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Final report

Demonstrating the value of an end-to-end feedback system for the beef supply chain

Project code: P.PSH.1238

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Date published: 28 February 2022

PUBLISHED BY
Meat and Livestock Australia Limited
PO Box 1961
NORTH SYDNEY NSW 2059

This is an MLA Donor Company funded project.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government and contributions from the Australian Meat Processor Corporation to support the research and development detailed in this publication.

Abstract

The purpose of this project is to pilot an end-to-end feedback system in a vertically integrated beef supply chain using processing intelligence for data capture and predictive analytics. One of the objectives of such a system is the ability to predict and mitigate risk. A risk that could not have been predicted was the outbreak of the Covid 19 pandemic just as the project kicked off. The pandemic significantly disrupted the project, however alternative plans were put in place to ensure the project was successfully completed. The learnings from this project have been converted to a Connected Beef Supply Chain Control Tower framework with design principles as the key contribution to the meat and livestock industry. To evaluate the framework an IT artifact was built using process intelligence and an industrial IIoT (Industrial Internet of Things) platform with integration to a variety of systems and sensors. This IT artifact has been designed at industrial scale with multi tenancy capability (i.e., the solution can be used by multiple businesses with complete security of their data, processes, and systems). With industry support this IT artifact can be converted to an operational, subscription as a service, solution for wide adoption. Broader industry engagement has also occurred, both at the technology level as well as overall adoption. Significant industry interest has been received and currently discussions are underway with several businesses.

Executive summary

Background

The purpose of this project is to pilot an end-to-end feedback system in a vertically integrated beef supply chain using processing intelligence for data capture and predictive analytics. The pilot demonstrates how individual animal data made available through the supply chain as well as ISC's data platform and applications (such as Livestock Data Link) can be extracted and analysed to provide feedback and insights to the various stakeholders in the beef supply chain. It shows how this information can be used for decision support to improve the overall outcomes of the beef supply chain.

Objectives

The overall objective was to provide supply and demand visibility across the supply chain through the development of decision support that achieves "the right animal for the right market at the right time". Fundamental to this process was the identification of individual animal data from breeding, backgrounding, feed lotting, and processing required to provide the necessary insights to achieve the objective.

Additional objectives included the identification of gaps in existing capabilities and capacities in data capture and management. Design and development of a cloud based (open access) system that accommodates diverse data sources and formats. Provision of a use case in establishing and improving the Red Meat Integrity System through valuable learnings of key programs (i.e., ISC data platform, LDL and eNVD) integrating with a solution provider system (Hitachi) and a supply chain system (ACC-ACBU). Identification of the value of industry data and the opportunities of integration with ISC's data platform. Evaluation of the outcomes of the on-farm pilot data management system and extrapolation across the supply chain. Provision of a clear journey map to digital agriculture transformation for each participant in the red meat supply chain.

Methodology

The methodology centred around a design led thinking approach, focusing on discovery workshops with the various stakeholder groups. Due to Covid restrictions many of these workshops were conducted virtually, see Appendix for process followed. Face to face workshops were held with a key subject matter expert at Australian Country Choice when restrictions permitted and later when access to Australian Country Choice Farms was no longer possible, farm visits were conducted on the Calliope Cattle Station. The discovery workshops included process mapping of the beef supply chain and data modelling.

Results/key findings

- Integration of the various systems from farm to processing is achievable at an individual animal level.
- The insights produced from this integration can improve the overall yield, efficiency and ultimately profitability across an integrated beef supply chain.
- The co-created framework for end-to-end feedback across the beef supply chain was operationalised through an IT artifact which proved that a combination of low code user interface development and appropriate use of public cloud infrastructure provides an effective platform for widespread deployment of a Connected Beef Supply Chain Control Tower.

Benefits to industry

- A Connected Beef Supply Chain Tower (Beef SCCT) can be provided to small, medium, and large businesses cost effectively.
- The ability to multi-tenant an overall Beef SCCT i.e., the core solution is designed and containerised in such a manner that a single instance of the solution may serve multiple customers provides the opportunity for a peak body such as MLA or Integrity Systems Company to provide this service to their stakeholders.
- The deeper insights provided by the Beef SCCT not only benefit those businesses with integrated beef supply chains they also benefit the individual supply chain partners who run standalone businesses e.g., breeding, or backgrounding farms, feedlots, or processing plants.

Future research and recommendations

- The Beef SCCT project has focused on conventional meat quality feedback data as provided via the ISC Livestock Data Link system. Opportunities exist to extend the research to include the new objective carcase measurement technologies that have been developed by MLA. The connection of this data to the data collected during the life cycle of an animal will provide significant insights into contributing factors from genetics to practices and procedures that contribute to high yield and quality.
- The capability exists to expand the Beef SCCT to include simulation and digital twining.
- The core architecture of the Beef SCCT provides the framework for extending the solution to facilitate the identification and measurement of Scope 3 Green House Gas Emissions as defined by the GHG Protocol and Emissions Reduction Fund.

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1. Background

This project aimed to pilot an end-to-end feedback system in a vertically integrated beef supply chain using process intelligence for data capture and predictive analysis. The selected partner business was Australian Country Choice (ACC) and later extended to Calliope Cattle Station. One of the objectives of integrating a supply chain in what the project later named the Connected Beef Supply Chain Control Tower [i.e. Beef SCCT], is to use the predictive analytics to monitor and predict disruption. The one major disruption that it could not predict was the Covid 19 pandemic which was spreading globally as the project commenced. Covid 19 has had a significant impact on the project as farm visits and face to face meetings with the Australian Country Choice team were not permitted for much of the project duration. Despite these significant restrictions the project commenced utilising virtual meetings. At the commencement of the project Hitachi was working with Australian Country Choice on the Cattle Management Intelligence project, a significant collaborative project that had its origins in P.PSH. 1057, the Hitachi – ACC Innovation Officer project. During the early discovery stages of this project, it became clear to the ACC Steering Committee that the Beef SCCT was very dependent on the individual cattle data that would be generated from the Cattle Management Intelligence (CMI) project. ACC requested that the Beef SCCT project team incorporate expediting the development of CMI into this project. This request was agreed to by MLA and Hitachi resulting in a reprioritisation of the early milestones. A further significant event occurred when Australian Country Choice embarked on an ERP (Enterprise Resource Planning) implementation, from this point access to the ACC project members was severely restricted and access to the IT team terminated. To avoid major postponements to the project, the Hitachi team, with MLA support, reached out to Calliope Cattle Station requesting permission to continue building and testing the Beef SCCT, this was granted, and the project was completed.

2. Objectives

The overall objective was to provide supply and demand visibility across the supply chain through the development of decision support that achieves “the right animal for the right market at the right time”. Fundamental to this process was the identification of individual animal data from breeding, backgrounding, feed lotting, and processing required to provide the necessary insights to achieve the objective, as illustrated in Figure 1 below.

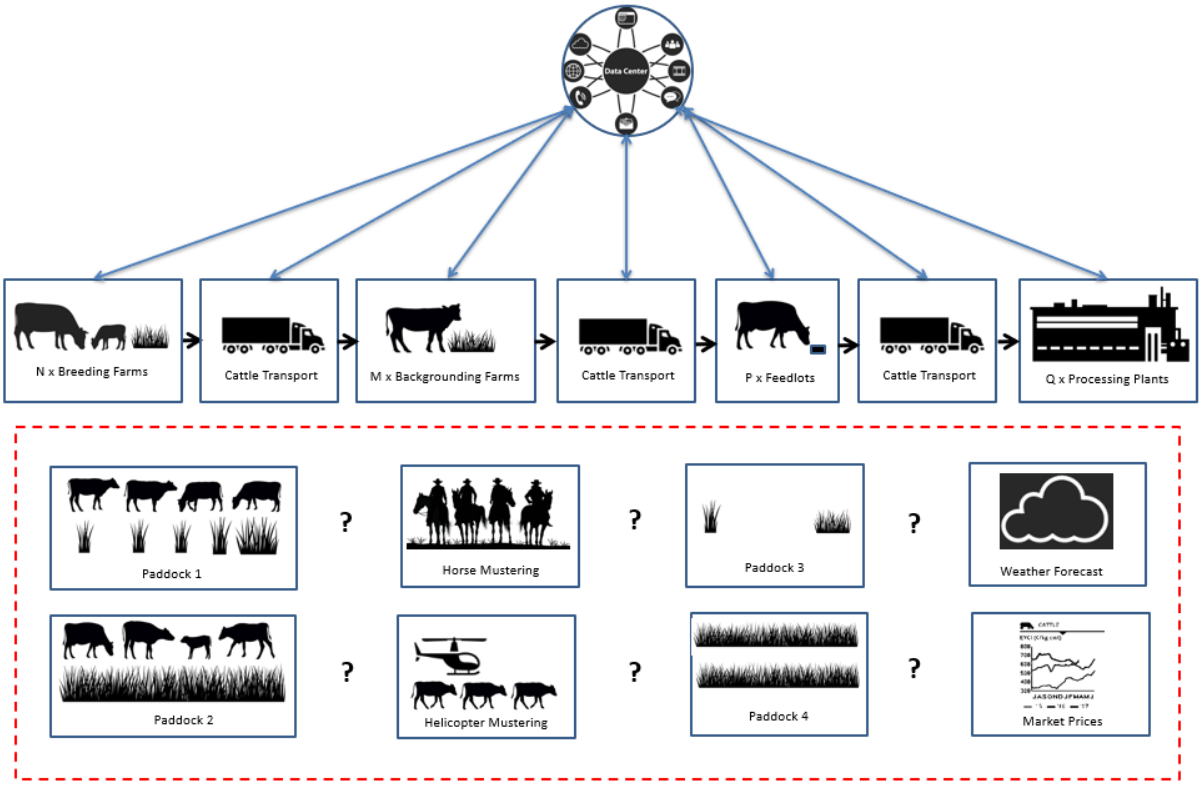

Figure 1: Illustration of Overall Objectives

Additional objectives included the identification of gaps in existing capabilities and capacities in data capture and management. Design and development of a cloud based (open access) system that accommodates diverse data sources and formats. Provision of a use case in establishing and improving the Red Meat Integrity System through valuable learnings of key programs (i.e., ISC data platform, LDL and eNVD) integrating with a solution provider system (Hitachi) and a supply chain system (ACC). Identification of the value of industry data and the opportunities of integration with ISC's data platform. Evaluation of the outcomes of on-farm pilot data management system and extrapolation across the supply chain. Provision of a clear journey map to digital agriculture transformation for each participant in the red meat supply chain.

3. Methodology

3.1 Design Led Thinking

The methodology centred around a design led thinking approach, focusing on discovery workshops with the various stakeholder groups. Due to Covid restrictions many of these workshops were conducted virtually, see Appendix for process followed. Face to face workshops were held with a key subject matter expert at Australian Country Choice when restrictions permitted and later when access to Australian Country Choice Farms was no longer possible, farm visits were conducted on the Calliope Cattle Station. The overall approach is illustrated in Figure 2.

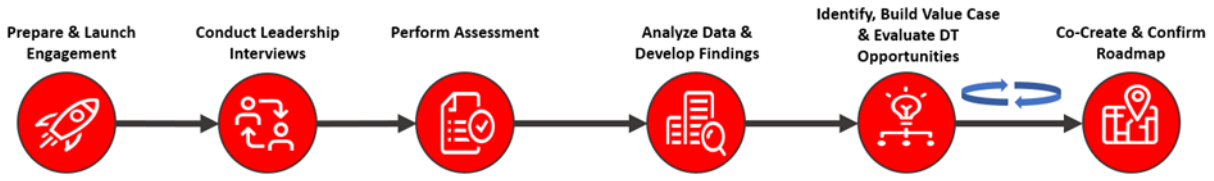

Figure 2: Design Led Thinking Methodology

3.2 Discovery Workshops

The discovery workshops included process mapping of the beef supply chain, as illustrated in Figure 3 below.

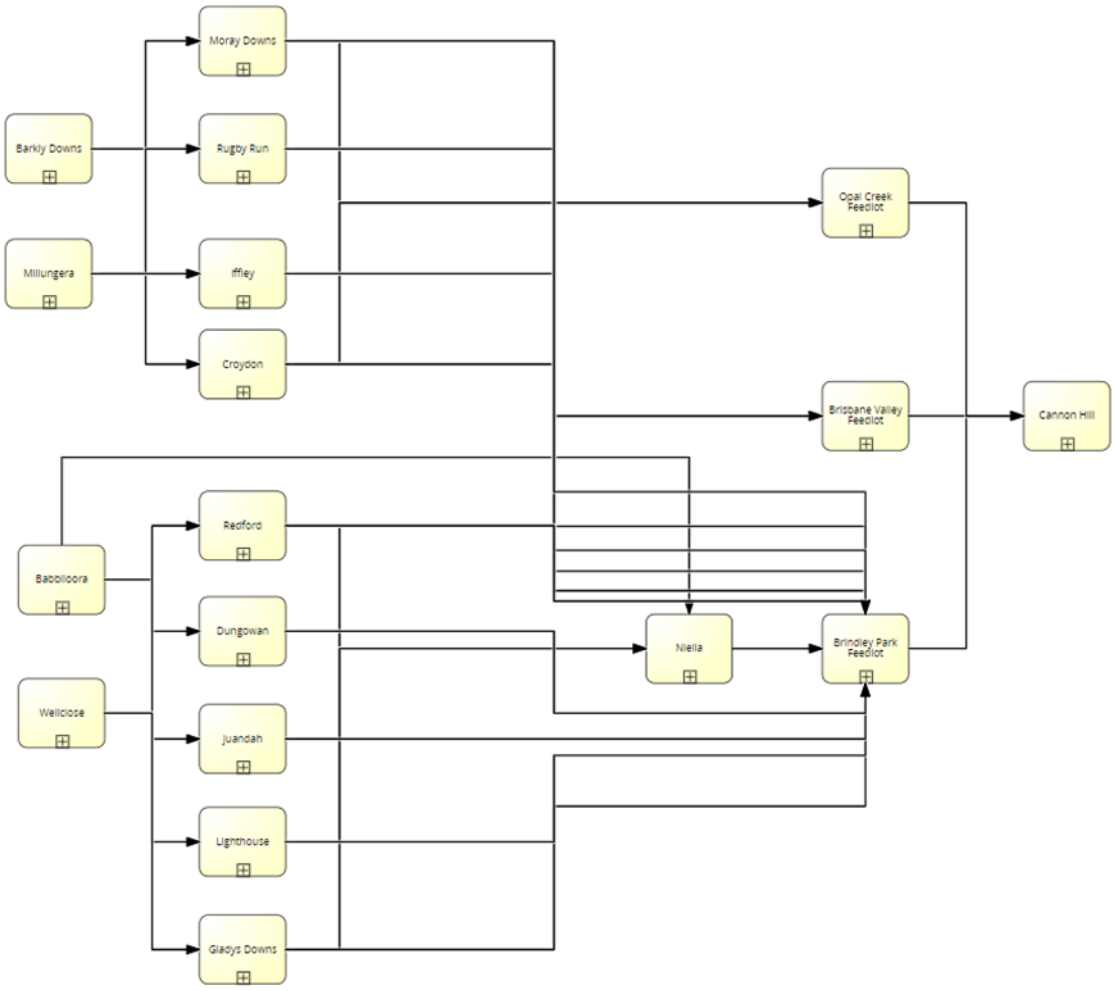

Figure 3: Process Map of ACC Beef Supply Chain

In addition to mapping of the supply chain, detailed data mapping was also conducted, see Figure 4 below.

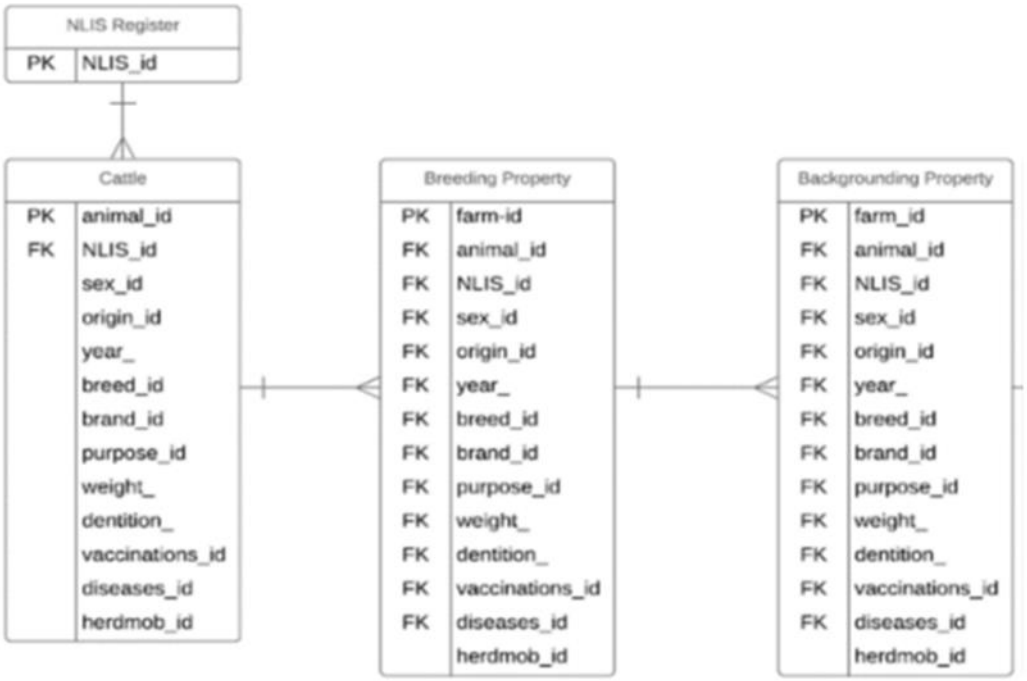

Figure 4: Data Model of ACC Beef Supply Chain

3.3 Incorporation of Cattle Management Intelligence

A key finding of the discovery process, in particular the data modelling exercise, was the gap in collection of individual cattle data from the breeding and backgrounding properties. As mentioned above the scope was expanded to include expediting the development of CMI and incorporating the data into the Beef SCCT. ACC implemented a crush side stock management system from supplier ProTrace[1]. ProTrace collects 70 data points per animal from the 14 properties in the ACC supply chain, see crush side system in Figure 5 below.

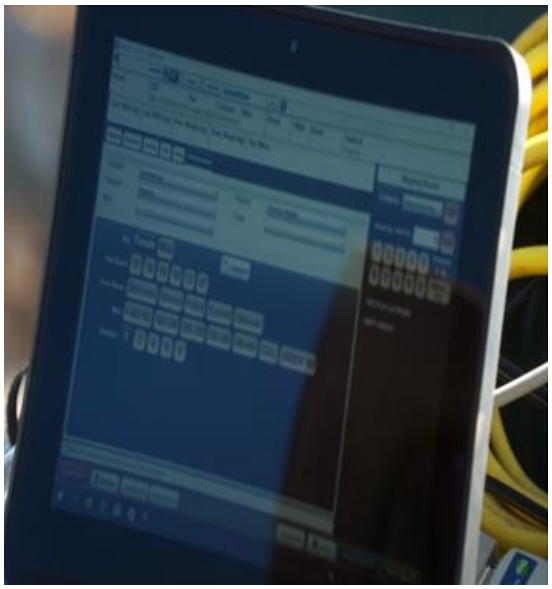

Figure 5: ACC's crush side data capture system

[1] www. protracesolutions.com

This data is downloaded to ACC's SQL[2] database in Cannon Hill overnight. The project team assisted with expediting integration with the ProTrace system, importing this data and automating the daily cattle records, stock movement advice, paddock books and prepopulating data into the management accounting system, as illustrated in Figures 6 and 7 below.

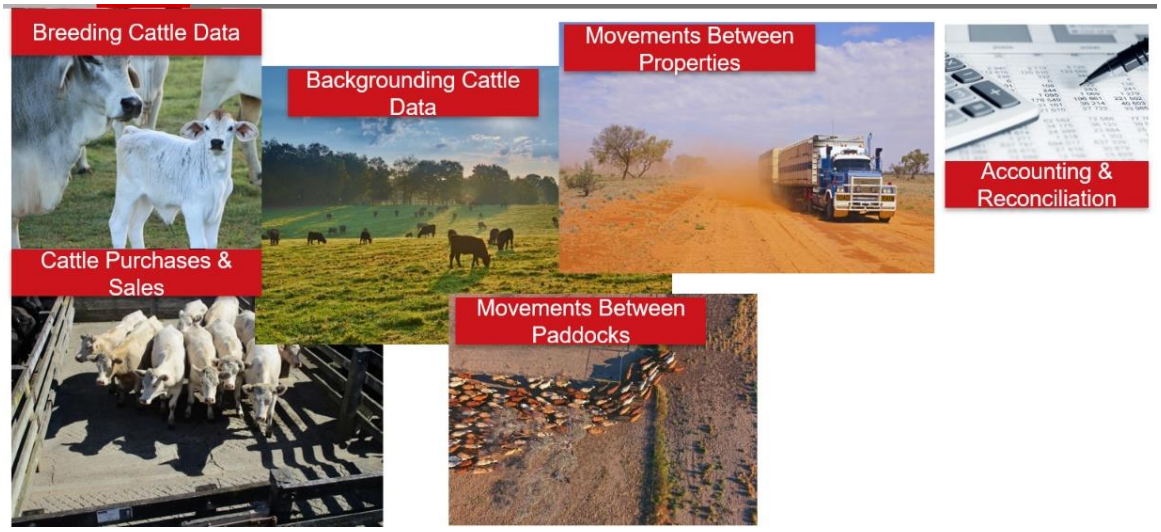

Figure 6: Scope of the Cattle Management Intelligence Solution

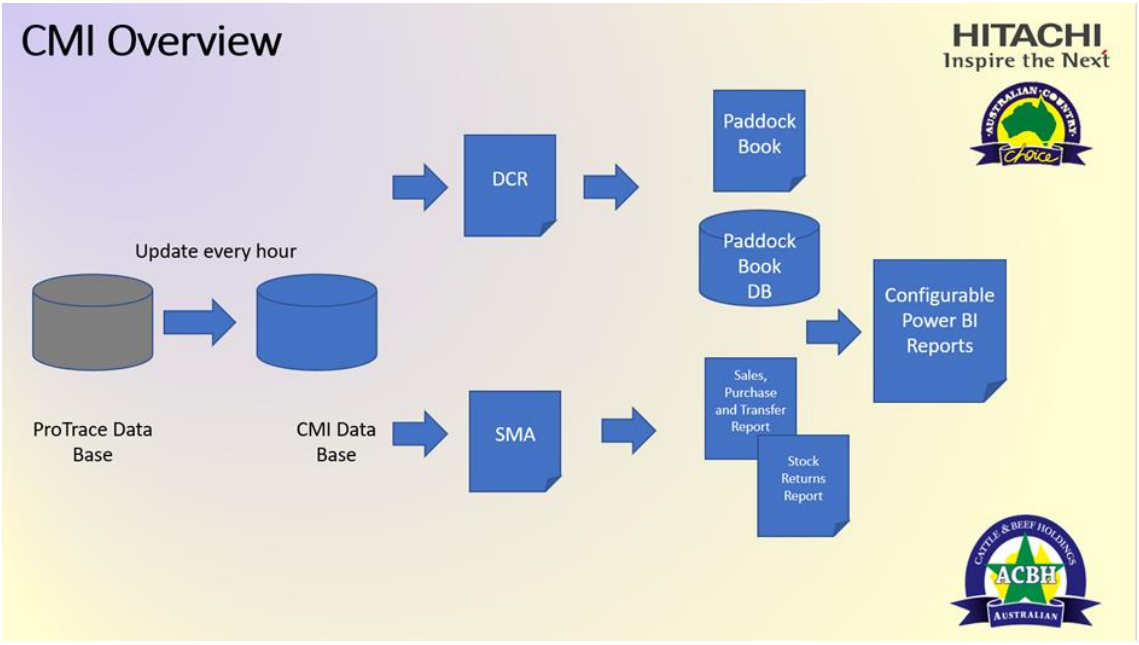

Figure 7: High level data flows for the Cattle Management Intelligence Solution

[2] www.microsoft.com/en-au/sql-server

This change of scope required several additional workshops in which the detailed design of the cattle management intelligence solution user interfaces and the data from the ProTrace SQL server database were mapped, coded, and configured by the development team and extensively tested. An example of the workshop outputs is given in Figure 8 below.

As is presented in the Results and Deliverables section, the Cattle Management Intelligence solution was subsequently completed as the priority.

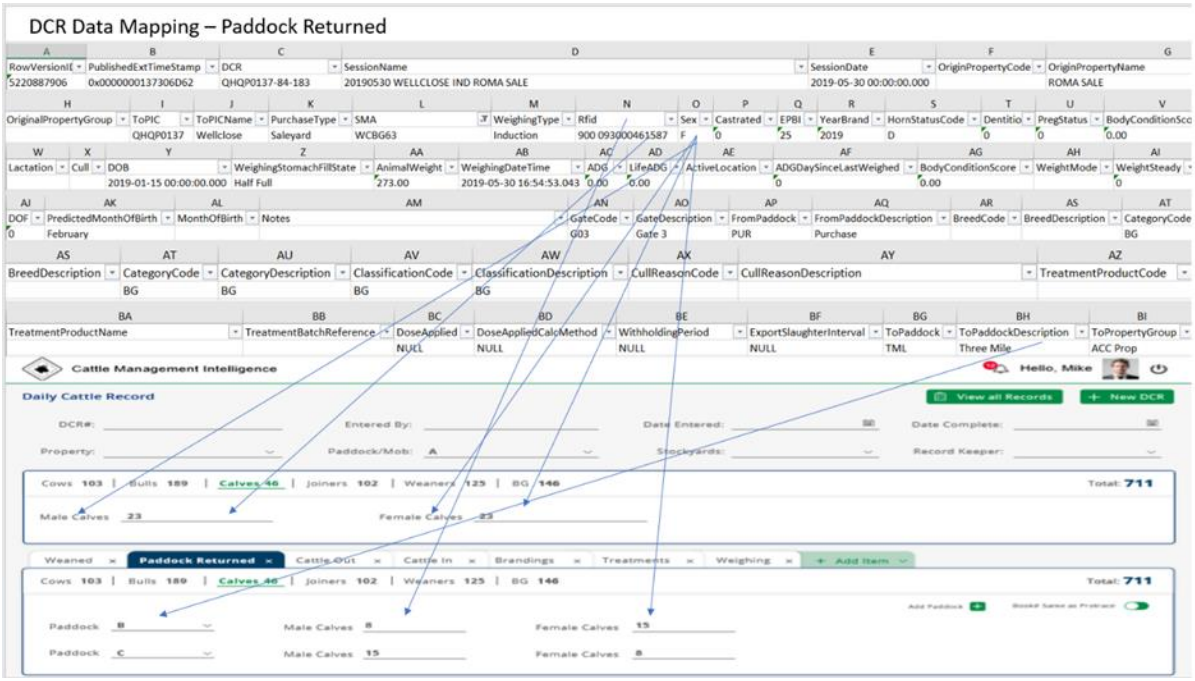

Figure 8: Detailed mapping and configuration of the Cattle Management Intelligence solution

3.4 Detailed Discovery Workshops – Key Supply Chain Decisions

While the CMI solution was expedited and expanded to be incorporated into the overall Beef SCCT framework, the remaining team members focused on the decision support modelling:

- Identification of the decisions that cattle producers need to make at strategic, tactical, and operational levels, the data required to make these decisions and requirements to convert the data to actionable insights.
- Identification of the additional systems and sensors required to support the above decisions including assessment of paddocks, feed on offer, weather monitoring and forecasting, tracking, and tracing cattle in transit and integration with the meat quality feedback systems.

While the cattle management intelligence system was being tested with live data from the ProTrace system the additional solution cores such as the cattle farm management system, autonomous cattle in transit track and trace system, and supply chain risk management system were designed, configured, and tested.

4 Results

4.1 Required Decision Support

Having described the problem that beef business and supply chain managers face at a high (strategic) level:

“Need to ensure that right animals are at the right stage in the supply chain, at the right stage of development (e.g., weight gain) to achieve future predicted demand”.

There are several follow-on decisions that need to be made at a tactical and operation level, especially with the critical dependency on external factors such as rainfall which directly impacts the availability of feed in paddocks. The tactical decisions were further analysed see Figure 9 and cross mapped to the supply chain see Figure 10.

Reference to Figure 4	Decision Required
1	How many cattle and species to stock on breeding properties to meet projected future market demand?
2	How many cattle and species to stock on backgrounding properties to meet projected future market demand?
3	How many cattle to have on feedlots and duration of grain feeding to meet projected future market demand?
4,5	How many cattle on each paddock and duration on each paddock?
6,7	Is supplementary feed required?
8	Will the weather change the date when the cattle should be moved?
9,10,11	When should cattle be moved?
12	Are adjustments to management practices required based on the meat quality achieved?

Figure 9: Key decisions required in the Beef SCCT

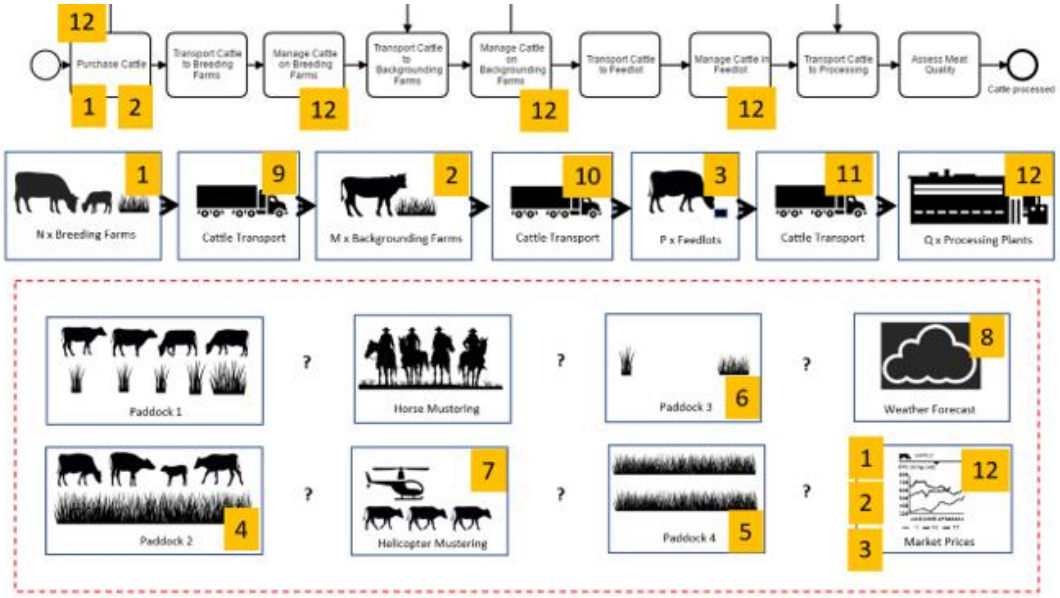

Figure 10: Cross mapping decisions with the high-level objectives

Each of these Tactical Decision require information, in some cases from many sources as is illustrated in the Decision Models which where documented see Figures 11 and 12.

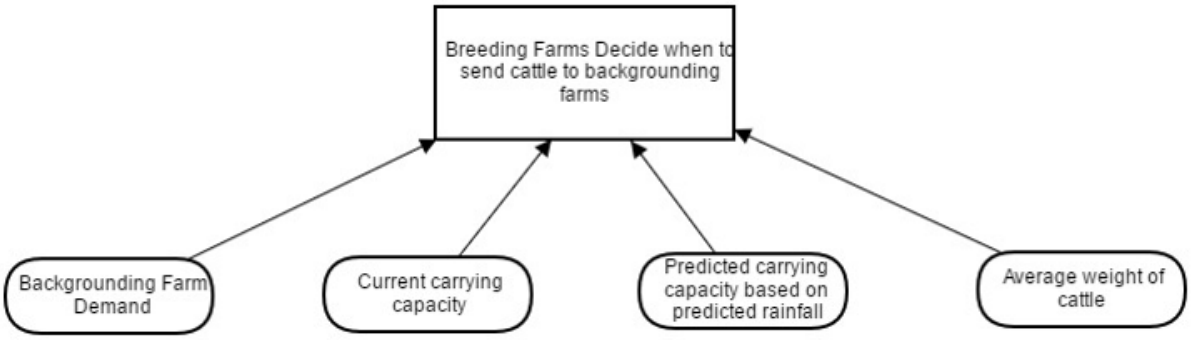

Figure 11: Core decision model structure for cattle movement

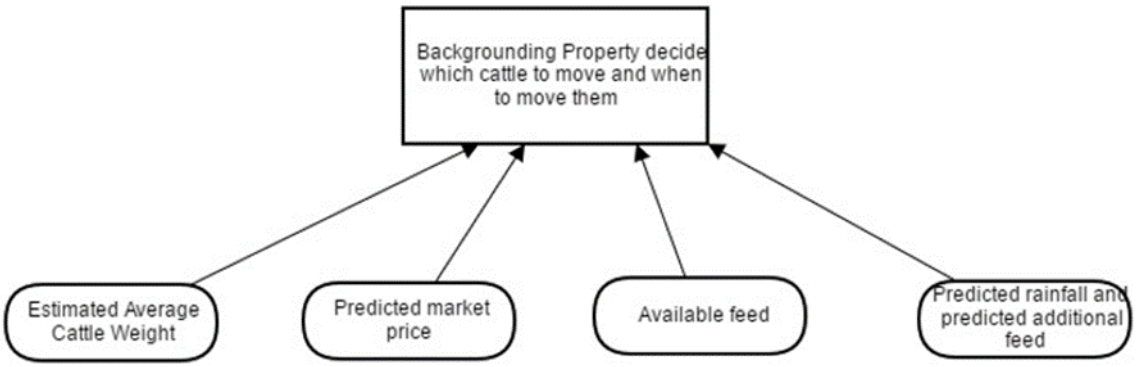

Figure 12: Core decision model for turn off

The feedback from the workshops was that the impacts of the above decisions are very significant. Examples were quoted of how a "turn off" decision, often made by intuition and observing the herd can be incorrect by as much as six weeks i.e., when the animals were mustered and weighed it was found that they were under the estimated weight (and optimal weight for processing) by an amount that represented six weeks of weight gain. Other examples were given of mobs left on a paddock for too long in anticipation of a rainfall event that did not occur, resulting in the paddock being grazed to a point that the grass regeneration was significantly impacted, and the productivity of the paddock impacted for a significant period.

The above are the problems that the Beef SCCT was designed to solve through collection of the appropriate data, from both systems and sensors, analysing the data and providing appropriate insight and support for these critical decisions.

4.2 Additional System and Sensor Requirements

To assess the quality of available data the project team extracted the entire ProTrace database, after data cleansing the dataset was reduced to 390 834 entries (data cleansing removed test data and data with errors) and ran several diagnostics across the data including using process mining both the

inductive visual miner algorithm as well as the directly follows inductive visual miner algorithm[3]. An output of one of the directly follows inductive visual miner analytics is shown in Figure 13.

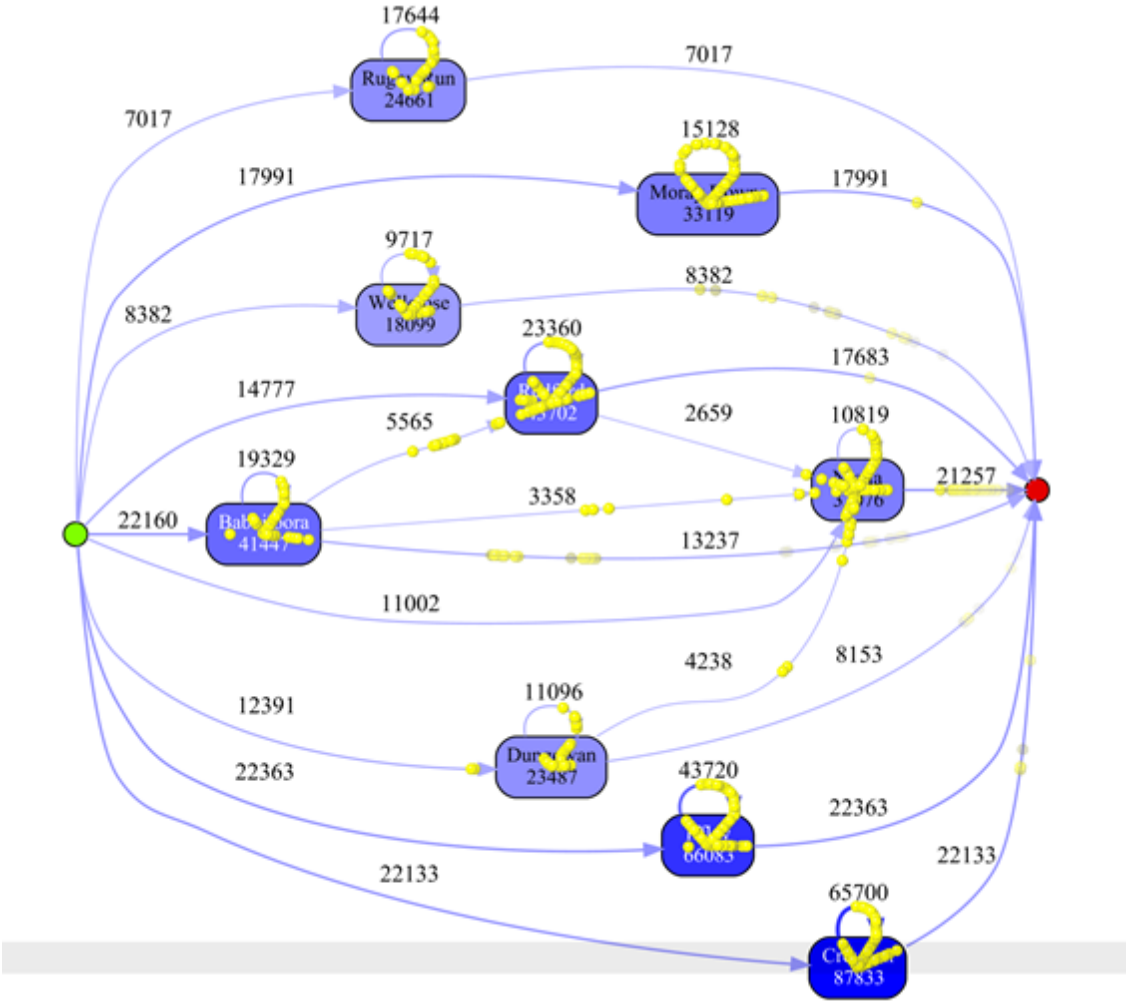

Figure 13: Output of the process mining analysis of ProTrace data

The output of the Directly Follows Visual Miner analysis is generated from the RFID of an individual animal as well as its location and the date and time of the entry in ProTrace. The algorithm will automatically detect each individual animal in the extensive database and connect the pathway (or supply chain) that the animal has followed. Due to the extensive amount of data that has been collected in ProTrace it is only possible to analyse the quality and extensiveness of the data using advanced analytics such as process mining.

The visual output displayed in Figure 13 shows that except for Babbiloora and Wellclose, data from the breeding properties is not captured on ProTrace. Further discovery and investigation are to be conducted with the ACC team to determine whether information obtained during the induction of

[3] http://www.processmining.org/

animals from the breeding properties to the backgrounding properties can be used to retrospectively determine key animal data from the breeding properties.

The output produced from the inductive visual miner output is an example of one of the analytics in the Beef SCCT solution. This type of analytic is available in several different modes. Firstly, as a discovery solution such as shown in Figure 14 where the event data is used to automatically recreate the individual supply chain path of every animal which will be a key input to understanding what parameters led to high quality/high price outcomes, this can also be displayed as a live simulation. Secondly, in a Compliance Checking mode where current events can be compared to a standard and any deviations identified. Thirdly, once sufficient historical data has been captured the opportunity exists to extend these algorithms to provide prediction of outcomes, based on historical factors and emerging trends and finally these predictions can also be used to develop prescribed actions, for example once a particular trend is identified a recommended course of action is prescribed.

The Beef Supply Chain Analysis also examined the collection of environmental data for example available biomass and weather. The analysis showed that except for Croydon Station which monitors both weather and biomass see Figures 14 and 15, no other station has an automated record of these factors. The standard current practice is based on visual observation and manual note taking.

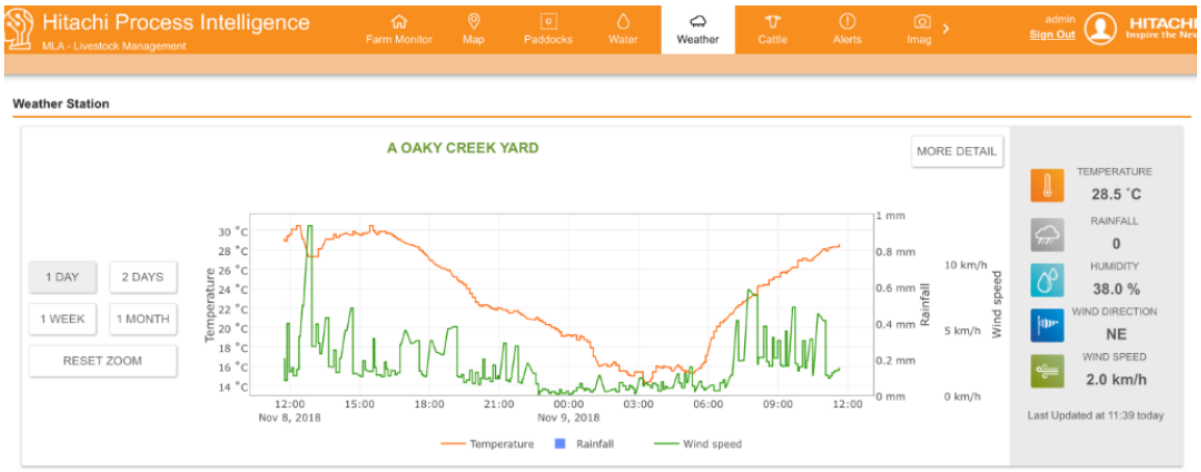

Figure 14: ACC Croydon's wethaer station

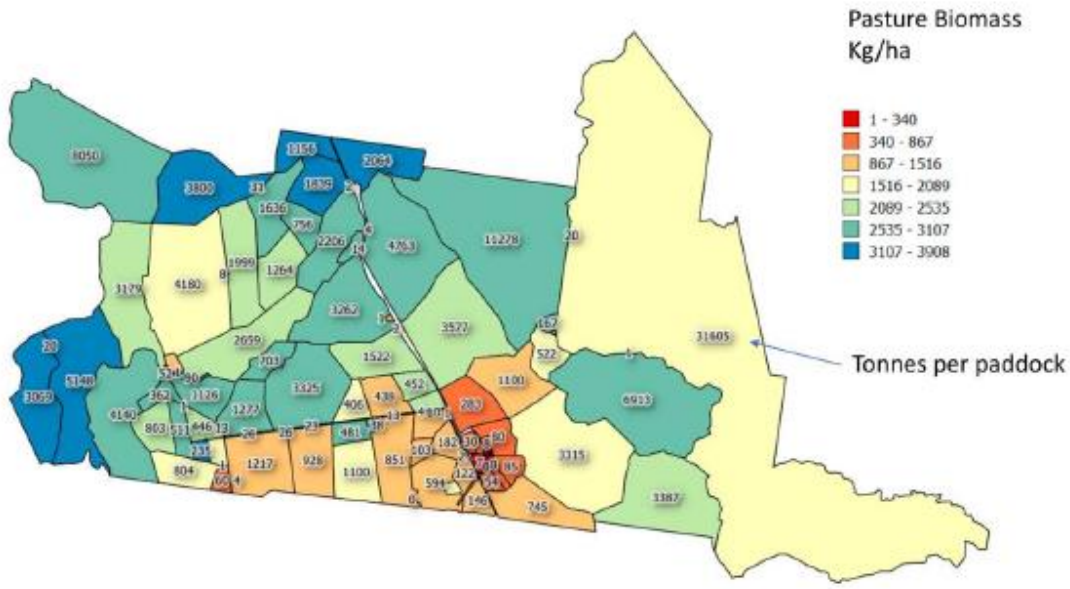

Figure 15: ACC Croydon Cibolabs pasture biomass analysis

While the Beef Supply Chain Assessment covered the entire ACC supply chain it is important to note that the purpose of this broader assessment was to understand the overall opportunity to ACC of a connected supply chain with feedback from processor to breeding property.

The results of the Beef Supply Chain Assessment are summarised in Schematic 1 below.

Supply Chain Area	Evaluation
Breeding Properties	There is no individual animal data collected at the Breeding Properties except for Babbiloora and Wellclose. A further investigation of the feasibility of implementing ProTrace on these properties to be discussed.
Backgrounding Properties	The backgrounding properties have advanced data collection with the ProTrace system, currently 70 data points are captured per animal, data is collected for both internal property movements as well as external movements e.g., purchases and transfers. Croydon has additional environmental monitoring e.g., weather and biomass.
Feedlots	The Feedlots are managed by a separate system to the properties, however the "Mobs Data" processed via the Cattle Management System provides the inputs to the feedlots. Further investigation is required into the feasibility of integrating into the existing feedlot system.
Processing	While direct access to the processing plant data is possible, ACC uses ISC's Livestock Data Link, and this source will be used in the project as it will be a more generalisable solution.

Schematic 1: Beef Supply Chain Assessment

4.3 Cattle Management Intelligence

The development of the Cattle Management Intelligence Solution (CMI), which is the core data source for the breeding, backgrounding, and feed lotting components of the Beef SCCT has been developed using co-creation, agile and design led thinking design principles. Starting with a request from ACC Management to digitise the current manual process of daily cattle records, stock movement advice and paddock books, currently processed in Microsoft Excel and Access, the solution has undergone numerous improvement cycles as ACC realised the benefits of automated digital systems on their properties and the business also changed, acquiring new properties, and expanding their herds. See CMI log in screen in Figure 16 below.

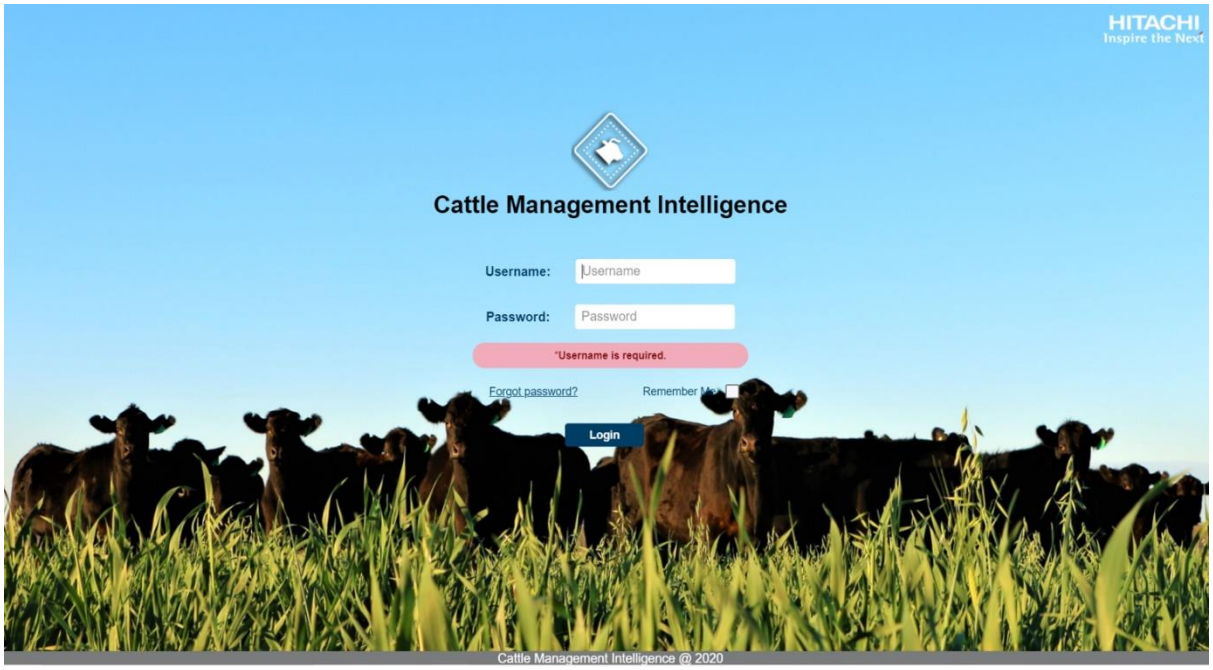

Figure 16: Sign in page of the Cattle Management Intelligence solution

The CMI Log In system is persona based, for example Property Managers will see the information that is relevant to them, as will Livestock Coordinators. A workflow system orchestrates the alerting on the required personnel that a process is ready for their approval and sign off.

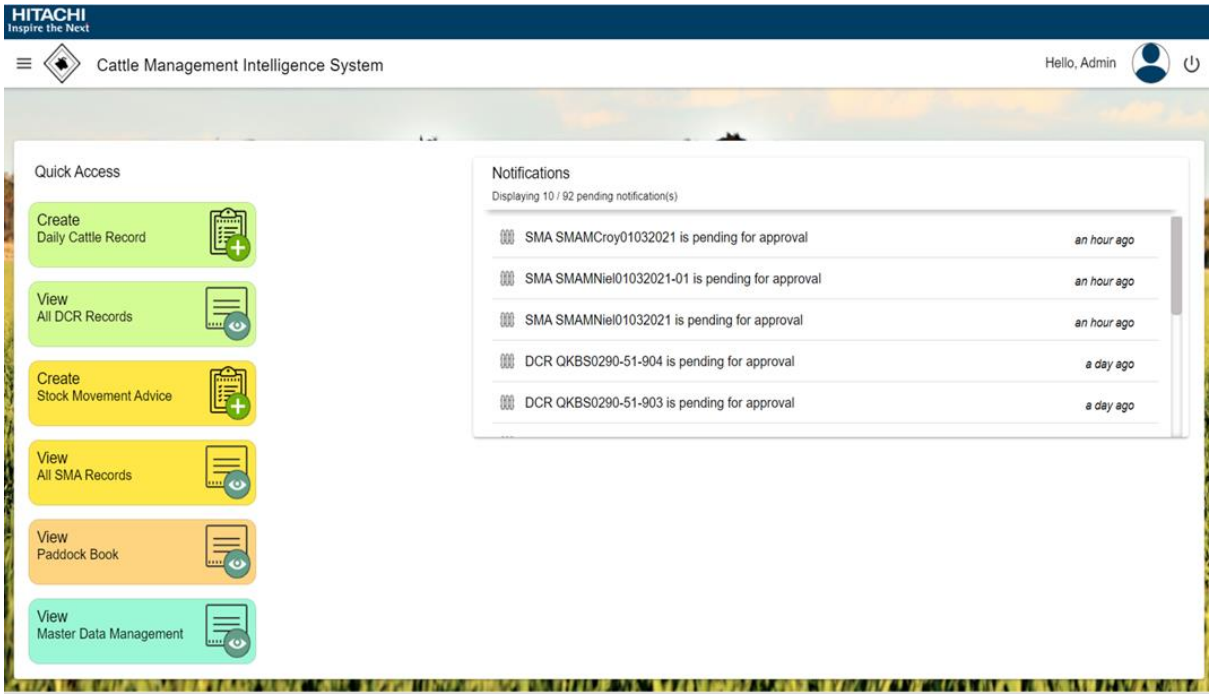

Figure 17: CMI Home Page

As is shown above, Figure 17, the CMI system includes the Daily Cattle Record, Stock Movement Advice, Paddock Book, Feedlot SAN (not shown in the above persona view) and a Master Data Management System that is able to create new data fields such as Users, Properties, Paddocks, Buyers and Agents.

A complete set of User Guides has been developed for the Cattle Management Intelligence solution. See DCR, SMA, Paddock Book, Master Data Management and Feedlot Purchases Guide attached in the supplementary package.

4.4 Tracking and Tracing of In Transit Cattle

As recommended in the Milestones 1 & 2 report, the Beef SCCT should not only monitor and provide decision support on stocking rates and turnoff, it should also monitor and alert when potential supply chain issues are detected more broadly across the business. In consultation with the owner of Calliope Cattle Station, one such area is the tracking of cattle trucks as the animals are transferred to feedlots or processing plants. Such tracking is important to a cattle business for the following reasons:

- **Driver Safety**: Cattle truck drivers often travel significant distances on remote roads, they also tend to the animals at various stages of the trip – it is important that the cattle truck is monitored to ensure that it is progressing to its destination and that the driver is safely back in the vehicle after attending to the animals
- **Animal** Safety: Animals can get stressed during transport and monitoring of conditions such as temperature in the truck is important from an animal welfare perspective. Drivers can be alerted when certain temperature thresholds are exceeded so that they may take actions to improve the conditions of the animals in transport.
- **Routing Optimisation**: Cattle trucks often travel on secondary and non-surfaced roads and can be susceptible to road closures and dangerous driving conditions during weather events, knowing where the cattle truck is allows a cattle business to provide guidance to a driver, rerouting the truck if possible or providing advice such as shelter in place until conditions improve.

To meet the above requirements a suitable tracker had to be found for assets such as cattle trucks. The tracker selected was the Cicada GPS tracker supplied by Binary Tech[4]. Binary Tech were recommended to Hitachi by Vodafone Business, who supplied the connectivity solutions for Calliope Cattle Station (see P.PSH. 1077).

An example of the Cicada GPS tracker is shown in Figure 18 below:

[4] https://www.binarytech.io/

Figure 18: GPS Trackers used for tracking cattle trucks

The Beef SCCT was designed with the following functionality:

- A route is entered into the Beef SCCT – waypoints (check points) are entered into the system via a GPS geo fence. For example, a radius around a cattle station, stock yard or a town or a fuelling stop. The planned time that the truck is expected to arrive is also entered (with acceptable tolerances).
- Temperature thresholds are also entered, with parameters for alerting, for example if the temperature in the cattle truck (cattle holding area) exceeds 38C or is lower than 10C an alert must be issued.
- Parameters for alerting potentially dangerous weather conditions are also set, for example, high rainfall or winds along a selected route.

The User Interface for this functionality is shown in Figure 19 below:

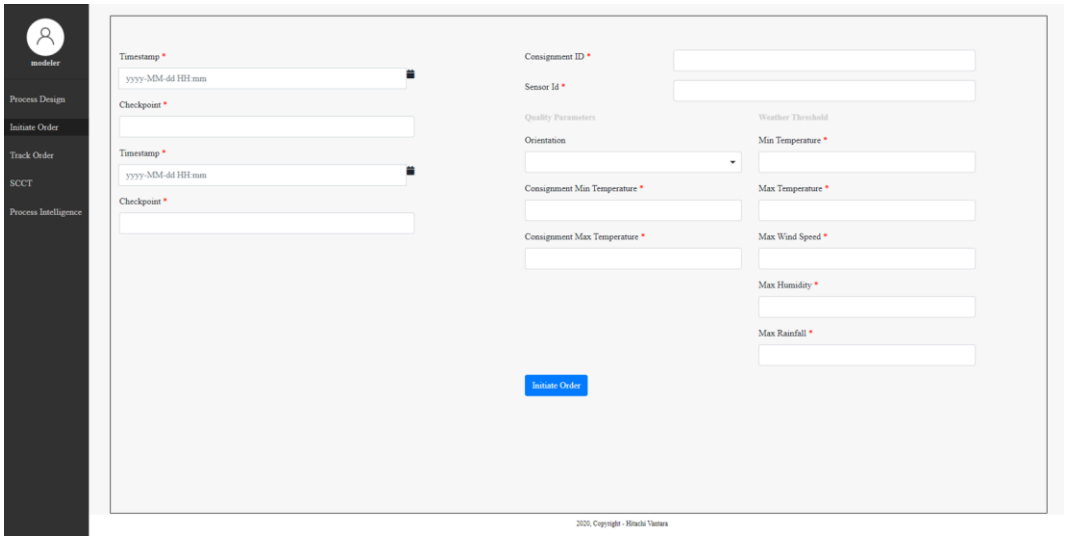

Figure 19: Configuration screen for tracking cattle trucks

Once the parameters are entered into the Beef SCCT the system will autonomously monitor the supply chain alerting via the Beef SCCT as well as mobile SMS alerts. The Beef SCCT user interfaces are shown in Figures 20 to 21.

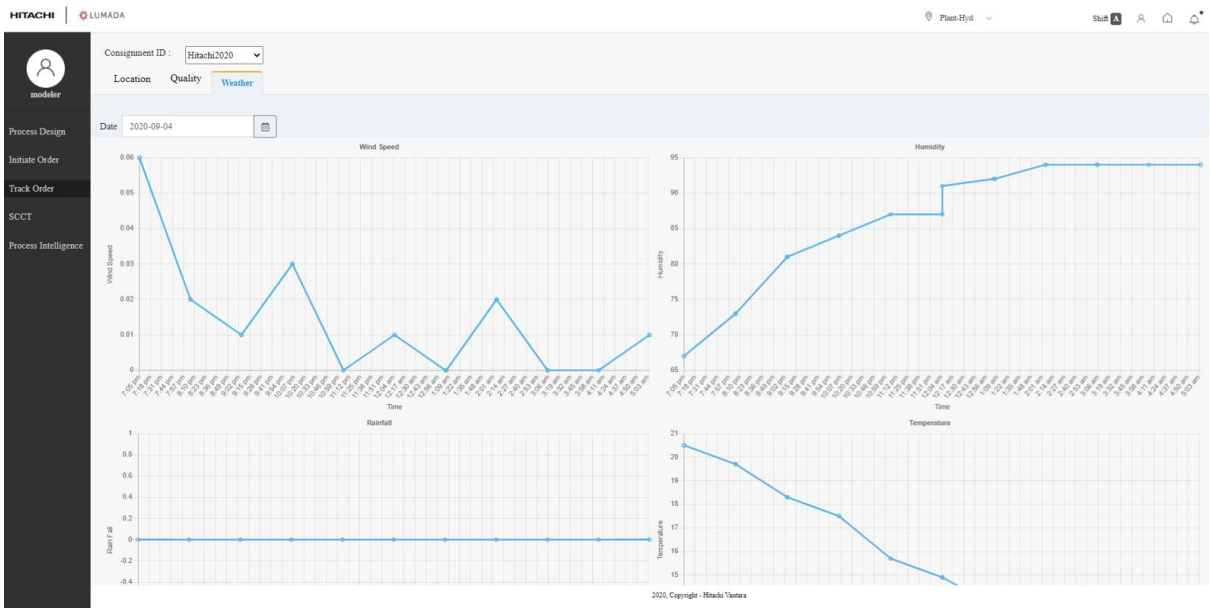

Figure 20: Tracking external risks for cattle transportation

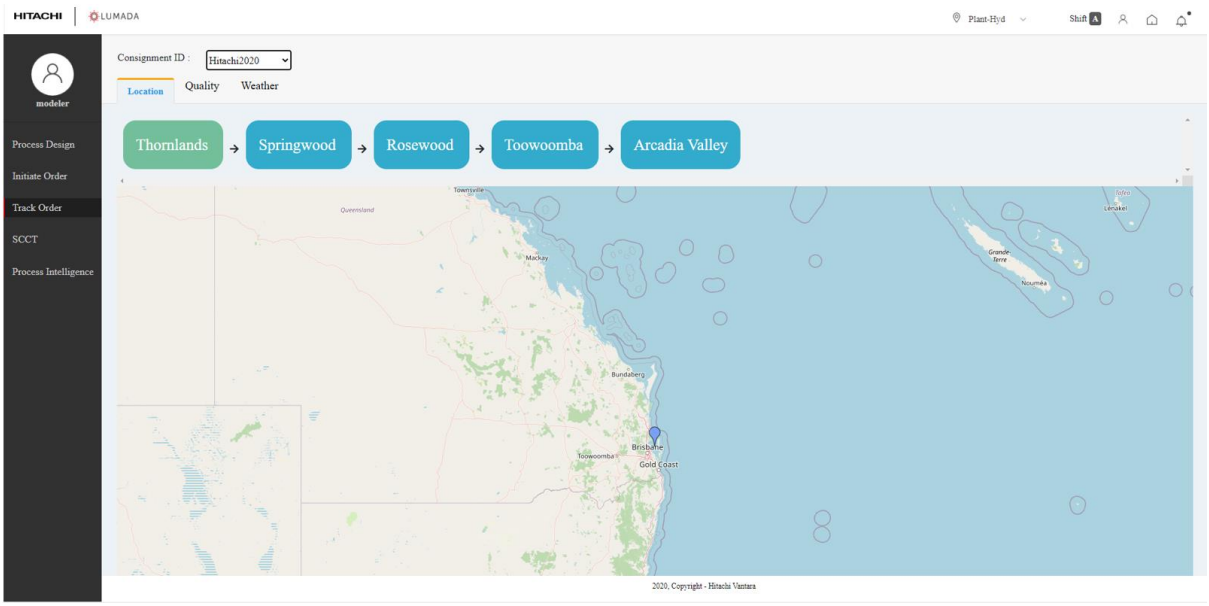

Figure 21: Beef SCCT ready to track a consignment

4.5 Design of the overall Beef SCCT Framework

In scoping the functional requirements of the Beef SCCT it is important to note that the original scope of the project called for a single supply chain (Barkly Downs, Croydon, Opal Creek and Cannon Hill) to be in scope. Hitachi decided that an all of business approach is more appropriate fir a Beef SCCT and have scoped for all ACC properties.

A flowchart of functional requirements for the Beef SCCT is attached in the supplementary package. A partial view of this is shown in Figure 22. Current functionality is highlighted in green while proposed future functionality is highlighted in two phases, Phase 1 (blue) and Phase 2 (orange).

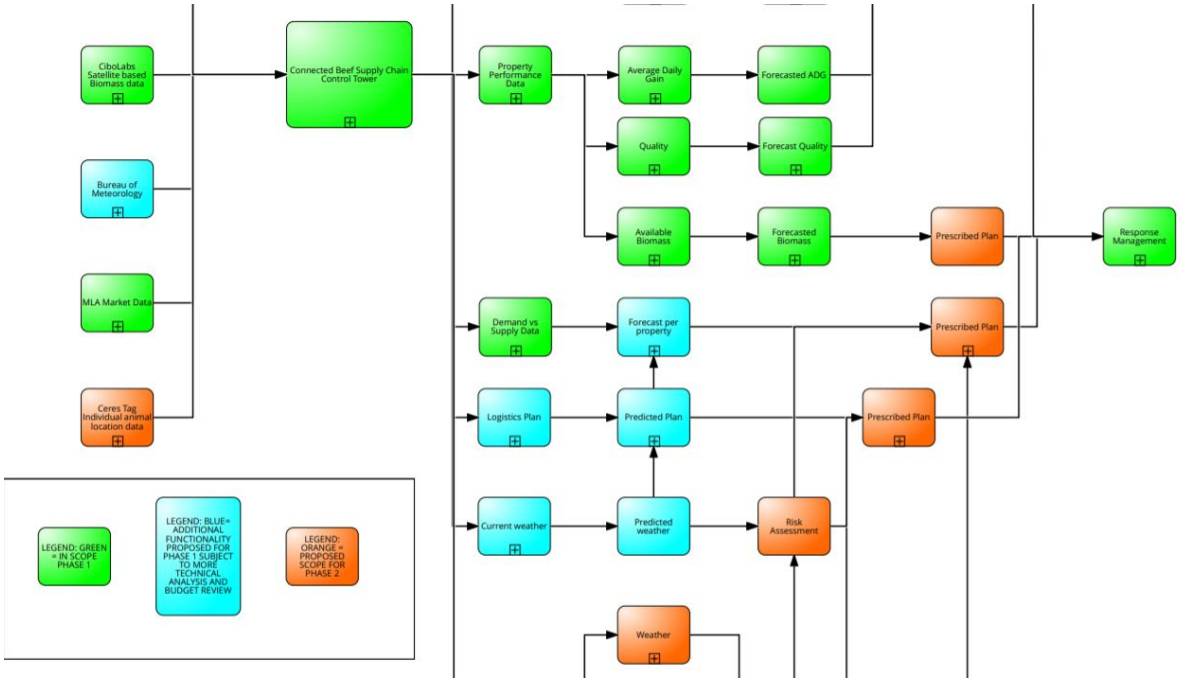

Figure 22: Partial view of process functionality, see supplementary material for full diagram

The Beef SCCT was subsequently developed from the three core solution cores: Cattle Property Management, Cattle Management Intelligence and Beef Supply Chain Tracking and Decision Support as illustrated in Figure 23.

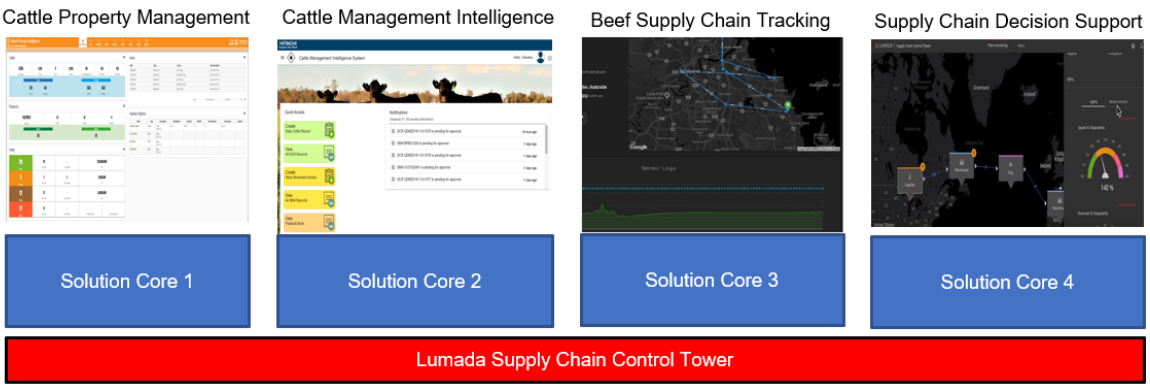

Figure 23: Beef SCCT solution cores

The following use cases have been developed in the Beef SCCT and the functionality is described below:

1. **Determining how many cattle and species to stock on breeding and backgrounding properties as well as feedlots to meet projected future demand.**

Solution Core 4, Supply Chain Decision support is configured to extract this data. This solution core uses process orchestration to execute the required decision support. The process orchestration is an executable business process management system (Dumas *et al*., 2018), which enables the business logic as represented in standard business process modelling notation, BPMN 2.0. (Greiger *et al*., 2018, Median *et al*., 2017) to be executed. The executable logic in the Beef SCCT is shown in Figure 24 below. This model provides decision support at the Strategic Level.

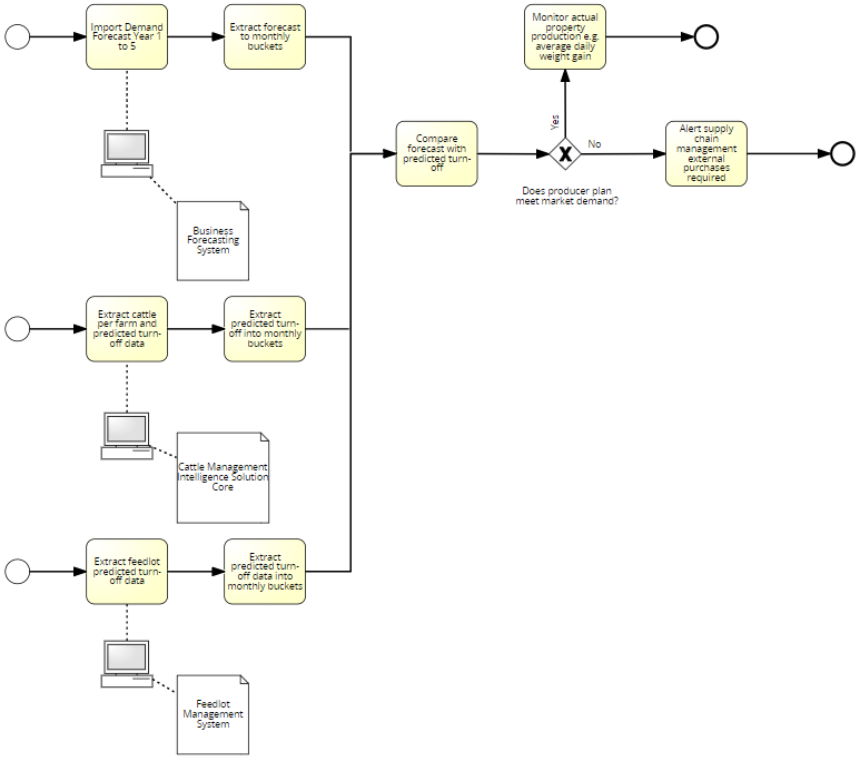

Figure 24: Designing the business process flow for the process orchestration engine- balancing supply and demand

Running data extracted from Australian Country Choice's ProTrace system for following properties: Babbiloora, Dungowan, Redford and Niella through the solution core provided several levels of decision support including the current weight range distributions of the animals ready for turnoff, as illustrated in Figure 25 below.

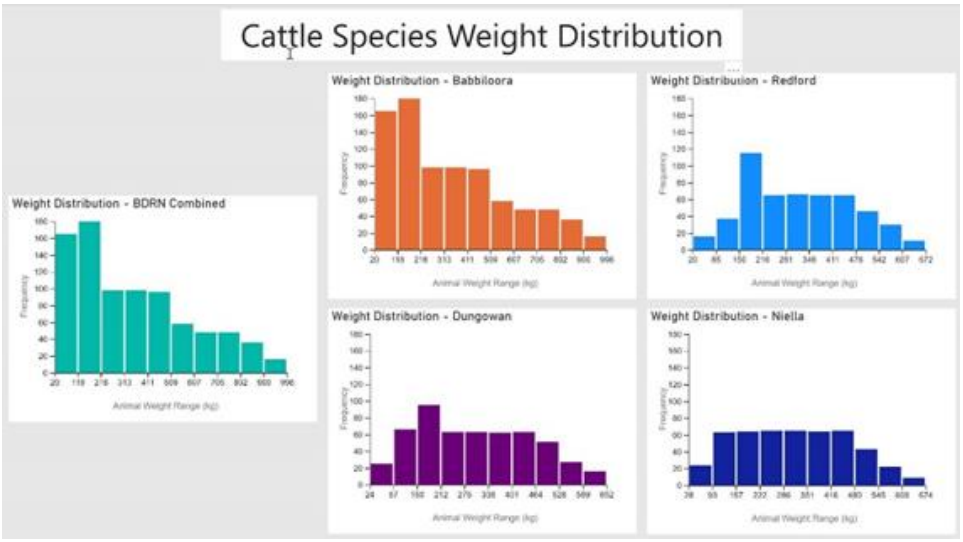

Figure 25: Analysing individual weights per property

2. What is the carrying capacity of each farm, and each paddock?

The following decision model, Figure 26, provides information at the Tactical Level for current state and at Strategic Level for future predicted climatic conditions.

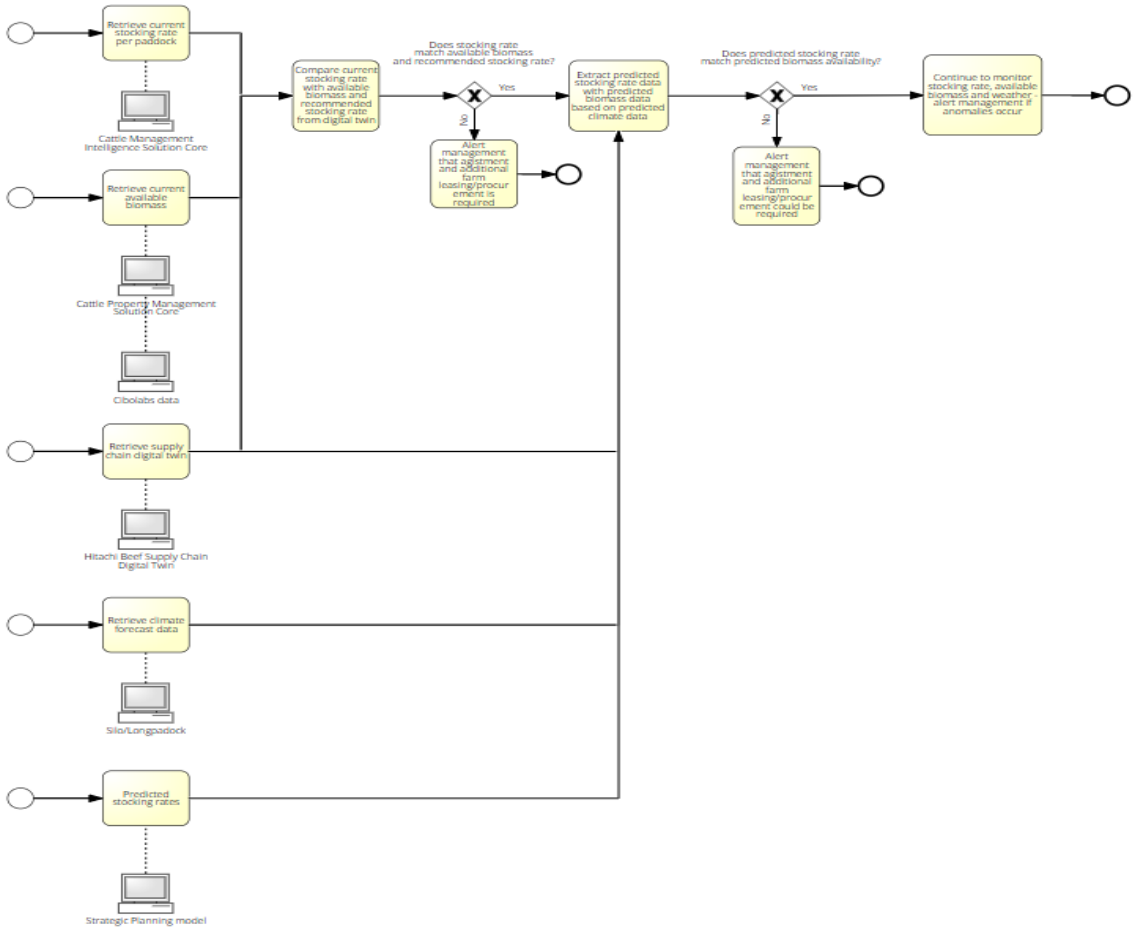

Figure 26: Designing the business process flow for the process orchestration engine - stocking rates per farm

In delivering the above decision support the solution core is extracting data from the CMI Paddock Book and Cattle Property Management System (biomass data imported from Cibolabs) as illustrated below (Figures 27 and 28):

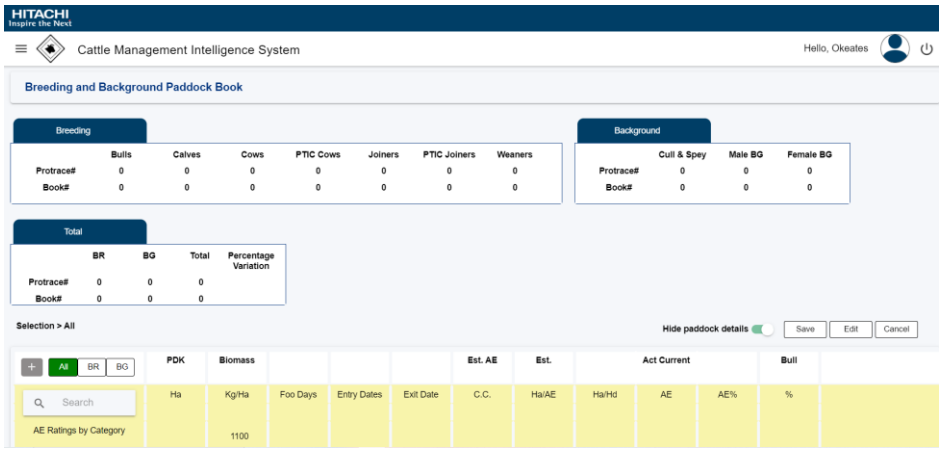

Figure 27: CMI Paddock book data

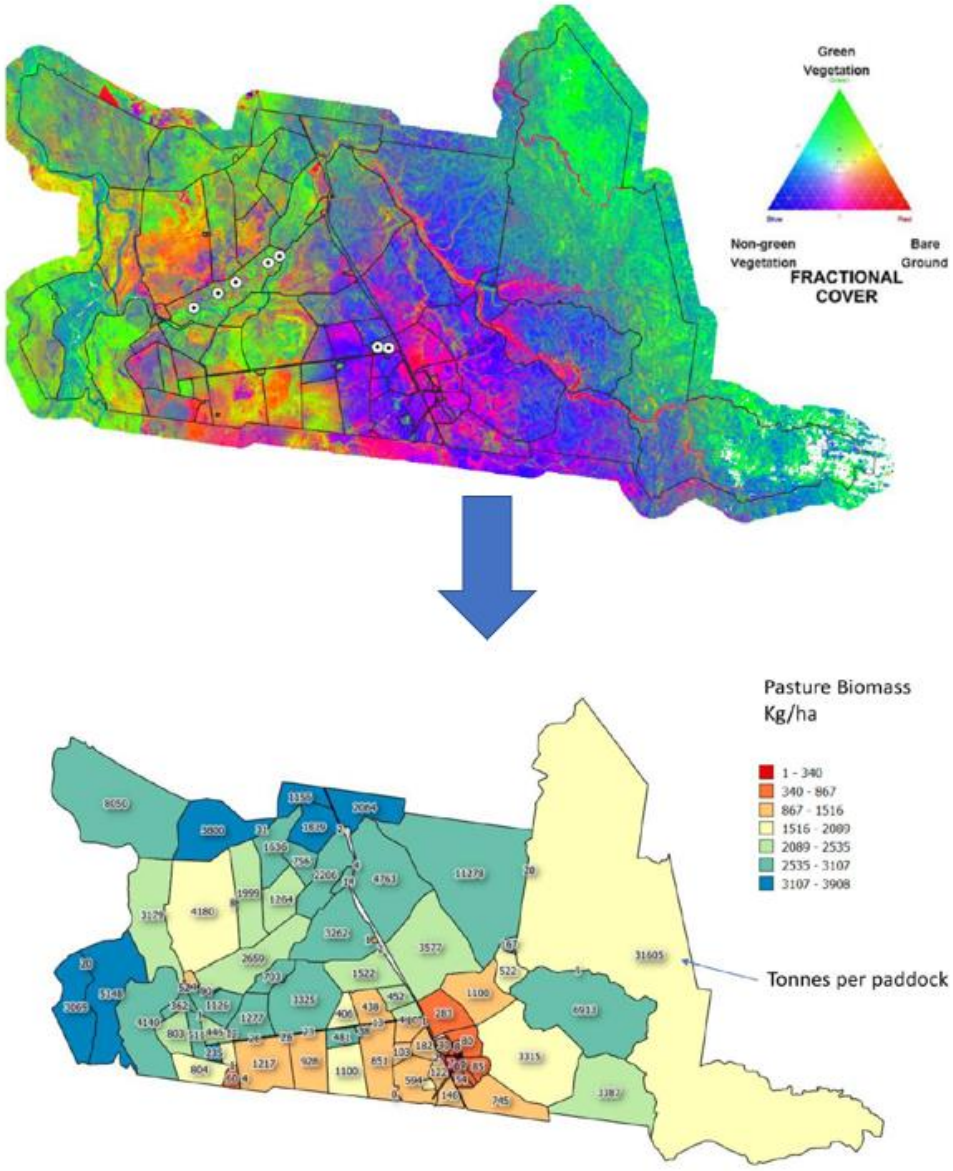

Figure 28: Cibolabs available feed

3. Determining when to turnoff animals

The Beef SCCT provides guidance on when to turnoff animals. Based on the average daily weight gain captured in the CMI solution as well as the available biomass from the Cattle Property Management solution the decision model factors in the medium term (2 to 3 week) weather forecast. For example, if the biomass in the available paddocks is reaching a low threshold, but the ideal average market weight for the mob is predicted to not be optimal, the weather forecast will be used to advise weather turnoff should occur soon or be delayed due to a good possibility of rainfall boosting biomass before turnoff.

4. Transporting animals between farms, to feedlots and processing

It is well documented that cattle lose condition during transport, and this results in loss of weight (requiring extra grazing to recover) and in the case of transport to processing has an impact on meat quality (Ferguson and Warner, 2008; Jorquera-Chavez et al., 2019). The Beef SCCT Tracking functionality allows for the cattle truck to be autonomously tracked including the temperature in the back of the truck to ensure conditions do not exceed pre-set thresholds. The weather along the truck's route is also monitored with the driver and business alerted if there is any risk of extreme weather that could affect either the truck's progress or the welfare of the animals.

4.6 Enterprise Level Control Tower

In designing the Beef SCCT, it is important to reiterate the purpose of a control tower, a "shared service centre that monitors and directs activities across the end-to-end supply chain to make it collaborative, aligned, agile and demand-driven" (Bleda et al. 2014). This tool enables organization leaders to react to and correct issues as they arise.

The enterprise level control tower, see Figure 29 below, was developed in Outsystems[5] a low code User Interface development platform which allows expediting of multiple systems onto a single platform such as the Beef SCCT.

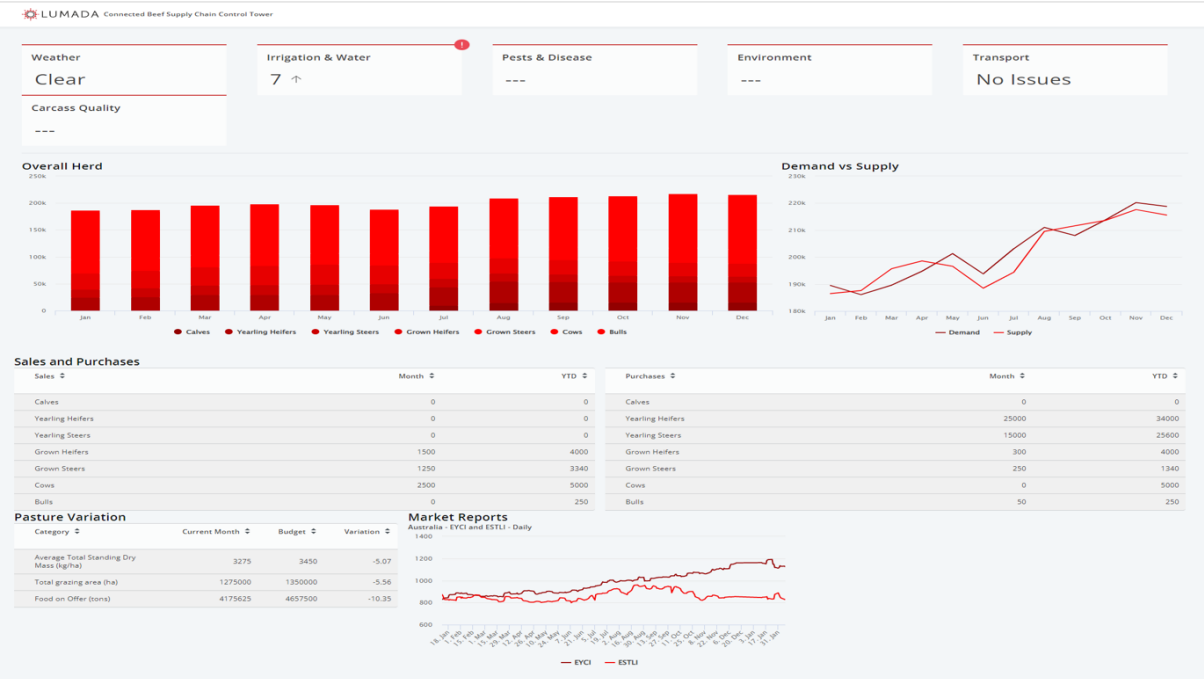

Figure 29: Operational Enterprise Level Beef SCCT

The Enterprise Level Beef SCCT integrates the data from the various solution cores developed during this project, as summarised in Figure 30.

[5] www.outsystems.com

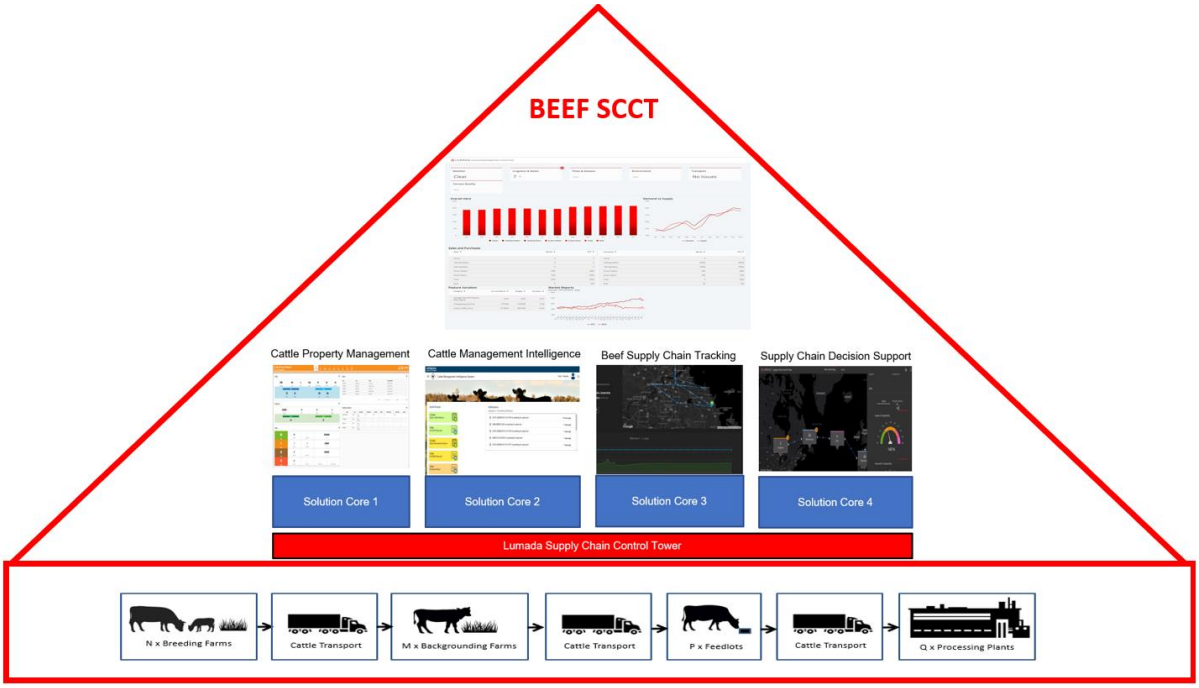

Figure 30: Beef SCCT integrating the solution cores for overall insights

As elaborated on in the key findings leveraging a low code user interface development solution as well as public cloud platforms allows for the rapid commercialisation of Beef SCCT at scale.

5 Conclusion

In conclusion despite significant challenges to this project from the impacts of Covid 19 and changes in business priorities at ACC the overall objectives were achieved. Despite these challenges the scope of the project was also extended initially to expedite the completion of the Cattle Management Intelligence solution and later the development of the cattle truck tracking systems.

5.1 Key findings

- Integration of the various systems from farm to processing is achievable at an individual animal level
- The insights produced from this integration can improve the overall yield, efficiency and ultimately profitability across an integrated beef supply chain
- The use of public cloud service providers, otherwise known as hyper scalers e.g. (Amazon Cloud Services, Google Cloud Services, Microsoft Azure or Oracle Cloud Infrastructure) for core platform services as well as efficient User Interface development solutions such as Outsystems and Appian allow the end-to-end beef supply chain to be connected efficiently and in a manner that allows for extensibility.

5.2 Benefits to industry

- The ability to scale required data processing services on demand using the above technology features ensures that a cost-effective Beef SCCT can be provided to small, medium, and large businesses.
- The ability to multi-tenant an overall Beef SCCT i.e., the core solution is designed and containerised in such a manner that a single instance of the solution may serve multiple customers provides the opportunity for a peak body such as MLA or Integrity Systems Company to provide this service to their stakeholders.
- The deeper insights provided by the Beef SCCT not only benefit those businesses with integrated beef supply chains they also benefit the individual supply chain partners who run standalone businesses e.g., breeding, or backgrounding farms, feedlots or processing plants. As highlighted below:
    - Breeding and Backgrounding Farms- receive feedback on the yield and quality performance of their product, this data can be used to improve breeding and backgrounding management. These farms also receive deeper insights to weather, transportation and external marketing factors that can assist with risk mitigation.
    - Feedlots- direct feedback from processing yield and quality data allows for improved feeding regimes as well as deeper insights into the root causes of cattle performance in the feedlot based on breeding and backgrounding history.
    - Processing plants can achieve significant productivity gains through purchasing of uniform cattle. Providing yield and performance feedback to their suppliers via the Beef SCCT helps the breeding and backgrounding businesses produce a more uniform animal. It furthermore provides the opportunity to segment high quality products into brands and thereby obtain a premium for the product.

5.3 Partner Engagement and Assessment

The Beef SCCT has been evaluated with a combination of simulated and real (ProTrace) data due to the unavailability of personnel and additional supply chain data because of Australian Country Choice's (ACC's) current focus on its ERP implementation. The Cattle Management Intelligence solution which became an integrated part of the Beef SCCT was fully tested with live ProTrace data by an ACC evaluation team and was formerly signed off as meeting all requirements. The design of the Beef SCCT cattle truck tracking solution was done in consultation with the owner of Calliope Cattle Station. Additional testing of Ceres Tags and Cibolabs solutions for incorporation into the Beef SCCT was also done at the Calliope Cattle Station. Demonstrations of the Beef SCCT were given to the owner of Calliope Cattle Station and the ACC sponsor of the project. The Beef SCCT was also demonstrated to another partner, who advised that the ACC management team were internally discussing revisiting CMI and the Beef SCCT, once the Oracle ERP implementation was complete.

During the project, presentations were also made to several MLA stakeholder groups including the Innovation Officer team.

5.4 Transformation and Facilitated Adoption

A key factor in the digital transformation process to establishing an end-to-end feedback system for the beef supply chain is acknowledging that each beef supply chain will have its unique ecosystem of stakeholders and systems. Establishing a Beef SCCT is essentially an integration exercise with the fundamental learning from this project that User Interface for the Beef SCCT needs to be rapidly

configurable and the integration of system API's (application programming interfaces) as seamless as possible. Hitachi's Lumada platform provides this ability with extensive libraries of existing API's available.

Facilitated adoption will be driven by the value proposition as illustrated in Figure 31 below.

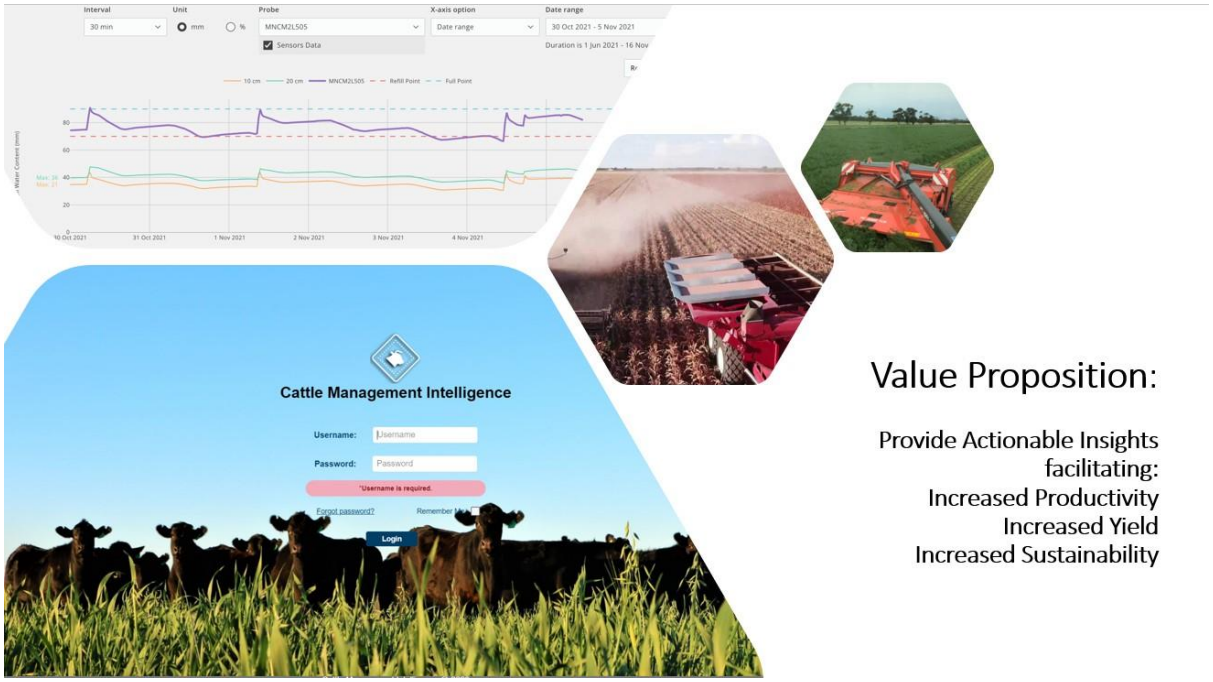

Figure 31: Promoting the Value Proposition for Beef SCCT

Facilitated adoption will also be enabled by reinforcing that the Beef SCCT integrates existing systems. From LDL to objective measurements to AgriWebb, Agriworld, Farmbot, Cibolabs, TruTest, Gallagher, Ceres Tags, Binary Tech, my MLA and the numerous other systems and sensors used by the beef industry today, the purpose of a Beef SCCT is to integrate this data to provide "actionable insights" as illustrated in Figure 32 below.

Figure 32: Key Deliverable: Actionable Insights through Integration

5.5 Visualisation vs Prediction and Prescription

During the above assessment phase, it was noted that ACC have made significant progress in extracting data from the ProTrace SQL server and displaying the data using Power BI. A typical example of such a Power BI report is shown in Figure 33.

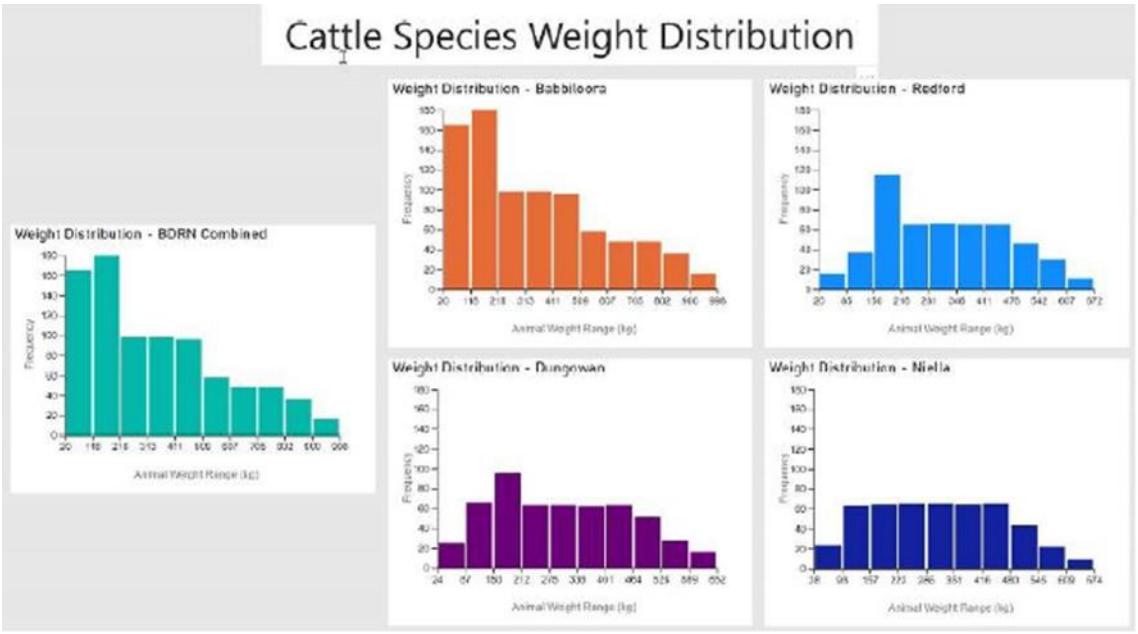

Figure 33: Typical Power BI Output

With reference to the Stages of Digital Transformation shown in Figure 34, it is important to note that Power BI provides visualisation of data i.e., Level 1 of the transformation chart and allows manual

analysis. This is a first and very critical step to digital transformation and improved insights across the value chain. It is also important to note that Power BI does not enable system integration, automatic analysis, prediction, and prescription that an IoT – digital platform such as the Beef SCCT. Power BI and Lumada SCCT's are often used synergistically by Hitachi customers.

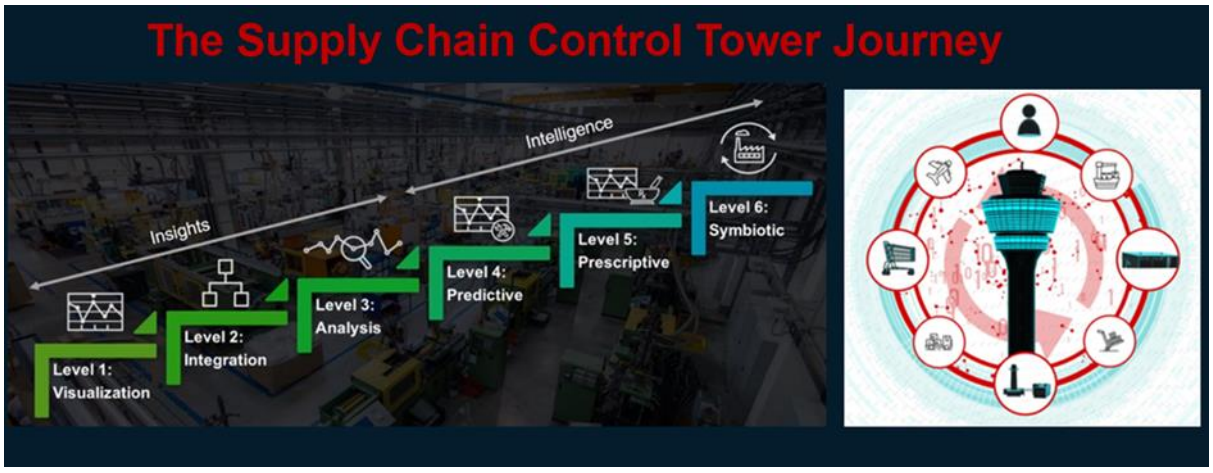

Figure 34: Supply Chain Control Tower Journey Map

The Power BI project has shown management at ACC the power of data and provided meaningful insights to the beef supply chain. This work will be greatly enhanced through the integration of systems and automation of analytics through the Beef SCCT.

5.6 Financial Analysis and Project Benefit Rationale

A cost benefit analysis was not possible as pilot deployment was not permitted at ACC due to the constraints mentioned. We have therefore deferred to the financial analysis done by Australian Beef Report (Holmes, P., McLean, I. & Banks, R. 2017. The Australian Beef Report, Bush Agribusiness Pty Ltd) as well as an independent review by Holmes and McLean of the value of collecting productivity data and using a platform which promotes best practice for our previous project (P.PSH.0815), which was a component of the Beef SCCT.

- An increase in herd productivity of 5%, which equates to an increase in EBIT/AE of $8.00
- Increased herd carrying capacity of 2.5%, which equates to an increase in EBIT/AE of $1.00
- Reduction in herd expenditure of -5%, which equates to an increase in EBIT/AE of $2.00
- Increase in labour efficiency of 10%, which equates to an increase in EBIT/AE of $6.00
- Increase in sale price of 2%, which equates to an increase in EBIT/AE of $3.00

The above equates to an increase in EBIT/AE of $20.00 which for a company with a herd AE of 250 000 represents additional annual profit of $5m.

Costing of a Beef SCCT solution needs to be done on a case-by-case basis, however the ability to create a core platform from which individual customer solutions can be configured significantly reduces the cost and furthermore provides the opportunity for a subscription-based model. Depending on the number of farms, farm sizes, mixed farming types and herd size, a monthly subscription fee can be charged. See Appendix for detailed financial analysis.

6 Future research and recommendations

- The Beef SCCT project has focused on conventional meat quality feedback data as provided via the ISC Livestock Data Link system. Opportunities exist to extend the research to include the new objective carcase measurement technologies that have been developed by MLA. The connection of this data to the data collected during the life cycle of an animal will provide significant insights into contributing factors from genetics to practices and procedures that contribute to high yield and quality.
- There is an emerging trend to use digital twins to predict future impacts in supply chains (Ivanov and Dolgui, 2020). The capability exists to expand the Beef SCCT to include simulation and digital twining. While this will be a continuous improvement process, it will provide a basis for prediction which will initially focus on short term prediction, followed by medium and longer term as the climate forecast data is improved and the algorithm correlating climate forecast with available biomass improved initially per farm and then per paddock, including soil types.
- The core architecture of the Beef SCCT provides the framework for extending the solution to facilitate the identification and measurement of Scope 3 Green House Gas Emissions as defined by the GHG Protocol[6] and Emissions Reduction Fund[7].

[6] https://ghgprotocol.org

[7] www.cleanenergyregulator.gov.qu/erf

7 References

Dumas, M., La Rosa, M., Mendling, J., and Reijers, H.A., (2018), Fundamentals of Business Process Management. 2nd Edition, Springer.

Ferguson, D.M. and Warner, R.D. (2008), "Have we underestimated the impact of pre-slaughter stress on meat quality in ruminants?", Meat Science. Vol 80 No. 1, pp 12-19.

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Ivanov, D. and Dolgui, A. (2020), "A digital supply chain twin for managing the disruption risks and resilience in the era of industry 4.0", [online] Production Planning and Control. Available from https://doi.org/10.1080/09537287.2020.1768450. [Accessed 7 May 2021].

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8 Appendix

8.1 Cost Benefit Analysis

Comprehensive data obtained from the Australian Beef Report (Holmes, P., McLean, I. & Banks, R. 2017. The Australian Beef Report, Bush AgriBusiness Pty Ltd) as well as an independent review by Holmes and McLean of the value of collecting productivity data and using a platform which promotes best practice (P.PSH.0815) is presented.

- An increase in herd productivity of 5%, which equates to an increase in EBIT/AE of $8.00
- Increased herd carrying capacity of 2.5%, which equates to an increase in EBIT/AE of $1.00
- Reduction in herd expenditure of -5%, which equates to an increase in EBIT/AE of $2.00
- Increase in labour efficiency of 10%, which equates to an increase in EBIT/AE of $6.00
- Increase in sale price of 2%, which equates to an increase in EBIT/AE of $3.00

The above equates to an increase in EBIT/AE of $20.00 which for a company with a herd AE of 250 000 represents additional annual profit of $5m.

With the current beef cattle herd estimated at 21.1 million[8] with an estimated 2.5 million cattle managed by large corporate businesses, additional annual profit to this sector alone could be as high as $100m pa.

In addition, there is also the issue of quality according to MLA's research[9], non-compliance with market specifications costs the beef industry an estimated $127-$163 million per annum, across four key markets. This includes value lost due to:

- downgrades (discounts) for out of specification carcases ($51 million per annum)
- carcase condemns ($64 million per annum)
- loss of meat and offal value due to animal health and disease ($12 – 49 million per annum).

Finally, the effective implementation of a Connected Beef Supply Chain Control Tower could enable more farmers to attain Meat Standards Australia compliance. According to MLA[10], 43% of adult cattle processed meet MSA standards, which in 2018-2019 delivered $198m in additional farm gate returns to beef producers with an average of $0.30/kg increased price paid.

The technology platform presents management benefits, which have the potential to positively influence the key profit drivers of a beef business, namely higher kilograms of beef per AE/yr, increased carrying capacity over time, improved labour efficiency and reduced herd expenditure. Whilst the benefits can only be estimated at this time, small changes in each of these drivers using optimised data capture and management can have a significant effect on business performance and cumulative changes will be compounding.

The management benefits from the optimised data capture and management system for commercial beef cattle and their associated outcome on the business are detailed in Table 1.

[8] https://www.beefcentral.com/markets/abares-outlook-2020-australian-herd-hits-30-year-herd-low/
[9] https://www.mla.com.au/research-and-development/livestock-data-link/
[10] https://www.mla.com.au/globalassets/mla-corporate/marketing-beef-and-lamb/documents/meat-standards-australia/2019-msa-aor_lr2.pdf

Table 1 Management benefits and associated potential outcomes

Management benefits	Potential outcome	Application for ACBH Croydon
Better matching of feed supply and demand (within & across years).	– Higher kg Beef/AE – Increased carrying capacity over time – More stable grazing pressure over time	✓ ✓ ✓
Better selection and management of breeding females	– Improved herd reproductive rate – Reduced herd mortality rate – Higher sale weight (through less older and poorer females being sold) – Reduced herd expenditure (less supplement & fodder necessary)	✗ ✗ ✗ ✗
Better management and timing of sale for growing cattle	– Higher sale weight – Improved weight for age – Higher kg Beef/AE – Reduced herd expenditure (less supplement & fodder necessary)	✓ ✓ ✓ ✓
More timely management interventions for all cattle (e.g. weaning, sale, paddock movements, starting and stopping supplementation etc.)	– Reduced herd expenditure – Improved labour efficiency – Higher kg Beef/AE	✓ ✓ ✓
Better meeting of market specifications	– Improved average sale price	✓

The identified potential outcomes for Croydon Station were:

- Higher kilograms of Beef/AE (function of increased reproductive rate, reduced mortality rate, improved sale weight)
- Increased carrying capacity over time
- More stable grazing pressure over time
- Reduced herd expenditure
- Improved labour efficiency
- Improved average sale price (through improved market compliance)

The impact of improvements in each of these outcomes is discussed. Each outcome is analysed independently of the others.

1. Higher kilograms of Beef per AE/yr

The top 25% of northern producers are reported to be achieving 18% better productivity than the average (100.6 vs 85 kg Beef/AE) which indicates significant improvement is possible. There is also room for improvement for the top 25%, but only the average is modelled. Table 2 shows the impact on EBIT/AE and COP from increases of 5-20% in the herd productivity of the average, ceteris paribus.

Table 2 Modelled benefit from improved kg Beef/AE

Change in herd productivity	**0%**	**5%**	**10%**	**15%**	**20%**
Kg Beef/AE	85.0	89.3	93.5	97.8	102.0
EBIT/AE*	$40	$48	$57	$66	$74
Cost of Production	$1.55	$1.47	$1.41	$1.35	$1.29

* For reference, every $10 in additional EBIT/AE represents over $50,000 additional profit per year for the data used.

2. Increased Carrying Capacity over time.

Through better matching of stocking rate to carrying capacity in the short and long term there are likely improvements in carrying capacity through less overgrazing and improved land condition. The improvements will be dependent on current land condition and grazing management but will be modest at best in most circumstances. Improvements of 2.5% and 5% are modelled Table 3. It is assumed that kg beef/AE and enterprise expenses remain unchanged for the additional AE and that overheads will increase by $50/AE.

Table 3 Modelled benefit from improved carrying capacity

Change in Carrying Capacity	**0%**	**2.5%**	**5%**
Number of AE	5,364	5,498	5,632
EBIT/AE*	$40	$41	$42
Cost of Production	$1.55	$1.54	$1.53

* For reference, every $10 in additional EBIT/AE represents over $50,000 additional profit per year for the data used.

The improvements are minimal, however there will be greater improvement in Return on Asset (ROA) due to increased returns over the overall asset base. However, the analysis consistently demonstrates that the returns from improving per animal unit performance will be greater than increasing number of animal units.

3. More stable grazing pressure over time

A more significant benefit for a beef business is likely to come from improved herd stability than from an increase in carrying capacity. Herd stability will result from better matching of stocking rate to carrying capacity, resulting in less selling and replacing of stock during seasonal variations. Previous analysis for the northern beef industry indicates that there is a strong relationship between herd inventory volatility and poor performing businesses; the better performing businesses have more stable inventory over time. However, this could not be validated from the data available for this project.

4. Reduced herd expenditure

A reduction in herd expenditure can be associated with management benefits as indicated in Tables 1 - 4. Lower herd expenditure, along with higher herd productivity, is a characteristic of better performing beef businesses.

Table 4 shows the changes to the performance measures resulting from reductions in herd expenditure.

Change in herd expenditure	0%	-2.5%	-5%	-7.5%	-10%
Enterprise Expenditure/AE	$40.31	$39.31	$38.30	$37.29	$36.28
EBIT/AE*	$40	$41	$42	$43	$44
Cost of Production	$1.55	$1.54	$1.52	$1.51	$1.50

For reference, every $10 in additional EBIT/AE represents over $50,000 additional profit per year for the data used.

5. Improved labour efficiency

Improving labour efficiency reduces the overhead cost structure of a beef business. The relationship between labour efficiency and overhead expenses from the Australian Beef Report by Holmes and McLean (2017) and the labour efficiency of the Top 25% (Table 1) were used to model the effect of improvements in labour efficiency on overheads per AE. The results of this modelling are shown in Table 5.

Table 5 Modelled benefit from improved labour efficiency

Change in labour efficiency	0%	10%	20%	30%
Labour Efficiency	1,520	1,672	1,824	1,926
EBIT/AE*	$40	$46	$52	$58
Cost of Production	$1.55	$1.48	$1.41	$1.33

* For reference, every $10 in additional EBIT/AE represents over $50,000 additional profit per year for the data used.

6. Improved average sale price

An improved average sale through better meeting market specifications is a likely benefit. However, the average price received will still be predominately determined by the overall market, and increased sales price benefits will be minimal.

Table 6 models the change in performance based on changes in income/kg (note income/kg produced is slightly different from average price received as kilograms produced and kilograms sold are not the same each year, however income/kg is a good proxy for price received).

Table 6 Modelled benefit from changes in income from $2.02/kg - $2.12/kg

Change in sale price	0%	1%	2%	3%	4%	5%
Income/kg	$2.02	$2.04	$2.06	$2.08	$2.10	$2.12
EBIT/AE*	$40	$42	$43	$45	$47	$48
Cost of Production	$1.55	$1.55	$1.55	$1.55	$1.55	$1.55

* For reference, every $10 in additional EBIT/AE represents over $50,000 additional profit per year for the data used.

Caveat

The critical factor in business performance is the capability and attitude of those in charge of the business. A capable manager, focussed on the fundamentals, with an efficient production system could further enhance and fine tune their management system with the powerful information this platform could generate. An inefficient manager that is not focused on the fundamentals, has the most to gain but is unlikely to realise the full benefit of the platform. The likely benefits of an optimised data capture and management system for whole of industry use are yet to be realised.

Special Note: The above data was obtained from Holmes, P., McLean, I. & Banks, R. 2017. The Australian Beef Report, Bush AgriBusiness Pty Ltd. Holmes and McClean were also commissioned to provide an independent review of the benefits of the P.PSH.0815 project which created a platform to capture on farm data and promote best practice.

8.2 Examples of ProTrace Data

ProTrace Data collected Crush side

DCR 4: Paddock Returned

RowVersionLi	PublishedExtTimeStamp	DCR	SessionName	SessionDate	OriginPropertyCode	OriginPropertyName
5220887906	0x0000000137306D62	QHQP0137-84-183	20190530 WELLCLOSE IND ROMA SALE	2019-05-30 00:00:00.000		ROMA SALE

OriginalPropertyGroup	ToPIC	ToPICName	PurchaseType	SMA	WeighingType	RfId	Sex	Castrated	EPBI	YearBrand	HornStatusCode	Dentitio	PregStatus	BodyConditionSco
	QHQP0137	Wellclose	Saleyard	WCBG63	Induction	900 093000461587	F	0	25	2019	D	0	0	0.00

Lactation	Cull	DOB	WeighingStomachFillState	AnimalWeight	WeighingDateTime	ADG	LifeADG	ActiveLocation	ADGDaySinceLastWeighed	BodyConditionScore	WeightMode	WeightSteady
		2019-01-15 00:00:00.000	Half Full	273.00	2019-05-30 16:54:53.043	0.00	0.00		0	0.00		0

DOF	PredictedMonthOfBirth	MonthOfBirth	Notes	GateCode	GateDescription	FromPaddock	FromPaddockDescription	BreedCode	BreedDescription	CategoryCode
0	February			G03	Gate 3	PUR	Purchase			BG

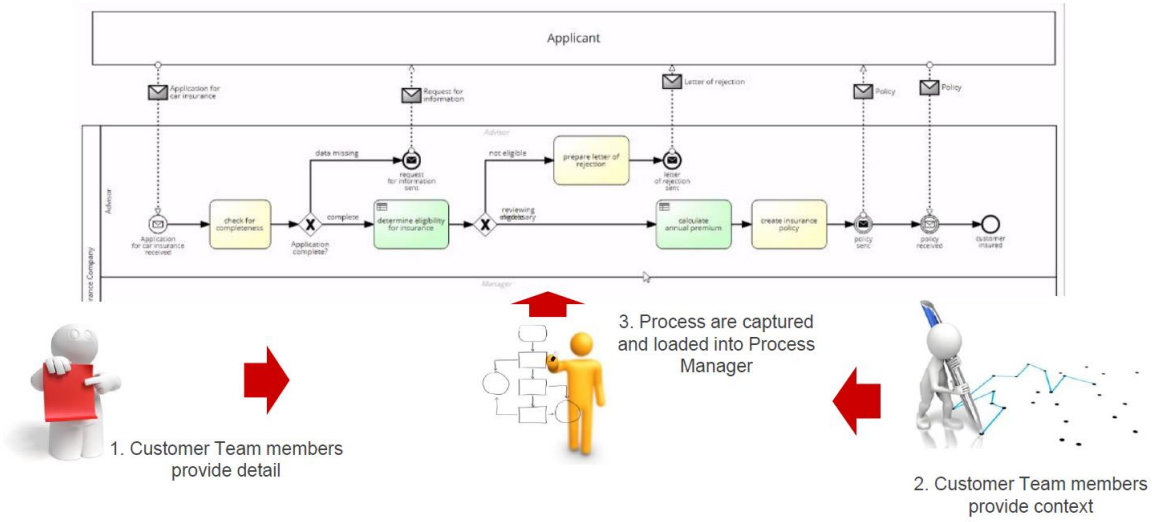
BreedDescription	CategoryCode	CategoryDescription	ClassificationCode	ClassificationDescription	CullReasonCode	CullReasonDescription	TreatmentProductCode
	BG	BG	BG	BG			

TreatmentProductName	TreatmentBatchReference	DoseApplied	DoseAppliedCalcMethod	WithholdingPeriod	ExportSlaughterInterval	ToPaddock	ToPaddockDescription	ToPropertyGroup
		NULL	NULL	NULL	NULL	TML	Three Mile	ACC Prop

8.3 Virtual Technical Consulting Approach

Enabling Virtual Collaboration 1

HITACHI
Inspire the Next



Enabling Virtual Collaboration 2

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