TRAKKA | Making Data Flow

Exploring a producer centric data sharing infrastructure for the red meat industry.

Final Report

By: Prof. Dave Swain, Will Swain, Jon Medway, A.Prof. Lihong Zheng, A.Prof. Ashad Kabir, Dr. Shawn McGrath, Mahir Habib, Rabin Dulal

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Author contact details

Name: Dave Swain
Phone: 0448811936
Email: dave.swain@terracipher.com

Food Agility CRC contact details

Level 20 / 135 King Street
Sydney NSW 2000

hello@foodagility.com
www.foodagility.com

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The project team would also like to thank the many organisations, both data publishers and data subscribers who engaged with the project to explore how AgriTrakka could work for them and shared their thoughts, opinions and feedback.

We appreciate that a data sharing infrastructure raises many questions about data sovereignty, data ownership and data rights and the discussions with the above groups have helped shape and form the direction of the project in a holistic manner.

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PROJECT DESCRIPTION

The Australian red meat industry has a wide range of technology solutions to improve business operational efficiencies, however the data produced by these systems remains frustratingly siloed, fragmented and inconsistent. Interconnecting these service providers and standardising the data shared between them could unlock latent value throughout the agrifood value chain. Any data sharing infrastructure must put data owners (producers) in control of their own data. The Trakka project explored the requirements of a producer centric data sharing infrastructure that could act as an ‘honest broker’ in the exchange of producer’s agribusiness data.

PROJECT PARTNERS

The Trakka project is a partnership between the following organisations.

The Food Agility
Cooperative Research Center

Integrity Systems Company Limited

TerraCipher Pty Ltd

Charles Sturt University

EXECUTIVE SUMMARY

This report provides details on a project that explored opportunities for a data sharing platform to support the Australian red meat industry. The project activities were motivated by a challenge to deliver real time animal identification and monitoring. Australian producers already utilise many forms of technology in their operations, which could provide real time, event[1] based, animal identification and monitoring. These technologies need to be interconnected in a way that puts the producer in control of their data. This core principle applies more broadly to a value driven data sharing infrastructure. The project used an action learning approach to develop a suite of technologies that allowed the project team to address questions related to the needs of the core infrastructure. Specifically this report consolidates the findings from the activities that address the three key elements required to deliver a value based data sharing solution:

- Data distribution: How can data be distributed between interconnected service providers, while ensuring the data owners remain in control?
- Data standardisation: How can data publishers and data consumers be sure they are "speaking the same language"?
- Item identification: How can each discrete item that has event data attributed to it, be identifiable in a robust way?

This research has important implications to drive new models that enable users to control their data and to enhance the value of their data throughout the supply chain. Siloed data occurs when there is ambiguity over data ownership or the source of data from third parties is locked into proprietary software. These factors result in data that cannot be easily moved to deliver value across services. The problem of data access is further compounded by a lack of standardisation causing friction for third party developers that want to use the data to drive new service offerings. Finally, the usefulness of data is its ability to describe the state of an item or system. As data is generated throughout the supply chain this needs to be linked and reliably tagged to an item or system that it is describing. Reliable identification underpins the value that can be extracted from data.

TerraCipher is a technology company that has a mission to turn 'Knowledge into Action'. The research conducted in this project is available for the red meat industry through the AgriTrakka platform. It allows producers to use the unique identification from cattle radio

[1] The term event is used throughout this report and refers to a discrete defined activity that has the potential to generate information. The information describing an event should be able to identify an item (animal) the event refers to, what the event is, who owns the item, where the item was generated and when the event occurs.

frequency identification (RFID) tags and the associated property identification (PIC) code as the basis to attribute standardised event data to the animal that can be transferred between service providers though connections commissioned by the producer. TerraCipher intends for their AgriTrakka platform to be the honest broker of Australian farmers' valuable agribusiness data.

The main beneficiary for this project will be primary producers in the red meat industry. It provides the opportunity for producers to take control of their data and to more easily connect to new service providers. The underpinning technology provides opportunities for new value offering throughout the supply chain. It also provides the ability for new service providers to more easily access critical data permissioned by the producer that could result in unrealised value.

The action learning approach allowed the project team to explore the foundational technologies and architectures that are required to underpin a data sharing solution. The developed applications simulated a range of data publishers including a data sharing layer and a number of data subscribers, allowing the team to validate critical assumptions quickly. Early testing incorporated the national livestock identification system (NLIS) test data. Simulated data subscribers included herd tracking endpoints as well as automated reporting. The data sharing layer was integrated into a dashboard enabling users to dynamically control the data flow from any data publisher through to a data subscriber. The simulated applications were fully functional and allowed the review committee and initial early adopters to test each application and evaluate the functionality.

The development of these core applications highlighted the foundational drivers for data sharing. The research team used the applications to evaluate different configuration options. The foundation for user controlled data sharing required an address system that allowed any data publisher to connect to any data consumer for each discrete event, while also including the data owner's unique identification. This system provided a dashboard with a user toggle button to configure the address and turn on the data flow, with each event being controlled separately. The data standardisation was formulated based on existing data schema and linked to the International Committee for Animal Reporting (ICAR) and ISC standards. All messages were encoded in a JSON[2] format and a JSON validator ensured publishers had accurate data formats and if there were inconsistencies useful information was provided to allow them to correct the messages. To ensure individual animal data was linked to a robust identification system we integrated all forms of identification into a single data repository. Ear tags both electronic and observational are important forms of identification. Given cattle

[2] JSON refers to Java Script Object Notation and is the most widely used data format defined by a standard syntax based on key value pairs. The key is a standardised label that a value can be assigned to.

can lose tags the research team explored opportunities to integrate unique biometric identification. A proof of concept muzzle identification system was developed.

The project has a number of recommendations:

- The data sharing infrastructure has achieved an overall technology readiness level (TRL) of 8. It is now functional and can be used by producers. User feedback will help refine the dashboard and it now needs to be made available and progress towards user adoption. Further integration of data publishers and data subscribers is also a critical next step.
- The data standardisation and validation has achieved a TRL 6. An initial set of events have been defined in alignment with ICAR and ISC, however it requires more events to be added to the schema. Further work needs to be conducted to manage the maintenance and extension of the schemas within an operational environment, including feedback mechanisms that provide producers and organisations the ability to comment on data standards.
- The muzzle recognition software has achieved a TRL 5. The key current unknown that will limit commercial value is to link industry application to image quality. To achieve this requires more work collecting high resolution standardised images to be able to determine the minimum image quality that can be used for accurate identification. Extending the muzzle recognition research to refine the image specification required to deliver an accurate muzzle recognition system so that it can be pragmatically applied by Australian producers.
- The uptake of data standardisation and event-based messaging will require early adopters to champion the value. Identifying and providing support to access data standardisation and data sharing will be critical to growing adoption rates. Additionally translating technical data standards into layman terminology that can be understood by non-technical readers will further lower the barriers to data standard adoption and increase the understanding of the potential business value.
- The AgriTrakka uploader is now available in the Google marketplace to allow producers to easily upload their excel or csv files directly to their AgriTrakka connections. This ensures producers can participate in sharing their data regardless of the technology they use. Further refinement and development of the uploader will deliver automated data pipelines that facilitate data standardisation and sharing via AgriTrakka including extending out the number of standardised events available to producers through the uploader.

INDUSTRY IMPACT METRICS

The industry impact from this project will come from the three core areas (for details of the assumptions and benefits calculation see appendices):

- Improved regulatory efficiency and accuracy for red meat producers through increasingly automated and standardised data transfer and the minimisation of data duplication.
- New value for red meat producers by enabling them to connect their data to new services providers, allowing a single packet of data to drive value through being utilised multiple times.
- New direct revenue streams for red meat producers that are able to transact data as part of either an animal transaction or separately to be used to develop marketable algorithms.

Enhanced regulatory efficiency $144 million industry savings in five years	**New value creation $450 million in new annual revenue in five years**
This technology could improve accuracy and efficiency of regulatory reporting, maintaining market access e.g. reducing manual data transactions with NLIS by 30% in two years and 90% in five years.	Increased data sharing controlled by producers, opens opportunities for new value creation e.g. 10% of producers will be accessing a new to market service provider in two years and 30% in five years.

Supply chain data sharing $450 million in new annual revenue in five years Industry wide data sharing can be facilitated by interconnecting any service provider with any other service provider and giving producers (data owners) the controls e.g. 5% of the industry will be using a data sharing exchange in two years and 30% in five years.	**Data standardisation $750 million of increased productivity in five years** Industry wide data standards drive new efficiencies by ensuring industry stakeholders are "talking the same language" and driving innovation from new insight linked to large scale machine learning e.g. 10% of producer derived data will align with ISC data standards within two years and 50% with five years.

PARTNER IMPACT STATEMENTS

Technology and Industry Partner - Will and Dave Swain from TerraCipher

TerraCipher's mission is to turn 'Knowledge into Action', which their core SaaS products have been designed to facilitate. The AgriTrakka project has enabled the TerraCipher team to work closely with the CSU research team to deep dive into a philosophically different approach to a data sharing infrastructure. A bottom up approach that empowers the data owner is the optimum solution, focusing on data distribution rather than data aggregation, however to enable this, many assumptions needed to first be clarified. These could not be addressed without the Trakka project. The TerraCipher team values partnerships with Universities that enable opportunities to explore innovative solutions. This project allowed the TerraCipher team to use an action learning methodology founded in engineering new products. These products could then be used to test assumptions and more thoroughly research the foundational elements that contributed to the working solutions.

The impacts from this project includes:

- A completed data sharing platform that is ready to start to generate revenue.
- A deep dive into JSON schemas to provide a framework that can robustly validate data being passed through the data sharing infrastructure.

- Growing a partnership with CSU that has been further developed to secure further funding to deliver research that has impact.
- Intellectual property that can be used to drive further commercialisation using vision recognition software for animal identification.

Research Partner - Ashad Kabir, Jon Medway, Lihong Zheng, Mahir Habib, Rabin Dulal and Shawn McGrath from Charles Sturt University

Charles Sturt University's mission is to build skills and knowledge in our regions. We exemplify this through our institutions and initiatives such as: The Gubali Institute, which creates impactful integrated agriculture, water and environment research; and The Global Digital Farm, which is an integrated digital learning, innovation and research environment working within a full scale, commercial, mixed farming operation. It is projects such as these that foster strong partnerships and facilitate innovative research that results in real world impacts. The Trakka project and the partnership with TerraCipher fits this remit perfectly and aligns with CSU's core mission. We believe the Trakka project and the AgriTrakka infrastructure has laid the foundations for an industry wide, producer centric, data sharing infrastructure. It also aligns strongly with broader pan industry initiatives including Australian Agrifood Data Exchange (AAFDX), which seeks to develop "An interconnected data highway for Australia's Agrifood value chain" and which CSU is a Tier 1 partner.

END-USER PROFILES

There are three core user groups that interface with the AgriTrakka infrastructure which include data owners, data publishers and data consumers. While these are separate groups, an entity can be a combination of these, for example, a service provider may both publish and consume data, or a producer may publish their own data through the AgriTrakka Uploader.

Producers / Data Owners

The Australian beef industry is made up of a diverse range of stakeholders throughout the supply chain, however in the context of the Trakka project breeder and finishing operations have been the focus across both northern and southern production systems.

The "messy middle" and controlling my data.

> **"**I utilise a lot of technology in my operation, which helps me solve specific problems I have, but I can see the opportunities for this data to drive more value for me than just looking at it on a graph. For example I'd love to be able to easily share my growth rates with my agent so they can target the right markets at the right time. I currently don't feel like I have control

> over my data because it is sitting in all these different systems. I can see that the AgriTrakka platform on the other hand will make data sharing clear, simple and easy. Being able to turn data flows on and off with a simple button is like magic.**”**

Data standardisation

> “As a cattle producer, I am interested in the possibility to aggregate data for cattle weights through Agritrakka to create a benchmark for current young cattle weight gains - how are other cattle in an area or state performing, allowing me to benchmark my own performance. Having my data will be in the same format and with the same headings no matter where it is coming from will allow me to compare my data much more easily.”

Lost tags and traceability - IDTrakka

> “As a non-breeder who purchases animals to grow to feedlot weight, there is a loss of premium when selling direct to feedlot if more than 10% of my animals have lost lifetime traceability. As an example, a recent sale to a feedlot (475 kg mean weight) contracted at $5.55/kg was reduced to $5.45/kg due to 5/45 animals having a non-breeder tag - a loss of >$2K on the load. The ability to be able to confirm the ID of individuals beyond a reasonable doubt and maintain lifetime traceability would maintain this premium, which could save me hundreds of thousands over the years.”

The above quotes from producers engaged in this project demonstrate the potential for Trakka apps to solve real-world problems for producers. Producer engagement was limited during the development phase covered by this project. A small number of users (10) were able to test and provide feedback on early iterations of the data sharing platform, predominantly with the NLIS database linked to running cattle audits. In general the producers liked the concept of being able to control their data and once they understood the dashboard controls they found it easy to use. The Trakka applications are now being explored in follow-up projects. For example, Trakka is currently being used in a project co-funded by MLA Donor Company and CSU (P.PSH.2201), delivering a dedicated whole application to support researchers to collect cattle weight data from producer properties. This application aligns two events (average cattle weights from Optiweigh and static cattle weights from the yards) and provides an endpoint to a database that researchers can access these standardised data. The Optiweigh data is accessed autonomously and the yard weight data is uploaded by producers using the uploader. This new project will seek to directly address the problems and opportunities suggested in the first two quotes above. Another new project proposal currently being developed with ISC/MLA is seeking to continue the development of ID Trakka. Researchers have also proposed to utilise Trakka to engage producers in large research projects, providing researchers access to data uploaded by collaborators.

Data Publishers

Data publishers are best characterised as third party service providers who generate, manage and host a producer’s data. More often than not this data is generated, hosted and used within the service providers infrastructure. Data publishers typically have proprietary data collecting hardware such as water sensors or in paddock weigh systems that generate data for producers. These data are typically made available and visualised via the service provider's proprietary dashboard, which is considered peripheral to the hardware. They can also include other service providers that generate publicly consumable data for example weather data from the Bureau of Meteorology or market data published by MLA.

Data publishers could include the following:

- Hardware based service providers such as: in-paddock weigh systems; water monitoring solutions; GPS ear tags; etc.
- Public databases and APIs that provide: weather data; market information; remote sensing satellite data; etc.

Managed data sharing policies / agreements.

> "As a service provider we have a responsibility to our customers to protect their sensitive agribusiness data. The AgriTrakka platform allows us to give our customers control over their well defined data in alignment with clear data sharing policies, minimising our risk yet still allowing producers to be able to share their data accordingly. It also allows our customers to take ownership and responsibility for their own data."

Minimising API management.

> "Well defined and performant APIs are an important part of our overall solution, however managing and maintaining these APIs come at a cost. AgriTrakka simplifies this by managing the complex routing and distribution of the data to the service providers chosen by the producer. Without AgriTrakka we would have to develop a bespoke integration with each service provider looking to access our data."

Data Consumers

Data consumers are service providers who utilise a producer's data to provide some service to them. Typically we think of applications such as industry platforms (NLIS), farm management software and dashboards, however data consumers can also include other providers such as government, researchers, banks, insurance companies, auction houses, agents and other agrifood value chain participants who can drive further value from a producer's data.

Access to a wide variety of different data.

> "AgriTrakka gives us the opportunity to access data we typically won't have access to. This has allowed us to improve our products and extend our value offerings back to producers."

Confidence in the data received.

> "Knowing that we are subscribing to data streams with built in data validation allows us to confidently build our solutions on top of the data we receive, knowing that we won't receive erroneous data."

Managed data sharing policies / agreements.

> "As a service provider consuming a producer's data it gives us confidence that the producer has explicitly commissioned the exchange of their data to us."

Researchers

Easy access to real world data.

> "As a researcher, the potential to utilise this tool to collect and aggregate data from producers within research projects and standardise the data represents significant opportunities. This will allow easy ways for producers to contribute data for data analysis. We have already included this methodology in a research proposal to MLA for the sheep industry."

Continued User Engagement

Throughout the AgriTrakka project we have been in constant informal discussions with producers and organisations (both data producers and data consumers), however these have mostly resulted in qualitative feedback that has helped inform decisions and understand the pain points of different stakeholders. As AgriTrakka begins being rolled out this engagement will continue with a focus on ensuring that continued iterative product improvement aligns with customer needs.

OBJECTIVES

The overall objective of the project was to develop, test and demonstrate how an event based messaging framework could deliver real time cattle information. This framework had to be accessible and able to drive a range of services that could link to specific value propositions for example:

- An event based messaging service that is available to receive and process event data that can be published through to data subscribers to deliver a specific service.
- An example of a machine to machine automated messaging service using RFID data
- An example of a mobile device application that generates event based messaging (PaddockTrakka)

The specific services that were developed were generated with user input but focussed on three areas of business operations:

- Regulatory e.g. an automated cattle transfer service (HealthTrakka) using an event based messaging
- Cost saving e.g. cost effective financial services application that uses the event based messaging (HerdTrakka)
- Increased price e.g. feedback from the supply chain using the event based messaging service (PerformanceTrakka)

The project team had a core objective to facilitate a bottom up approach where the technology empowered producers to take control of their data. This objective was founded on the principle that if the red meat industry wanted to leverage value from their data then this had to start with producers. For producers to engage in greater use of data it would require them to feel empowered and that they could see there would be value from their active participation.

The project used an agile methodology and linked this to an action learning cycle which was facilitated by building complete systems the objective was to identify key learnings. These learnings apply to three technical elements of the event based messaging framework and used for the final report:

- Data sharing
- Data standardisation
- Robust identification associated with assigned ownership

METHODOLOGY

Introduction

The overall action learning approach applied to this project, used the development of example applications to understand the core capabilities and functional and non-functional requirements of a user centric data sharing infrastructure. The core functional features to ensure a robust scalable data sharing solution require the ability to:

- assign data ownership to accurately identified items (cattle and farms)
- ensure data has a standardised format linked to measurable events
- enable owners to connect data from events to services.

The final solutions were evaluated for technical readiness using the technology readiness levels (TRL)[3]. The action learning methodology aimed to refine the technology solution and deliver to TRL 8 or 9.

There are a number of terms that cut across all three research areas, these include:

- events - are specific and discrete things that happen to an individual item e.g. weighing a cow.
- event messages - refer to the digital record of a specific event for an individual item e.g. the packet of data related to the weight of a cow describing the cow's id, the weight value and weighing method.
- data publishers - refer to the source of an information event
- data subscribers - relates to the final destination for an information event
- users - are owners of the cattle and ownership relates to cattle associated with a property identification code (PIC)
- message broker - is the control point that manages the routing of messages between data publishers and data subscribers and most importantly this is the point that a user can control the flow of data.

[3] TRL ranks technologies from 0 to 9 with 0 being conceptual / initial scientific research and 9 being a fully commercialised implementation of a solution. TRLs 1 - 3 represent the reduction of scientific uncertainty, TRLs 4 - 6 represent the reduction of engineering uncertainty and TRLs 7 - 9 represent the reduction of operational / application uncertainty with TRLs 7 and 8 being targets for technologies to be ready to enter the market place.

Connecting and controlling data

The challenge of connecting and controlling data was addressed by developing a centralised dashboard that allows data owners to dynamically and securely connect source data through to third party services. Source data was generated to represent transactions for:

- compliance linked to national livestock identification cattle transfer and audits,
- health records linked to vaccination events and recording health state,
- monitoring cattle performance linked to cattle live weights
- cattle management through cattle movement between paddocks

For each of these source events the connecting data involved developing a data stream associated with a data publisher. These streams included automated data uploads using an API interface between the Trakka data exchange and the data publisher. In many cases users will access data from devices that relate to specific information events, for example weight data captured on a crushside data logger. These data are typically made available as comma separated value (csv) files and are typically transferred to an office computer. To enable data connections between these csv files and the Trakka data exchange a browser based uploader was developed. The uploader was developed to maximise producer participation by enabling them to share their data via the exchange, regardless of the technology they use.

The control layer for the data exchange required the team to test and evaluate tools that allowed a web interface to programmatically control a messaging address layer. To ensure the correct data could be managed by a user the address layer needed to link the unique ID of each information event that was published by each data stream through to each service provider. This architecture is initially captured through a database layer and represented through a user dashboard. The connections are activated through a user controlled toggle button, one for each of the possible connection layers. The individual addressing represents unique combinations of available publishers and subscribers. Figure 1 provides an example of the user dashboard representing the toggle activated connection layers.

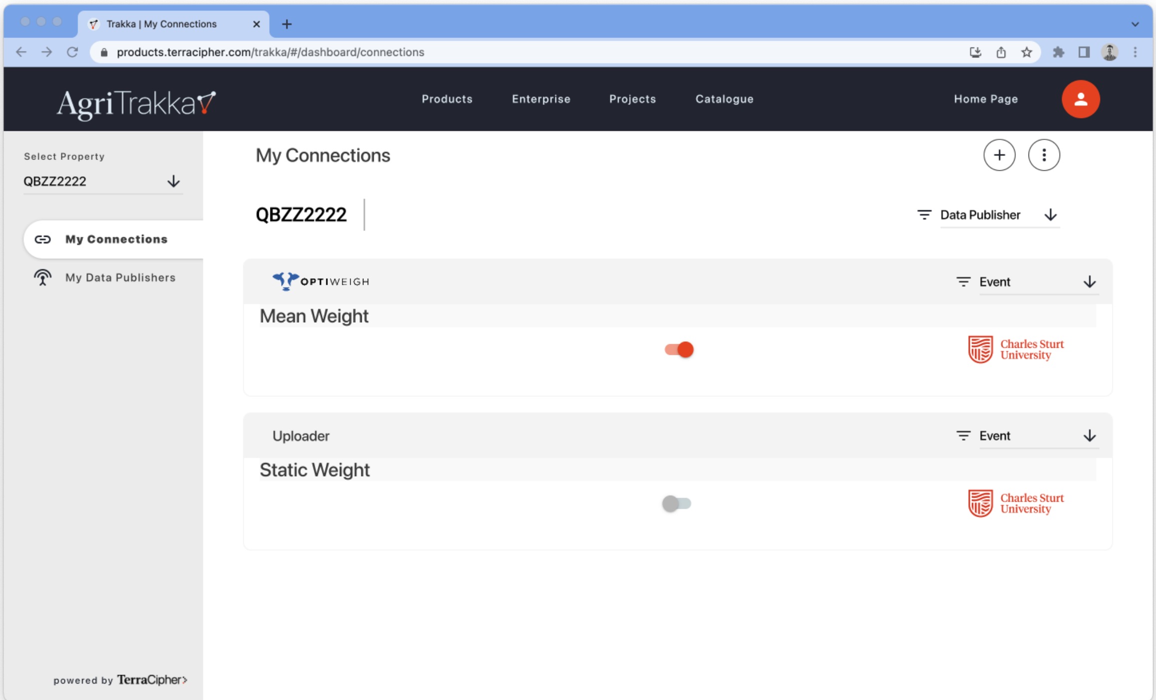

Figure 1 - AgriTrakka dashboard showing connection layers and activation toggle buttons to connect data publishers with data subscribers.

The data connection layers were tested using two address protocols. In addition server side automated service provisioning was tested to determine latency and accuracy of the deployments.

Secure data transfer is a critical requirement for the data sharing layer. A number of options were explored including access control at the message layer and the opportunity to include security via an API access point. The ability for third party data providers to securely publish data related to a property or individual animal was also explored. Integrating this security within the existing protocols was considered an essential requirement. Secure data sharing relates to the requirement for users and owners of the data to be sure they understand the implications of connecting a data pipeline. Connecting data includes providing users with clear and concise terms and conditions that relate to the end point as seen in Figure 2. Data subscribers should have dedicated message end-points where they only access the message and information events that have been assigned to them by the owner of the data.

Options for provisioning data publishers included direct messaging, using an integrated web-socket via a restful API using push notifications. As a data sharing architecture the system allowed users to access and control data flows. However, the system doesn't provide data storage and only holds on to data for as long as it takes to transact movement between data publishers and data subscribers, allowing the data exchange to act as an honest broker.

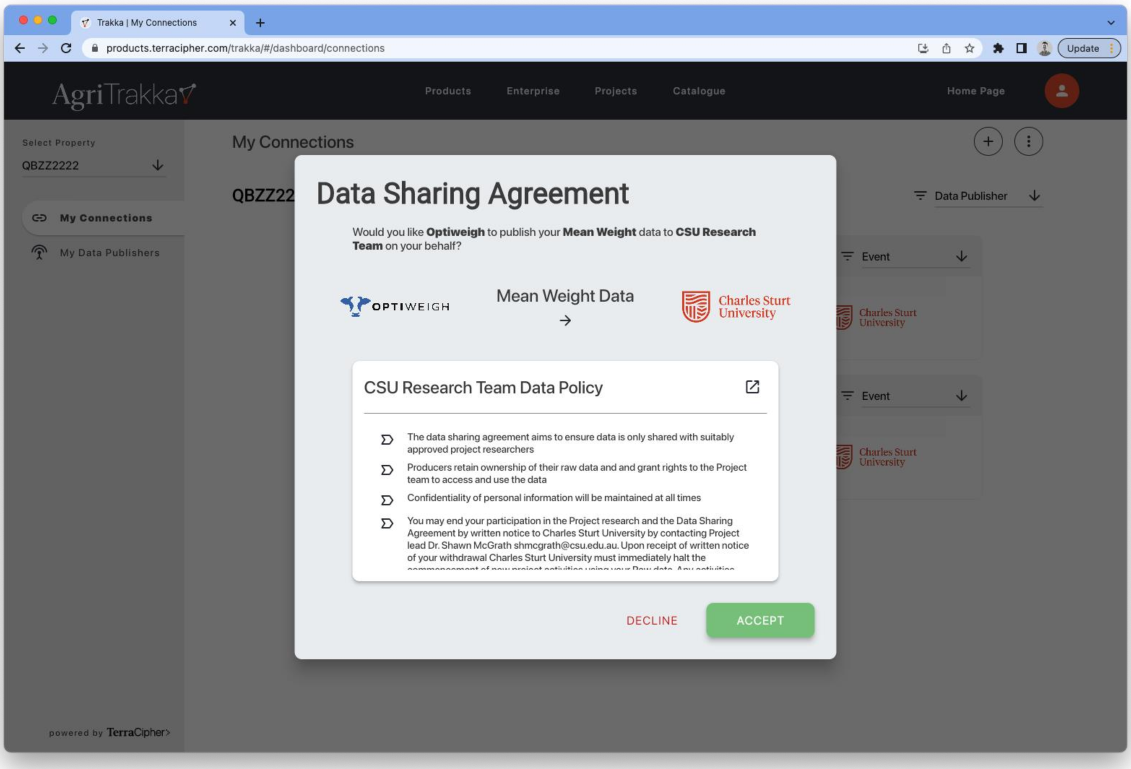

Figure 2 - An example of a data sharing agreement between the producer and CSU with a link to the long form version.

Delivering data standardisation

Data standards enable farmers to understand and accept new technology and get more value from their digital technologies. Data standardisation improves the value proposition and minimises the barriers to data exchange and reuse.

Existing Data Standards

The International Committee for Animal Recording (ICAR) is an International Non-Governmental Organization (INGO) that provides an open secure network to share animal data standards. Users learn from, and interact with fellow members and related stakeholders in global animal production. Integrity System Company (ISC), an entirely owned and operated subsidiary of Meat & Livestock Australia, established an open-source animal schema GitHub repository[4] that contains the JSON standard for Animal Data Exchange (ADE). The ISC schema objects are derived from the ICAR schema repository[5].

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[4] https://github.com/integritysystemscompany/animal_schema.git
[5] https://github.com/adewg/ICAR.git

Both the ICAR and ISC schemas were used as the foundations for the event based messaging data standards used in the Trakka project. It was important to leverage existing standards where possible with modifications and additions only being implemented where necessary. This project did not seek to evaluate the validity or accuracy of data definitions with the existing standards, but rather evaluate the schemas' structures in the context of an event based data exchange.

The ICAR and ISC schemas were designed to capture livestock event information within a farm context, however limitations were recognised when considering data interchange between third parties. Those schemas didn't include important event-related information, such as explicitly stating who the data owner is and how the event was triggered. Furthermore, some domain specific events were not captured, such as castration and weaning.

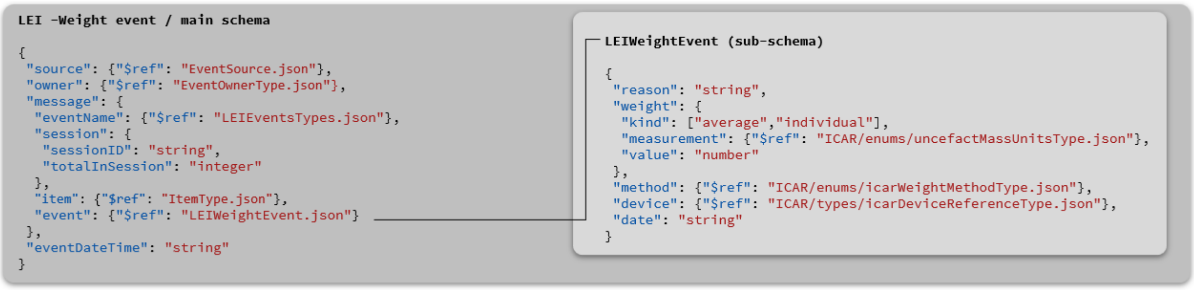
In this project, a PhD student developed the livestock event information (LEI) schema for enabling data sharing through an event based messaging service. As discussed above, the proposed LEI schema complies with the ICAR and ISC schemas and further addresses their limitations.

Evaluating Data Standards

Gomez et al. (2021) proposed a set of metrics as part of the SCORUS project and grouped them into five categories that will be used to evaluate the three schemas. The five categories are:

1. **Existence of types and collections:** To identify the existence of a document type *t* in a schema.
2. **Nesting depth**: The deeper the information is embedded, the higher the cost to access it. This is true unless the intermediary information is also required. Knowing the nesting level of a document type facilitates the estimation of the cost of going down and back through the structure to access the data or to restructure the extracted data with the most suitable format.
3. **Width of the documents:** The matrix for the complexity of a document type in terms of its number of attributes and their types, atomic or complex (documents or arrays of nesting documents).
4. **Referencing rate:** For a collection with documents of a certain type *t*. This metric indicates the number of attributes (of other types) that are potential references to documents of type *t*.
5. **Redundancy**: Data redundancy can speed-up access and avoid certain expensive operations (e.g., joins). However, it negatively impacts the memory footprint of the base and makes coherency enforcement more difficult. There is a cost, programming is more complex and all this impacts the maintainability of the applications.

The structural analysis presented here focused on the weight event for the three schemas. Figure 3 shows the weight event core schema and the detailed data related to the weight. These JSON schemas present numerous selections regarding the existence of collections, the nesting of documents, and the referencing and duplication of documents. The metrics identified corresponding to the criteria are introduced in Table 1 below.



(a) LEI Weight event's JSON schema

(b) ICAR Weight event's JSON schema

(c) ISC Weight event's JSON schema

Figure 3 - Weight Event data for LEI, ICAR, and ISC schemas

Table 1. Criteria and metrics used (Gomez et al., 2021)

No.	Criteria to consider	Metrics
1	Favor the existence of the collection Weight Event	colExistence
2	Avoid copies of documents tSource	docCopies
3	Avoid copies of documents tSession	docCopies
4	Avoid copies of documents tProducer	docCopies
5	Reduce references to the collection Animal	refLoad
6	Reduce the complexity of the collection tWeight	colExistence, docWidth
7	Favor the nesting of tmethod in Weight	colExistence, docExistence, docDepthInCol
8	Favor the existence of the collection icarEvent-CoreResource	colExistence

Figure 4 is a comparison of the three different schemas broken down into 4 individual cases. In Case 1 each of the eight criteria is given the same amount of weight, in which case LEI achieves the highest results. In Case 2 the weights of the three schemas are extremely near to one another where the "weight" property of the schemas was given priority. Similarly, the weights of the three schemas are extremely near to one another in Case 3, which assesses the referencing to the "animal" property. LEI's weight value was greater than ICAR and ISC in Case 4, which equated the relevance of the "source", "session" and "producer" properties to having an equal amount of weight.

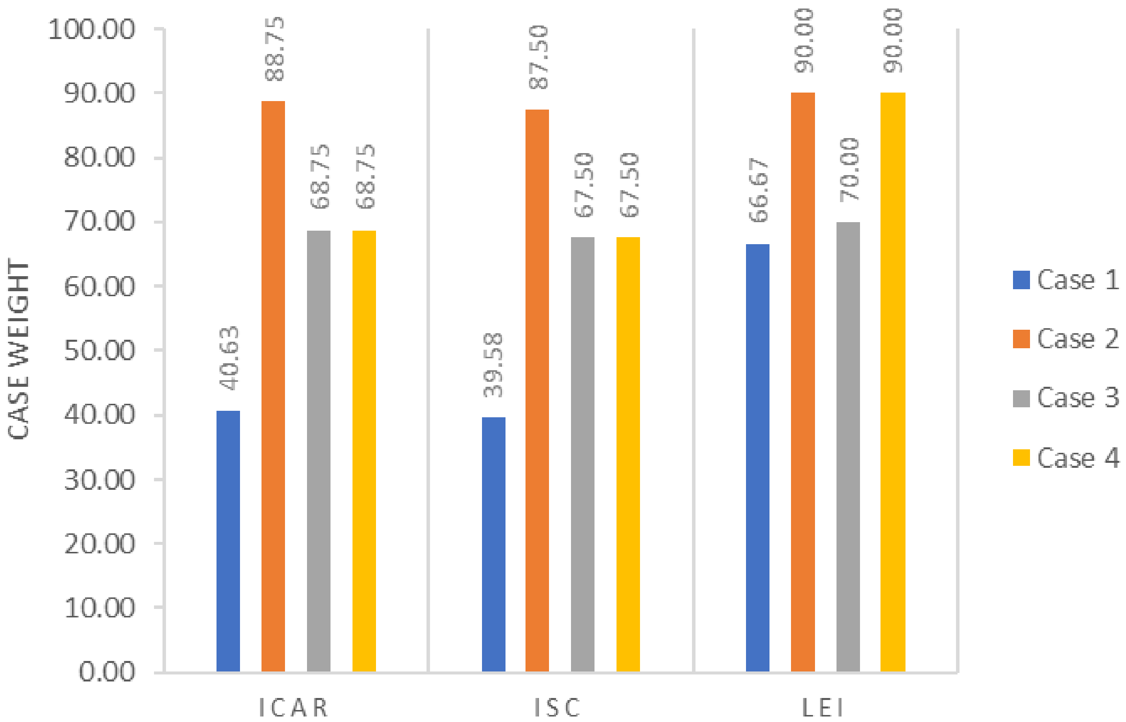


Figure 4 - Schemas evaluation

LEI Schema Structure

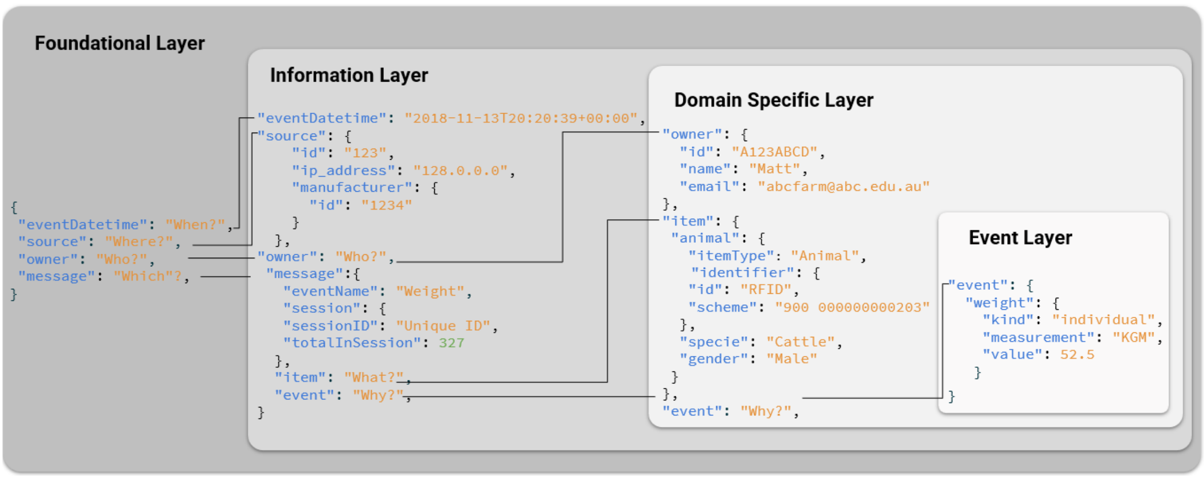


Figure 2. LEI schema structure

The LEI schema is divided into four layers: foundational, information, domain-specific, and event. Each layer captures different types of information that are relevant to the event. The foundational layer, as its name suggests, provides the receiver with basic contextual information about the event. This includes three essential properties: eventDatetime, source, owner, and message.

The eventDatetime property, which answers the question "When?", contains the date and time stamp of when the event was recorded and is in ISO 8601 format. This information is crucial for tracking and documenting changes made to the data over time. The source property, which answers the question "Where?", identifies the event's cause and includes information about the hardware or software that caused the event, such as an IP address. This information can help to understand the origin of the event and the device that has recorded it.

The message property, which answers the question "Which?", indicates which events have been captured, such as breeding, vaccinations or health status. Furthermore, it is divided into four sub-properties: eventName, session, item, and event. The eventName property indicates the name of the captured event, and the data type for it is a string. The session property is concerned with providing a unique number for the captured event and the number of animals in that session.

The information layer provides high-level summary information about the event that has been captured, in other words, metadata about event information. It includes detailed information about the eventDatetime, source, eventName, and session properties.

The owner's property, which we questioned by asking "Who?", includes information about the farmer/producer who raises the livestock. This information includes their property identification code (PIC), name, and address. This is important for tracking and identifying the owner of the animals. Additionally, this information provides a way to understand the animal production context.

The item's property, which we questioned by asking "What?", contains information about live animals, specifically cattle, which are associated with the event. This information includes the animal's identification, such as RFID or NLISID, type, and description. The animal's identification is essential for tracking the animal's movements and accessing the animal's medical history or genetics evaluations. Additionally, the type and description of the animal can help to understand the animal's characteristics.

Both the owner's and the item's properties are detailed in the domain-specific layer, which describes the animal and who owns it. The domain-specific layer provides more detailed information about the animal and its owner, making it possible to understand its production context.

Finally, the event layer of the LEI schema is designed to provide detailed information about the event that has been captured. The event's property is designed to answer the question "Why?". The event property is an important component of the LEI schema and provides a comprehensive and standardised way of recording and analysing livestock events, ultimately leading to more efficient and effective cattle management practices. This information is specific to the event and can vary depending on the event being captured. For example, a weight event would include information about the weight of the animal, the method used to weigh the animal, and any relevant observations or notes, while a registration event would include information about the animal's registration number, the date of registration, and the reason for registration.

This information in the event's property is essential for understanding the context of the event and the reasons why it took place. It can be used for research purposes and for making data-driven decisions. Additionally, it is important for understanding the event's significance and for regulatory compliance. Overall, the four layers of the schema, each answering one of the fundamental questions (When? Where? Who? Which? What? Why?)

It is important to mention that each event message relates to an individual item, ensuring that the discrete data packet has all the contextual information contained within it. Rather than containing a list of items in an event message, the sessionID is used to associate event messages together. While this might seem cumbersome, this ensures “loose coupling” can persist between services publishing and subscribing to messages. Event subscribers should have no knowledge or dependencies on data publishers, all the information required for the subscriber to carry out their service is contained within the message.

Delivering robust identification systems

Increased biosecurity and food safety requirements raise the demand for efficient traceability and identification systems of livestock in the supply chain. Currently, cattle are identified through their NLIS tags. Cattle identification systems include manual visual identification and automatic electronic identification. Traditional cattle identification systems such as ear tagging (Awad, 2016), ear notching (Neary & Yager, 2002), and electronic devices (Ruiz-Garcia & Lunadei, 2011) have been used for individual identification in cattle farming. However, tag losses, duplication, electronic device malfunctions, and fraud of the tag number can compromise these forms of identification. Correspondingly the cattle information can’t be retrieved. This leads to financial loss for producers and increases the biosecurity risks for the supply chain.

Cattle's visual identification system follows a general pattern recognition framework, retrieving the animal's unique biometric and visual features to identify them accurately. The unique features for cattle identification include the muzzle print, face, body coat pattern, and iris pattern. The biometric features-based approaches can offer an accurate and efficient solution for individual cattle identification using traditional feature-based classification methods like SIFT, pattern matching, principal component analysis and Euclidean distance.

Machine learning-based methods including Support Vector Machine, K Nearest Neighbor, and Artificial Neural Network improved the recognition accuracy through grouping or mapping operations in the feature space (Hossain et, al. 2022). Nowadays, convolutional neural networks show the super capability of mining deep features through multiple layers of filters. The successful applications of object detection improve their performance not only in controlled research situations but also in commercial real world applications.

In this project, the team investigated a new deep learning-based approach to identify cattle using visual images. It compared and contrasted existing methods to demonstrate how the unique muzzle print could help to derive more accurate identification.

An AI/ML cattle identification pipeline was developed. To facilitate the pipeline, firstly requires image data collection and secondly development of muzzle identification AI/ML model.

Image data collection:

1. Several publicly available datasets were identified. For more details refer to our recently published survey paper. The best one we selected is from the University of Nebraska- Lincoln (http://doi.10.5281/zenodo.6324360). This dataset has a total of 4923 muzzle images for 268 feedyard yearlings of three cattle breeds (Angus, Angus x Hereford, and Continental x British cross). But it only contains clean and cropped images showing the cattle muzzle area.
2. We captured more cattle photos from the CSU farm over the past 12 months. A total of 27 steers in the CSU farm were photographed. However, the quality of the cattle muzzle images was heavily influenced due to weather, illumination conditions, light reflection, motion blur, and other factors. We have learned some lessons for future image capture system design.

Muzzle identification and model development

A literature review was used to compare several deep learning models. Using the literature review the YOLO model was selected due to its computation efficiency and identification accuracy.

The model was customised and trained using the image dataset for cattle identification purposes. This part consists of three steps: 1). Training sample annotation, 2). Model training and validation, 3). Testing and model finalisation.

The prepared dataset was manually labeled with the muzzle portion for each image using a bounding box. All labeled images were randomly divided into training (80%) and validation (20%).

The model was trained using Vertex AI, a google cloud platform service. After successfully training the model, the trained cattle ID model was used to identify cattle and their muzzles in each image. This process results in a visualised bounding box around the muzzle. The bounding box region is analysed to determine the cattle identification.

RESULTS

Introduction

By developing individual example applications it provided the opportunity to test configuration settings and optimise the overall architecture. The results were evaluated against functional needs for users and the ability to meet core technical specifications. The TRL level was evaluated based on these two attributes.

Connecting and Controlling Data

Configuring Connections

A successful data exchange must be able to connect any data publisher with any data subscriber, on behalf of a producer. Configuring the architecture's routing protocol to accommodate the vast number of potential connections represented a challenge.

The initial address configuration connected unique ID's of data publishers, data owners and data subscribers. While this system provided reasonably adequate connections, testing demonstrated there were situations where users needed to control individual information events supplied by a single data publisher. For example a user may want one type of event to be published but not another from a single publisher. Under this configuration it was either all the event data or none. Through the action learning approach testing demonstrated a particular problem linking the uploader to different published events. The automated address configuration was further refined to include event information. The addition of event information provided greater control for the users but also added increased complexity for the dashboard. For example if there were five data providers with five events going to five data subscribers this results in 125 individual data connections.

By working with users it was clear that in most cases users would aggregate across two of the three options e.g. data publishers, information events and data subscribers. This aggregation reduces the complexity back to 25 collective data connections. The user interface was refined to allow user controlled aggregation with the associated group toggle buttons. This solution has yet to be fully tested but the initial results suggest it has enough flexibility to accommodate further refinement and ensure a practical user experience is delivered.

The connections backend configuration and dashboard has achieved TRL 8.

Configuring Data Publishing

The development of data publisher streams for both autonomous machine to machine connections as well as direct controlled manually configured connections enabled the project to explore a number of solutions. While directly and autonomously connecting to the message broker allowed high data throughput and true real time data exchange, it also required a more complex configuration. Testing autonomous machine to machine connections using Taggle calf alert devices demonstrated that direct access to the message broker allowed high volume, near real time data traffic with low latency. The average time from the source of the information event to arriving in the subscriber database was around 4 seconds. These data came from a remote location in the Northern Territory. The system was easily able to manage 100's of messages per minute and overall successfully ingested approximately 450,000 messages. This test case allowed the team to test a push protocol that is best suited to direct access to the message broker.

A more typical configuration for data publishing was either through the Trakka team accessing third party APIs e.g. Optiweigh or NLIS or data publishers accessing the message broker via a Trakka restful API. To facilitate this connection the Trakka team developed a microservice restful API endpoint for each event. By considering individual events the architecture allowed the integration of a JSON schema validator to ensure messages met the ISC / ICAR data standards implemented through the project's LEI standards. The API utilised Shaipup, an algorithm hosting capability. This infrastructure had the additional benefit of providing secure access through OAuth username and password access. Testing demonstrated that this system can provide easy access for users. The system was also linked to the AgriTrakka Uploader, a customised spreadsheet add-on allowing users to cut and paste their CSV formatted event data, standardise it and upload it through the web based spreadsheet tool to be published to their AgriTraka connections (see Figure 5 and 6).

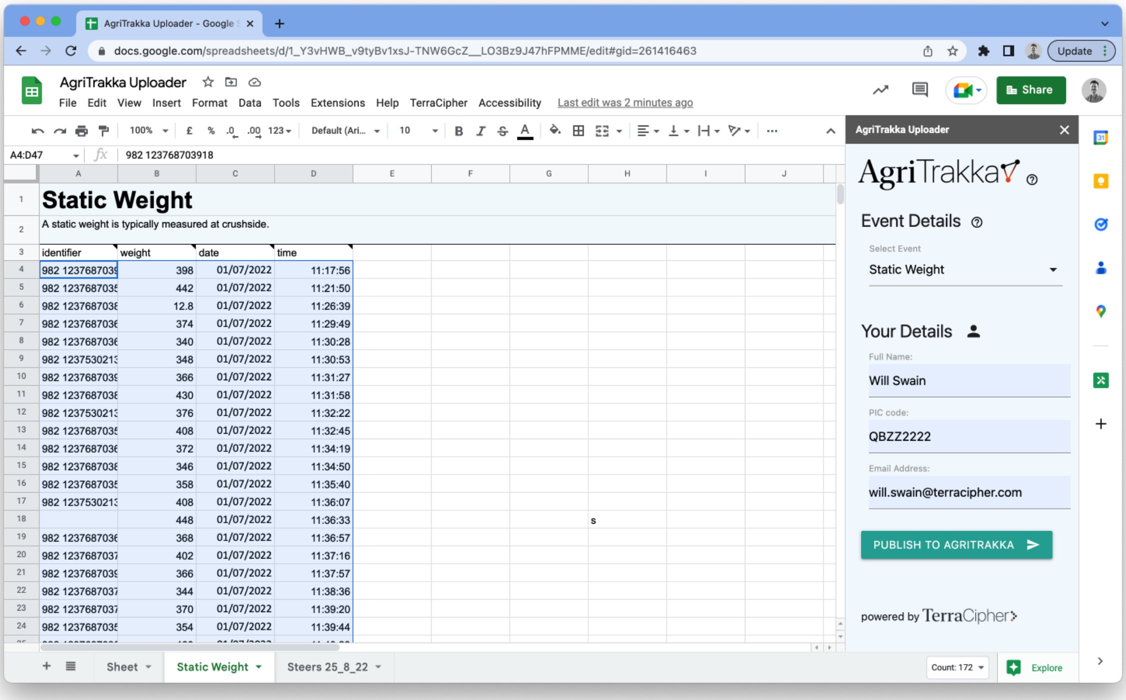


Figure 5 - Spreadsheet data uploader standard template.

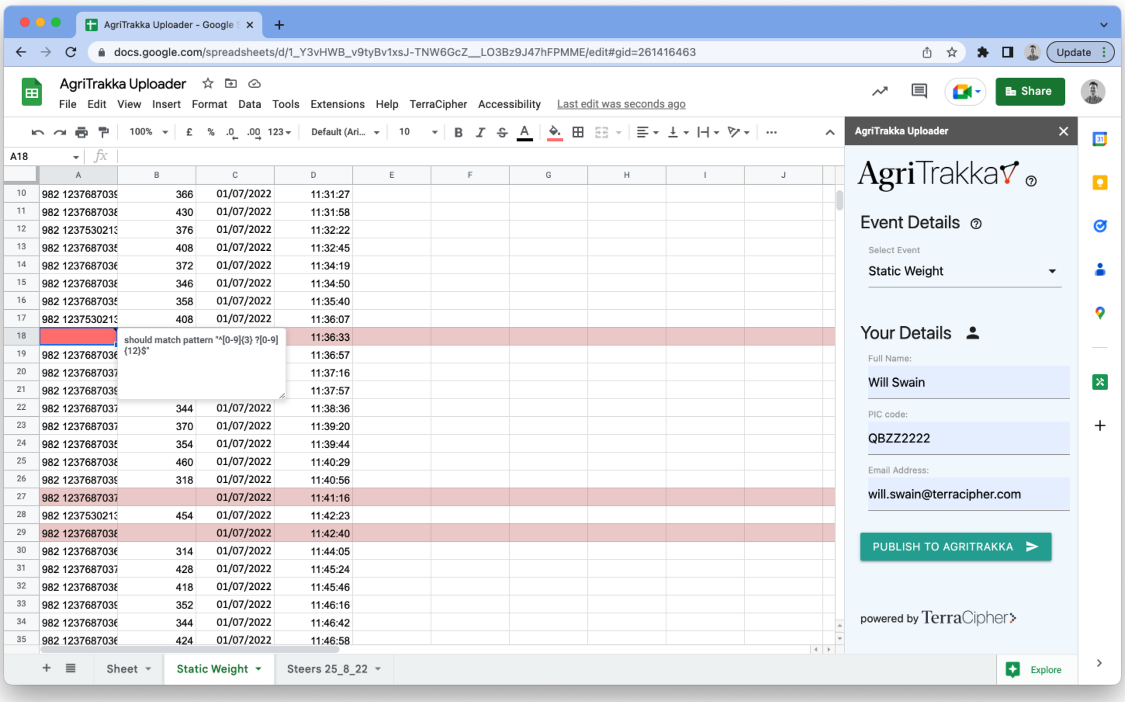


Figure 6 - Spreadsheet data uploader data validation using data standards.

The data publisher configuration and backend has achieved TRL 8.

Configuring Data Subscriptions

Evaluating the requirements for data subscribers to access data was tested using the data endpoint applications. The project tested both push and pull data configurations. Data push refers to data being immediately transferred from the message broker to the data subscriber. Data pull requires the data subscriber to poll the message broker. The pull architecture is easier to implement and was facilitated by providing restfulAPI endpoints that data subscribers could access. This configuration proved both easier to configure and allowed data subscribers to control the data flow. The push flow required Trakka to align more closely with data subscribers and could be most effectively optimised through a direct connection to the message broker. Data security was maintained by configuring the message broker with restricted username and password access for each data subscriber. The major advantage of the push messaging was the ability to link this to event based alerts. The HerdTrakka application was used to test this feature and provided a tool that was able to use an event status to trigger an email alert when certain thresholds were met. For example the PerformanceTrakka feature of HerdTrakka, developed later in the project, alerted the team when animals on the CSU farm reached a certain threshold based on their weight event data.

Based on the testing, the current configuration allows subscriber access using a restful API endpoint via a poll (pull configuration). The configuration for the polling frequency is in the hands of the data subscriber and allows them to optimise their API calls based on their application requirements.

The end testing of the connection and control protocol identified some critical technical challenges. These included checks that event messages were delivered before they were deleted from the message broker. Careful acknowledgement with batch processing was able to ensure messages were only deleted once the subscriber confirmed the messages were delivered.

All event messages related to a subscriber use the addressing protocol to ensure they are routed to the correct end point. The addressing also ensures a user endpoint is generated. This received all messages for that user. This endpoint provides some redundancy as well allowing message counting to provide performance logging.

The data subscriber configuration and backend has achieved TRL 8

Data standardisation

As discussed in the methodology section LEI extends ICAR and ISC to deliver data standards for event messaging applications. The schema for event messages in the LEI are either modified (i.e., deleting some properties) or redefined (i.e., deleting and adding properties) from ICAR and ISC, and based on real world data retrieved from the CSU digital farm. Appendix 1 shows the different types of events LEI captures. Appendix 2 shows the data types that have been used in LEI from ICAR or ISC or defined in LEI, and their definition.

To evaluate the usefulness of the LEI schema, a series of simulated case studies were developed. The use cases were based on livestock management from the Charles Sturt University farm. Our case studies comprised 14 scenarios, each containing one or more events. These scenarios were chosen to cover the different types of livestock events.

Case Studies

To explore a range of scenarios we used simulated data from four producers and one slaughterhouse. Producer A (PIC is A123ABCD) is a breeder with 100 breeding cows and 100 young stock, 50 heifers and 50 steers. Producer A also has three bulls, but is planning to buy two more for the next breeding season. Producer B is a backgrounder (PIC of B123ABCD) buys weaned cattle, carrying around 200 animals and aims to grow them a target weight for a feedlot. Producer C (PIC of C123ABCD) runs a small feedlot carrying 100 cattle and selling them finished into a local domestic processor. Producer D (PIC is D123ABCD), runs a small angus cattle stud as a seed stock producer. He keeps 100 cows, 50 heifers, 50 bull calves, and 30 bulls on his land. The slaughterhouse followed the requirements of the National Livestock Identification System (NLIS) using PIC code E123ABCD to track animals movement through the abattoir. The fictitious properties are used to generate scenarios that can be used to test the validity of the LEI schema to generate event data that can be used through an event message brokering service. These scenarios do not cover all possible scenarios but do provide a representative overview of different event data to determine the opportunity to deliver standardised event messages. Code snippets of each scenario have been included after each scenario, except where there are multiple events, in which case they are in the appendix.

Scenario 1 - Selling and purchasing livestock and associated livestock movements:

Producer A sold fifty steers to Producer B on January 17, 2021, and the animals arrived at Producer B's pasture on January 19, 2021.

In this scenario, three events are required to be captured. The first event is a departure for sale, which indicates that the cattle have left the farm of Producer A and are being sold. The second event is the arrival at the purchaser's property, which indicates that the cattle have arrived at Producer B's farm. The third event is the change of ownership event which must be recorded, this documents the transfer of ownership from Producer A to Producer B. These events are important for tracking the movement and ownership of the cattle and ensuring that proper record-keeping is maintained.

LEI fully supported these two movement message events by including the source of the event, the date and time for capturing the event, the owner of the livestock, the livestock themselves, and finally, details of the event. While ICAR partially supports these message events because the event's source and the cattle owner's properties are missing, the same is true for ISC, which has duplicated these ICAR events.

Scenario 2 - Livestock movement for agistment:

Producer A received fifty weaned heifers to agist from Producer D on January 30, 2021, these livestock were transferred from Producer D's yard on January 27.

Similar to Scenario 1, two movement events are needed for this scenario, the difference is the purpose of the movement and the nullification of the "changeOfOwnership" field. The first event is a departure for agistment (i.e., removal of animals from a property) the second event is an arrival for agistment, which implies that cattle came to producer A's farm for feeding purposes. Additionally another 2 events would be required once the agistment ended with the reason being "AgistmentReturn" as outlined by the ICAR standards.

As previously stated, this scenario is similar to scenario 1, so LEI fully supports all types of movement message events, whereas ICAR and ISC only partially do because the message event's source and the cattle owner's properties are missing.

Scenario 3 - Livestock movement and associated records to complete a purchase transaction:

Producer C purchased 100 steers from Producer B on February 2, 2021. Upon arrival in Producer C's paddock on February 5, 2021, one of the steers was injured during transport and had to be euthanized. Producer C then provides Producer B with a report containing the induction weights of each animal, which will serve as the basis for their valuation.

Three additional events have been recorded in this scenario on top of the two movement events that would occur: first, the death of an animal, which occurred as a result of the cattle being injured while being transported from Producer B to Producer C. Second, the observed status event occurred, so Producer C visualised that one of the incoming steers was injured. Hence, we conclude that the status observed event is the reason for the death event's occurrence in this scenario. Third, weight events can be performed by machines or by producers for various purposes, such as recording or health checking. The below code snippet represents an automated event generated by a walk over weigh system.

```json
{
  "eventDateTime": "2022-02-02T14:30:23Z",
  "source": {
    "id": "Walkover Weigh",
    "serial": "2Vr93trD",
    "ip_address": "128.0.0.0",
    "manufacturer": {
      "id": "Agtech Company"
    }
  },
  "owner": {
    "id": "C123ABCD",
    "name": "Pro Cattle",
    "email": "proCattle@beef.com",
    "givenName": "Carol",
    "familyName": "Cattle"
  },
  "message": {
    "eventName": "Weight",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "982 123456789101",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Unknown"
      }
    },
    "session": {
      "sessionID": "1548",
      "totalInSession": 99
    },
    "event": {
      "weight": {
        "kind": "individual",
        "measurement": "KGM",
        "value": 352.5
      },
      "method": "WalkOver"
    }
  }
}
```
JSON individual weight event

LEI fully supported the three events by including the source of the event, the date and time for capturing the event, the owner of the livestock, the livestock themselves, and finally, the details of the event. The ICAR scheme doesn’t provide information on the event's source and the cattle owner's properties are missing, whereas ISC only partially supports death and weight events, as these two events have been duplicated from ICAR. The status observed event is not supported because it does not exist in the schema.

Scenario 4 - Livestock Sent to Abattoir:

25 steers were slaughtered in the abattoir on March 1st, 2021. This scenario is similar to Scenario 3's euthanized event. Like Scenario 3's first event, LEI fully supports death events, but ICAR and ISC partially support it because the event's source and the cattle owner's properties are missing.


```json
{
  "eventDateTime": "2021-03-01T09:53:23Z",
  "source": {
    "id": "TEYS Online System",
    "ip_address": "128.0.0.0"
  },
  "owner": {
    "id": "C123ABCD",
    "name": "Pro Cattle",
    "email": "proCattle@beef.com",
    "givenName": "Carol",
    "familyName": "Cattle"
  },
  "message": {
    "eventName": "Death",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "982 123456789101",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Male"
      }
    },
    "session": {
      "sessionID": "un1q31d",
      "totalInSession": 25
    },
    "event": {
      "deathReason": "Consumption",
      "explanation": "Production",
      "disposalMethod": "Slaughter",
      "disposalOperator": "TEYS",
      "disposalReference": "s147987"
    }
  }
}
```

Scenario 5 - Artificial insemination:

Producer A completed the AI for the 55 heifers on March 4, 2021.

In this scenario, the artificial insemination (AI) event captured the insertion of sperm directly into the uterus. Furthermore, in a different scenario, this AI event could also capture an embryo transfer, which is the process of transferring fertilised ova from a donor heifer to a recipient heifer, who will then rear the calf.

LEI fully supported the AI event by including the source of the event, the date and time for capturing the event, the livestock owner, the livestock themselves, and the event's details. ICAR has very detailed reproduction related event information, however ISC does not draw on or extend these events.


```
{
 "eventDateTime": "2021-03-04T07:30:23Z",
 "source": {
   "id": "Aarons Computer",
   "ip_address": "1.1.1.1",
   "manufacturer": {
     "id": "Apple"
   }
 },
 "owner": {
   "id": "A123ABCD",
   "name": "Producer A Beef",
   "email": "prodA@beef.com",
   "givenName": "Aaron",
   "familyName": "Farmer"
 },
 "message": {
   "eventName": "Insemination",
   "item": {
     "itemType": "Animal",
     "animal": {
       "identifier": {
         "id": "982 123456789101",
         "scheme": "rfid"
       },
       "specie": "Cattle",
       "gender": "Female"
     }
   },
   "session": {
     "sessionID": "11871198",
     "totalInSession": 55
   },
   "event": {
     "rank": 3,
     "inseminationType": "Insemination",
     "sireIdentifiers": [
```

```
        {
          "id": "982 111111111111",
          "scheme": "rfid"
        }
      ],
      "sireOfficialName": "Big Bull",
      "sireURI": "02347234-UKE98234982734987",
      "straw": {
        "id": {
          "id": "CHA8SDCKJ",
          "scheme": "IMV Identification"
        },
        "isSexedSemen": true,
        "sexedGender": "Female",
        "preservationType": "Frozen"
      },
      "eventEndDateTime": "2021-03-04T07:30:23Z",
      "semenFromFarmStocks": true,
      "farmContainer": "125a 2021-01-03"
    }
  }
}
```


Scenario 6 - Pregnancy testing:

On April 10th, 2021, almost five weeks later, Producer A carried out pregnancy tests and identified 50 pregnant heifers.

The pregnancy check event always follows the insemination event, which indicates the number of days of pregnancy and the embryo's gender.

By identifying the event's source, the time and date it was recorded, the livestock owner, the animals, and the event's specifics, LEI provided full support for the pregnancy check event. As mentioned above, ICAR's comprehensive reproduction related events also include the pregnancy check event, however ISC doesn't include or extend the pregnancy check event.


```
{
 "eventDateTime": "2021-05-10T07:30:23Z",
 "source": {
   "id": "Aarons Computer",
   "ip_address": "1.1.1.1",
   "manufacturer": {
     "id": "Apple"
   }
 },
 "owner": {
   "id": "A123ABCD",
   "name": "Producer A Beef",
   "email": "prodA@beef.com",
```

```
    "givenName": "Aaron",
    "familyName": "Farmer"
  },
  "message": {
    "eventName": "PregnancyCheck",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "982 123456789101",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Female"
      }
    },
    "session": {
      "sessionID": "un1qu31d4",
      "totalInSession": 55
    },
    "event": {
      "checkMethod": "Palpation",
      "result": "Pregnant",
      "foetalAge": 35,
      "foetusCount": 1,
      "foetusCountMale": 1,
      "foetusCountFemale": 0,
      "exceptions": [
        "normal",
        "due in DEC"
      ]
    }
  }
}
```


Scenario 7 - Parturition:

On the 1st of December 2021, the 50 heifers belonging to Producer A gave birth to 35 bull calves and 15 heifers. Two events were captured in this scenario: the first is parturition which is when a cow gives birth, and this event is used to determine the pedigree of a born calf. The second is birth, which is about the newborn calf, and often the producer at the beginning uses a local identification code or tag to mark the new calf. We refer to it in the schema as VID, which stands for visual identification code.

LEI provided comprehensive support for both birth and parturition events by identifying the event's source, the time and date it was recorded, the livestock owner, the animals, and the event's circumstances. ICAR partially accepts these events due to the absence of the event's source and the cattle owner's properties; however, ISC does not because the events do not exist in the schema. Code snippets in Appendix.

Scenario 8 - Registration:

Producer A earmarked the 50 young animals with RFID tags in the range 900 000000000203-900 000000000252 on December 2, 2021.

In this scenario, the farmer complies with the NLIS regulation by placing an order for new RFIDs and linking them to the VIDs of newly born calves or older RFIDs, if any have been lost.

LEI fully supported this registration event by including the source of the event, the date and time for capturing the event, the livestock owner, the livestock themselves, and the event's details. While ICAR partially supports the event because the event's source and the cattle owner's properties are missing, the same is true for ISC, which has duplicated this ICAR event.


```
{
 "eventDateTime": "2021-12-02T13:35:25Z",
 "source": {
   "id": "Aarons Mobile",
   "ip_address": "1.1.1.1",
   "manufacturer": {
     "id": "Apple"
   }
 },
 "owner": {
   "id": "A123ABCD",
   "name": "Producer A Beef",
   "email": "prodA@beef.com",
   "givenName": "Aaron",
   "familyName": "Farmer"
 },
 "message": {
   "eventName": "Registration",
   "item": {
     "itemType": "Animal",
     "animal": {
       "identifier": {
         "id": "900 000000000203",
         "scheme": "rfid"
       },
       "specie": "Cattle",
       "gender": "Male"
     }
   },
   "session": {
     "sessionID": "14785",
     "totalInSession": 50
   },
   "event": {
     "registrationReason": "Born"
   }
 }
}
```

Scenario 9 - Weaning:

Producer A weaned five calves on August 10th, 2022.

Because the event does not exist in both ICAR and ISC schemas, only LEI fully supports the weaning event.


```
{
  "eventDateTime": "2022-08-10T13:35:25Z",
  "source": {
    "id": "Aarons Computer",
    "ip_address": "1.1.1.1",
    "manufacturer": {
      "id": "Apple"
    }
  },
  "owner": {
    "id": "A123ABCD",
    "name": "Producer A Beef",
    "email": "prodA@beef.com",
    "givenName": "Aaron",
    "familyName": "Farmer"
  },
  "message": {
    "eventName": "Weaning",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "900 000000000203",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Male"
      }
    },
    "session": {
      "sessionID": "wean1",
      "totalInSession": 5
    },
    "event": {
      "startdate": "2021-08-05T13:35:25Z",
      "age": 252,
      "reason": "Age",
      "weaningMethod": "Yard"
    }
  }
}
```

Scenario 10 - Treatment:

On January 8, 2022, a veterinarian injected Dectomax (batch number 1122346T, expiration date November 4, 2022) into each of the calves on Producer A's farm. As a result, all animals are subject to a 42-day withholding period.

In this scenario, and because it includes information about the animals, their vaccines, the doses they received, the date of expiration, and the person who administered the injections, the treatment event is regarded as one of the essential events. The farmer's priority while purchasing animals from another farmer is to consider this kind of event since it impacts the animal's health.

This treatment event was given complete support by LEI, which included the inclusion of the source of the event, the day and time for capturing the event, the livestock owner, the cattle themselves, and the event's specifics. Even though ICAR only gives limited support for the event because it does not know where it came from or who the livestock owner is, ISC, which copied this event from the ICAR schema, is in the same boat.


```
{
 "eventDateTime": "2022-01-08T13:35:25Z",
 "source": {
   "id": "AM05 Automed Injector",
   "ip_address": "1.1.1.1",
   "manufacturer": {
     "id": "Automed"
   }
 },
 "owner": {
   "id": "A123ABCD",
   "name": "Producer A Beef",
   "email": "prodA@beef.com",
   "givenName": "Aaron",
   "familyName": "Farmer"
 },
 "message": {
   "eventName": "Treatment",
   "item": {
     "itemType": "Animal",
     "animal": {
       "identifier": {
         "id": "rfid",
         "scheme": "123"
       },
       "specie": "Cattle",
       "gender": "Male"
     }
   },
```

```
    "session": {
      "sessionID": "Dec-2021-Calves",
      "totalInSession": 50
    },
    "event": {
      "medicine": {
        "name": "DECTOMAX Injectable endectocide",
        "approved": "APVMA Approved",
        "registeredID": {
          "id": "46128",
          "scheme": "APVMA"
        }
      },
      "procedure": "injection",
      "batches": [
        {
          "id": "1122346T",
          "expiryDate": "2022-11-04T00:00:00Z"
        }
      ],
      "withdrawals": [
        {
          "productType": "Vaccination",
          "endDate": "2022-02-17T07:30:23Z"
        }
      ],
      "dose": {
        "doseQuantity": 8,
        "doseUnits": "MLT"
      },
      "site": "shoulder",
      "responsible": "Vessna Vet 0400 111 111"
    }
  }
}
```


Scenario 11 - Castration:

Producer A surgically castrated 30 calves with a scalpel on February 25th, 2022, while the remaining five calves were castrated with rubber rings. A veterinarian performed the castration.

In practice, castration involves removing the testicles of male calves. Castration is one of the husbandry procedures performed during calf marking. This scenario contains a wealth of information, including the castration type, methods, and performer. Accordingly, this type of event provides health-related information that affects the animal's health status.

The castration event is not present in either the ICAR or ISC schemas.

Summary

Table 2 compares the LEI schema with the ICAR and ISC schemas in terms of the events they capture. This table demonstrates that LEI is able to deliver added benefits for event messaging applications.

Table 2: Case study summary

Events		ICAR	ISC	LEI
1	Departure	Partially	Partially	Full
2	Arrival	Partially	Partially	Full
3	Death	Partially	Partially	Full
4	Status observed	Partially	Not supported	Full
5	Weight	Partially	Partially	Full
6	Audit	Not supported	Not supported	Full
7	Insemination	Partially	Not supported	Full
8	Pregnancy check	Partially	Not supported	Full
9	Birth	Partially	Not supported	Full
10	Parturition	Partially	Not supported	Full
11	Registration	Partially	Partially	Full
12	Weaning	Not supported	Not supported	Full
13	Treatment	Partially	Partially	Full
14	Castration	Not supported	Not supported	Full

Full	The event fully captured in the schema with all required information
Partially	The event captured in the schema but missing information such as owner and source
Not supported	The event not supported by the schema

Both ICAR and ISC provide a robust data definition through their respective closely aligned schemas. ICAR is more developed but ISC is built to accommodate local Australian livestock scenarios. The LEI schema is focussed on delivering a data framework based on ICAR and ISC but refined to deliver event messaging. In particular, event messaging requires additional information that provides context to ensure any recipient of the message is able to decipher the full information.

The data schema framework has achieved TRL 6

Robust identification systems

The AI/ML Muzzle Print as a Biometric using Vision Recognition has been built on the Vertex AI google cloud platform (see Figure 7).

The proposed pipeline has basically three sections. The first is automatic data pre-processing, and the second method is an active training of the cattle ID model. The final section is a visualization of the trained model.

Automatic annotation

To make the process automatic, automatic annotation is a critical step. To label the data, a muzzle detector which is already trained on the YOLO model is used. As the image is provided to the ML pipeline, it first detects the muzzle in the provided image (see Figure 8). Then a label will be assigned to the muzzle image automatically according to pre-captured information either from the NLIS tag or management tag.

Accuracy of muzzle detector

We use (Intersection over Union (IoU), a commonly used term in object detection to evaluate the model performance. IoU means the area of the overlap between the predicted and ground truth bounding box. We used images captured in the CSU farm to test the muzzle detector. The accuracy of the muzzle detector is 0.997 mAP(mean Average Precision) at 0.5. Where mAP_0.5 mAP _ 0.5 means the average of AP (average precision) when the IoU is greater than 50%. The sample of the detected bounding box is shown in the following figures.

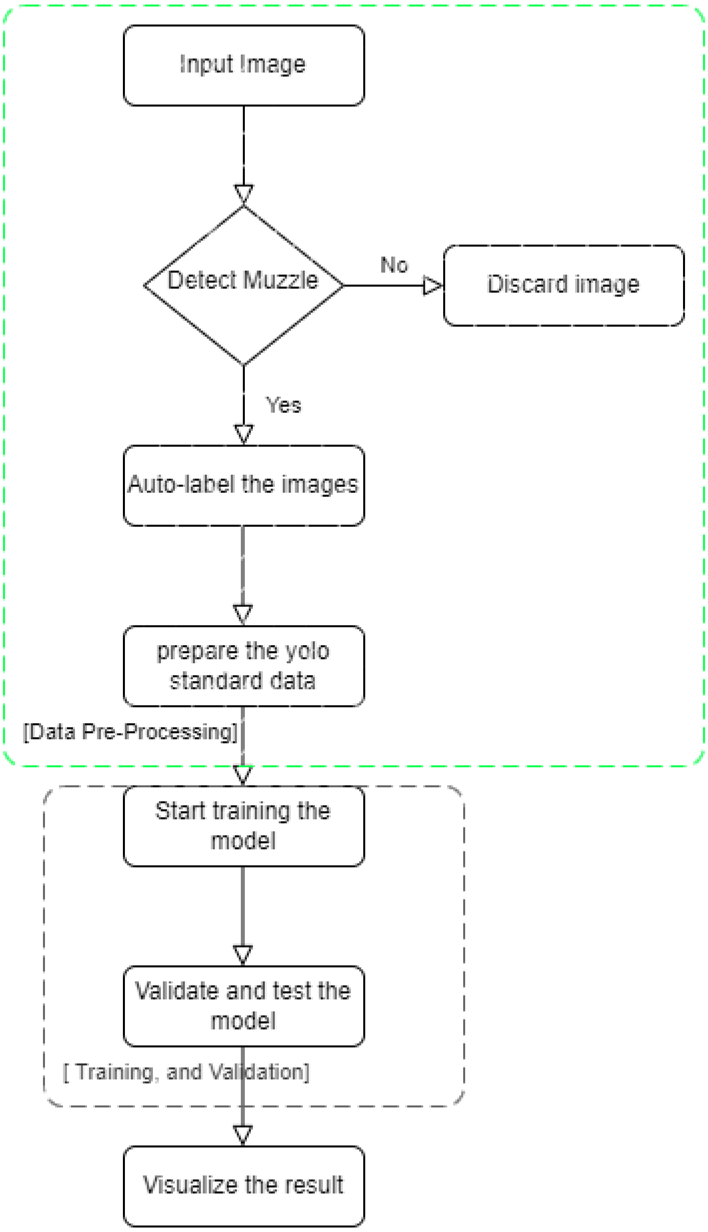


Figure 7 - Methodology of muzzle recognition using deep learning techniques.

Figure 8 - Detected muzzle with green box (bounding box)

Muzzle identifier

The data obtained from the CSU farm was insufficient to identify the individual cattle. The publicly available muzzle image data was used to evaluate the image identification capability of the model. These images were successful in training the YOLO v5 model and identifying the cattle identification correctly. The minimum number of photos per individual cattle in the aforementioned data was eight. The accuracy of the muzzle identifier was (mAP_0.5) 0.811. The identification results from the muzzle identifier is shown in the following figure 9.

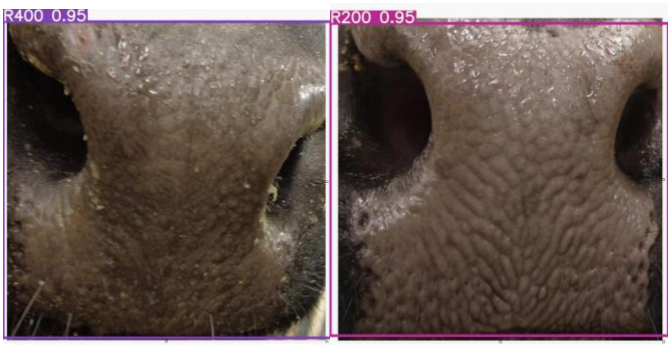


Figure 9 -Sample of identified cattle with bounding box

Figure 9 shows a sample of identified cattle. R400 and R200 are ear tag numbers of the cattle and 0.95 is the confidence score of the model.

However, there were some cattle that were mis-identifiied. Out of 20 animals, 2 animals were misidentified. Further work is required to determine the optimum image quality that will deliver reliable identification under a typical cattle management scenario. Understanding the number and quality of the images required to derive successful identification will help progress the muzzle print technology.

The muzzle print identification has achieved a TRL 5

HIGHER DEGREE BY RESEARCH STUDENTS

Mahir Habib's PhD - A Microservice-based Framework for Sharing Livestock Event Information:

Improving productivity and maintaining an efficient work zone is a considerable challenge (Chaudhry et al., 2020) because most farmers manage administrative duties manually using CSV files or paper copies. The present mechanism for leveraging farmer data is a centralised-base system (Transferring Cattle-Type in the Details Method, 2008). The Australian red meat industry, most notably the beef industry, has utilised technology to increase product value through quality assurance programs facilitated by the NLIS (NLIS Cattle Advisory Committee, 2016). These technologies have opened the door for Agtech companies to develop solutions for farmers, however farmers now have a problem with managing and leveraging the data produced by these various systems (Whitacre et al.,2014). Microservice based architectures and the philosophies that underpin them pose to alleviate these challenges.

Further, through an individual animal's lifetime they will experience various events. Birth, age, missing, weight, immunisation, breed, purchase, sale, and transfer of cattle ownership are all factors that must be recorded. Insurers, banks, health and food authorities, and other local businesses, as well as the producers themselves, stand to gain significantly from recording such events in a standardised way. These factors are essential for farmers to maximise their profits and produce high-quality red meat (DAWE, 2016).

As the number of technologies and companies that work with cattle in Australia grows, all applications are moving towards microservice architecture, which has better performance and scalability to support and manage a specific task or goal, and can help businesses reach their goals quickly (Kousiouris et al., 2019). Performance, scalability, stability, testability, and security are all areas where the microservices architecture framework can make a positive impact.

A framework based on microservice architecture will be created to facilitate the sharing of cattle lifecycle events between producers and consumers. This research has two primary components.

1. **Proposed data standard**. At this research stage, the goal is to look closely at existing standards to analyse and adapt them with the proper data parameters. The proposed standard can expand and support different kinds of events with different parameters. The new schema for this standard will not only help with tracking cattle, but it can also

be used in smart cities and by governments in the future. This data standardisation is needed to make sending and sharing data easy. To make this happen, the schema for livestock event information (LEI) will be made to match the International Committee Animal Recording (ICAR) schema and the Integrity System Company (ISC) schema. It will let third-party hardware and software use data schemas to standardise their data to be exchanged.

2. To obtain substantial benefits from the proposed data standardisation, it is essential to implement an **architecture** that provides several advantages for developing applications as tiny, individualised, and adaptable services. Consequently, this section of the research will propose a generic design for a cloud-based, microservices-based software architecture. The architecture is prepared to integrate with LEI, smoothly transfer livestock information, and provide consumers with easy access to this information. Open-source technologies will be used to build the proposed architecture, and a smart farming scenario is used to test it.

Rabin Dulal's PhD - Developing vision recognition software for cattle identification

The project is developing a robust and reliable cattle identification method that uses machine learning to underpin biophysical features of cattle. NLIS tags used in Australia keep a record of Property Identification Code (PIC), birth, migration, health treatment history, and other necessary information. But the information can not be retrieved if the tags lost, are manipulated, hacked, or duplicated, which means it has vulnerability and may suffer biosecurity risks. On the other hand, there is a heavily manual data uploading process for the producer to ensure the cattle information is updated.

To facilitate automatic livestock management, biometric technologies can be applied with help of advanced machine learning technology with the wish of better performance than the NLIS tags. Among biometric technologies currently used are iris pattern, retina pattern, muzzle pattern, and DNA tracking (Awad, 2016). Iris pattern and retina image pattern are very effective but, it is difficult to capture the images. Coat pattern would be another option, which shows a promising result but is limited to a small group of herds, and works only on those animals having different colors (Andrew, 2019). Moreover, for those cattle whose body color is pure, a coat pattern is not an appropriate approach. Cattle identification based on muzzle pattern is a general method that can be used in all breeds, and animals (Kumar et al., 2017). Moreover, the project is to investigate a few-shot learning method that can cope with the challenge with fewer training samples. The developed technology of machine learning and computer vision has been applied in precision livestock management, including critical disease detection, vaccination, production management, tracking, health monitoring, and animal well-being monitoring (Mahmud et al., 2021).

CONCLUSIONS AND RECOMMENDATIONS

This project has successfully demonstrated a user controlled data sharing platform that allows cattle producers to direct standardised data to endpoints that they choose. Throughout the project the action learning methodology enabled the team to test the infrastructure by working with test users and passing test data through the system. By passing over 750,000 messages to over 20 endpoints (subscribers) representing 12 different events the project evaluated configuration options.

A small number of users (10) were able to test and provide feedback on early iterations of the data sharing platform. Most of the testing was focussed on interactions with the NLIS database linked to running cattle audits. In general the producers liked the concept of being able to control their data and once they understood the dashboard controls they found it easy to use. The limited number of endpoints and standardised events restricted their ability to get more value. The automated cattle audit and links to HerdTrakka did provide users with a quick and easy way to check their inventory in the NLIS. Producers found this information useful and it helped them more quickly identify inconsistencies between their farm management records and the NLIS database. More work is needed to deliver useful endpoints and engage with producers to enable Trakka to fit within a broader data management infrastructure.

At the start of the project there were significant uncertainties regarding the technical solution to deliver unique message addressing. This solution needed to allow users to control their data and link a complex array of data providers, event messages and data subscribers. The implementation required a number of iterations to test both the address protocols and the necessary security requirements. The solution demonstrated how it is possible to separate data providers from data subscribers ensuring data security but still route messages through a user controlled dashboard. The messaging layer allows a number of protocol options. The initial goal was to allow subscribers and publishers to directly interact with the message layer. However, after testing options and working with a small number of example publishers and subscribers the final solution included a server layer running a restful API. This layer provides credentialled security, allows public private keys to be used by data publishers to publish messages on behalf of a cattle producer and validates the event messages with detailed feedback for messages that don’t meet the schema specification. The API service then controls the message flow through to the message queue. Future developments will allow a broader range of publishing options including gRPC and direct web-sockets. The developments are aimed at increasing opportunities for automated direct machine to machine data exchanges. In the short-term it is recognised that cattle producers will predominantly use spreadsheet software to upload data. A web based uploader was developed to make it easy for cattle producers to upload their data. The project was able to demonstrate the potential value of automated data exchange using data ingested through the API via Optiweigh data and using a direct connection to the exchange through work with the Northern Territory DPI. The work completed in this project has laid the foundations for a highly scalable data exchange. The value of this infrastructure will be realised when there are more events that can be added via the web based uploader as well as a community of data publishers that publish cattle producers data directly to the data exchange. Interactions with the message layer are directly linked to enabling data publishers to deliver more value from the data they generate.

The importance of data standardisation was realised as a direct result of building the infrastructure and testing message options. It became clear the message body was best suited to a JSON schema. Standardising and validating the message body ensures subscribers can confidently access the message through automated code. Each data subscriber nominates the list of events they require and these events are passed directly to a dedicated queue. The queue is accessed via a restful API layer. Messages are only deleted from the queue when the API acknowledges it has passed the data to the subscriber. This configuration allows secure scalable access. Future work can provide more direct access to the message queue to enable a continuous flow of messages allowing more real time data exchanges. Using Trakka to collect data for researchers as part of a separate research project highlighted the importance to ensure users were clear on the terms and conditions of the subscriber end-point.

Assigning event information to items requires a method for linking the digital asset to the real world asset. Underpinning this linkage is a robust identification system. The red meat industry has world leading electronic traceability via the national livestock identification system and this project was able to leverage the unique cattle RFID. However, there are instances where cattle will lose an RFID tag and this can break the link between the digital asset and the real world cattle asset. This challenge was addressed through IDTrakka which provided a data repository that captured all available forms of identification. By incorporating multiple forms of identification it reduces the reliance on any single piece of data. IDTrakka incorporated the options to upload images for cattle to allow users to visually compare an animal. This system allows a user to use the visual image to determine the ID of the animal. Using photo via manual assessment is time consuming and not practical for large numbers of cattle but could provide a tool to help identify cattle with lost tags so the RFID tag can be replaced and linked back to earlier RFID tag numbers. By creating a repository for a number of different forms of identification the project also explored how new forms of identification might support strong identification. Muzzle prints like fingerprints are unique to individual cattle. The project explored opportunities to use vision recognition software based on machine learning algorithms that could provide automated identification. This work demonstrated that there was potential for automated vision recognition software. However, muzzle print biometrics needs to operate within the constraints of an operational farming system. Further work is required to evaluate the minimum specification for images that can be used to successfully train a machine learning model and also be used via the model to identify an animal. Once the image specification is determined further testing for hardware that can be used on a property to capture the required images.

NEXT STEPS

This project has laid the foundation for a commercially viable beef cattle data exchange. The system is currently deployed and available for producers within the limited constraints of specific projects. As identified previously the next steps will be to find opportunities to use the technology to deliver project activities that require end to end solutions. It is anticipated that initial uptake will be slow due to the limited number of events, data publishers and data subscribers. By focussing on whole of project applications this will allow users to access the technology as part of a dedicated complete application. A recent example of delivering a dedicated whole application has been the use of Trakka to support researchers to collect cattle weight data from producer properties. This application aligns two events (average cattle weights from Optiweigh and static cattle weights from the yards) and provides an endpoint to a database that researchers can access these standardised data. The Optiweigh data is accessed autonomously and the yard weight data is uploaded by producers using the uploader.

The challenge will be to find suitable projects and use cases that leverage the message brokering capability and allow producers to gain direct benefits from automated data transfer, data standardisation and linking event data to a range of potential endpoints. Some examples could include:

1. The NLIS database connects to the Trakka message broker using the API endpoints to enable any NLIS data actions to be published directly to a cattle producers dashboard so they can automatically share the data with any interested end-points.
2. Identifying and making available a list of events that can be directly used in the eNVD and passing these data directly to any endpoints that are facilitating automated eNVD.
3. Provide an IDTrakka service so that producers can coordinate their cattle identification information and any updates are published via Trakka and made available to any services the producer is using.
4. Work with research projects that are collecting producer data to help standardise and coordinate data collection.

As new users are on boarded feedback on their experiences interacting with the software will be used to update features and provide interactive feedback.

Commercialisation of the vision recognition software IDTrakka will be progressed. The technology has

PROJECT TEAM

Prof. Dave Swain
Project Lead

TerraCipher Pty Ltd

Jonathan Medway
CSU Project Lead

Charles Sturt University

A.Prof. Lihong Zheng
Machine Learning and Computer Vision Lead

Charles Sturt University

A.Prof. Ashad Kabir
Data Standardisation Lead

Charles Sturt University

Will Swain
Design & Development

TerraCipher Pty Ltd

Dr. Shawn Mcgrath
Senior Research Fellow

Charles Sturt University

Mahir Habib
PhD - Data Standardisation

Charles Sturt University

Rabin Dulal
PhD - Machine Learning and Computer Vision

Charles Sturt University

PUBLICATIONS LIST

1. Hossain, M. E., Kabir, A., Zheng, L., Swain, D., McGrath, S., & Medway, J. (2022). A Systematic Review of Machine Learning Techniques for Cattle Identification: Datasets, Methods and Future Directions. *Artificial Intelligence in Agriculture*, *6*, 138-155. https://doi.org/10.1016/j.aiia.2022.09.002 (SJR: Q1, Scopus percentile: 96%, cite score: 9.4)
2. Dulal, R., Zheng, L., Kabir, A., McGrath, S., Medway, J., Swain, D., & Swain, W. (2022). Automatic Cattle Identification using YOLOv5 and Mosaic Augmentation: A Comparative Analysis. *In International Conference on Digital Image Computing: Techniques and Applications (DICTA)*, IEEE (Accepted/In press) (CORE ranking: B)
3. Alsinglawi, B., Zheng, L., Kabir, M. A., Islam, M. Z., Swain, D., & Swain, W. (2022). Internet of Things and microservices in supply chain: Cybersecurity challenges, and research opportunities. *In Proceedings of the 36th International Conference on Advanced Information Networking and Applications (AINA-2022)*, Vol. 451, pp. 556-566. LNNS. Springer. https://doi.org/10.1007/978-3-030-99619-2_52 (CORE ranking: B) (CSU/DRSU funded Publication)

Media

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Food Agility media release (7 November 2022) “Take control of your data with AgriTrakka” https://www.foodagility.com/posts/take-control-of-your-data-with-agritrakka

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Kabir, A., 2022. Invited speech on Artificial Intelligence and Smartphone Apps: Recent Advancements and Opportunities, International Conference on Recent Progresses in Science, Engineering and Technology (ICRPSET 2022), Bangladesh, 26-27 Dec, 2022 - Ashad Kabir

Awards

Mahir Awards

1. The Best Paper Award from CSU on the 4th of Nov 2021 in the Tri Faculty HDR competition.
2. Honourable Mention For the Poster Presentation Awards at the IEEE NSW section UNITE 2022 on the 8th of July 2022, and
3. Appreciation Award for participating in the workshop at the IEEE NSW section UNITE 2022 on the 8th of July 2022.
4. On the 28th of July 2022, Gulbali Accelerated Publication Scheme from CSU.

Rabin Awards

1. CSU Tri-faculty HDR Support Scheme

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APPENDICES

Benefits calculations

Enhanced regulatory efficiency:

Assuming this will save on average three weeks of time for a producer each year and assuming 25,000 producers with an average salary of $100k per annum this equates to an annual saving of $144 million.

New value creation:

Assuming new services that deliver new revenue opportunities for those businesses that proactively engage in identifying these new income streams this could lift total new sales revenue from new products and services by 10%. Examples could include direct selling of premium products, tourism linked to industry stories based on data and valuation of identifying complementary business opportunities for example carbon sequestration or trading data to deliver algorithmic insight. Taking an annual beef market valuation of $15 billion and 30% of producers deriving added income from new products and services through their ability to leverage data sharing that would deliver added annual revenue of $450 million.

Supply chain data sharing:

There are many opportunities to drive value through data sharing through the supply chain. In this example we base the calculations on the information provided by Auctions Plus stating that cattle with a complete life history command a 20% premium in their auctions. We assume that the broader opportunities will generate on average a 10% premium and 30% of producers will gain these benefits across a $15 billion annual market valuation. With these assumptions the new annual value from supply chain data sharing could be $450 million.

Data standardisation:

There are intrinsic data management efficiencies derived from data standardisation as well as the opportunity to leverage automation reducing manual data entry costs. However, data standardisation will create the opportunity for more rapid innovation derived from the ability to potentially leverage better quality data through advances in tools such as machine learning. It is difficult to estimate the value that data standardisation will bring, however, the poultry and dairy industries provide a glimpse of how data standardisation and associated amalgamation linked to genetic improvement over a prolonged period of time (decades) can result in doubling productivity. For this estimate we assume long-term productivity improvements through data standardisation in the beef industry over a 50 year time period will result in a 50% increased market valuation. The discounted annual rate of improvement will see a 5% increase on the $15 billion over five years resulting in $750 million of new production efficiencies in five years.

Table 1: Events in LEI that have been modified or redefined from ICAR or ISC or that have been proposed

LEI Event type	Modified	Redefined	Proposed	Note
Weight	x	✓	x	2 properties have been deleted (traitLabel, timeOffFeed), added 2 properties (reason, date), and the "weight" property redefined to have 3 properties instead of referencing an incomplete ISC type.
Score	x	✓	x	All scores (fat, frame, condition, muscles) have been merged into this event and added 1 property (date).
Arrival	x	✓	x	Merged "change of ownership" event on it, renamed "consignment" property to "shipment" and added 1 property (date).
Departure	x	✓	x	Merged "change of ownership" event on it, renamed "consignment" property to "shipment" and added 1 property (date).
Death	✓	x	x	Deleted only the first part and added 1 property (date).
Registration	✓	x	x	Deleted only the first part and added 1 property (date).

Retag	✓	x	x	Deleted only the first part and added 1 property (date).
Treatment program	✓	x	x	Deleted only the first part and added 1 property (date).
Treatment	✓	x	x	Deleted only the first part and added 1 property (date).
Diagnosis	✓	x	x	Deleted only the first part and added 1 property (date).
Daily Milking Averages	✓	x	x	Deleted only the first part and added 1 property (date).
Feed Intake	✓	x	x	Deleted only the first part and added 1 property (date).
Milking Dry Off	✓	x	x	Deleted only the first part and added 1 property (date).
Milking Visit	✓	x	x	Deleted only the first part and added 1 property (date).
Abortion	x	✓	x	There were no properties, so 4 properties were added (reason, method, note, date).
Heat	✓	x	x	Deleted only the first part and added 1 property (date).
Insemination	✓	x	x	Deleted only the first part and added 1 property (date).
Parturition	✓	x	x	Deleted only the first part and added 1 property (date).
Pregnancy Check	✓	x	x	Deleted only the first part and added 1 property (date).

Semen Straw	✓	x	x	Deleted only the first part and added 1 property (date).
Status Observed	✓	x	x	Deleted only the first part and added 1 property (date).
Lactation Status Observed	✓	x	x	Deleted only the first part and added 1 property (date).
Birth	x	✓	x	Added 3 properties (EID, VID, date) and deleted "animalDetail".
Cue mate insertion	x	x	✓	Built from scratch.
Weaning	x	x	✓	Built from scratch.
Audit	x	x	✓	Built from scratch.
Castrate	x	x	✓	Built from scratch.
Pulse check	x	x	✓	Built from scratch.
Respiration	x	x	✓	Built from scratch.
Find age by dentition	x	x	✓	Built from scratch.
Hoof trimming	x	x	✓	Built from scratch.
Horn tipping	x	x	✓	Built from scratch.
Dehorning	x	x	✓	Built from scratch.
Location	x	x	✓	Built from scratch.

Table 2. Data Types have been used in LEI events

Data Types	Datatype source	Note
uncefactMassUnitsType	ICAR	Enumeration for mass units for the weight from UN/CEFACT trade facilitation recommendation (Kilogram, Gram, Pound, Metric Ton, Microgram, Milligram, Ounce, Pound net.)
icarArrivalReasonType	ICAR	Enumeration for animal arrival reasons to a specific property (farm, slaughter yard…).
iscConsignmentType	ISC	Shipment for the stock movement details include origin, destination, loading and unloading time, and driver details.
iscTransactionCostType	ISC	Describe the animal transaction cost.
icarAnimalCoreResource	ICAR	Schema for representing animal details.
icarAnimalIdentifierType	ICAR	Unique animal scheme and identifier combination.
icarAnimalSpecieType	ICAR	Enumeration for species of animal, we added extra 2 items ("Camel", "Kangaroo").
icarDateTimeType	ICAR	ISO8601 date and time. MUST contain a time zone. UTC recommended.
icarBreedIdentifierType	ICAR	Identifies a breed using a scheme and ID.
icarBreedFractionsType	ICAR	Type of the proportion of the denominator that this breed comprises.

icarProductionPurposeType	ICAR	An enumeration defines the primary product for which this animal is bred or kept. If animals are kept for breeding or live trade (sale), specify the end purpose of that breeding/trade (meat, milk wool). 1 extra value had been added (Pet).
icarAnimalStatusType	ICAR	An enumeration defines the status of the animal either absolutely and/or concerning the location on which it is recorded Off-farm signifies that the animal is no longer recorded at the location.
icarAnimalReproductionStatusType	ICAR	Enumeration for different possible reproduction statuses of an animal.
icarAnimalLactationStatusType	ICAR	Enumeration for different possible lactation statuses of an animal.
icarParentageType	ICAR	Use this type to define a parent of an animal.
icarRegistrationReasonType	ICAR	Enumeration for registration reason: Born, or Registered (induct existing animal).
iscWithdrawalType	ISC	Withholding period with an end date that applies to the specific food chain because of a task that occurred to the animal such as treatment administered.
icarTraitAmountType	ICAR	Type for measuring by kilogram or pound.
icarDeathReasonType	ICAR	Coded reasons for death include disease, parturition complications, and consumption by humans or animals.

icarDepartureKindType	ICAR	Enumeration for the kind of departure. Type of destination or transfer. Agistment would refer to a case when cattle are taken in for feeding on pastureland upon contract, though in the UK animals are more commonly sent "to/on tack."
icarDepartureReasonType	ICAR	Enumeration for departure cause.
iscDiagnosisType	ISC	Diagnosis description for an animal.
iscOrganisationType	ISC	Organization or farm owner details.
icarFeedDurationType	ICAR	The duration of the feeding.
icarConsumedFeedType	ICAR	Provides the consumed feed and the amount the animal was entitled to. Amounts are real weights.
icarConsumedRationType	ICAR	Provides the consumed amount of feed and the amount the animal was entitled to. Amounts are real weights.
icarDeviceReferenceType	ICAR	The details of a device (model, which represents manufacturer, model, hardware, software versions, and the serial number) that does a specific task instant weight.
icarReproHeatDetectionMethodType	ICAR	Enumeration for the method of detecting the heat of an animal.
icarReproHeatCertaintyType	ICAR	Enumeration for the certainty of a specific heat.
icarReproHeatSignType	ICAR	Enumeration for the signs of the heat (Slime, Clear slime, Interested in other animals, Standing under, Bawling, Blood).

icarReproHeatIntensityType	ICAR	Enumeration for the method of insemination (Very weak, Weak, Normal, Strong, Very strong).
icarReproInseminationType	ICAR	Enumeration for the method of insemination (natural service, run with bull, insemination, implantation).
icarReproSemenStrawResource	ICAR	Describes a semen straw.
icarReproEmbryoResource	ICAR	Describes an implanted embryo.
icarLocationIdentifierType	ICAR	Location identifier.
iscLotAssessmentType	ISC	Assessment for the lot for changing the ownership in order of sale or purchase.
icarMilkDurationType	ICAR	The duration of the milking.
icarMilkingTypeCode	ICAR	The type of milking (manual or automated).
icarMilkingMilkWeightType	ICAR	The amount of milk milked.
icarQuarterMilkingType	ICAR	Provides the milking result and optionally sampling and characteristic details.
icarAnimalMilkingSampleType	ICAR	Describes the details of a sample of milk taken from the quarter for laboratory analyses.
icarMilkCharacteristicsType	ICAR	Milk characteristics of the quarter.
icarMilkingRemarksType	ICAR	Enumeration for different possible milking remarks.
icarReproCalvingEaseType	ICAR	Enumeration for calving ease.

icarReproPregnancyResultType	ICAR	Enumeration for the result of pregnancy diagnosis (empty/pregnant).
icarReproSemenPreservationType	ICAR	Enumeration for the method of semen preservation (liquid usually with extender, frozen).
icarAnimalGenderType	ICAR	Enumeration for sex of the animal.
iscMedicineReferenceType	ISC	Medicine basic details.
iscDoseType	ISC	Quantity of dose administered.
iscCourseSummaryType	ISC	Medicine course summary.
icarWeightMethodType	ICAR	The method by which the weight is observed. Includes loadcell (loadbars), girth (tape), assessed (visually), walk-over weighing, prediction, imaging (camera/IR), front end weight correlated to the whole body, and group average (pen/sample weight).
LEIAbortionMethodTypes	LEI	Enumeration for the abortion methods.
LEILotDetailType	LEI	The lot details for changing the ownership in order of sale or purchase.
LEIScoresTypes	LEI	Enumeration for the score's name.
LEIEventsTypes	LEI	Enumeration for all events names.
LEIAbortionReasonTypes	LEI	Enumeration for the abortion reason.
LEICastrateMethod	LEI	Enumeration for the castration methods.
LEIDehorningMethod	LEI	Enumeration for the dehorning tools.

LEIWeaningMethod	LEI	Enumeration for the weaning method.
LEIWeaningReason	LEI	Enumeration for the weaning reason.
icarDeathDisposalMethodType	ICAR	Coded disposal methods include approved service, consumption by humans or animals, etc.
EventOwnerType	LEI	It defines that the object should have a property called "id" which is required. It also defines the object as a combination of two types, represented by the "allOf" keyword. The object must have all the properties and constraints defined in both the schema referenced by "$ref": "ISC/types/iscOrganisationType.json" and "$ref": "ISC/types/iscPersonType.json" This means that the object should have all the properties defined in the "iscOrganisationType.json" and "iscPersonType.json" files. The schema describes a data owner, which can be a cattle producer, crop farmer or any other type of owner, and it should have a unique identifier.
EventSource	LEI	It defines that the object should be a combination of two types, represented by the "allOf" keyword. This means that the object should have all the properties defined in the "icarDeviceResource.json" file and the properties defined in the second element of the allOf array. The second element of the allOf array has a property called "ip_address". The "ip_address" property is a string type. It should be in the format of "ipv4".

		This schema describes a device or software from which the event originates.
ItemsTypes	LEI	Enumeration for the items types such as "Animal", "Crop", "Machinery"...etc
ItemType	LEI	It defines that the object should have a property called "itemType" which is a string type, and it is referred to another JSON file, "ItemsTypes.json". It also defines the object as one of three types, represented by the "oneOf" keyword. Each type has its own set of required properties and constraints on the values of those properties. For example, if the "itemType" is "Animals", the object must have a property called "animal" which is an object type, and it is referred to another JSON file "ICAR/resources/icarAnimalsCoreResource.json".

Case Studies Sample JSON Code Snippets

Scenario 1 - Selling and purchasing livestock and associated livestock movements:

Departure Event - Sale


```
{
 "eventDateTime": "2021-01-17T14:13:23Z",
 "source": {
   "id": "CSUFarm-Computer",
   "ip_address": "128.0.0.0",
   "manufacturer": {
     "id": "DELL"
   }
 },
 "owner": {
   "id": "A123ABCD",
   "name": "Producer A Beef",
   "email": "prodA@beef.com",
   "givenName": "Aaron",
```

```
    "familyName": "Farmer"
  },
  "message": {
    "eventName": "Departure",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "982 123456789101",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Male"
      }
    },
    "session": {
      "sessionID": "un1Que1d1",
      "totalInSession": 50
    },
    "event": {
      "departureKind": "Sale",
      "departureReason": "Sale",
      "shipment": {
        "id": {
          "scheme": "sale invoice",
          "id": "123456789"
        },
        "origin": {
          "id": "A123ABCD",
          "name": "Producer A Beef",
          "email": "prodA@beef.com"
        },
        "destination": {
          "id": "B123ABCD",
          "name": "Producer B 4 Beef",
          "email": "b4beef@beef.com"
        },
        "vehicles": [
          "ABC123",
          "CBA321"
        ]
      },
      "changeOfOwnership": {
        "lot": {
          "lotId": "1256"
        },
        "purchaser": {
          "id": "B123ABCD",
          "name": "Producer B 4 Beef",
          "email": "b4beef@beef.com"
        },
        "transactionCost": {
          "currency": "AUD",
          "totalCost": 42250
```

```
        }
      }
    }
  }
```

Arrival Event - Purchase


```
{
  "eventDateTime": "2021-01-19T14:13:23Z",
  "source": {
    "id": "123",
    "ip_address": "128.0.0.0",
    "manufacturer": {
      "id": "Apple"
    }
  },
  "owner": {
    "id": "B123ABCD",
    "name": "Producer B 4 Beef",
    "email": "b4beef@beef.com"
    "givenName": "Bob",
    "familyName": "Farmer"
  },
  "message": {
    "eventName": "Arrival",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "982 123456789101",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Male"
      }
    },
    "session": {
      "sessionID": "un1Que1d1",
      "totalInSession": 50
    },
    "event": {
      "arrivalReason": "Purchase",
      "shipment": {
        "id": {
          "scheme": "sale invoice",
          "id": "123456789"
        },
        "origin": {
          "id": "A123ABCD",
          "name": "Producer A Beef",
          "email": "prodA@beef.com"
        },
```

```
        "destination": {
          "id": "B123ABCD",
          "name": "Producer B 4 Beef",
          "email": "b4beef@beef.com"
        },
        "vehicles": [
          "ABC123",
          "CBA321"
        ]
      },
      "changeOfOwnership": {
        "lot": {
          "lotId": "1256"
        },
        "purchaser": {
          "id": "B123ABCD",
          "name": "Producer B 4 Beef",
          "email": "b4beef@beef.com"
        },
        "transactionCost": {
          "currency": "AUD",
          "totalCost": 42250
        }
      }
    }
  }
}
```

Scenario 2 - Livestock movement for agistment:

Agistment Departure Event - Agistment

```
{
 "eventDateTime": "2021-01-27T14:13:23Z",
 "source": {
   "id": "Prod D Computer",
   "ip_address": "128.0.0.0",
   "manufacturer": {
     "id": "HP"
   }
 },
 "owner": {
   "id": "D123ABCD",
   "name": "Pro Ducer",
   "email": "proDucer@beef.com",
   "givenName": "Dorothy",
   "familyName": "Farmer"
 },
 "message": {
   "eventName": "Departure",
   "item": {
     "itemType": "Animal",
```

```
      "animal": {
        "identifier": {
          "id": "982 123456789101",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Male"
      }
    },
    "session": {
      "sessionID": "un1Que1d2",
      "totalInSession": 50
    },
    "event": {
      "departureKind": "Agistment",
      "departureReason": "Production",
      "shipment": {
        "id": {
          "scheme": "agreement",
          "id": "123456789"
        },
        "origin": {
          "id": "D123ABCD",
          "name": "Pro Ducer",
          "email": "proDucer@beef.com"
        },
        "destination": {
          "id": "A123ABCD",
          "name": "Producer A Beef",
          "email": "prodA@beef.com"
        },
        "vehicles": [
          "ABC123"
        ]
      },
      "changeOfOwnership": null
    }
  }
```


Agistment Arrival Event - Agistment


```
{
 "eventDateTime": "2021-01-30T14:13:23Z",
 "source": {
   "id": "123",
   "ip_address": "1.1.1.1",
   "manufacturer": {
     "id": "Apple"
   }
 },
 "owner": {
   "id": "A123ABCD",
```

```
    "name": "Producer A Beef",
    "email": "prodA@beef.com",
    "givenName": "Aaron",
    "familyName": "Farmer"
  },
  "message": {
    "eventName": "Arrival",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "982 123456789101",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Male"
      }
    },
    "session": {
      "sessionID": "un1Que1d2",
      "totalInSession": 50
    },
    "event": {
      "arrivalReason": "Agistment",
      "shipment": {
        "id": {
          "scheme": "agreement",
          "id": "123456789"
        },
        "origin": {
          "id": "D123ABCD",
          "name": "Pro Ducer",
          "email": "proDucer@beef.com"
        },
        "destination": {
          "id": "A123ABCD",
          "name": "Producer A Beef",
          "email": "prodA@beef.com"
        },
        "vehicles": [
          "ABC123"
        ]
      },
      "changeOfOwnership": null
    }
  }
}
```


Scenario 3 - Livestock movement and associated records to complete a purchase transaction:

Animal Observed Status Event - During Transportation

```
{
 "eventDateTime": "2021-02-02T15:13:23Z",
 "source": {
   "id": "123",
   "ip_address": "128.0.0.0",
   "manufacturer": {
     "id": "Apple"
   }
 },
 "owner": {
   "id": "C123ABCD",
   "name": "Pro Cattle",
   "email": "proCattle@beef.com",
   "givenName": "Carol",
   "familyName": "Cattle"
 },
 "message": {
   "eventName": "StatusObserved",
   "item": {
     "itemType": "Animal",
     "animal": {
       "identifier": {
         "id": "600 000000000199",
         "scheme": "rfid"
       },
       "specie": "Cattle",
       "gender": "Female"
     }
   },
   "session": {
     "sessionID": "123",
     "totalInSession": 1
   },
   "event": {
     "observedStatus": "Injured",
     "note": "found 1 of the steers was injured on the truck and needs to be euthanized
RFID: 600 000000000199",
     "responsible": "Carol"
   }
 }
}
```


Animal Death Event - During Transportation


```
{
 "eventDateTime": "2021-02-02T17:13:23Z",
 "source": {
   "id": "123",
   "ip_address": "128.0.0.0",
   "manufacturer": {
     "id": "Apple"
   }
```

```
 },
 "owner": {
   "id": "C123ABCD",
   "name": "Pro Cattle",
   "email": "proCattle@beef.com",
   "givenName": "Carol",
   "familyName": "Cattle"
 },
 "message": {
   "eventName": "Death",
   "item": {
     "itemType": "Animal",
     "animal": {
       "identifier": {
         "id": "600 000000000199",
         "scheme": "rfid"
       },
       "specie": "Cattle",
       "gender": "Female"
     }
   },
   "session": {
     "sessionID": "5",
     "totalInSession": 1
   },
   "event": {
     "deathReason": "Injured",
     "explanation": "injured during transportation",
     "disposalMethod": "OnPremise",
     "disposalOperator": "Vessna Vet",
     "disposalReference": "receipt123"
   }
 }
}
```


Weight Event - Automated Walkover Weigh


```
{
  "eventDateTime": "2022-04-28T14:30:23Z",
  "source": {
    "id": "Walkover Weigh",
    "serial": "2Vr93trD",
    "ip_address": "128.0.0.0",
    "manufacturer": {
      "id": "Agtech Company"
    }
  },
  "owner": {
    "id": "C123ABCD",
    "name": "Pro Cattle",
    "email": "proCattle@beef.com",
```

```
      "givenName": "Carol",
      "familyName": "Cattle"
    },
    "message": {
      "eventName": "Weight",
      "item": {
        "itemType": "Animal",
        "animal": {
          "identifier": {
            "id": "rfid",
            "scheme": "rfid"
          },
          "specie": "Cattle",
          "gender": "Unknown"
        }
      },
      "session": {
        "sessionID": "1548",
        "totalInSession": 99
      },
      "event": {
        "weight": {
          "kind": "individual",
          "measurement": "KGM",
          "value": 352.5
        },
        "method": "WalkOver"
      }
    }
}
```


Scenario 7 - Parturition:

Parturition Event


```
{
  "eventDateTime": "2021-12-01T13:35:25Z",
  "source": {
    "id": "Aarons Mobile",
    "ip_address": "1.1.1.1",
    "manufacturer": {
      "id": "Apple"
    }
  },
  "owner": {
    "id": "A123ABCD",
    "name": "Producer A Beef",
    "email": "prodA@beef.com",
    "givenName": "Aaron",
    "familyName": "Farmer"
  },
  "message": {
```

```
    "eventName": "Parturition",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "982 123456789101",
          "scheme": "rfid"
        },
        "specie": "Cattle",
        "gender": "Female"
      }
    },
    "session": {
      "sessionID": "6454456",
      "totalInSession": 20
    },
    "event": {
      "isEmbryoImplant": false,
      "damParity": 1,
      "liveProgeny": 1,
      "totalProgeny": 1,
      "calvingEase": "DifficultVeterinaryCare",
      "progeny": [
        {
          "identifier": {
            "id": "1-1dec2021",
            "scheme": "VID"
          },
          "specie": "Cattle",
          "gender": "Male"
        }
      ]
    }
  }
}
```


Calf Birth Event


```
{
  "eventDateTime": "2021-12-01T13:35:25Z",
  "source": {
    "id": "Aarons Mobile",
    "ip_address": "1.1.1.1",
    "manufacturer": {
      "id": "Apple"
    }
  },
  "owner": {
    "id": "A123ABCD",
    "name": "Producer A Beef",
    "email": "prodA@beef.com",
```

```
    "givenName": "Aaron",
    "familyName": "Farmer"
  },
  "message": {
    "eventName": "Birth",
    "item": {
      "itemType": "Animal",
      "animal": {
        "identifier": {
          "id": "1-1dec2021",
          "scheme": "VID"
        },
        "specie": "Cattle",
        "gender": "Male"
      }
    },
    "session": {
      "sessionID": "78975",
      "totalInSession": 50
    },
    "event": {
      "registrationReason": "Born",
      "EID": "",
      "VID": "1-1dec2021"
    }
  }
}
```

Scenario 11 - Castration:


```json
{
 "eventDateTime": "2022-25-02T13:35:25Z",
 "source": {
   "id": "Aarons Computer",
   "ip_address": "1.1.1.1",
   "manufacturer": {
     "id": "Apple"
   }
 },
 "owner": {
   "id": "A123ABCD",
   "name": "Producer A Beef",
   "email": "prodA@beef.com",
   "givenName": "Aaron",
   "familyName": "Farmer"
 },
 "message": {
   "eventName": "Castrate",
   "item": {
     "itemType": "Animal",
     "animal": {
       "identifier": {
         "id": "900 000000000203",
         "scheme": "rfid"
       },
       "specie": "Cattle",
       "gender": "Male"
     }
   },
   "session": {
     "sessionID": "Dec-2021-Calves-Castration",
     "totalInSession": 35
   },
   "event": {
     "castrateMethod": "Surgical",
     "note": "Removed using a scalpel",
     "responsible": "Vessna Vet 0400 111 111"
   }
 }
}
```

TRAKKA | Making Data Flow

By: Prof. Dave Swain, Will Swain, Jon Medway, A.Prof. Lihong Zheng, A.Prof. Ashad Kabir, Dr. Shawn McGrath, Mahir Habib, Rabin Dulal

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FA071

hello@foodagility.com

@FoodAgility

foodagility.com