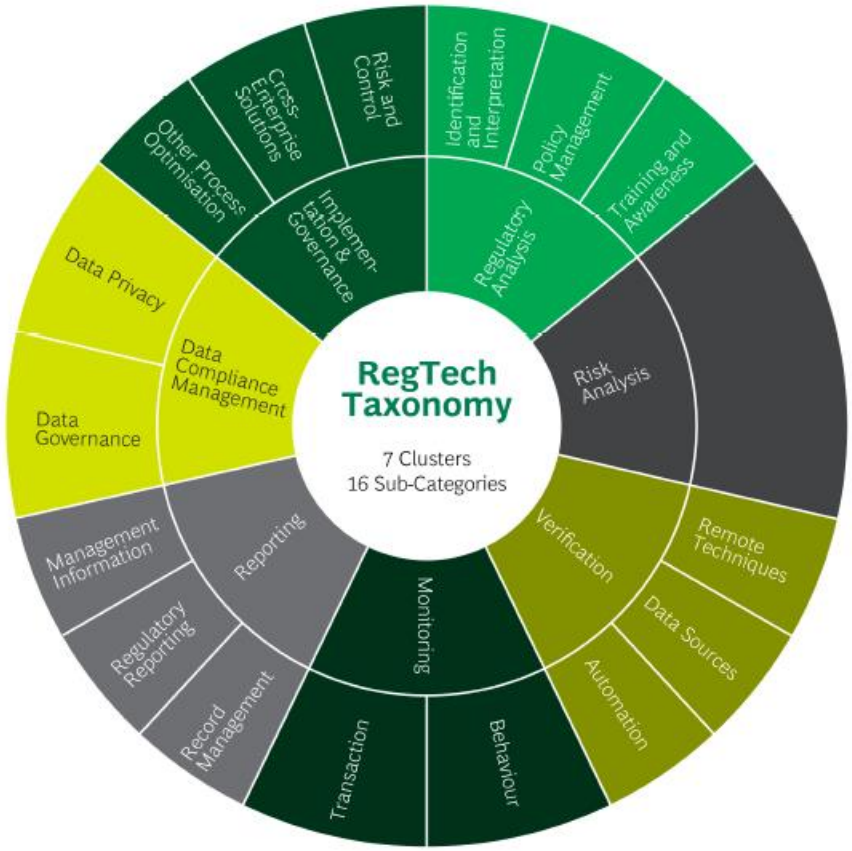
- The most standardised element of financial transactions for interoperable traceability is Society for Worldwide Interbank Financial Telecommunication (SWIFT). Established in 1973, with the support of 239 banks operating in 15 countries, SWIFT now acts an international clearinghouse for wire transfer messaging. SWIFT does not transfer funds but standardises the messages that go from one bank to another. This minimises errors and enhances the rigor of data exchanged. The system is based on IS0 20022 which is a methodology that harmonises previously non-interoperable formats and systems to establish a collection of 'message definitions' and a process of how these can be applied to specific business domains.
- Collective regulatory models and frameworks in addition to highly regulated national frameworks. The industry is commonly subject to international regulatory frameworks and regulators and they often cooperate to enforce these. For example;
    - Financial Action Task Force (FATF) - an inter-governmental body that sets the global standards for combating financial crimes and threats to the integrity of the international financial system. The standards are endorsed by 180 countries and universally recognised as the international standard for anti-money laundering and countermeasures against terrorism financing. A country review showing elements of noncompliance has serious ramifications, to the point that if a country is placed on a noncooperative list, then financial transactions must be curtailed.

[5] https://www.ausbanking.org.au/policy/the-future/open-banking/

- The Australian Securities Exchange is implementing one of the world's first industrial scale uses of blockchain in financial services in 2022. This will be a replacement platform for its now dated Clearing House Electronic Sub Register System (CHESS) and will enable the ASX to demonstrate the compliance of its processes with domestic and international requirements and standards on the conduct of clearing and settlement facilities.[6]

However, unlike other industries, the financial services sector is subject to more regulatory activism (changing laws, enforcement, fines) which is highly publicised, and often results in major fines and reputational damage. As a result, the moniker 'regtech' is most associated with this sector. To date, there are approximately 600 regtech companies worldwide with specific focus on financial services, with 80 head quartered in Australia.[7] These companies have collectively raised $6 billion in venture capital. The relative maturity of regtech in the sector has enabled a sophisticated taxonomy of solutions to be developed that helps industry stakeholders to keep abreast of emerging capabilities.[8]

Figure 4: Regtech solves an increasingly diverse range of challenges



Source: Wray et al. (2020)

Industry groups facilitating change: The RegTech Association was founded in 2017 as a non-profit organisation that focuses on what is needed to support the growth of the sector, and to accelerate RegTech adoption in Australia. As foreshadowed in the Productivity Commission report (above), despite the apparent demand for such products and services, a major barrier for regtech firms has been the elongated sales cycles to get their technologies into incumbent and large organisations,

[6] https://www2.asx.com.au/markets/clearing-and-settlement-services/chess-replacement/about-chess-replacement
[7] https://www.bcg.com/en-au/publications/2020/australia-global-regtech-hub-poised-for-growth
[8] https://www.bcg.com/en-au/publications/2020/australia-global-regtech-hub-poised-for-growth

particularly banks. There are several reasons for this which include a paradox of choice – in the financial sector there has been an explosion of regtech products; difficulties integrating with legacy IT systems in large institutions; and the bureaucracy associated with making purchase decisions inside large organisations.

The Association also brings together government, regulators, regulated entities, professional services and founder-led regtech companies to ensure collaboration between all of the parties, promoting the RegTech industry as widely as possible, resulting in action in the uptake of RegTech proof of concepts and deployed RegTech solutions across the eco-system.[9]

Dairy industry

Industry characteristics: The dairy industry is highly regulated and must observe strong adherence to strict internal quality standards. Monitoring is critical for all segments: fluid milk, cheese, butter, cultured products, ice cream, UHT processing and powders. The food safety testing market is led by technology convergence and the increase in demand for rapid, accurate, and reproducible technology systems, along with strong certifications.

Drivers of traceability:

- Foodborne illness concerns driving authorities to promote new regulations
- New breakthrough technologies enabling smart packaging
- Technological advances in information and communication technologies resulting in progress in supply chain management and economic savings.

Systems in response: The dairy industry appears to be adopting advanced technologies more quickly than its peer industries in the agricultural sectors. The following forecasts are indicative of market growth for these technologies in the near-term suggesting adoption and implementation. In particular, the market for adulteration testing is expected to grow rapidly given the industry emphasis on food safety (Frost and Sullivan Global, 2017).

Table 6: Forecast market size (global) by technology category in the dairy industry

Interconnectivity and interoperability	Advanced processing technology	DNA testing or fingerprinting	Internet of clean for food safety
Deep Automation On-site testing and monitoring In-factory integrated services Full accessibility and traceability Smart packaging Intelligent labels	Ultra-high pressure Pulsed light Cold plasma technology Small-scale filtration Enhanced sensory properties Time and energy reduction Lean operations	Bio-illumination techniques Bacterial nucleic acids detection kits Pathogen libraries Synthetic phages for bacterial identification Testing kits	Smart food safety Compliance fulfilment Food safety management Auditory control Quality assessment Online support
$1.3billion by 2021	$750 million by 2021	$11.5 billion by 2021	$1.7 billion by 2021

[9] https://www.regtech.org.au/About

The dairy industry is also starting to leverage IoT applications focusing on the enabling technologies that make the concept of connected safety a reality, or 'Internet of Clean' compliance. The convergence of new technology under the categories of micro/nano technology and advanced materials, life sciences testing kits, engineering in thermal processing and pulsed light, as well as data analytics and digitisation, mean the development of smart solutions for integrated testing services, on-site environmental monitoring, farm-to-table surveillance and intelligent traceability solutions are being built (Frost and Sullivan Global, 2017).

Blockchain platforms are also being explored in Australia to meet structural industry and market challenges.[10] In spite of growing global demand, Australia's falling global market share (from 16% to 6% over the past 30 years) is a concern. In 2018, the ACCC highlighted the power imbalance between farmers and processors which, when coupled with uncertain global prices, supermarket discounting, falling processor margins, means lower farmgate prices. Additionally, fewer larger farms and productivity gains are now seen as dependent on the better use of data and technology. Blockchain enabled smart contracts are one part of the response to these challenges. The industry is working together to look at mandatory codes of practice, standard contracts, milk trading platforms to redress these imbalances and to enable the capture of information throughout the chain – how milk is produced, provenance, processing, costs and margin sharing. The standard contract also allows for automation – e.g. when minimum quality conditions are met and verified on the platform, automatic payments can be enabled when the system is connected to banking infrastructure. Such systems make use of GS1 global standards for data interoperability as well. The overall benefits are purported to be increased transparency and reduced fraud risk.

In 2014, a research project called the Bovlac Platform developed ontologies and taxonomy for traceability in the dairy industry (Bhatt et al., 2016). The project leveraged the ValueGoR web-centric platform developed for traceability:

- It allows consumers to scan with a smartphone the QR-Code on the product package to read the product history
- It deploys domain ontologies and is based on RFID or NFC radiofrequency and bar code identification technologies
- It uses a semantic database implementing the domain ontology
- It manages a GS1 EPCIS repository
- The system transmits data during production phases in real time to a portal
- The system is adaptable to different product processes and supply chain models.

Existing GS1 infrastructure can now be utilised in aid of traceability in the dairy industry, although no specific guidelines have yet been created. It is also noted that with batch processing of milk across farms, there is no unique identifier for the property of origin. However, in Australia the government has initiated the National Food Traceability Project under which GS1 has partnered with Deakin University and major industry stakeholders (e.g. national retailers and food suppliers) in the development of traceability implementation guidelines.[11]

Emerging opportunity sets across the dairy supply chain revolve around technology convergence, for example (Frost and Sullivan Global, 2017):

- Potential mass adoption of products related to dairy food testing consist of pathogen detection testing kits to be applied in lab or factory.

[10] https://australiandairyfarmers.com.au/blockchain-and-real-time-payment-system/
[11] https://www.agriculture.gov.au/market-access-trade/traceability-project

- Enhance processing and manufacturing - implement product, ingredient, or process improvements in order to maximise food safety, particularly pulsed electric field, hyperbaric processing, ultrasound, and cold plasma, allow minimising microbiology and chemical risk.
- Improve traceability - leverage microbial genomic expertise to track the source of contamination in real time, trying to avoid product spoilage or recalls due to inappropriate safety procedures and testing modes.
- Create smart products - implement smart labels and intelligent packaging solutions for temperature, pH, and humidity sensitive dairy products. Exploit biosensing technologies and flexible electronics to generate smart products.
- Encompass the IoT trend - enhance interconnectivity and interoperability among devices and platforms across the dairy industry for food safety applications enabling full access to all processed data to make optimal decisions.

Seafood industry

Industry characteristics: The seafood industry is increasingly competitive, global, and complex. It has similar characteristics to the red meat supply chain in that the product changes form throughout its journey in the supply chain and cold chain transport is a critical step in the process. In contrast to industries such as automotive and pharmaceutical, individual seafood firms in the supply chain may range from household-level producers to large multinational corporations (Bhat et al., 2016).

Drivers of traceability:

- The global regulatory environment - many developed countries have recently implemented traceability laws that require a “one-back one-forward” data dissemination and storage principle.
- Consumers are placing greater expectations on suppliers’ ability to verify the authenticity, value, sustainability, and safety of seafood.
    - Verification of catch/harvest location can enhance a brand or market name that attracts a premium price.
    - Information on the region of catch adds value when an area produces something highly prized, such as ahi tuna. Management authority (for example, Regional Fisheries Management Organisations) information adds value and applies to species like tuna, swordfish, Patagonian toothfish.

The main barrier to effective supply chain traceability systems and frameworks include a lack of a common ontology and associated standardisation across the industry. This is most acute in the differences between definitions of seafood species across jurisdictions. For example:

- the Canadian Food Inspection Agency (CFIA) lists nearly 800 species of seafood, while The U.S. Food and Drug Administration (U.S. FDA) lists more than 1,800 species. The similarity between the CFIA and U.S. FDA lists is approximately only 500 species
- Such misalignment in the terminology surrounding species leads to compliance challenges and limits traceability effectiveness
- When expanded to differences for other countries with differing terminologies to identify catch location, the need to establish a common ontology is critical.

Systems in response: Many firms in the seafood industry already have internal traceability capabilities, both for the purpose of inventory tracking and/or to meet the regulatory requirements of major global markets. Bigger seafood companies have invested in ERP systems which support many aspects of internal traceability while improving business efficiencies. In contrast, smaller firms may manage traceability-related data in paper form, or in a combination of electronic and paper form.

In 2019, GS1 released the Foundation for Fish Seafood Aquaculture Traceability Guidelines which outline standards for identification, data capture and data sharing to meet the challenges of the industry.

Industry groups facilitating change: The Institute of Food Technologists Global Food Traceability Centre set up the Interoperable Seafood Traceability Technology Architecture Project. The project identified the following deficiencies in the industry that impede effective traceability and associated market and regulatory compliance:

- There was no common model for product identification.
    - Due to the global nature of the industry, a universally unique identification number was considered essential for advancing the success of traceability.
- Data verification occurred in a variety of ways.
    - For example, double-checking manual data entries through paper audits either internally or through a third-party inspector.
    - Some firms conduct mock product recalls to identify data gaps and sources of error.
- Lack of uniform requirements and standards for collecting and sharing information.
    - Firms fulfill contractual and regulatory data sharing and storage requirements using diverse approaches, which impede the speed with which products can be traced, increase the opportunity for errors, and increase the overall cost of meeting traceability requirements.
- Defining what constitutes a traceable item varied widely in the industry:
    - In some situations, a single fish constitutes a traceable item.
    - In other situations, a shipping container full of fish from various sources is the traceable aggregate “lot,” “batch,” or “item.” The definition of “lots” as a traceable item is widely variable in the industry.
    - Processors may combine catch from multiple vessels into the same “lot” leading to a loss of detailed information that may be critical for effective traceability.
    - Distributors or shippers may then combine several such “lots” into a larger aggregate “lot,” potentially leading to further loss of detailed information or a midchain “black hole”.
- In general, the seafood industry does not organise data into forms that may be shared easily up and down the value chain.
- Standardised protocols for data sharing, including the form which data take, and the standardisation of definitions such as “lots,” are essential for successful whole-of-supply-chain traceability in the industry.
- A single organisation that maintains a global registry is seen as the best way to reduce complexity and facilitate the adoption of traceability systems.

Case studies in the Seafood industry for traceability initiatives and technology pilots: In Iceland, a fish processing plant conducted an ‘eTrace’ project to track the fresh catch through to processing and packaging for distribution. The goal was to specify, develop, and evaluate an electronic traceability system that integrates different information sources relating to food safety and enterprise management systems. The project utilised:

- The GS1 EPCIS standard
- RFID data
- A unified modelling language (UML) for food traceability.

The project incorporated data from logistics and stock management processes, use of production equipment, and transformation processes, while also collecting data from ‘transition’ points that

could provide traceability information from the production process. The project included 9 GS1 Identification Keys including;

- Global Location Number (GLN)
- Global Returnable Asset Identifier (GRAI)
- Serialised Global Trade Item Number (SGTIN).

Lastly, the project used a data repository, TraceTracker to store and manage standardised "event" data (the "what, why, when and where") of individual items, and to allow sharing of information. The system provides the opportunity for sharing with other stakeholders in the value chain (Bhatt et al., 2016).

In 2013, METRO Group (Germany) piloted a German project for fish products—called "Traceability in the Cloud"—centred on recording data electronically, with decentralisation via an integrated software platform, and based on GS1 open international standards. METRO needed a platform that could interoperate with their different suppliers' systems.

- The system has a search engine allowing retrieval of details about individual batches.
- It made data available to consumers via barcodes on packaging or information on invoices via the fTRACE internet platform or smartphone application.
- fTRACE also offered decentralised data management for ease of integrating diverse databases and interfaces.
- The traceability solution is built on a real-time event repository used in its RFID program and based on GS1's EPCIS and is scalable and extendable to non-food sectors.
- As fish products travel through the supply chain from fishermen to processors to distribution centres and on to METRO Cash and Carry locations, the identification data are scanned at various points along the way.
- The GS1 EPCIS and Core Business Vocabulary (CBV) standards together provide the foundation for all trading partners to share real-time information about the movement, history and status of the fish products as they travel through the B2B2C supply chain (Bhatt et al., 2016).

In 2014, a pilot study in Spain and Slovenia examined moving from a paper-based traceability system to one that is based on electronic technologies aquaculture companies (Bhatt et al., 2016). They developed and tested an interoperable architecture that is based on the standardised EPCglobal Architecture Framework. The system architecture was designed to help small to medium enterprises in the aquaculture sector, and used the following;

- Web services to integrate traceability data generated in the form of events, captured in RFID systems, with information about the environment collected with a Wireless Sensor Networks infrastructure
- The system has four main components,
    - RFID Readers, Sensors, and Data Input devices
    - set of capture and query applications
    - traceability repository
    - set of web services.

The architecture allows sharing of some of the collected information (for example, aspects relating to product origin, quality, and handling) at retail with the customer. Items carry an ID that is stored as a URL and conveyed by a QR Code to a smartphone, identifying the smallest logistic/traceability unit in a machine-readable format and including times and dates, names of processing steps and states, and locations and pointers to sensor data (temperatures) retrieved from the traceability events. The information is combined with generic textual information about the product (for

example, fish type, size, and description), nutritional information, and expiration dates, for presentation in a web page with images, graphs, maps, diagrams, and descriptions. Field test deployment challenges arose due to the offshore work environment and harsh environment and structure of the processing plants considered.

Horticulture industry

Industry characteristics: The fresh fruit and vegetable industries are globalised and supply a wide range of products. In most countries, the industry is fragmented with many types of suppliers, distributors, wholesalers, shippers, and importers, working to serve food service operators and food retailers. This makes industry-wide generalisations difficult as company characteristics tend to vary by the product or product group each one supplies (Bhatt et al., 2016).

Drivers of traceability (Frost and Sullivan Global, 2018):

- Regulatory food safety requirements
- An increasing perception of threats to food integrity driving the use authentication technology and certification services as insurance measures
- The increasing risk of reputational damage from food scandals, causing consumer mistrust, drives demand for transparent systems
- Evolving labelling regulations, legislative protections and trade requirements impose a greater cost on exporters that do not improve their traceability systems
- Co-dependency of the food value chain drives market leaders to invest in new technology systems throughout the supply network
- The time to recall, noting that the distance travelled by the products varies and requires food manufacturers to sustain the freshness of the products.
- Customer requirements that necessitate real-time solutions to provide up-to-date visibility and monitoring capabilities.

Restraints on adopting technologies include (Frost and Sullivan Global, 2018):

- High capital cost for smaller supply network members limiting the uptake of interoperable, integrated systems
- Uncertainty over best practices to meet the needs of variable food sectors
- Increasing complexity of modern supply chains creates barriers to segregating ingredients and batches in convoluted supply chains

Some challenges that present opportunities include the following:

- In most food chains there are long tails of small/medium-sized enterprises. A key difficulty is a lack of access to IT infrastructure resources for these firms. In this context, strategically placed clients that can store information and upload to a common information model upon being connected, can be used to facilitate traceability outcomes.
- Once basic traceability functionalities are established (e.g. visibility, authentication, validation) more enhancements can be developed like networks enabling route optimisation, inventory management, and better cold chain management.

Systems and frameworks in response: The following forecasts are indicative of market growth for these technologies in the near-term suggesting adoption and implementation will increase.

Traceability infrastructure market (Frost and Sullivan Global, 2018): In the APAC region, revenues generated by firms offering food traceability infrastructure are estimated to grow from $4bn to $9bn in the period 2018-2023. Revenue from the sale of systems that gather information for analysis and decisions making (e.g. KDE systems) are expected to outperform those that create the data in the field (e.g. CTE products). This is because as new technologies like blockchain, real-time location

systems/IoT sensors are implemented (CTE), the data they produce will need to be interpreted in the context of business operations and the supply chain (KDE).

However, KDE information gathering, and processing remains a high-cost endeavour. Sophisticated systems are currently restricted to premium products or large integrated manufacturers. The development of these platforms by large players exerts pressure on suppliers to commit to integration with these platforms.

Recent market share by revenue statistics reflect the dominance of large ERP systems providers whose products meet the requirements of KDE functionality. For example, in 2017, IBM, SAP and Oracle had a combined 90% market share.

Authentication technology and services market (Frost and Sullivan Global, 2018): This sector is still emerging and is much smaller in revenue terms than the traceability technology market. However, the emergence of profiling technology for food authentication will grow the market for diagnostic equipment and testing with some estimates of growth from $16m to $24m in the period 2017-2023. The use of specialised authentication services will also become increasingly relevant given the market drivers mentioned above. At present there are three analytical testing companies that dominate this nascent market, and which combined account for 80% market share. These are EuroFins, Oritain and Asure Quality.

Industry groups facilitating change: In 2006, The Produce Traceability Initiative (PTI) was created in the US to better help the industry manage its regulatory requirements regarding traceability. Formed jointly by four major industry associations (Canadian Produce Marketing Association, GS1 US, Produce Marketing Association, United Fresh Produce Association), the PTI is mandated with improving produce trace-back procedures while developing global standards for an industry traceability framework.

As a result, a common language for product identification and numerical identification has been developed using GS1 standards (e.g. GTINs) and many firms have since been able to utilise internal traceability systems. The main enabling factor in the success of traceability systems of the horticulture sector has been the standardisation of a traceable unit of product in the “case”. This has greatly simplified the interoperability of the traceability systems within this industry (Bhatt et al., 2016). The identity of the brand owner and type of product also use standardised terms. This information, in addition to information required by the market or regulators is typically captured in labelling solutions affixed to the cases of product (Bhatt et al., 2016). It is of note that the adhesive label applied to most apples purchased in Australia denotes the property of origin, and that this is a significant advancement over many other food sectors.

However, the PTI does not maintain a centralised database of this information as might be expected (Bhatt et al., 2016). By taking a collaborative approach with supply chain stakeholders, those entities have been encouraged to modify their business processes. This approach has been successful in overcoming the heterogenous nature of the industry and is acknowledged as effective model of future engagement with industry, NGOs, and government.

Verification: In general, the verification of data processes along horticulture supply chains remains the domain of third-party auditors. Data verification is often duplicated unnecessarily due to lack of networked systems among supply chain participants and a lack of standardisation of verification procedures. The lack of information sharing remains a barrier to realising the full value from traceability models.

Authentication and Verification/Certification services will grow in size and value: Geographical origin services and species analysis testing are already being used in wine, fruit juice and coffee to ensure quality is maintained. Other profiling services include ethical sourcing, sustainability, unique ingredients, religious codes and anti-fraud services. The rise of industry groups and for-profit companies to facilitate certification in this context is a significant method by which to establish authenticity and compliance. Below are some examples of such organisations (Frost and Sullivan Global, 2018).

Table 7: Example Certification Services provider matrix

Company	Sustainability and ethical Sourcing	Geographical Origin	Organic/ Residue Free	Unique Designation	Other
International Olive Council	Y	Y		Y	Y
Openseas	Y	Y			Y
Unique Manuka Factor (Honey)		Y		Y	
Fishwise	Y	Y			
Acquaculture Stewardship Council	Y	Y			
Marine Stewardship council	Y				
American Spice trade Org	Y				
Intertek (general)					Y
Fair Trade	Y	Y		Y	
Biogro			Y		
B Corporation			Y	Y	
Asure Quality (NZ Govt. owned)		Y	Y	Y	Y
Demeter (general)	Y		Y		
Bearau Veritas (general)	Y	Y		Y	Y
SGS (general)				Y	Y
Vtrust (general)					Y

Source: Frost & Sullivan (2018). Traceable Value Chain and Authentication in the APAC Food Industry, Forecast to 2023

Predictions (Frost and Sullivan Global, 2018):

- Certification agencies and authentication services will expand to countries with high-value food exports, such as Japan and Australia, working closely with producers and manufacturers.
- Revenue growth for producers will be enhanced where companies can implement marketing programmes that engage consumers with relevant traceability information.
- APAC will grow to be the largest market for authenticity testing and chain of custody technology by 2023, in response to the consumer demand and regulatory changes in China.

- Large food manufacturers will incorporate authenticity testing and software into their quality systems. Certification agencies will shift standards to reflect those of the market leaders.

4.3.7 Lessons from the global scan

Drivers of traceability are typically regulation, consumer expectations, and business process efficiency

The following three common themes are evident which are driving the need for traceability and verification systems across multiple industries:

1. The volume and velocity of regulation and regulatory change across most industries is increasing but the root cause differs by industry. In food related industries it is being driven primarily by food safety concerns. In other manufacturing industries, it can be product defect/liability/recall concerns. Dealing with the regulatory burden is made more complicated by the nature of supply chains having to navigate cross border jurisdictional regulatory frameworks.
2. Consumer preferences and expectations are changing in ways that require the ability to track and manage data about products so that a variety of product attributes can be verified according to consumer preferences. This is in addition to emerging extra-regulatory expectations around concepts like having a culture of good manufacturing practices, strong customer-centricity, and taking verifiable measures to meet sustainable business practices (Frost and Sullivan Global, 2013).
3. Digital transformations are well underway in all industries allowing for business processes to be optimised. While such efforts are typically focused on technology applications and adoption at the single firm entity level, little regard has been given to the changing ways in which business data and information is being generated and the potential risks and benefits of sharing this data between entities in the supply chain.

Collective effort through industry groups is highly effective

Most industries depend upon collective representation through industry groups/bodies to help overcome the communication challenges required to enable collaboration within industry supply chains. These groups have been effective in laying the groundwork for traceability requirements such as standardisation and technology collaborations.

The need for interoperability and standardisation is required to deal with complexity

The common challenge impeding the establishment of effective traceability measures in all supply/value chains in all industries is complexity. Complexity is derived from;

- The number of stakeholders in an industry and actors in a supply chain
- The number of products and variations in any given chain
- The multitude of systems and processes deployed by each actor in the chain to manage their business processes
- The variety of data and information produced and the need to communicate it
- The cross border, international nature of trade and associated regulation.

To navigate complexity and proactively manage risks, reduce costs, and increase revenues depends on three contingent outcomes:

1. The effective sharing of information which requires trust gained through verifying the accuracy and rigor of data exchanged within and between businesses for the purposes of traceability.

2. That in turn requires the existence of interoperable information systems between businesses along the chain.
3. Effective interoperability relies on sharing a common technology architecture/framework between systems utilised by those businesses – otherwise known as ontologies (Bhatt et al., 2016).

In addition, intra and inter-firm relationships play a significant role. The quality of these relationships can be affected by a lack of strategic alignment, operational understanding, trust, commitment, benefit sharing, and ultimately collaboration. As a result, there is often a reluctance by supply chain actors to invest in the necessary assets and skills, and an unwillingness to share sensitive information that would otherwise enable the adoption of traceability technologies.

Strong inter-firm relationships are particularly important because most of the benefits that are realised from implementing a traceability system are not within the control of a single company in the chain. Achieving the expected outcomes is therefore dependent upon the behaviour of other chain members, and not solely on the sophistication of the traceability practices and technology of an individual firm. The lower the uncertainty over the behaviour of others, the greater a firm's confidence will be to invest traceability processes and technologies. Inter-firm relationships affect firms' expectations as to what returns the information and traceability system should deliver.

Achieving national/global traceability architectures must address these fundamental realities of supply chains and be able to accommodate the diverse practices of individual firms, as well as the information needs and contractual agreements across entire chains with different levels of trust and strategic alignments (Bhatt et al., 2016).

GS1 is widely deployed as a means of standardisation across industries to facilitate interoperability for traceability and compliance

Many industries utilise the capabilities of the GS1 organisation to establish standardisation and overcome challenges of interoperability between systems in their supply chains.[12] In 2015, the Global Meat and Poultry Traceability guidelines for the beef supply chain were released by GS1.[13]

GS1 standards form a common language for traceability solutions. GS1 collaborates with companies who design, develop and deploy traceability solutions with intent to enable effective adoption of standards resulting in greater interoperability across trading partners.

GS1 collaborates with academic institutions, NGOs and industry associations. GS1 is neutral, technology agnostic and not-for-profit, which also enables collaborations with other industry organisations, such as ISO, CGF, and governments and regulatory bodies.

GS1 operates in 115 countries and collaborates with industry end users of all types and sizes:

- Retailers across all industries
- Fresh foods, foodservice and consumer packaged goods companies
- Healthcare manufacturers, distributors and providers
- Apparel and general merchandise companies
- Transport and logistics companies
- Construction and rail companies.

[12] www.gs1.org

[13] https://www.gs1.org/docs/traceability/GS1_Global_Meat_and_Poultry_Guideline_Part2_Beef_Supply_Chain.pdf

Unique identification numbers are given for unit-level products, cases, pallets, and shipping containers that are further used downstream for backward traceability. The main identifiers are as follows:

- GS1 Global Traceability Standard (GTS2): Introduces two key concepts for interoperable traceability:
  1. Critical Tracking Events (CTEs), these are the actual events, such as receiving, packing, shipping, transporting, that occur to the traceable object during its lifecycle, and
  2. Key Data Elements (KDEs), these are the elements of data that describe the actual instances of the CTEs.
- Global Trade Item Number® (GTIN) and Global Location Number (GLN): GS1 identification standards uniquely identify the objects that are moving throughout supply chains and the locations to which and from which they travel. Identification keys enable the connection of physical and information flows within a trading partner's processes as well as across different trading partners' processes.
- Barcodes and EPC-enabled RFID tags: Barcodes and EPC/RFID, data capture standards, along with data sharing standards the Global Data Synchronisation Network® and EPCIS (Electronic Product Code Information Services) enable automated processing and sharing of information between and across trading partners. EPCIS is a critical component for traceability systems. EPCIS enables trading partners to share information about the physical movement and status of products across supply chains.
- Global Data Synchronisation Network® (GDSN): The GDSN is the world's largest product data network. GDSN makes it possible for any company, in any market, to share high-quality product information seamlessly. High quality product content is uploaded, maintained and shared automatically, ensuring trading partners have immediate access to the most current and complete information needed to exchange products on both local and global markets. Any company that needs to send or receive product information can take advantage of GDSN by subscribing to a data pool. This enables the user to set up product content and synchronise it with all trading partners, so that reliable data for all markets at one time.
- Electronic Product Code Information Services (EPCIS): EPCIS is a standard that enables trading partners to share information about the physical movement and status of products as they travel throughout the supply chain. It helps answer the "what, where, when and why" questions to meet consumer and regulatory demands for accurate and detailed product information. The goal of EPCIS is to enable disparate applications to create and share visibility event data, both within and across enterprises. This sharing is aimed at enabling users to gain a shared view of physical or digital objects within a relevant business context. EPCIS is intended to be used in conjunction with the GS1 Core Business Vocabulary (CBV) standard. The CBV provides definitions of data values that may be used to populate the data structures defined in the EPCIS standard. The use of the standardised vocabulary provided by the CBV standard is critical for interoperability and querying of data by reducing the variation in how different businesses express common intent.

Understanding the benefits of interoperability and limitations in evaluating interoperability are barriers to technology adoption

The benefits of interoperability stem from competitive advantages that can be generated as a result. These include (Bhatt et al., 2017):

1. New or improved products and services - for example, greater functionality or customer satisfaction
2. Innovative forms of business cooperation - for example, collaborative product design

3. More effective supply chain management - for example, reduction of operating costs, increase in quality.

However, measuring the return on investment (ROI) in creating interoperable systems across a supply chains is difficult, this can be a barrier to adoption of traceability systems given the significant amount of analysis required to justify investment. The following highlights the nature of the analysis needed to articulate the benefits to the red meat industry (Bhatt et al., 2017).

- The ROI from interoperability and traceability will vary significantly depending on the underlying characteristics of each business in the supply chain, and the scope/objectives for investing in interoperability and traceability.
- ROI is generated from both operational impacts (like costs, revenue, market size/value, quality, and transaction costs) and strategic impacts (how firms can plan to generate longer term benefits) and both need to be articulated.
- Trying to compare ROI is difficult because it requires assessing the degree of interoperability in each system being compared, and the environment into which it was implemented. The ROI from traceability will be affected by the extent to which it is imbedded in a business or supply chain's operation and management systems, as well as the environment in which the system operates. These factors are highly variable and hard to measure.
- Interoperability itself, as for traceability, does not generate the ROI. Rather, it facilitates increased efficiency/effectiveness of existing business processes (such as traceability systems, inventory management, customer/consumer responsiveness, and innovation, including new product development). Thus, the ROI depends on the effective/efficiency of each business process prior to implementation, and to what extent performance can be improved.
- Given the forgoing factors, an industry level analysis could produce findings too generic for transferable conclusions while findings from case studies of individual businesses and supply chains could be too specific. To be helpful, analyses must balance industry and enterprise-level considerations.
- The lack of a solution to this problem negatively impacts the willingness of potential funders to support an initiative designed to quantify the benefits of interoperability and traceability.

4.3.8 Conclusions

This section provided a global scan of how other industries are engaged in the task of establishing end-to-end traceability for their supply chains in the context of demonstrating compliance with their regulatory and market requirements.

An analysis of the common themes and lessons that emerge point toward the general direction ISC can take to progress the red meat integrity system. Across most industries, there is a general state of complexity that works against establishing traceability systems as the foundation capability to achieve better business and compliance outcomes. In order to overcome these, it is important to mobilise industry stakeholders around joint efforts to create standards that facilitate interoperability between the multitudinous systems, processes and frameworks deployed by participants. Allied to this work will be the need to articulate in detail the value of establishing such systems for all participants.

4.4 Applicability of verification systems to the Australian red meat industry

In order to understand the readiness and to assess the demand from the red meat industry for the application of new integrity approaches and technology solutions, a series of discussions were held with red meat supply chain participants encompassing producers, processors, retailers, government, industry bodies and MLA's international market representatives. Those who took part in the discussions were encouraged to reflect on the impacts of existing verification systems and on opportunities for the development of new approaches to these systems. Whilst there are examples of the uptake of novel approaches to achieve product verification, traceability or compliance, such as Meat Messaging and the embedding of eNVDs into domestic retail supply chain programs, there was an overarching sense that there are missed opportunities within the existing systems which should be addressed before proceeding with the extension or evolution of the integrity system. Indeed, there was a general message across most discussions that there is limited scope for the integration of new approaches, particularly automated and advanced digital technologies, if foundational work on consistent and harmonised standards was not completed first. Meaning for example, ensuring consistent use of language across standards (i.e. AUS-MEAT, SAFEMEAT). Feedback from the international market representatives confirmed this view by acknowledging the lack of understanding that consumers and those involved in the trading of red meat products have of Australia's integrity system. The lack of understanding suggests that additional value is not being realised on the back of the verification systems in place, nor is there evidence that the incorporation of additional elements or technologies has market demand and is likely to yield additional supply chain value.

Understanding the limitations of the existing integrity systems permits supply chain participants to reflect on the system developments that are likely to enhance the value proposition and encourage uptake. There is a strong appetite for the development of integrated, interoperable and cost-effective digital solutions that provide enhanced data transfer across the supply chain and provide additional efficiencies, value and opportunities for continual improvement. The focus on interoperability between systems is of importance when communicating the attributes that Australia's integrity system delivers globally to trading markets and consumers. It is unrealistic to anticipate worldwide adoption of Australian-based systems and it is therefore appropriate to evolve existing systems to ensure interoperability using a common product and data ontology. An evolved integrity system must also address the 'weakest link' principle by delivering a complete supply chain value proposition. As is the case in many sectors, supply chain complexity impacts on the development of systems that are equally beneficial to all participants. It is therefore critical that the value of any proposed system is communicated to all supply chain participants and that complete supply support is established.

5. Conclusions and recommendations

The intent of these foundational investigations was to identify processes by which Australia's red meat integrity system can progress from its current whole-of-life traceability design to a complete whole-of-supply-chain traceability system. Consistent with this intent is a need to articulate an equitable value proposition and subsequently incentivise all supply participants. The following recommendations are proposed to enable the ongoing evolution of Australian red meat integrity system in accordance with ISC's S*trategic Plan for the Integrity System 2025 and Beyond*:

1. Define the key global standards and ontologies that facilitate integration and interoperability of verification systems underpinning Australia's red meat integrity systems.
2. Develop a more compelling and equitable value proposition for the existing verification systems before incorporating new elements.
3. Identify and evaluate opportunities to adopt technologies/solutions that provide enhanced digitalisation and digital interoperability.
4. Pursue and adopt new technologies that enable a whole-of-supply-chain traceability system but only after 1, 2 and 3 are achieved and there is clear and compelling return on investment.

In light of these recommendations, and others arising from the foundational projects, some reprioritisation of the objectives within the ISC S*trategic Plan for the Integrity System 2025 and Beyond* may be required.

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7. Appendices

7.1 Appendix 1: ERP / GRC Systems

What effective and ERP/GRC system should look like today

Key functions and benefits of ERP/GRC software

These systems provide several key functions including:

- Streamlined operations: Store and track data from across the organization—including third-party integrations—to consolidate and streamline business functions.
- Workflow automation: Automate routine processes and free up human capital with AI and machine learning. Order management, inventory control, financial management, human resource functions, and sometimes even basic project management tools can be automated.
- Advanced analytics: Get big-picture insights and gauge the success of business initiatives with detailed reporting and analytics dashboards.
- Enhanced accessibility: Can utilise IoT-enhanced platforms, such as cloud-based software and mobile apps, for better visibility into daily operations.[14]

Competitive advantages of using ERP/GRC software

Businesses that utilise an ERP-like solutions to streamline (compliance) operations can capture potential benefits such as:

- Increased operational efficiency: Through process automation and lean workflow management, an ERP platform can significantly boost operational efficiency and productivity.
- Better data management: Data mismanagement and disorganisation can stagnate a business, preventing it from reaching its full potential. But with platform software, individuals across a business can find the information they need in a single system, rather than juggling multiple tools and risking duplicate or inaccurate data.
- Informed business decisions: With advanced analytics comes deeper insights, giving decision-makers greater breadth of detail and a better understanding of business initiatives. The reporting capabilities of ERP software empower leaders to make more informed decisions and better position their business for success.[15]

An illustrative example in food production, where there is an increased focus on food safety requirements, can be those companies that need to maintain a certain degree of freshness for all their perishable goods. If a business produces guacamole, for example, it can use ERP software to source its avocados, plan production cycles around acquisition and distribution dates, and adjust processes to minimise food waste and ensure the product meets regulatory standards.

Trends in the ERP sector are enabling more cost effective and flexible access

Adoption of cloud-based ERP software is rising among small and midsize businesses (SMB). This can be attributed to the various cost benefits offered by cloud-based ERP, such as ease of access,

[14] https://www.softwareadvice.com/erp/#buyers-guide
[15] https://www.softwareadvice.com/erp/#buyers-guide

flexibility to scale operations, lower upfront investment, and elimination of maintenance hassles due to hardware not being on premises.

ERP vendors to offer industry-specific customised systems: There is growing demand for generalised ERP capabilities to meet the requirements of specific industries (Frost and Sullivan Global, 2013). Solutions that meet local regulations, industry requirements, and stakeholder needs are found to be more effective. Generalist solution providers are typically large enterprises that cannot justify the amount of time and money spent on customisation (e.g. IBM, SAP etc). Small and medium-sized solution providers can provide similar functionality, better focus on customer value, and potentially lower cost.

Growing use of mobile ERP: With organizations increasingly allowing their employees to access company resources on mobile devices, many ERP vendors are upgrading their solutions to offer mobile functionality. Mobile ERP helps users access company data and perform business operations, both back end and front end, from any location while on the move.[16] In the context of emerging IoT technology and data production, wider traceability coverage up and down the supply chain is being enabled.

[16] https://www.softwareadvice.com/erp/#buyers-guide

7.2 Appendix 2: Traceability best practice across industries

Traceability 'best' practices across industries recognised as global leaders in traceability compared with the common practices of the seafood industry. A comparison is made to the beef industry and is indicative only.

Industry best practices					Common practices	Gaps, needs, issues	Common practices	Gaps, needs, issues
Recommended Process	**Automotive**	**Horticulture**	**Pharmaceuticals**	**Finance**	**Seafood**	**Seafood**	**Beef**	**Beef**
Product Identification - Human- and machine-readable codes on each product that represent at least a unique global identifier. The unique global identifier is composed of a global identification number that identifies the product type and a lot number that identifies data at a finer scale (for example, dates, vessel, production facility, etc.) The original harvest lot number should be identified and linked to all other "lot" or "process/batch" numbers generated during supply chain activities	Direct part marking (DPM). Every part is marked with a code.	Labels with machine and human-readable data affixed to each case.	Unique GTIN, lot number, expiration date contained in bar code on each package.	SWIFT code ensures standardized identification of all transactions occurring between financial institutions.	Wide range of practices— barcodes, stamps, hand-written labels.	Challenge in managing/integrating multiple IDs (POs, work orders, packing orders, etc.) that get generated during critical tracking events. Major logistic issues due to seafood granularity and 'lot' aggregation issues at every level.	NLIS and PICs enable product ID to slaughter which is retained via barcodes until secondary processing (i.e. boning). Lot/batch identification achieved through addition of machine/human readable labels affixed to each carton/package. Product transformation subsequently occurs and a wide range of identifications practices occur as product enters commerce.	Disaggregation process (i.e. boning) and product transformation are challenging product identification activities due to the speed of the process. Variation of granularity through chain must be overcome to enable individual product identification from birth to consumption of product.
Data addition – All data generated by each node in the supply chain are linked to the unique global identifier. When a new lot number is assigned, previous lot numbers are linked to it. All KDEs are linked to the unique identifier.	Each component of a Subassembly scanned on the production line. Subassembly identifier linked to components using ERP system.	Each firm enters and stores additional data which are linked to a GTIN and lot number.	California e-pedigree: record of all handlers of drug accompanies product. Data added at each node.	Each firm inputs data according to global SWIFT standards.	Wide range of practices including electronic and paper based systems.	Major granularity issues across the supply chain. Mid-chain black holes due to combining 'lots'. Challenging to add data in a fast-moving fresh product processing line. Other product forms less challenging.	Wide range of practices persist with paper-based and electronic systems utilised. KDEs are passed to the next supply chain node as required though they are not linked to a unique global identifier.	The supply chain is unable to generate unique identifiers for product at the end of the supply chain and therefore data addition occurs only primarily in node to node interactions. Issue is linked to variation in granularity through chain.
Data partition – Firm-level partitioning or "data-siloing" is minimized to provide access to product data via the architectural portals (conditional on proper "permissions" and high-level security). Clear	ERP system generates automatic reports and handles electronic queries.	Industry standard: one-back, one-forward protocol GTIN and lot number tracked by each firm.	Electronic ERP systems facilitate mandatory data partition.	Enforced by mandatory adherence to industry standards.	Manual partition in the case of a recall or mock recall. Automated systems rare.	Government-issued fish tickets include core traceability information. Seafood industry does organize data that can be easily shared down the value chain. Certain KDEs are required by the retailer	One up, one down systems common. Data sharing through chain is dependant on the level of vertical integration. Data-siloing is common at points of ownership transfer.	Standards and ontology to facilitate permission-based sharing of CTEs and KDEs through chain are required. ERP systems should provide virtual integration of the supply chain and

Industry best practices					Common practices	Gaps, needs, issues	Common practices	Gaps, needs, issues
Recommended Process	**Automotive**	**Horticulture**	**Pharmaceuticals**	**Finance**	**Seafood**	**Seafood**	**Beef**	**Beef**
definitions of data requirements are needed.						(country of origin, species etc.). Data are partitioned at producer level and again at each value chain node.		overcome commercial barriers.
Data storage - All or most data should be stored at the level of the individual firm. Some "core" traceability data could be stored at the "architectural cloud" level if efficient and secure	Each firm stores its own data. Large amount of data-cloud-storage used.	Each firm stores its own data in electronic format.	Turkey: central government database. California: data copy stored by each firm.	Each financial institution responsible for storing granular data. SWIFT systems stores aggregated data in central databases.	Wide range of practices. Storage in firms' computer systems or file cabinets. Information silos are common.	Data input and access may be far slower than real time, especially if paper-based. Fish ticket systems mostly paper-based. May take years to enter logbook data. Need lower cost ERP systems for small companies. Lack of access to infrastructure and human capital (skills) in remote areas of the world.	Paper or data (local, server and cloud) storage systems used throughout the supply chain. Most data is retained within commercial boundaries with core traceability data transferred to the next supply chain node by direct paper or electronic means.	Transposition errors arise as paper based systems are transferred to digital formats. A consistent electronic format should be prevalent within each business with an overarching aggregated database capturing core integrity system data.
Data transmission – Data are transmitted electronically (via data portals) with required permissions. Unique identifiers transmitted with both the data and the product. Data can be transmitted using predesigned modules and/or menus that best meet the strategic needs of individual firms and supply chains	Electronic messaging facilitated by ERP system.	Electronic messaging of GTIN, lot number, date, and firm identification.	Data transmitted with product (California), or data in electronic form sent to central database (Turkey).	Standardised Electronic encrypted messaging. Records linked to financial transactions.	Some electronic messaging but interoperability a big problem. Data often sent physically with the product.	Most firms as well as the value chains lack systems, infrastructure and access to key communication technologies.	Paper and electronic messaging used. Adoption of electronic messaging systems such as eNVD hampered by user reluctance and interoperability issues. Manual collation of data occurring at multiple nodes of the supply chain.	Connectivity and usability hampers uptake of electronic systems, particularly during production. Web-based data portals are needed to overcome the interoperability and manual collation issues.
Data security and access – Architectural framework must be secure to protect privacy and intellectual property of individual companies. Access is granted by each firm via "permissions" to users of data. Different classes of	Manufacturer has power over chain and can initiate data requests. Secure storage.	Secure storage at each firm, can be queried by the firm for a recall.	Secure government database, or each handler can track product back.	Secure electronic. Transfer requests authorized prior to money exchanged between corresponding accounts.	Data may not be secure if paper based. Encryption of electronic data common. In fragmented seafood value chains data may be closely guarded.	Seafood industry will not trust a traceability system without testing and validating security systems. Concerned that cloud portals may provide access into an entire firm's database. Use early adopters to	Paper based systems have limited opportunity for data security practices. Electronic data may be stored locally though remote server or cloud based are used. The high degree of fragmentation in red	Secure storage of electronic data in a consistent format is an urgent next step for the industry. Elevating individual company data into an industry wide system that is dependent on cloud storage and

Industry best practices					Common practices	Gaps, needs, issues	Common practices	Gaps, needs, issues
Recommended Process	**Automotive**	**Horticulture**	**Pharmaceuticals**	**Finance**	**Seafood**	**Seafood**	**Beef**	**Beef**
data may have different permission requirements.						test and demonstrate the system. The level of security should reflect the degree of risk.	meat supply chains generally results in data being securely stored by companies at each node.	permissions will be a hesitant additional step. The value of such an approach would have to be understood and the risks known.
Data collection and measurement - Industry must define KDE's and standardize measurement. Data collection is by individual firms using a variety of techniques (such as paper, electronic sensors, scanners) An interface where manually recorded data can be converted to electronic form for transmission is needed.	Electronic scanners read DPM codes.	Barcode scanners and integration with ERP system.	Barcode scanners commonly used.	Standardised electronic systems that incorporate mandatory protocols.	Wide range of practices including some bar code and other devise scanners. Manual data entry and measurement common.	Reliance on physical measurement and recording of weights, temperatures etc. may lead to measurement and transcription error. Unclear what needs to be standardized? Need for standardizing species name—especially given merging of common names and species mislabelling and fraud. Retailers moving to placing the species and common name of fish on the packaging.	Wide range of practices. Very limited use of automated data collection and analysis systems. Manual data collection is common and occurs in multiple formats throughout the supply chain.	Supply chain critical KDEs and CTEs must be defined and collection, measurement and analysis strategies determined. Where practical, data collection should be automated.
Data validation – Architecture may identify key missing data in transmission process. Architecture can also transmit 3rd party authenticators for firm-level data or other firm-level validation information.	Built in checks to ERP system.	Third party auditors are the norm.	Push towards globally unique identifiers and serialization.	Transaction records and verifications audited by third party auditors, Check's built into proprietary systems.	Wide range of practices. Third party auditors common. Manual double-checking of data. Some use of electronic systems with built-in validation. Primary processor may validate catch data, Enforcement agencies may also validate catch data.	Primary producer data may be difficult to validate. In the seafood industry there is a need for different classes of data validation including authenticating vessels and processors (typically government), certifying the data process used by harvesters and processors (third parties), and data validation using double-checking or computer algorithms.	Third party auditors are common. Manual checking of data common, particularly around NVDs.	Where possible, automate data validation. Develop systems or architecture that drive the industry to a systems based audit approach.

7.3 Appendix 3: Technology companies focussing on traceability and verification

Company	Business Description	Product Offering (Description)	Specific Type
AgKonect	Developer of mobile mapping application designed to assist in integrated pest management. The company's data platform sets up projects, builds an interface, and provides further services including analysis, mapping and reporting systems, enabling clients to improve production with safer technology and also reduce food deterioration and business inefficiency.	Software as Service (SaaS) with annual licence fee. A desktop manager and apps. Mobile Data systems.	Mobile Application, Platform
AgriChain	Provider of agricultural supply chain platform intended to connect and transfers information between supply chain participants. The company's platform offers services like supply chain tracking, stock management, information and eliminate unnecessary paperwork and dockets, reduce supply chain inefficiency and risk, enabling agricultural industries to make better-informed decisions through greater control and visibility over the supply chain.	Management Software Solution. Uses Mobile software, Logistics providers and a web application to provide end-to-end visibility	Platform
AgriDigital Pty Ltd	Developer of a cloud-based blockchain enabled commodity management platform designed to make supply chain simple, easy and secure from farmer to consumer. The company's platform manages all the contracts, deliveries, inventory, orders, invoices and payments all in one place and in real time, enabling agricultural professionals to make transaction and settlement of agricultural commodities and to manage supply chain risk in an easier way.	Cloud-Based Commodity Management Platform for buying, storing and selling grain. Block-Chain Based Solution	Cloud-Based, Blockchain Software, Platform
AgriLedger	--	Uses Distributed Ledger Technologies (DLT), each item can be traced from the seed all the way to the end consumer.	Ledger Technology
Agriwebb Pty Ltd.	Developer of a farm management software designed to track and record the actions of livestock. The company's software help farmers to collect all the necessary data in real-time, even offline and assemble it with full transparency and it also offers paddock treatment and crop recording services, enabling farmers to track, keep, analyze and update farm inventories, pasture and livestock data via a cloud-based record-keeping notebook.	Offers farm management app, Task Managementm individual animal management, farm inventory, Grazing management, farm mapping, weight goals, pasture management, operational planner, Reports, Audit and compliance	Mobile App
Agrometrics, Inc.	Developer of a cloud-based software designed to provide consulting and technological alternatives for the global agriculture domain. The company's platform leverages the use of technology in combination with perceptive	"comprehensive, integrated technology platform that can serve as an operating	Operating system, ML, Blockchain, Platform

Company	Business Description	Product Offering (Description)	Specific Type
	techniques, providing clients with insights for decision making in a way that would reduce costs, improve productivity, quality, and profits.	system plays a vital role in Digital Farming and Market Linkage"	
Agtrix	Supply chain systems for agriculture industry	Range of GIS and location monitoring softwares	GIS Software
Agunity Pty Ltd	Developer of a blockchain-based mobile application designed to connect farmers and cooperatives and help them record sales and farming information securely. The company's application uses blockchain and integrates distributed cryptoledger to track and record all transactions, creates a network of small farmers and updated all information related to crop imports, exports and exchange, enabling small farmers of developing countries to automate agricultural processes, sell harvests and buy supplies efficiently.	Integrated services: Deploy products and services, connect with local groups and end-users, data reporting, analysis of behaviours in rural communities, risk management, communication, detailed reports	Smart phone operating system
Agworld Pty Ltd	Developer of a farm management software designed to improve the world of agriculture. The company's farm management software helps to track the farm performance, enabling farmers to increase their production and profitability and be economically and environmentally sustainable.	Tracking and traceability platform	--
Aries Technology, Inc. (i-Agritrack)	"CropTracer provides you with intelligent crop management. Using pinpoint traceability, a bad batch of produce is no longer catastrophic and can be easily identified and isolated, mitigating the financial impact of crop disease	With CropTracer a simple barcode scan can help you follow produce during its journey from soil to shelf along with a wealth of data about its point of origin down to the exact location it was grown from."	Barcode
AutoMed	Developer of an automatic livestock medication system designed for medication delivery, compliance, disease prevention and traceability for the livestock industry. The company's device automatically calculates and delivers both fixed and weight based treatments simply by synchronizing with existing livestock tools and farm management systems, records livestock data in real time and effectively manages operations of the farmers, enabling livestock producers to manage and optimize their yield from livestock.	Automation System integrated with existing farm management systems to deliver, record and calculated livestock treatments.	Automation System
Bar Code Integrators, Inc.	--	Hardware and Software for advanced information systems for all stages of processes	Warehousing software and Barcode solutions

Company	Business Description	Product Offering (Description)	Specific Type
Bio-Rad Laboratories, Inc. (NYSE:BIO)	Bio-Rad Laboratories manufactures and supplies systems used to separate and analyze chemical and biological materials to life sciences and healthcare companies.	--	--
BIZERBA GmbH & Co. KG	Provider of weight-measurement technology to the food-processing, industrial and retail industries. The company provides hardware and software solutions for the accurate assessment of product weight. The company is a provider of shop scales, cash registers, retail software and inventory-management systems, industrial weighing and data technology, price and goods-labeling systems and related training services.	Softwares include traceability, ERP Systems, applications	Traceability & Network software. Logistics hardware
Blockpit GmbH	Developer of a tax reporting and portfolio monitoring platform designed to provide real-time tax calculation and generate legally approved, zero-knowledge tax reports. The company's platform automates tax calculation, facilitates performance optimization, releases asset economics tool and expands tax alliance, enabling traders to easily calculate the taxation of virtual currencies.	Blockchain software to autosync transactions	Blockchain Software, Mobile app, web app
Bytable	Provider of an online marketplace for local foods intended to help farmers keep track of all farm related data from anywhere. The company create trustworthy data chains that track products from farm to fork using blockchain technology and the internet of things enabling users to reduce costs, limit risk, and build quality brands for every stakeholder in the food supply chain while giving consumers the tools they need to make better decisions about the food they buy and the companies they support.	Food systems for traceability and transparency	IoT Devices and Mobile application
Can-Technologies Inc.	Can-Technologies Inc. offers information technology, control, electrical, and mechanical engineering solutions. The company provides electrical, drives, motion control, instrumentation, and monitoring and supervisory system solutions. Additionally, it offers software solutions, safety services, energy services, building management, and industrial network design services. The company caters to automotive, consumer products, environmental, infrastructure, mining and metals, packaging, pharmaceutical, steel, food and beverage, material handling, and oil and gas sectors. Can-Technologies Inc. is based in Cambridge, Canada.	Systems including data collection, equipment monitoring, Barcode/RFID, Vision systems, Sorting, Control Systems, Safety and improvement	Hardware and software

Company	Business Description	Product Offering (Description)	Specific Type
Carlisle Interconnect Technologies Inc.	Carlisle Interconnect Technologies Inc. designs, manufactures, and distributes wire and cable products.	Hardware applicable to traceability systems	Wires, RF/Microwave products
Cedar Creek Company Pty. Ltd.	Provider of specialized software and hardware solutions committed to offering customized production recording solutions to industry clients. The company provides a range of services including inventory management, automated animal health recording, foodchain data management and data integration, striving to provide customized solutions at a reduced cost.	Software and hardware used to track and monitor the quality of carcases. This system allows for automation, traceability, analytics and regulatory-abiding-practices.	Hardware and software
Cherry Software Limited	Operator of a software development company intended to build custom software systems to meet the needs of small and medium sized businesses across the UK. The company specializes in creating bespoke software systems built using the latest development tools such as Microsoft .NET and SQL Server, enabling businesses to get the software they need to run their business successfully.	--	--
Cisco Systems Australia Pty Limited	Cisco Systems Australia Pty Ltd supplies and supports generic Internet working products and technologies in Australia. The company offers networking products, including switches, routers, network architecture and security products, and access and WAN products; wireless and mobility products comprising indoor access points, outdoor and industrial access points, wireless LAN controllers, and cloud managed and controllerless access points; security, networking, collaboration, and data center software products; Internet of Things solutions; and security products, such as firewall, malware protection, email and endpoint security, workload security, and multi-factor authentication products, as well as services for security.	Networking, Software, IoT devices, Mobility and Wireless, Data Centre, Cloud	Networking, Software, IoT devices, Mobility and Wireless, Data Centre, Cloud
Cisco Systems, Inc. (NasdaqGS:CSCO)	Cisco Systems, Inc. is the world's largest hardware and software supplier within the networking solutions sector. The infrastructure platforms group includes hardware and software products for switching, routing, data center, and wireless applications. Its applications portfolio contains collaboration, analytics, and Internet of Things products. The security segment contains Cisco's firewall and software-defined security products. Services are Cisco's technical support and advanced services offerings. The company's wide array of hardware is complemented with solutions for software-defined networking, analytics, and intent-based networking. In collaboration with Cisco's initiative	Networking, Software, IoT devices, Mobility and Wireless, Data Centre, Cloud	Networking, Software, IoT devices, Mobility and Wireless, Data Centre, Cloud

Company	Business Description	Product Offering (Description)	Specific Type
	on growing software and services, its revenue model is focused on increasing subscriptions and recurring sales.		
CloudFarming	Products from farming operations to quality assurance and traceability	Integrated hardware and software solutions across operations. Labour management, Detailed Yield Tracking, Safety, Quality Assurance and Product traceability.	Application and robot
Cognex Corporation (NasdaqGS:CGNX)	Cognex Corp provides machine vision products that help automate manufacturing processes. The firm's products include vision software, vision systems, vision sensors, and ID products. Vision software combines vision tools with a customer's own cameras and peripheral equipment and can help with several vision tasks, including part location, identification, measurement, and robotic guidance. Vision systems combine a camera, processor, and vision software into a single package. Vision sensors deliver simple, low-cost solutions for common vision applications, such as checking the size of parts. ID products read codes that have been applied to items during the manufacturing process. Cognex generates the largest proportion of its sales in the United States and Europe.	Software, Automation and Barcoding	Software, Automation and Barcoding
Computer Associates, Inc.	Provider of specialized enterprise resource planning (ERP) software and related services intended for industry-specific information systems. The company's product offerings include both on-premise ERP applications as well as web-based Software as a Service (SaaS) ERP applications, tailored for industries such as seafood and other food processing and distribution, millwork, lumber and building materials, precious metals refining and jewelry manufacturing, enabling clients to work productively, make confident decisions and respond quickly to new opportunities.	Cloud-Based, QuickBooks-ready Software for food processing and distribution	Cloud-Based Software
Conservis Corp.	Provider of a farm management system designed to advance the business of agriculture. The company's system improves efficiency in operations, helps users to share information with stakeholders, improves traceability and implement sustainable practices and turns business data into actionable insight, enabling growers and producers meet growing, global demand for agricultural products and take informed decisions.	Farm Management Software. Agricultural Software Platform . Farm & Financial Plans, Purchasing, Ownership splits. Applications, Web applications.	Platforms, Web and Mobile Application

Company	Business Description	Product Offering (Description)	Specific Type
Datalogics, Inc.	Developer of a typesetting and database publishing software designed to offers PDF developer technologies. The company's typesetting and database publishing software licenses software development kits for working with PDF files and EPUB files as well as offers a typesetting and database publishing platform, enabling software developers to bring their products to market faster and with superior eBook and PDF capabilities.	Enterprise PDF Technologies. Software for developers (PDF SDKs, PDF Tools & Digital Publish)	PDF Technologies
Dear Systems	Suit of softwares to track, disassemble bulk purchases, capture all food & real time inventory production costs		Suit of Hardware and Software
Ecogistix	Developer of agricultural management platform designed to help farmers business grow and achieve digital transformations. The company's cloud-based SaaS (software as a service) platform helps in the management of inventory, order, transportation, fulfillment and team by keeping an automatic track on all the activities and functionality on real-time, enabling farmers to increase operational efficiency, improve customer satisfaction and distributors to meet safety compliance with food traceability solutions.	Platform that offers; Traceability, Team management, inventory management, order management, Transportation Management, Fufillment Management	Platform
Eka Software Solutions	Developer of commodity management software. The company's software is driven by the cloud, blockchain, machine learning, and analytics, and help companies manage commodity trading, enterprise risk, compliance, procurement, supply chain, operations, logistics, bulk handling, processing, and decision support, enabling companies to accelerate growth, increase profitability, improve operational control, and manage risks and exposures.	Offers a trusted marketplace for farmers and buyers where crops can be tracked and traced as they move through the supply chain.	Marketplace
Elynx	"Mobile tablet based app for livestock management. Record data for individual animals and for whole mobs. System captures RFID, weight, treatments, history and all key animal data. Calculates average daily gain. Records all movements. Full paddock book functionality includes mapping and forage records. Integrates with StockaID. Synchs with cloud. Powerful export and reporting functions."		Mobile Application
EMNS Inc.	Developer of a supplier quality management software. The company's software measures supplier quality, implements supply chain traceability, simplifies regulatory compliance, improves supplier collaboration, gathers supplier data and improves time to market and supply chain metrics, enabling manufacturers	A cloud application that integrates processes and creates visibility across companies' supply chains.	Cloud-Based Software

Company	Business Description	Product Offering (Description)	Specific Type
	to easily connect and collaborate with their suppliers improving material quality and simplifying ongoing regulatory compliance.		
Escavox Pty Ltd	Developer and provider of solutions intended for the issues that inherently affect the value of fresh food supply chains. The company offers a B2B solution that uses a range of technologies and commercial models to improve supply chain efficiency, enabling to meet the more exacting demands of markets, customers and consumers.	"Escavox provides independent and objective data on the performance of fresh food supply chains, from farm to retail shelf, so better informed decisions can be made about the management of product and investments in the supply chain."	Cloud-based data provider
FoodLogiQ, LLC	Developer of a supply chain transparency software designed to validate supplier compliance with food safety and act. The company's software specializes in supplier management, food safety compliance, quality incident and whole-of-supply-chain traceability to validate supplier compliance with food safety and act, enabling food companies to improve global supply chain visibility, streamline supplier management, build quality issue tracking and reporting.	A web and mobile app that offers "true farm-to-fork traceability from grower to distribution center, to the retailer or restaurant".	Web and Mobile Applicatiion
Fresh Supply Co. Pty. Ltd.	Developer of unified software platform designed for API -led connectivity. The company's platform brings together five different types of software in the current supply chain into an integrated layer, enabling agricultural producers to get traceability in their supply chain and elevate their brand.	A public ledger option allowing consumers to authenticate products.	Blockchain Software (Public Ledger)
GrowSafe Systems Ltd.	Developer of data acquisition technology intended to improve animal well-being and farm profitability. The company's platform automatically measures bio-metric and environmental inputs in livestock production environments, continuously monitoring individual animal health and performance status, enabling users to monitor individual animals, measure and predict their market value and identify and treat targeted animals without human intervention.	"GrowSafe's data platform is a fully integrated system providing physical sensing, predictive analytics and cognitive computing. Commercial applications built on the platform collect data across the animal production supply chain, enabling new insights, enhancing decision making.	Integrated Software and Hardware
GS1 Australia	--"The GS1 traceability system integrates with existing legacy systems to grow as your business grows and adapt to the changing complexity of supply chains. At GS1 Australia we are ready to help you tackle some of your greatest supply		Compliance and Software

Company	Business Description	Product Offering (Description)	Specific Type
	chain challenges, providing you with the building blocks for your company to move with the times and grow with demand."		
Hitachi Australia Pty Ltd	Hitachi Australia Pty Ltd engages in the import and distribution of power products, electronic components, industrial equipment and systems, digital presentation products, consumer products, and security solutions in Australia. The company was founded in 1983 and is based in North Ryde, Australia. Hitachi Australia Pty Ltd is a subsidiary of Hitachi, Ltd.	"Information such as ordering of parts is managed on the blockchain, and trace management of parts and product information across multiple manufacturers is realized."	Blockchain Software
Hitachi, Ltd. (TSE:6501)	Hitachi Ltd provides IT services and has an expertise in the range of business fields, including financial services. The company's main products and services include system integration, consulting, cloud services, servers, storage, software, telecommunications and networks, and ATMs. Hitachi operates in various segments namely, Information and Telecommunication Systems; Social Infrastructure and Industrial Systems; Electronic Systems and Equipment; Construction Machinery; High Functional Materials and Components; Automotive Systems; Smart Life and Ecofriendly Systems; Financial Services; and Others.	"Information such as ordering of parts is managed on the blockchain, and trace management of parts and product information across multiple manufacturers is realized."	Blockchain Software
Hyxus	Developer of agricultural management platform designed to empower the agricultural world. The company's platform tracks agriculture items, manages performance records of inventory lifecycle events, integrates data, and generates reports, enabling agricultural producers and manufacturers to streamline operations and make data-driven decisions.	Hyxus is a centralised cloud-based platform that enables traceability, inventory operations and analytics.	Cloud-Based Software
Impinj, Inc. (NasdaqGS:PI)	Impinj Inc operates a platform that enables wireless connectivity to everyday items by delivering each item's identity, location, and authenticity to business and consumer applications. Its platform includes endpoint integrated circuits (ICs) product, a miniature radios-on-a-chip, which attach to and identify their host items; and connectivity layer that comprises readers, gateways, and reader ICs to wirelessly identify, locate, authenticate, and engage endpoints via RAIN, as well as provide power to and communicate bidirectionally with endpoint ICs. Geographically, the company has a business presence in the Americas, Asia Pacific, Europe, Middle East and Africa, of which key revenue is derived from the operations in the Asia Pacific region.	"Impinj (NASDAQ: PI) helps businesses and people analyze, optimize, and innovate by wirelessly connecting billions of everyday things—such as apparel, automobile parts, luggage, and shipments—to the Internet.	RFID and Applications

Company	Business Description	Product Offering (Description)	Specific Type
Infor, Inc.	Developer of an enterprise planning software created to provide cloud-based industry-specific business applications. The company's vertical software automates and integrates business processes, enabling companies in healthcare, fashion, retail, distribution and public sector to easily manage inventory and logistics to manage their suppliers, partners, customers and employees.	"CloudSuite™ Food & Beverage is a complete, yet flexible software solution that has all the right ingredients to help overcome business challenges that are unique to the Food and Beverage industry—such as managing short lead-times, evolving your channel-to-market strategy, and meeting ever-changing regulatory requirements."	Cloud-Based Software
Innovapeak Ltd. (Safefood 360)	Developer of a food safety management platform designed to help businesses get full control over food safety, quality and compliance management. The company's platform helps to schedule, record and report on all elements of a food safety system and contains carefully developed modules for HACCP planning, prerequisite programs, management, risk assessment modelling, monitoring, document control, supply chain management and utilities, enabling food safety plants to keep all records in one place with 24/7 access with one-click reports.	Offers a traceability module which allows businesses to set up and conduct traceability tests and audits. This is intended to help businesses align with GFSI requirements	Traceability Module
Intermec, Inc.	Provider of wired and wireless automated identification and data collection products. The Company designs and develops data capture and information management modules between mobile workers, assets and customers.	--	--
International Business Machines Corporation (NYSE:IBM)	"IBM Food Trust™ is the cloud-based blockchain solution providing an open, flexible and trusted way for members to share food data, derive value from the contributions of others, develop breakthrough functionality – and soon – choose where and how they deploy."		Cloud-Based Software, blockchain software
James Tyler	James Tyler is a cold chain logistics platform that delievers "fresh dairy, meat, seafood, fruit and premium wine to over 90 cities in China". This platform protects the brand and authenticity of our local food and beverages, while also promoting confidence and trust in the ultimate buyers.		Logistics Provider
John Deere Limited (Australia)	John Deere Limited (Australia) imports and distributes agricultural equipment and replacement parts; and consumer and commercial equipment, and related replacement parts.	Sensing solutions, telematics, program management, product testing, integrated displays	Sensors, management and displays

Company	Business Description	Product Offering (Description)	Specific Type
Laava ID Pty Ltd	The Smart Fingerprint provides information on provenance, traceability, blockchain and marketing for each unique item. This protects customers against fake products, while also protecting businesses from reputational damage. Customers are able to easily scan Smart Fingerprints , which can be feasibly and cheaply integrated.		Barcode, Blockchain
Linkfresh Software Group Limited	Provider of enterprise resource planning software. The company's enterprise resource planning software provides real time insight into traceability, food safety and compliance from a single point of reference to the fresh food industry.	"The LINKFRESH solution provides critical fresh produce industry functionality, not available in a standard ERP solution, such as Grower Accounting, Traceability, Consignments, Farming and Quality Control.	Business Managemet Software Package
M2M Connectivity Pty Ltd	"Smart Farming/Smart Agriculture is not just for large farms and research centres, but is starting to impact small and medium-sized farms. The farming industry is receptive to technical innovation and is already embracing the IoT, using information from sensors, machinery and weather stations. It is the ability to capture, harness and analyse vast amounts of data to take informed decisions that is set to revolutionise the agricultural sector and is starting to deliver tangible benefits and measureable ROI (return on investment) for farms of all types and sizes." One of the applications of this technology is animal tracking.		Sensors (tags, machinery and weather stations) and Internet of Things
Mar-Kov Computer Systems Inc.	Provider of manufacturing software, information management, management system, and process manufacturing. The company operates within the industries of automation/workflow software, other software, and business/productivity software.	Trace Child allows you to "trace everything that was made or shipped with an ingredient or component lot. Trace Parent on the other hand allows you to trace the process behind making the particular product lot.	--
MASS Group	With its fully integrated production management, genealogy and traceability capabilities, TME® tracks the processing of food from the receipt of ingredients to the sale to its final destination for safety, quality, and compliance. TME® can also be used to track the packaging and distribution of food crops and finished goods to wholesalers and retailers, thereby enabling manufacturers to identify		Barcode

Company	Business Description	Product Offering (Description)	Specific Type
	and locate products that have already been distributed in case of a necessary recall.		
Merit-Trax Technologies Inc.	"Each TRAX-IT software module integrates production management, quality assurance and traceability data collection which stores the data in one integrated database. This integrated database amplifies your business management capabilities using dynamic reports, dashboards, and key performance indicators in real time. Merit-Trax Technologies is a recognized expert and contributor for the implementation of barcode, RFID and traceability technology in the food industry. Merit-Trax works with food industry companies and associations to ensure that it provides the maximum benefits of food software systems."		Integrated Database
MyOrigins	"An integrated eCommerce, digital and blockchain based technology. For Australian Merino growers, MyOrigins provides data collection and management tools in the form of an Android smartphone app. We'll even supply the phone! For brands, MyOrigins provides the opportunity to connect directly with growers and provide consumers with confidence in the ethical production of their goods. For consumers, MyOrigins provides a trusted traceability platform that allows them to connect with the grower responsible for the fibre in their goods."		Digital blockchain technology, Data and management tools on a phone
NATIVE(Business/ Productivity Software)	Developer of a cloud-based business-to-business software designed to democratize agricultural data to enable market transparency. The company's software connects buyers with growers and farmers and provides them the opportunity to access crops before or as soon as they are harvested, with complete tractability from seed-to-sale, enabling growers to meet the rising demand for traceable food.	"NATIVE is a two sided software platform. The first software tools are utilized at the beginning of the supply chain: the farm. Our post harvest management system built for farms is an inventory and CRM hybrid, enabling farmers to capture real harvest data and allocate goods to their buyers immediately upon harvest. Each farm also has a NATIVE marketplace they can use to communicate inventory to wholesale buyers who do not have static, recurring orders.	Supply Chain Software, Harvest Management System

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PairTree	Developer of a customizable farm-scale analytics and visualization dashboarding platform intended to provide services to the digital supply chain. The company's technology is designed to service farmers, by centralizing all data streams that are associated with their operational decision-making process, enabling farmers to provide additional opportunities to agribusiness service providers.	"Pairtree Intelligence is building a network of progressive device and service suppliers that wish to build a better connected world and supply meaningful decision solutions. The Pairtree ecosystem is considered to be a key element of allowing resource managers to understand how they might improve their decision making process.	Suite of Hardware and Software
Picarro Inc.	Provider of an optical stable isotope measurement instrument designed to cater the needs for availing a sustainable environment. The company's instrument is used in a wide variety of scientific and industrial applications, including atmospheric science, air quality, greenhouse gas measurements, gas leak detection, food safety, hydrology and ecology, enabling clients to detect targeted molecules at part per billion, or at better resolution.	--	--
RedLine Solutions, Inc.	Redline Solutions is a Santa Clara, CA based private company whose line of business is Computer peripheral equipment.	A Unique Device Identification (UDI) device that verifies and standardises product serialisation and barcodes.	UDFI barcode verifiers
Seagull Scientific, Inc.	Developer of labeling and bar-coding software. The company offers applications for Label, Barcode, RFID and Card Printing that enables any organization to improve safety, security, efficiency and compliance by marking and identifying any and all items of importance.	"BarTender® barcode and label software is an integral component of the logistics, warehousing, transportation, compliance and traceability labeling strategies of the world’s supply chains. BarTender can help you accelerate your value chain transformation, providing integrated business planning and interoperability	Barcode and label software
SGS Australia Pty Ltd	SGS Australia Pty Ltd provides inspection, verification, testing, and certification services in Australia. The company offers outsourcing, risk management, technical consultancy, and training services. It also provides agricultural services such as soil, mycotoxin, and Genetically modified organism (GMO)	With the incorporation of cloud, artificial intelligence and blockchain technology, Transparency-One is capable of monitoring and tracking all suppliers, ingredients and facilities in the supply chain. This is a digital solution intended	Cluod-Based Software, Artificial Intelligence & Blockchain Technology

Company	Business Description	Product Offering (Description)	Specific Type
	testing; analytical; food and feed safety; collateral management; logistics; upsourcing; pre-shipment inspections etc.	to build consumer trust. All Species ID is a single test that can identify all species within a food sample, including pathogens, allergens and potential adulteration.	
SGS SA (SWX:SGSN)	Switzerland-listed SGS is the largest and one of the oldest companies in the testing, inspection, and certification industry. The company's primary activities involve testing products and materials, inspecting sites/industrial equipment, and certifying products and systems to ensure global/company standards. SGS is one of only four TIC companies that operate globally across numerous industries, including agriculture, food and life science, and transport services. SGS was first listed in 1981 and employs more than 96,000 people worldwide.	With the incorporation of cloud, artificial intelligence and blockchain technology, Transparency-One is capable of monitoring and tracking all suppliers, ingredients and facilities in the supply chain. This is a digital solution intended to build consumer trust. All Species ID is a single test that can indentify all species within a food sample, including pathogens, allergens and potential adulteration.	Cluod-Based Software, Artificial Intelligence & Blockchain Technology
Smart Paddock	Developer of a farm management tool designed to modernize the global livestock industry through intelligent IoT data analysis. The company's farm management tool is based on a small, lightweight, multi-sensor eartag for livestock which remotely monitors the animal's health and location as well as provides early indication of health-related issues via a browser or smartphone application, enabling farmers to increase production efficiency and improve animal health and well-being.	The Bluebell is a multi-sensor eartag that is capable of tracking heartrate, temperature, location and movement to search for potential health issues relating to livestock. It is also able to offer real-time information through a web and mobile app platform.	Sensor & Web and Mobile Application
Software Objectives	--	Remote monitoring and controlling of agricultural and industrial processes	Remote system
Sparrows (freight)	Developer of a shipping logistics program to track and monitor freights and assets for APAC's leading brands. The company aims to use a combination of software and hardware to provide users with customisable checkpoint alerts when shipments or assets are leaving and approaching destination, set up safe thresholds, get alert if there is an issue and better visibility over the entirety of their operation, enabling users to save money and optimize their time.	Sparrows provide the technology to bring full visibility to your supply chain - to allow you to track and monitor the location, storage and movement of high value and perishable goods. The technology includes features such as:	Supply Chain Software

Company	Business Description	Product Offering (Description)	Specific Type
		alerts that generate action, live tracking and shipment history.	
Stid Electronic Identification Limited	"STid has developed an innovative range of UHF readers and passive tags for tracking critical items. The GAT nano ultra compact integrated antenna readers meet the needs of a broad range of applications in industrial traceability and logistics manage assets, track and trace large quantities of RFID-tagged crates, pallets, rolls, containers and items in real-time."		UHF Readers & Sensors
SwarmFarm Robotics	Developer of robotics technology built for agricultural sector. The company's technology replaces large tractors and sprayers so that farmers can use autonomous, collision-avoiding robots that can spray on crops with accuracy, enabling farmers to avoid the problem rural labour shortage by spraying crops in swarms.	Robots that are able to autonomously run agricutltural practices while also collecting important data for farmers.	Automation System
Thermo Fisher Scientific Australia Pty Ltd	Thermo Fisher Scientific Australia Pty. Ltd., doing business as Datataker, manufactures analytical instruments and laboratory equipment for pharmaceutical and biotech companies, hospitals and clinical diagnostic laboratories, universities, research institutions and government agencies, and environmental and industrial process control applications in Australia.	--	--
Thermo Fisher Scientific Inc. (NYSE:TMO)	Thermo Fisher Scientific sells scientific instruments and laboratory equipment, diagnostics consumables, and life science reagents. The firm operates through four segments: analytical technologies (23% of sales); specialty diagnostic products (15%); life science solutions (26%); and lab products and services (41%).	--	--
Tie Up Farming Pty Ltd	Provider of farming operations platform intended to specialize in precision agriculture and traceability. The company's platform combines precision agriculture services like weather stations and soil sensors, with practical tools like costings per block and full traceability systems along with performing analytics includes disease modelling, weather forecast and yield forecast, enabling agriculture industry to access information regarding spray drift warning, frost warning and storage monitoring.	"Tie Up Farming is an end-to-end software solution for horticultural agribusinesses. Our Smart Dashboard centralises all of your agribusiness' data in the one place, allowing you to oversee all of your farm's operations. Using a full suite of modules, our cloud-based farm management software can be tailored to help you plan, manage, forecast and budget your farm operation from	Cloud-Based Software

Company	Business Description	Product Offering (Description)	Specific Type
		planting to packing. Our Smart Dashboard allows you to visually map, track and forecast your future harvests, record and manage your day-to-day production activities, comply with Global Gap, pass audit with flying colours, export with ease, and more."	
TraceTracker Innovation ASA	Developer of a software intended for value chain traceability in complex supply chains. The company's software captures, stores and presents information which is shared on real-time basis, enabl;ing the industries to get a complete business key performance indicators and operational dashboards monitoring in every process.	"GPAS is an innovative and comprehensive cloud-based Brand Protection, Track & Trace and Consumer Engagement Service that drives business value by addressing problems and challenges that organisations face when operating within global markets."	Cloud-Based Software
Trimble Inc. (NasdaqGS:TRMB) Trimble Australia Solutions Pty Ltd	Trimble Inc provides location-based solutions that are used in global positioning system (GPS), laser, optical and inertial technologies. Its products portfolio includes 3D laser scanning, flow and application control systems, monitoring systems, water management, and navigation infrastructure. It also manufactures laser and optics-based products, and GPS products. The company serves various industries which include agriculture, architecture, civil engineering, survey and land administration, construction, and geospatial. It derives most of its revenues from the US and Europe with the rest coming from Asia Pacific and other markets.	"Growers could bypass relying on the retailer altogether by adopting item-level traceability, another solution developed by HarvestMark. Item-level traceability is where every single product has its own unique QR code that the consumer can scan with his or her smartphone to learn more about the product. This information can include the field and lot where the product was harvested, the date it was harvested and sometimes even the crew that harvested it."	Barcode
Trust Codes Limited	Developer of a verification technology system. The company develops a verification technology software that helps in ensuring product authenticity, serialisation of product codes, brand protection and anti-counterfeits.	With this consumer accessible digital item identity, Trust Codes® helps food and beverage brand owners combat product fraud, engage with consumers and comply with regulatory	Cloud-Based Software

Company	Business Description	Product Offering (Description)	Specific Type
	"Trust Codes® is a powerful cloud based platform which creates a unique digital identity for every product/item to make it traceable. Our technology goes beyond 'mass-serialisation' because each and every cryptographic identity is web addressable to create a persistent and traceable item level digital fingerprint.	requirements. Trust Codes®' novel use of cryptographically unique codes to identify each and every item/consumer good and optional blockchain technology integration provides a transparency platform for food, beverage, nutraceutical and pharmaceutical brands, leveraging the power of mathematics and algorithms to deter and catch criminals & counterfeiters. With Trust Codes®, no downloaded app is required to engage openly with consumers."	
YottaMark, Inc.	Provider of traceability and authentication solutions intended for brand protection. The company's SaaS allows codes to be traced or authenticated anywhere with just a mobile phone or through the internet, enabling brand owners to detect and deter diversion, counterfeiting and fraud with ease.	"YottaMark provides instant product authentication anywhere, anytime by anyone. Manufacturers, brand protection personnel, law enforcement officials – even consumers – can instantly verify the authenticity of products with YottaMark security codes with a camera phone, SMS, a handheld scanner or access to the Internet. YottaMark delivers yes/no results combined with Instant Alerts and Threat Maps."	Barcode
Zebra	Zebra Technologies designs a large suite of products for the automatic identification and data capture market including mobile computers, barcode scanners, RFID readers, specialty printers for barcode labeling and personal identification, and related software and supplies. The company operates in two segments: asset intelligence and tracking; and enterprise visibility and mobility, which account for roughly 35% and 65% of total sales, respectively.	"iCertainty, a Zebra Technologies Validated partner, implemented a solution to effectively track and trace cheese from the receiving dock to point of sale. The FareTrace application is a cloud based, food traceability solution that tracks products by their unique lot numbers while monitoring both the	Cloud-Based Software

Company	Business Description	Product Offering (Description)	Specific Type
		original and adjusted shelf life. The granular detail is essential as traceability becomes even more complex with multi-ingredient foods or the re-packaging of foods from bulk state to individual portions.	
GrowData Development	GrowData Developments is a privately owned Australian company which specialises in management software for the horticultural industry. We have been building and selling management software to the horticulture industry for 17 years and during this time we have developed an extensive client base which ranges from clients with 5 hectares to multinationals with 20,000 plus hectares under production. We have well in excess of 200,000 ha. under GrowData management.	GrowData makes it easy for you to track all your cost inputs down to crop, variety and block level. This information is critical to enable you to plan, monitor and analyse the performance of your business. GrowData makes audits a breeze. Food safety and quality assurance compliance is an important area of management and GrowData is constantly being updated to meet the requirements of international QA systems such as GlobalGAP.	Software
FreshChain	FreshChain is a fully integrated, blockchain enabled, paddock to plate assurance system that verifies the food you eat. In just a few seconds, we can provide traceability throughout the supply chain and provide real time insights to make better decisions during a products life-cycle.	Growers and Producers Manage your product throughout the supply chain, managing risk. Call out your passion for freshness and quality to create meaningful relationships with your customers. Wholesalers and Retailers Manage quality from receipt to customer. Establish direct connections with consumers. Actionable insights like never seen before.	QR Code