BLOCKCHAIN FOR THE MEAT INDUSTRY: WHERE AND HOW?

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1.0 EXECUTIVE SUMMARY

The origin of red meat products has been found to be one of the important factors that drive consumers' purchase decisions. Unsurprisingly, therefore, there are instances where red meat products have been falsely marked with a popular country of origin, such as Australia, in order to take advantage of the perception of premium quality associated with the meat products from these countries. This is believed to have a significant impact on the Australian meat industry and remains as a challenge to be addressed, as it not only damages the reputation of Australian meat products, but also increases the competition that Australian meat faces especially in niche markets.

In order to help address this challenge of counterfeit products, the project described in this report investigated the use of blockchain technology to establish product traceability for the Australian red meat industry. The project team examined (1) what types of information, (2) at what places along the meat supply chain, and (3) how the information should be collected in order to facilitate the use of blockchain technology.

Throughout the project, the team has worked closely with relevant stakeholders to ensure that all the proposed tools and approaches proposed are realistic and feasible to those working within the red meat processing sector. This final report consolidates the project's findings and demonstrated how these could be applied by the Australian Meat Processor Corporation (AMPC) and red meat processors.

The research team utilised the Supply Chain Operations Reference (SCOR) framework as the basis for process modelling. The team started by analysing the operations in the current red meat supply chain and through this developed a base scenario. In this the entry of a quartered carcase into the boning room highlighted where, under current processing practices, one-to-one traceability is lost. Developed from the base scenario, the project team proposed two further scenarios which would provide improved traceability: the first focussed on traceability at the batch level; and the second on one-to-one traceability.

The batch level traceability scenario tracks all the products leaving meat processing facilities and therefore has little impact on the current processing practices of meat processors. The one-to-one traceability, however, needs to address the challenge of primal cuts mixing in the boning room. A redesign to the boning room is proposed to address this issue. The redesign proposes altering the current continuous flow of primal cuts into an approach that employs small batches, and then utilises RFID technology to pass the traceability information automatically from one work station to the next in the boning room.

As this second option of one-to-one traceability requires operational changes to the current meat processing practices (and hence additional investment), two ROI analyses were conducted to assess the feasibility of this approach. The first ROI analysis focuses on understanding the fixed cost implications of developing one-to-one traceability. With the assumed throughput and carcase weight, the cost of establishing one-to-one traceability will be 1.19 cents per kilogram in Year 1, and 0.04 cent per kilogram from Year 2 and onwards.

The second ROI analysis considered a number of benefits resulting from the use of one-to-one traceability. With an assumed price increase of 5 cents per kilogram, and annual labour cost savings of

$60,000, the ROI analysis results indicated that there would be a positive cashflow of 0.7 cent per kilogram in Year 1, which rises to 1.85 cents per kilogram after Year 2.

This report showcases the potential benefits and cost implications of a blockchain enabled traceability system to the Australian red meat industry through the one-to-one traceability scenario. The potential uses of the additional data from the implementation of a blockchain traceability system are also discussed in relation to the wider context of the red meat industry. Finally, the report also reviews possible funding models for implementing such a blockchain traceability system into the industry acknowledging that this would require the participation and engagement of multiple parties along the length of the value chain.

While providing the desired traceability is unquestionably challenging, the potential benefits inherent in securing Australia's global reputation as a quality red meat producer and the potential for improved market outcomes would appear to be considerable. Furthermore, current market indications are that there will be a growing demand for provenance information in both the domestic and international markets. Thus, early implementation of a blockchain-supported system would clearly place Australian producers, processers and retailers in a competitive position.

Recommendations to develop this initial research project further include undertaking a market survey, targeting both domestic and international end consumers, in order to collect the market perceptions of the benefits of one-to-one traceability. A pilot implementation of the proposed one-to-one traceability within a typical meat processing facility is also needed in order to confirm our initial understanding of the main technical requirements and implementation challenges.

Once one-to-one traceability is in place, the resultant blockchain data could be harvested to identify how it could be used to facilitate better business decision making. Such decisions might include, but are not limited to, (1) understanding the optimum product mix that should be produced, (2) which types of meat are trending on the market, and (3) consumer preferences in relation to the production locational differences for meat products.

2.0 INTRODUCTION

Red meat supply chains require collaboration between diverse parties from the farm-gate to the retail outlets where consumers purchase their meat. Within these supply chains, meat is transformed from a 'raw commodity' into value-added products in different forms (frozen, chilled etc.), with different cuts, and in different packages that match the target market needs.

From the product providers' perspective handling by different actors, at different places, and at different times along the supply chain poses significant operational challenges to the maintenance of proper processes, record keeping, hygienic standards, and smooth and efficient coordination between the parties involved. Failure to address these challenges will lead to sub-optimal activities which is detrimental both to the individual meat supply chains and the industry as a whole. As recognised by the AMPC, a fragmented supply chain results inefficiencies and wastage and, ultimately, this threatens the Australian meat industry's global competitiveness.

Furthermore, operations conducted overseas can introduce significant risks to the quality and authenticity of supplies. For example, the Meat and Livestock Australia (MLA) has pointed out that only half of the Australian branded beef in the Chinese market was actually came from Australia (MLA, 2018). Thus, the viability of the meat export trade could be significantly impacted if such risk factors are not properly managed, as has been demonstrated in the decline of Brazilian beef exports in 2017 following a number of meat scandals (Marshall, 2017).

In fact, for many consumers the country of origin or detailed information about the origin of meat products is one of the most important factors that drive their purchase decisions (Mennecke et al. 2007; Font i Furnols et al. 2011). With this in mind, it is clear that meat product traceability would provide potential consumers with detailed information about the products they intend to purchase, as well as reassurances in relation to product quality and authenticity. As an example, The Australian newspaper (2018) reported that commercial trials with nanoparticles injected into beef have been conducted by one Australian meat exporter in order to ensure the authenticity of beef for the Chinese market. Similar traceability studies conducted for the U.S. beef industry have also indicated the need for traceability (World Perspective, 2018). With the expansion of the world's middle-classes and the resultant growth in overseas markets, providing meat traceability information to consumers is becoming even more important for the Australian red meat industry.

Recent technological advances have made it relatively easy for consumers to check product information on the spot (e.g., using QR codes) when such information exists. Therefore, if trustworthy information about meat products could be provided, it would be a significant catalyst to 'assure' consumers of their authenticity and thereby help to 'persuade' them to choose Australian red meat with a consequential improvement on the suppliers' market share.

Blockchain technology, which underpins digital currencies (e.g. bitcoin), provides the ability to record sequential events and their timestamps throughout a supply chain. Its availability and maturity present significant opportunities for any supply chain where products need to transact through different parties with different trust levels, and at different times. This feature makes blockchain a technology that has the potential to revolutionise the whole concept of food safety and traceability through greater data and system integration. It offers the capability to capture the time and nature of various events and, due to blockchain's inherit security, create records that cannot be tampered with. Furthermore, a blockchain allows different parties to verify and audit transactions in an inexpensive way.

With this background in mind, this project aimed to conduct an initial exploration into the use of blockchain technology for the red meat industry to establish product traceability. The project began with an exercise to map the processes within the current red meat supply chains. During this, the use of blockchain technology for meat product traceability was investigated. Specifically, the research centred on where and how blockchain technology could be used. Return on investment (ROI) analyses were then conducted, based on how and what types of technologies should be used for tracking meat products and the level of tracking (i.e., one-to-one or batch level traceability). The ROI analyses underpinned an analysis of potential funding structures if the blockchain technology were to be adopted for meat product traceability.

A key aspect of this report is on where and how to establish meat product traceability. Given the nature of meat supply chains, the focus was on the operations conducted in meat processing facilities as they are instrumental in establishing product traceability. One limitation to this report relates to the export of live animals. While such exports represent a significant part of the overall Australian meat supply chain, it is out of scope for this research project as the AMPC has no control over the processing of such animals in overseas locations.

3.0 PROJECT OBJECTIVES

The primary objective of this project is to examine the potential use of blockchain technology within the red meat supply chain to determine if there are opportunities to improve the efficiency, control, authenticity and, ultimately, marketability of Australian red meat. This will be accomplished through:

- // Establishing a clear understanding of the current red meat industry supply chains, processes and practices with a focus on processors.
- // Identifying gaps within the red meat supply chain management processes that may hinder the adoption of blockchain technology and make recommendations to address them with reference, as appropriate, to other industries already undertaking similar processes.
- // Examining any data integration issues with the implementation of a blockchain system into the red meat supply chain.
- // Communicating the research findings with the AMPC membership in order to obtain feedback on where and how blockchain may be best applied.
- // Conducting a number of ROI analyses that consider potential scenarios for implementing blockchain based on feedback from industry collaboration.
- // Examining potential funding models for deploying and testing a blockchain system within the red meat industry.

4.0 METHODOLOGY

This section describes the multi-methodological approach the research team adopted to investigate traceability for the red meat industry. Such approaches combine multiple methodologies to explore research problems (Singhal & Singhal, 2012a, 2012b), and are particularly useful for formulation, approximation, analysis and solution of complex logistics and supply chain problems (Srivastava, 2007).

Specifically, we used the Supply Chain Operations Reference (SCOR) model as the basis for processing mapping, and this approach was strengthened by further process decomposition beyond the SCOR model and the collection of detailed information, such as process time and resources required, for each process step. The data collected in the SCOR modelling element were then fed into an ROI calculator as variable costs/benefits which, together with fixed investments, produced the results for ROI analyses. It should be noted that the SCOR modelling and the ROI calculation tool were developed in the form of a web-based application, so that those working in different functional areas and different organisations could easily collaborate and cooperate on a common project.

4.1. SCOR Process Mapping

Process mapping is "a valuable communication device to understand how processes operate and where responsibility lies" (Collier & Evans, 2007, p.273). Accurate process mapping, at the right level of granularity, facilitates the identification and recording of all related activities and thus ensures that proper data collection takes place.

The project team employed the SCOR model as the basis for process mapping, with the details of the approach to be found in Appendix 2 – Process Maps. Once the overall process maps had been developed, they were used to capture the specific inputs, outputs, and resources associated with the activities at each process step (See Appendix 2). Particular attention was given to factors such as costs and time that were consumed by each individual activity, which were subsequently used as inputs for the ROI analyses.

4.2. Scenario Building

The research team used a number of scenarios to investigate the integration of blockchain technology into meat processing facilities and assessed the associated costs and benefits for each scenario. A base scenario ("as-is" scenario) was constructed which reflected the existing meat processing operations. The base scenario served two purposes: 1) to acquire a thorough understanding of the current operations; and 2) to serve as the basis for the development of different scenarios where traceability is established.

Based on the desired level of traceability, two scenarios (the "to-be" scenarios) were constructed in this report. The first of these focussed on traceability at the batch level, i.e., providing meat traceability based on the current batch processing information within meat processors. This, however, does not allow for one-to-one traceability. In order to offer one-to-one traceability, the current meat processing flow will need to be adjusted slightly. The second scenario was designed to provide one-to-one traceability, based on a proposed boning room redesign.

Once the scenarios had been constructed, comparisons between the "as-is" and the "to-be" scenarios highlighted the changes needed in order that these could become the focus of further and more detailed investigation.

4.3. Data Collection

The focus for data collection was to determine the nature and attributes of the information that would need to be collected to enable the use of blockchain, and how this corresponded with the physical flows. Given that meat products are packaged in processor facilities, the meat processing stage is the key to establishing traceability throughout a supply chain. Thus, the project team focused on this stage through a case study based on the processes undertaken at Australian Country Choice (ACC) – which was recommended by AMPC as an industry exemplar. The project team undertook a walkthrough of the ACC processing facility from the entry of a live animal through all the processing stages to the end retail/bulk pack, and this underpinned the development of the "as-is" scenario.

Building on the resultant "as-is" scenario, the project team examined the data requirements for a blockchain enabled supply chain through considering the following aspects:

- What data would be the focus for collection along the red meat supply chain?
- Where along the supply chain this data would be collected?
- How the data would be collected at these points? and
- Who would be involved in this data collection process?

As mentioned earlier, in order to facilitate this data collection exercise, the project team developed the SCOR modelling and the ROI analysis application as a web-based application, which was supported by both frontend and backend developments. The frontend allowed users to interact with the tools and enter information as required. The backend, which was supported by a database, stored all the information and conducted all the intermediary data manipulations and calculations.

4.4. ROI Analyses

ROI analyses were conducted based on the data collected from the SCOR process mapping exercise. As explained earlier, two different scenarios involving the use of blockchain technology were constructed to allow informed decisions about where and how the blockchain technology could be used for the red meat industry.

The data in the ROI analyses included two major categories. The first category included the fixed costs which deal with the additional expenditure needed for the purchase of common infrastructure and equipment to collect information for meat traceability. These costs will be incurred no matter how many animals pass through a meat processing facility.

The second category focussed on the variable cost and the time components. To collect the information in this category, we tracked the processing costs and time elapsed for an animal to transition from the gate to the primal cuts and compared the cost and time differences between the "as-is" and "to-be" scenarios. As we were more interested in the net costs/benefits brought by the process changes, the common process components between the two scenarios were "discounted" from the ROI analyses. By doing so, the research team reduced the errors introduced by parameter estimation for these common processes, and thereby improved the accuracy of ROI analyses. Another key consideration was the number of primal cuts an animal is processed into, as this helped determine how many tags would be needed – a potentially key cost driver especially when using more expensive tags. All these elements enabled the calculation of the net costs/benefits for one animal as it is processed through a meat processing facility.

In the ROI analyses, the research team also specified the amount of expected benefits in order to allow the team to develop a better understanding of the potential cost recovery options. Total expected price increases (per kilogram) and total expected labour cost savings were two sources of benefits used to help users decide the potential ROIs.

Based on the fixed costs, the variable costs, and the benefits per animal, the throughput of a meat processor was used as a parameter to gauge the impact of the size of meat processors on the ROI. Sensitivity analyses of key parameters, such as a variable tag cost per head, processing throughput, and system integration as the fixed costs, were also conducted to provide a wider picture of the ROI. The results were designed to assist meat processors in swiftly assessing their relative position in regarding to the expected ROI.

5.0 PROJECT OUTCOMES

Outcomes from this project include:

- Process maps for both the "as-is" and the "to-be" scenarios.

// Recommendations on where and how data could be collected to establish traceability.
// The proposed boning room redesign to enable one-to-one traceability.
// The development of the web-based application to conduct process mapping and ROI analysis.
// The ROI analysis results based on two "to-be" scenarios where both barcodes and Radio Frequency Identification (RFID) tags were investigated.

Each of these elements will be discussed in greater detail in the following sections.

5.1. Process Maps

A key outcome of this project was the development of process maps based on the SCOR framework to capture the stages within red meat processor systems. An "as-is" process map was first developed in order to better understand the current meat processing operations. In parallel, this allowed the identification of potential opportunities where blockchain technology would provide improved levels of traceability.

Figure 9 (in Appendix 2 – Process Maps) presents the process map for the current operations ("as-is"), which traced the product movement from the feedlot to final handover to product transport operators. The creation of this process map enabled the research team to develop a more in-depth understanding of the red meat processing stages and established the basis on which the two "to-be" scenarios could be constructed. While both "to-be" scenarios highlighted the changes required to ensure product traceability, they offered two clearly distinguishable possibilities for traceability.

The first "to-be" scenario (Figure 10, Scenario 1) focussed on traceability at the batch level, whilst the second "to-be" scenario examined the one-to-one traceability (Figure 11, Scenario 2). The process map for the "to-be" scenario with one-to-one traceability highlighted that there was a need to redesign systems in the boning room in order to ensure traceability was maintained throughout the red meat processing system. In the case of ACC this represented the point at which tracing a particular cut of meat back to the source animal was lost, due to the use of a conveyor system to enable the efficient transfer of processed primal cuts from the operators' stations into the steam cleaning and vacuum sealing processes.

5.2. Traceability Data Collection

Given that data will be instrumental in establishing traceability across meat supply chains, the project team analysed the content ('what'), the place ('where'), the data collection method ('how'), and the people who will be collecting the data ('who') for each of the "to-be" scenarios. The results are summarised in Table 1 in which each of these aspects have been arranged in chronological order within the table starting from the point at which an animal enters a processor's system to the exit of packaged products for distribution and retail. The relevance of each data requirement to the two "to-be" scenarios is also included for ease of reference. In compiling these details the project team have also highlighted a number of supply chain technologies which could be used to facilitate the collection and transfer of the data from each stage.

Table 1: Summary table of blockchain data and content requirements

What	Where	How	Who	Scenario Application
1. Source location and processor identification	Animal's entry into processor's facility.	Scan of animal's RFID ear tag into a processor's system by using current methods.	Slaughter floor operator	Starting record pertinent to both traceability scenarios
2. Date and shift of processing	After a carcase has been halved on the slaughter floor	EAN barcode labels are currently attached to each half carcase	Operator responsible for conducting inspections and affixing EAN barcode labels to each half carcase	Relevant to both scenarios
3. Progress through processing stages - data collection points are dependent on the level of traceability and could include the following:				
a) Chilling room – date and time of entry and exit	Upon entry and exit of carcase from the chilling room	Scan of EAN barcode label attached to carcase	Operator moving carcases in/out of chiller	Relevant to both scenarios
b) Carcase grading – records for date and time of grading along with any relevant measurements and readings (e.g. the Meat Standards Australia grade, pH, weight, etc).	Grading station	Incorporation of relevant data fields from processor's current systems into the blockchain record for a carcase	Operator responsible for assessing each carcase	Scenario 2
c) Boning room – date and time for the entry of a carcase and for the exit of primal cuts	Upon entry of carcase into boning room prior to being quartered and on exit from the	Scan of barcode labels attached to carcase on entry into boning room and of labels attached to	Operator responsible for quartering and removing barcode labels prior to the	Scenario 1 – record would only reflect the date and time a carcase was received for

What	Where	How	Who	Scenario Application
associated with that carcase	boning room of the sealed primal cuts	sealed primal cuts on exit from the boning room	boning room and operator packing primal cuts after processing in the boning room	quartering prior to entering the boning room Scenario 2
4. Product type – classification of retail or bulk meat cut	Upon entry into relevant processing line and on exit as a packaged retail/bulk pack	Scan of barcode labels attached to sealed primal cuts and of labels attached to retail/bulk packs prior to packing	Operator loading sealed primal cuts onto processing line and by the operator packing finished retail/bulk packs for transport	Relevant to both scenarios
5. Dispatch and retailer/wholesaler details	Upon exit of packaged products from processor and entry into retailer/ wholesaler	Scan of barcode labels attached to packaging prior to shipment and on being received by retailer/ wholesaler	Operator loading packs for transport and unloading at destination	Relevant to both scenarios

5.3. Proposed Boning Room Redesign

In order to achieve one-to-one traceability as outlined under Scenario 2, the flow through the boning room requires modification in order to avoid the mixing of primal cuts from different animals. The project team examined a potential redesign of the flows through the boning room as outlined in Figure 1 and Table 2. The aim of this redesigned process was to try to minimise the disruption to current arrangements and thereby keep the cost of the changes to a minimum. In the redesigned processes, the traceability information would be maintained through the use of RFID and/or barcode labels and tags to facilitate data capture and transfer from the barcode labels attached to the carcases prior to entering the boning room. The fundamental idea was to break the current continuous flow of primal cuts on the conveyor belt into smaller batches that could be loaded into a traceable tray/container, with the actual batch size being determined by the volume of the container being used. The traceability information is maintained when primal cuts are transferred between different trays/containers as the information attached to these trays/containers is transferred at the same time.

Under the current process, the barcode attached to a half carcase is scanned before it is reduced into quarters and sent into the boning room. These barcodes ensure traceability up to this point in the system as they have one-to-one relationships with the animal ear tags. However, the scan of these barcodes represents the last instance in which a scan of carcase is recorded in a meat processor's facility. However, in order to achieve one-to-one traceability, the records will need to be maintained to at least at the primal cuts' level. This could be accomplished by a number of different means, depending on the layout of the processor's facility, the locations of equipment, and the available technology. For example, the traceability information could be automatically read and passed on by RFID readers/writers fixed alongside conveyor belts, or through a button press which triggers the transfer of information between tags.

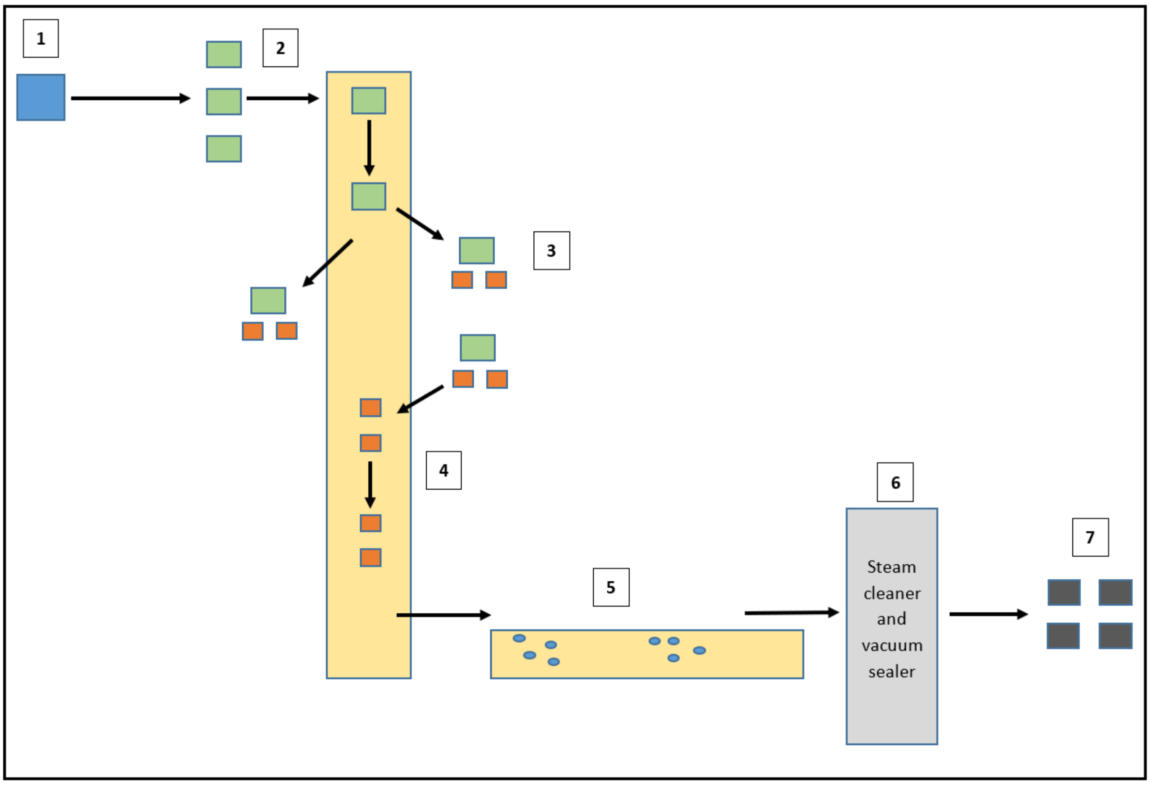

Figure 1: Overview of redesigned boning room processes.

More specifically, when a half carcase is divided into quarter carcases, these quarter carcases could either be placed into separate RFID tagged trays or attached to separate RFID tagged hooks. This step represents the first handshake. The tags associated with these trays or hooks would then be linked back to the barcode information on the half carcases to ensure the traceability information is carried forward into the boning room (Step 1 in Table 2).

When the quarter carcases are processed into smaller pieces, the operators would need to ensure that all pieces from the same quarter carcase are put into tagged trays which are linked (within the information system) to the tray/hook of the quarter carcase. This step is the second handshake (Step 2 in Table 2). This linkage could be established using RFID technology and would *not* involve any manual operation from the operators on the floor. All the trays with these smaller pieces can then be placed on the conveyor belt for further processing.

The activities at the operator stations are similar to those described in Step 2. The key change from the current process is that instead of taking one piece of meat into the operator station, a tray of smaller pieces is pulled off the conveyor belt for further processing. In this sense, the current continuous flow of cuts on the conveyor belt simply becomes a flow with small batches. The size of the batch could be controlled when the quarter carcases are processed into smaller pieces. When operators process these small pieces into primal cuts, they once again transfer the processed primal cuts into RFID tagged containers and put these containers back on the conveyor belt. This will need a third handshake to pass the information on the tray with small pieces into containers with primal cuts (Steps 3 and 4 in Table 2).

Table 2: Stage summary for redesigned boning room processes and traceability details

Stage	Physical Flow	Traceability System
1	Half carcases quartered prior to entering boning room – quartered pieces are placed in trays/attached to hooks to maintain separation from other carcases.	Each quartered carcase is labelled/tagged to maintain data record for details transferred from the barcode label removed prior to entering the boning room.
2	Trays holding quartered carcase pieces are loaded onto conveyor system.	Each tray carries a label/tag linking the quartered carcase back to source animal details.
3	Trays are removed from conveyor at operator stations to be processed into primal cuts. All primal cuts from a quartered carcase are placed in containers to maintain separation from cuts being loaded onto conveyor by other operators.	Once a tray is removed from the conveyor the details from the label/tag are recorded and transferred to each container receiving the primal cuts from a quartered carcase. Each container carries a label/tag to maintain traceability record.
4	Labelled/tagged containers with primal cuts are loaded back onto conveyor system by operators.	The containers maintain the traceability record for the primal cuts through attached labels/tags.
5	The containers containing the primal cuts are unloaded onto a conveyor system prior to steam cleaning and vacuum packing.	Data is read off labels/tags on containers and transferred to separators on the conveyor or alternatively it is transferred straight to the carton labelling at Stage 7 as described below.
6	Primal cuts pass through steam cleaner and vacuum sealer.	Data read off containers prior to primal cuts being transferred to the conveyor is transferred to a label/tag attached to each sealed primal cut or alternatively to the carton.
7	Sealed primal cuts are loaded into cartons for transport/storage before further processing. As the primal cuts ensure one-to-one traceability, the carton can be packed with more than one animal.	Data read off the primal cuts is associated with labels/tags attached to each carton, ensuring traceability to the original carcase (or carcases) is maintained.

When the primal cuts are unloaded onto another conveyor system prior to steam cleaning and vacuum packing, the information associated with the primal cut containers needs to be transferred to the conveyor belt, which is the fourth handshake (Steps 5 and 6 in Table 2). This transfer could be established in several ways. For example, virtual separators could be placed on the conveyor belt and used to mark each container when the primal cuts are unloaded. Another way to transfer the information would be to attach RFID tags to the conveyor belt and associate particular RFID tags on the conveyor belt with the RFID tag on the primal cut container when it is unloaded. Once all the primal cuts are unloaded onto the conveyor belt, the sequence of the primal cuts will need to be maintained until these primal cuts are sealed and labels attached to them.

The last handshake happens when the primal cuts are sealed and labelled (Step 7 in Table 2). In this step, once a primal cut is sealed, a label is printed based on the information from the conveyor belt and attached to the primal cut. This label will include the one-to-one traceability information, alongside all the existing requirements for primal cut sealing and packaging. The labels used here could be RFID tags or barcode labels. The choice of label employed will depend on the cost considerations for an individual processor, as well as whether the labelling technology could be used in downstream processes. For example, if RFID tags are used, it might be possible to automate the next stage of picking and packaging which is currently manually operated.

5.4. Web-Based Application Deployment

As discussed earlier, the project team developed the SCOR model and the ROI analysis as a web-based application to facilitate the data collection exercise. By using a web-based approach, the tool offers easier collaboration and communication among different stakeholders across the meat supply chains.

Specifically, the SCOR modelling part of the web-based tool allows users to enter information regarding two processes: one for the “as-is” scenario, and one for the “to-be” scenario. It should be noted that while the terms “as-is” and “to-be” are used in the report, users are not limited to simply comparing a future scenario with an existing one. Rather, the naming of these two scenarios is designed to ensure that users can differentiate between any two scenarios they want to investigate and compare. The two scenarios are listed side-by-side in the web-based application, as shown in Figure 2, thereby allowing users to see the commonalities and differences between them. In this particular example, both the cost and time fields are set to be zero as there is no difference between the “as-is” and “to-be” scenarios at this process step. By assuming the common cost components and processing times to be the same, the research team could better focus on the differences between scenarios and therefore conduct more accurate ROI analyses.

Within each process step, users have the opportunity to name the process step, provide a description and associated notes relating to the process step, and more importantly, record detailed cost and processing time information for the process step, as shown in Figure 3.

Once all the information regarding the two scenarios is entered into the tool, an ROI analysis could be conducted. Users would be asked to provide parameters related to the ROI analysis and the related fixed costs information and expected system wide benefits. Based on the data entered, the ROI calculation would be conducted, and the results displayed to the users.

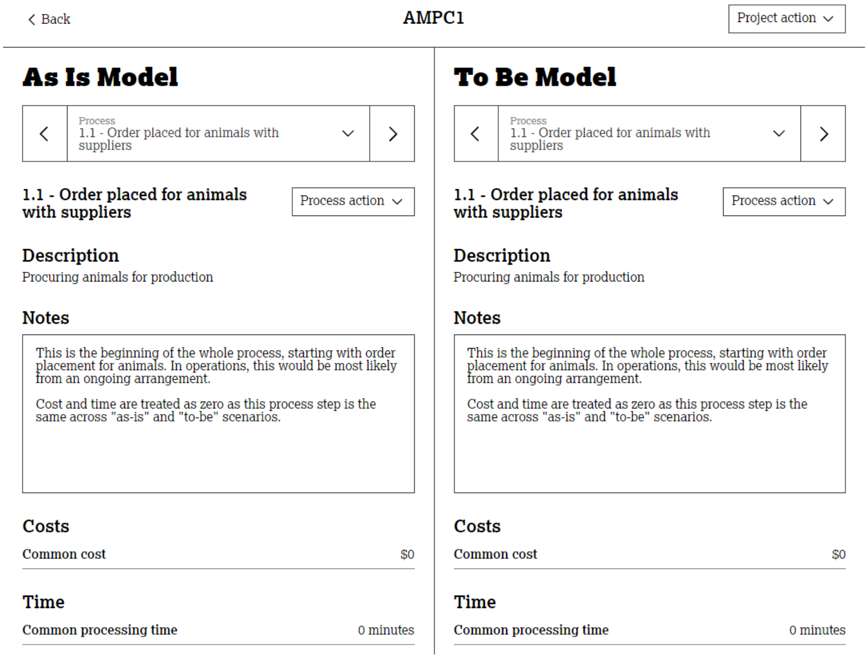

Figure 2: Side-by-side view of one step from "as-is" and "to-be" scenarios.

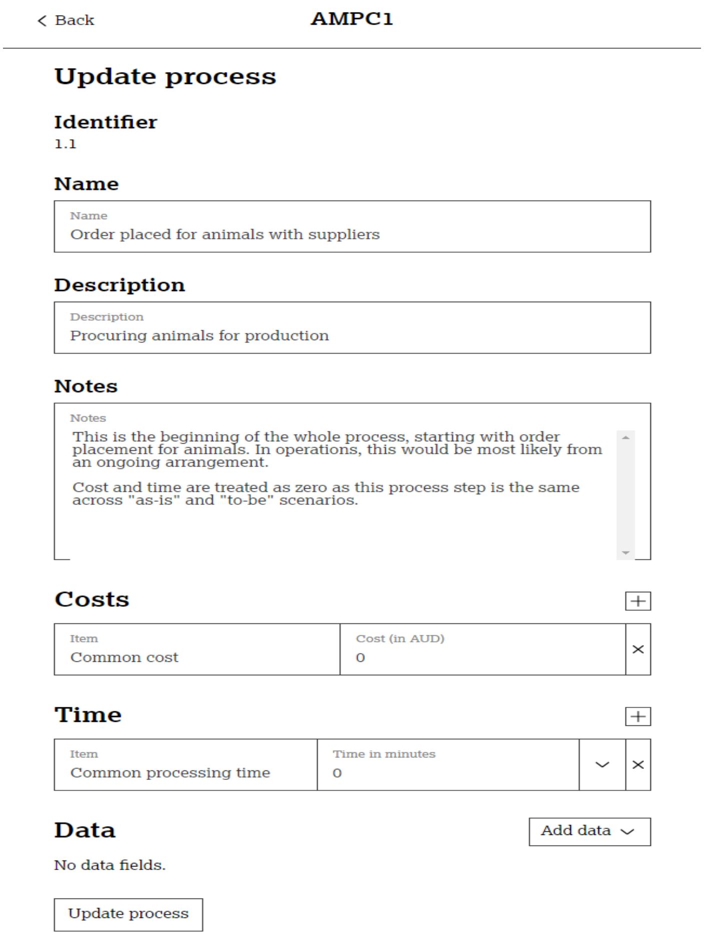

Figure 3: Data to be collected at each process step.

5.5. ROI Analysis Results

Typically, an ROI analysis involves many parameters. In this project, ROI analyses needed to consider factors such as the potential and likely range of costs associated with implementing a blockchain traceability system, as well as the size of the meat processor facility and the expected benefits from implementing such a system. It should also be noted that factors such as operating costs and processing efficiencies might be different across AMPC members, therefore the ROI analyses presented in this report should be interpreted based on the assumed parameters.

Furthermore, the results from ROI analyses are only "snapshots" reflecting the system performance with the given parameters. In this sense, the results presented in this report are demonstrative of the capability of the web-based tool, rather than trying to cover every aspect of ROI analysis for blockchain enabled traceability for red meat supply chains.

With these limitations in mind, this section presents the ROI analysis results on the systems with one-to-one traceability. Two sample ROI analyses are offered, both of which assume that RFID technology is used for transferring information among different stages in the meat processing facilities for traceability purposes. In terms of tags used for primal cuts, the first ROI analysis assumes that barcodes are used, which matches with current operational practices. The second ROI analysis investigates the use of RFID tags for primal cuts. The details of the cost parameters and benefit components included in the ROI calculation are presented in Appendix 3 – Cost Parameters and Benefit Components in the ROI Analyses.

ROI analysis one: cost of establishing one-to-one traceability

The first ROI analysis focused on getting a broad understanding of how much the one-to-one traceability would cost. Thus in this ROI analysis only the fixed costs were considered (presented in Table 3). Specifically, this ROI analysis assumed that the processing cost and processing time per carcase would remain unchanged, there would be no expected system wide benefits (such as sell price increase), and hence only the fixed costs were included in the ROI analysis. We assumed the annual throughput would be 150,000 animals and the average carcase weight was 180 kilograms. Aligning with current practices, barcodes were assumed to be used to carry one-to-one traceability information for the primal cuts.

As there were no benefits considered, the ROI analysis in Table 3 is, in effect, a cost analysis. As a result, the net inflows across the 5-year period are all negative, which means there will be additional costs to implement the one-to-one traceability. In total, with the assumed cost components in Table 3, the net inflow in Year 1 is –$322,217, and –$10,000 from Year 2 to Year 5. With the assumed throughput and carcase weight, the net inflow per kilogram will be –1.19 cents in Year 1 (i.e., additional cost of 1.19 cents per kilogram), and –0.04 cent per kilogram from Year 2 and onwards (i.e., additional cost of 0.04 cent per kilogram).

Unsurprisingly, from this first ROI analysis, it is concluded that establishing one-to-one traceability obviously would incur additional costs for a processor. However, it should be noted that there are direct and indirect benefits could be derived from one-to-one traceability.

Table 3: ROI analysis one: cost of establishing the one-to-one traceability.

Parameters		
Cost of Labour (Hourly Salary)	$25.00	
Cost of Capital	10.00%	
Number of Animals Processed Annually	150,000	
Carcase Weight	180	kg

Per Head Differences	Cost	Time
AS-IS	$0.00	0
TO-BE	$0.00	0
Cost and Time Savings (Benefits)	$0.00	0
Additional Costs and Time	$0.00	0

Expected System Wide Benefits		
Sell price increase per kilogram	$0.00	/kg
Labour cost savings per year	$0.00	

Fixed Costs	Year 1	Year 2	Year 3	Year 4	Year 5
System integration	$300,000				
System maintenance		$10,000	$10,000	$10,000	$10,000
Reader/writer to transfer data from barcodes	$2,385				
Tags attached to trays	$402				
Readers/writers at workstations	$14,307				
Tags for workstation trays	$177				
Reader to transfer data from tags to system	$2,385				
Tags on conveyor into vacuum steamer	$177				
Reader to transfer data to barcodes	$2,385				
Total Fixed Costs	$322,217	$10,000	$10,000	$10,000	$10,000

Variable Costs	Year 1	Year 2	Year 3	Year 4	Year 5
Total per head additional cost	$0	$0	$0	$0	$0
Total per head additional time in $	$0	$0	$0	$0	$0
Total Variable Additional Costs	$0	$0	$0	$0	$0

Benefits	Year 1	Year 2	Year 3	Year 4	Year 5
Total expected price increases	$0	$0	$0	$0	$0
Total expected labour cost savings	$0	$0	$0	$0	$0
Total per head cost savings	$0	$0	$0	$0	$0
Total per head time savings in $	$0	$0	$0	$0	$0
Total Benefits	**$0**	**$0**	**$0**	**$0**	**$0**

	Year 1	Year 2	Year 3	Year 4	Year 5
Net Inflow	-$322,217	-$10,000	-$10,000	-$10,000	-$10,000
Average net inflow per kilogram	-$0.0119	$0.0004	$0.0004	$0.0004	$0.0004

Output	
Net Present Value (NPV)	**($353,915)**
PV (Fixed Costs)	$353,915
PV (Variable Costs)	$0
PV (Benefits)	$0
Benefit Cost Ratio	0.00%

ROI analysis two: one-to-one traceability with benefits

In the second ROI analysis, we assumed that RFID tags will be applied to all the primal cuts, with a total tag cost per animal of $6. This was based on 60 primal cuts per animal and a unit price of $0.10 per RFID tag. At the same time, we assumed a $0.05 per kilogram sell price increase, together with a labour cost saving of $60,000 per year as the expected benefits. These benefits were assumed based on a marginal price increase for consumers' willingness to pay for one-to-one traceability, and as a result of using the RRID technology, the performance improvement (hence labour saving) from the current sorting and packing operations. These assumptions were aimed at providing a broad order level of potential benefit for cost recovery considerations. The one-to-one traceability was established in the same way as in the first ROI analysis and incurred the same level of fixed costs for the RFID technology and associated systems. The results are presented in Table 4.

As expected, the net inflow for Year 1 is the lowest among the five years due to the upfront fixed cost investment. However, with the given assumptions, especially the sell price increase, the ROI analysis results in a positive net inflow. This means that the cost expenditure in Year 1 could be recovered by the sell price increase and labour cost savings. The ROI analysis results indicated that there will be a positive cashflow of 0.7 cent per kilogram in Year 1 and this rises to 1.85 cents per kilogram for Years 2 to 5. Looking at the two benefits in isolation, it can be calculated that with no labour saving, a sell price increase of 3.6 cents per kilogram is required to break even against the fixed cost investment over the five-year period. Conversely, with no sell price increase, a labour saving of just under $1 million per year would be required to break even with the fixed cost investment.

In this particular case and as shown in Table 4, the net present value of the ROI analysis is $1,772,716, with a benefit cost ratio of 1.43:1 (equivalent to an ROI of 43%). The benefit cost ratio indicates that the investment in one-to-one traceability will have a positive return, provided that there is a sell price increase of 5 cents per kilogram and an annual labour cost savings of $60,000. It will be noted that most of the benefits emanates from the sell price increase rather than labour cost savings.

Sensitivity analyses

This section aims to provide a wider picture of the ROI, through a sensitivity analysis which considers exemplar ranges for a number of key parameters: variable tag cost per head, processing throughput, and system integration as the fixed costs. These sensitivity analyses address the limitations of "snapshots" for the results presented earlier and thereby allowing a better understanding of the ROI.

Figure 4 investigates the impact of the total variable tag cost per head on the ROI. It plots the net inflow per kilogram (in cents) for Year 1 (the yellow line) and Years 2-5 (the blue line) for a processing facility with an annual throughput of 150,000 animals, assuming a potential sell price increase of 5 cents per kilogram, and an annual labour cost savings of $60,000. The total tag cost per head was used as a variable, ranging from per head cost of $0.0 (e.g., using existing barcodes) to $15.0 (e.g., using more expensive RFID tags or in the case that there are more primal cuts per head). In Figure 4, if the net inflow per kilogram is greater than 0, then it means the investment will have a positive ROI.

Table 4: ROI analysis two: one-to-one traceability with benefits.

Parameters		
Cost of Labour (Hourly Salary)	$25.00	
Cost of Capital	10.00%	
Number of Animals Processed Annually	150,000	
Carcase Weight	180	kg

Per Head Differences	Cost	Time
AS-IS	$0.00	0
TO-BE	$6.00	0
Cost and Time Savings (Benefits)	$0.00	0
Additional Costs and Time	$6.00	0

Expected System Wide Benefits		
Sell price increase per kilogram	$0.05	/kg
Labour cost savings per year	$60,000.00	

Fixed Costs	Year 1	Year 2	Year 3	Year 4	Year 5
System integration	$300,000				
System maintenance		$10,000	$10,000	$10,000	$10,000
Reader/writer to transfer data from barcodes	$2,385				
Tags attached to trays	$402				
Readers/writers at workstations	$14,307				
Tags for workstation trays	$177				
Reader to transfer data from tags to system	$2,385				
Tags on conveyor into vacuum steamer	$177				
Reader to transfer data to barcodes	$2,385				
Total Fixed Costs	$322,217	$10,000	$10,000	$10,000	$10,000

Variable Costs	Year 1	Year 2	Year 3	Year 4	Year 5
Total per head additional cost	$900,000	$900,000	$900,000	$900,000	$900,000
Total per head additional time in $	$0	$0	$0	$0	$0
Total Variable Additional Costs	$900,000	$900,000	$900,000	$900,000	$900,000

Benefits	Year 1	Year 2	Year 3	Year 4	Year 5
Total expected price increases	$1,350,000	$1,350,000	$1,350,000	$1,350,000	$1,350,000
Total expected labour cost savings	$60,000	$60,000	$60,000	$60,000	$60,000
Total per head cost savings	$0	$0	$0	$0	$0
Total per head time savings in $	$0	$0	$0	$0	$0
Total Benefits	**$1,410,000**	**$1,410,000**	**$1,410,000**	**$1,410,000**	**$1,410,000**

	Year 1	Year 2	Year 3	Year 4	Year 5
Net Inflow	$187,783	$500,000	$500,000	$500,000	$500,000
Average net inflow per kilogram	$0.0070	$0.0185	$0.0185	$0.0185	$0.0185

Output	
Net Present Value (NPV)	**$1,772,716**
PV (Fixed Costs)	$353,915
PV (Variable Costs)	$3,752,879
PV (Benefits)	$5,879,510
Benefit Cost Ratio	143.17%

As would be expected, the net inflow per kilogram for one-to-one traceability is almost a linear function of the total variable tag cost per animal. The Year 1 (yellow) line is constantly dominated by the Years 2-5 (blue) line as most of the fixed costs are invested in Year 1. In Figure 4, the net inflow per kilogram in Year 1 changes from about 4 cent/kg to –4.3 cent/kg, when the total variable tag cost per head changes from $0.0 to $15.0. This indicates that, as the total variable tag cost per head increases, the ROI changes from a positive position to a negative one and the transition occurs at about $7.5 per head for the total tag costs per animal. With the fixed capital costs incurred in Year 1, from Year 2 onwards (where there are only the variable and system maintenance costs), the net inflow per kilogram increases by about 1.1 cent/kg.

While a range of $0.0 to $15.0 was used to conduct the sensitivity analyses for the total variable tag cost per head, a realistic estimate for the RFID tags per animal would be around $6 to $8, based on the input the research team received from a Singaporean RFID expert. Therefore, if RFID tags are used for traceability, it would be expected that positive ROIs could be established from Year 1, provided that there is a sell price increase of 5 cent/kg and a labour cost saving of $60,000 per annum.

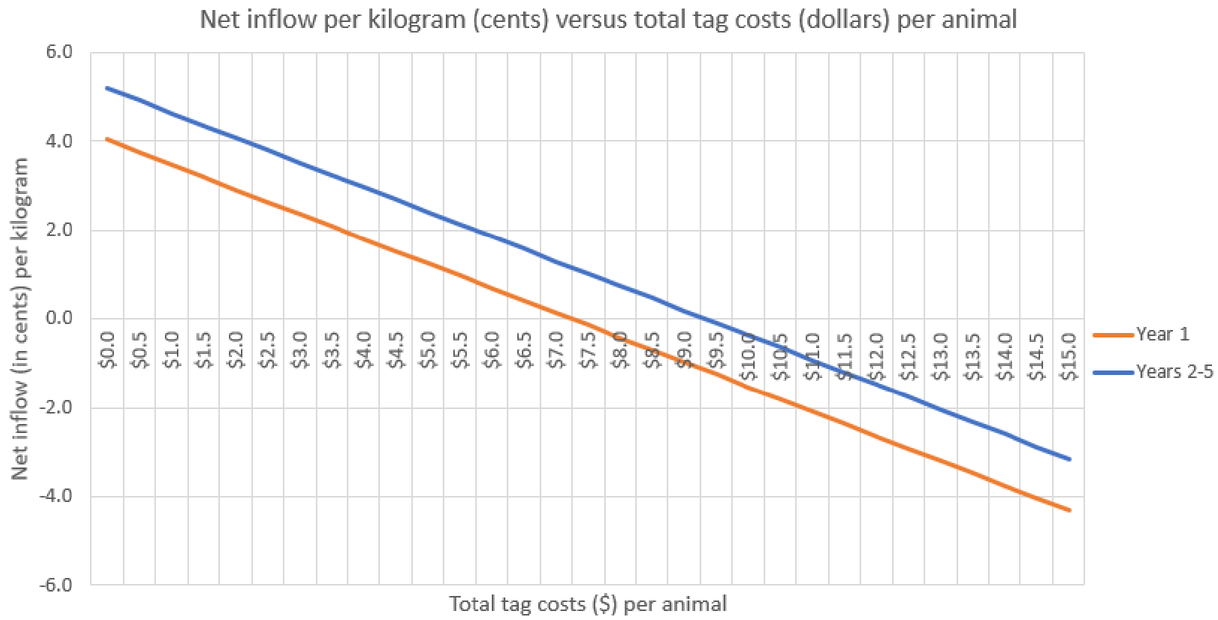

Figure 4: Net inflow per kilogram for one-to-one traceability compared with total tag costs per animal (Assuming annual processing throughput of 150,000 animals, potential sell price increase of $0.05/kg, annual labour cost savings of $60,000).

Figure 5 considers the relationship between the total variable tag cost per head and the annual throughput for Year 1. It plots a heat map for Year 1 net inflow per kilogram in cents as a function of processing capacity and total variable tag cost per head, assuming a potential sell price increase of $0.05/kg and annual labour cost savings of $60,000. Each row in the figure represents the total variable tag cost per head ($/head, ranging from $0 to $15), and each column represents an annual processing capacity (in heads, ranging from 20,000 to 300,000). In effect Figure 5 provides an overall picture of the net inflow generated by the one-to-one traceability and whilst considering different sizes of processors in parallel.

Self-evidently, the higher the total tag costs and the lower a processor's capacity, the more challenging it will be for a processor to establish one-to-one traceability. However, as the capacity of processors increases, one-to-one traceability becomes increasingly affordable.

Tag costs per head	Processing Throughput (heads)														
	20,000	40,000	60,000	80,000	100,000	120,000	140,000	160,000	180,000	200,000	220,000	240,000	260,000	280,000	300,000
$0.00	-2.3	1.4	2.6	3.2	3.5	3.8	4.0	4.1	4.2	4.3	4.3	4.4	4.4	4.5	4.5
$0.50	-2.6	1.1	2.3	2.9	3.3	3.5	3.7	3.8	3.9	4.0	4.1	4.1	4.2	4.2	4.2
$1.00	-2.8	0.8	2.0	2.6	3.0	3.2	3.4	3.5	3.6	3.7	3.8	3.8	3.9	3.9	4.0
$1.50	-3.1	0.5	1.7	2.3	2.7	3.0	3.1	3.3	3.4	3.4	3.5	3.6	3.6	3.6	3.7
$2.00	-3.4	0.2	1.5	2.1	2.4	2.7	2.8	3.0	3.1	3.2	3.2	3.3	3.3	3.4	3.4
$2.50	-3.7	0.0	1.2	1.8	2.2	2.4	2.6	2.7	2.8	2.9	2.9	3.0	3.1	3.1	3.1
$3.00	-4.0	-0.3	0.9	1.5	1.9	2.1	2.3	2.4	2.5	2.6	2.7	2.7	2.8	2.8	2.8
$3.50	-4.2	-0.6	0.6	1.2	1.6	1.8	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.5	2.6
$4.00	-4.5	-0.9	0.3	1.0	1.3	1.6	1.7	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.3
$4.50	-4.8	-1.1	0.1	0.7	1.0	1.3	1.5	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.0
$5.00	-5.1	-1.4	-0.2	0.4	0.8	1.0	1.2	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.7
$5.50	-5.3	-1.7	-0.5	0.1	0.5	0.7	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.5
$6.00	-5.6	-2.0	-0.8	-0.2	0.2	0.5	0.6	0.8	0.9	0.9	1.0	1.1	1.1	1.1	1.2
$6.50	-5.9	-2.3	-1.0	-0.4	-0.1	0.2	0.3	0.5	0.6	0.7	0.7	0.8	0.8	0.9	0.9
$7.00	-6.2	-2.5	-1.3	-0.7	-0.3	-0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.6	0.6	0.6
$7.50	-6.5	-2.8	-1.6	-1.0	-0.6	-0.4	-0.2	-0.1	0.0	0.1	0.2	0.2	0.3	0.3	0.3
$8.00	-6.7	-3.1	-1.9	-1.3	-0.9	-0.7	-0.5	-0.4	-0.3	-0.2	-0.1	-0.1	0.0	0.0	0.1
$8.50	-7.0	-3.4	-2.2	-1.5	-1.2	-0.9	-0.8	-0.6	-0.5	-0.5	-0.4	-0.3	-0.3	-0.2	-0.2
$9.00	-7.3	-3.6	-2.4	-1.8	-1.5	-1.2	-1.0	-0.9	-0.8	-0.7	-0.7	-0.6	-0.6	-0.5	-0.5
$9.50	-7.6	-3.9	-2.7	-2.1	-1.7	-1.5	-1.3	-1.2	-1.1	-1.0	-0.9	-0.9	-0.8	-0.8	-0.8
$10.00	-7.8	-4.2	-3.0	-2.4	-2.0	-1.8	-1.6	-1.5	-1.4	-1.3	-1.2	-1.2	-1.1	-1.1	-1.0
$10.50	-8.1	-4.5	-3.3	-2.7	-2.3	-2.0	-1.9	-1.7	-1.6	-1.6	-1.5	-1.4	-1.4	-1.4	-1.3
$11.00	-8.4	-4.8	-3.5	-2.9	-2.6	-2.3	-2.2	-2.0	-1.9	-1.8	-1.8	-1.7	-1.7	-1.6	-1.6
$11.50	-8.7	-5.0	-3.8	-3.2	-2.8	-2.6	-2.4	-2.3	-2.2	-2.1	-2.1	-2.0	-1.9	-1.9	-1.9
$12.00	-9.0	-5.3	-4.1	-3.5	-3.1	-2.9	-2.7	-2.6	-2.5	-2.4	-2.3	-2.3	-2.2	-2.2	-2.2
$12.50	-9.2	-5.6	-4.4	-3.8	-3.4	-3.2	-3.0	-2.9	-2.8	-2.7	-2.6	-2.6	-2.5	-2.5	-2.4
$13.00	-9.5	-5.9	-4.7	-4.0	-3.7	-3.4	-3.3	-3.1	-3.0	-3.0	-2.9	-2.8	-2.8	-2.7	-2.7
$13.50	-9.8	-6.1	-4.9	-4.3	-4.0	-3.7	-3.5	-3.4	-3.3	-3.2	-3.2	-3.1	-3.1	-3.0	-3.0
$14.00	-10.1	-6.4	-5.2	-4.6	-4.2	-4.0	-3.8	-3.7	-3.6	-3.5	-3.4	-3.4	-3.3	-3.3	-3.3
$14.50	-10.3	-6.7	-5.5	-4.9	-4.5	-4.3	-4.1	-4.0	-3.9	-3.8	-3.7	-3.7	-3.6	-3.6	-3.5
$15.00	-10.6	-7.0	-5.8	-5.2	-4.8	-4.5	-4.4	-4.2	-4.1	-4.1	-4.0	-3.9	-3.9	-3.9	-3.8

Figure 5: Heat map of net inflow per kilogram in cents for one-to-one traceability in Year 1 when considering total variable tag cost per head and annual throughput (Assuming a potential sell price increase of $0.05/kg, annual labour cost savings of $60,000).

Similarly, Figure 6 considers the relationship between the total fixed cost and the annual throughput in Year 1. It plots a heat map for Year 1 net inflow per kilogram in cents as a function of processing capacity and fixed costs in Year 1, again assuming a potential sell price increase of $0.05/kg and annual labour cost savings of $60,000. Each row in the figure represents the total fixed costs in Year 1 ($, ranging from $100,000 to $1,000,000), and each column represents the annual processing capacity (in heads, ranging from 20,000 to 300,000). As expected, the increase of fixed cost investment would have a higher impact on the processors with smaller processing capacities.

Fixed cost investment	Processing Throughput (heads)														
	20,000	40,000	60,000	80,000	100,000	120,000	140,000	160,000	180,000	200,000	220,000	240,000	260,000	280,000	300,000
$100,000	-0.1	0.8	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6
$200,000	-2.8	-0.6	0.2	0.5	0.8	0.9	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.3	1.4
$300,000	-5.6	-2.0	-0.8	-0.2	0.2	0.5	0.6	0.8	0.9	0.9	1.0	1.1	1.1	1.1	1.2
$400,000	-8.4	-3.4	-1.7	-0.8	-0.3	0.0	0.2	0.4	0.5	0.7	0.8	0.8	0.9	0.9	1.0
$500,000	-11.2	-4.8	-2.6	-1.5	-0.9	-0.5	-0.2	0.1	0.2	0.4	0.5	0.6	0.7	0.7	0.8
$600,000	-14.0	-6.1	-3.5	-2.2	-1.5	-0.9	-0.6	-0.3	-0.1	0.1	0.2	0.4	0.5	0.6	0.6
$700,000	-16.7	-7.5	-4.5	-2.9	-2.0	-1.4	-1.0	-0.6	-0.4	-0.2	0.0	0.1	0.3	0.4	0.4
$800,000	-19.5	-8.9	-5.4	-3.6	-2.6	-1.9	-1.4	-1.0	-0.7	-0.5	-0.3	-0.1	0.0	0.2	0.3
$900,000	-22.3	-10.3	-6.3	-4.3	-3.1	-2.3	-1.8	-1.3	-1.0	-0.7	-0.5	-0.3	-0.2	0.0	0.1
$1,000,000	-25.1	-11.7	-7.2	-5.0	-3.7	-2.8	-2.2	-1.7	-1.3	-1.0	-0.8	-0.6	-0.4	-0.2	-0.1

Figure 6: Heat map of net inflow per kilogram in cents for one-to-one traceability in Year 1 when considering fixed costs in Year 1 and annual throughput (Assuming a potential sell price increase of $0.05/kg, annual labour cost savings of $60,000, and total variable tag cost of $6 per head).

6.0 DISCUSSION

6.1. Funding Structure of Technology Deployment

While meat processors play an essential role in achieving one-to-one traceability, it does not mean that meat processors should be solely responsible for establishing such a tracing system. There is a need to consider the up- and down-stream stages in the red meat value chain. The end-to-end implementation of a blockchain system throughout the value chain would represent the ideal situation, in which all the stages and transitions from a live animal to a consumer's purchase are securely traceable using the principles of a blockchain network. This highlights the importance of approaching the implementation of a traceability system from an industry wide perspective in the initial stages of its design.

Another reason for considering a collaborative approach to implementing a blockchain traceability system is that this distributes the cost burden necessary to implement the required changes, enables a supply chain wide agreement on common standards, and coordinates the roll out/purchase of technology and implementation. While having a blockchain system solely within the meat processing stage of the value chain still contributes towards the overall improvement of traceability and visibility of the flows of red meat, the lack of participation of other meat supply chain players, especially the down-stream ones (e.g., distributors), would undermine the value created by such a traceability implementation.

Furthermore, offering traceability information would benefit the industry as a whole. It would be unfair for the meat processors to solely bear the cost of the initial investment. Red meat supply chains, due to their nature, involves multiple players. These players would need to work together to ensure that traceability information is provided as a coordinated effort and with minimal investment across the whole supply chain. More specifically, the funding structure needs to answer the two key questions:

- Who should bear the initial investment and the ongoing operational costs to maintain traceability?
- How should the benefits be distributed across supply chain players?

Depending on the answers to the above questions, and in light of the relatively few players in the meat supply chains, two funding structures could be considered. The first funding approach would focus on repaying investment first, then distributing benefits; the second would employ a coordinated investment and benefit distribution approach.

Specifically, the first funding approach would be designed to repay the investment first. Any benefits that are derived from the provision of traceability will be initially used to (proportionally) repay the players who have contributed to the initial investment. The distribution of the remaining benefits would then be negotiated through a benefit distribution strategy among supply chain players, especially the meat processors and farmers. The second funding structure starts with a co-investment plan and then distributes the benefits based on the contribution made by each party across the supply chain. This strategy would be particularly advantageous for players with large processing capacities.

With both funding structures, it is anticipated that those who contribute more towards the initial investment would have a stronger voice in the negotiation of benefit distribution, not least as this would reflect the risk factors associated with such investments.

6.2. Potential Benefits/Profits

Given the limited number of cases that have seen blockchain implemented (or are being considered) along an end to end supply chain, it is difficult to identify the specific benefits and profits which would potentially flow from implementing such a traceability system. Nevertheless, the following section discusses a number of relevant issues in order to understand the rationale underpinning the proposed or actual implementation of blockchain technology.

Market advantage in a future market

Food provenance is becoming an increasingly important consideration for consumers, particularly within export markets where there have been cases of fraudulent products entering the retail stream. This has been observed in the Chinese market where red meat has been falsely marketed as a high-quality Australian product. To date, various companies have implemented a number of strategies to try to avoid such issues and these are mainly focussed around the use of tamper proof packaging to ensure the authenticity of the product reaching the retailers. While these measures offer potential solutions, they do not guarantee the provenance of a product. Blockchain has the ability to secure the supply chain in a digital manner which can also be combined with the physical measures already being taken to protect a brand's perception within the retail market. Given that blockchain and parallel approaches to ensuring provenance are still mostly in the early stages with few commercial examples operating, there is a potential for any early adopters of the technology to gain advantages such as product competitiveness or customer loyalty. Food provenance and safety concerns are unlikely to dissipate, and a brand which gives consumers confidence in its authenticity and quality may secure or capture more market share in the future.

On the other hand, consumers are likely to be interested in more than just provenance information as a number of brands are already using smart packaging technologies to engage with consumers. This is particularly relevant in cases such as online retail outlets which are widely used by consumers in China to purchase their everyday grocery items. Brands seek to differentiate themselves by engaging with consumers in providing the 'story' behind a product. In the case of red meat this might take the form of providing the background of the farming region where the animals were reared and the approaches used by farmers to produce high quality meat, which subsequently offers opportunities for marketing down to state or regional levels.

Variable costs of implementation

In terms of the profitability of a blockchain enabled supply chain as detailed in the section of ROI analyses, it is relevant to note that the costs of implementation and the resulting profit margin are likely to vary between processors. A key reason for this is that the stages observed in the boning room in the case of ACC are likely to be common to large processors given their large production volumes, but this may not be the case in smaller scale processors. With smaller daily volumes and more limited capacities for capital expenditure, smaller processors may potentially operate the boning room with a greater capacity for one-to-one traceability. This would for example, be the case in situations where a whole or half carcase is fully processed into primal cuts before the next one is brought into the boning room. Having said this, it should also be noted that smaller processors may not have an integrated system for tracking the movement of a carcase through their system up to the boning room as in the case of the ACC. It follows that meat processors who want to adopt blockchain based traceability systems will need to map their operations and conduct ROI analyses – for example by using the web-based application developed in this project. In parallel, AMPC as an industry body may conduct a more detailed level of study to understand the operations adopted by AMPC members in order to determine the exact requirements for the industry to take a blockchain enabled traceability system.

Labour cost savings/automation

Developments in automated red meat processing have the potential to integrate well with traceability systems such as the one proposed by the project team. Advances in technologies to automate the operation of the boning room offer a potential solution to the mixing of primal cuts as these systems would process carcases in sequence on a staged production line. As has been observed in the case of lamb processing, automation is becoming increasingly used by larger processors in order to avoid being outcompeted by companies who invest in such technology (Business Insider Australia, 2016). In the case of lamb, the improved uniformity and quality of products produced by an automated line has been shown to deliver improved returns for processors adopting the technology. While it would be extremely difficult to estimate what the impact of similar automation would be within the beef sector, it would seem likely that it would result in similar benefits once the approach has been perfected.

Regulatory compliance and risk reduction

Adoption of increased traceability systems within the various agricultural sectors and food processing industries may also be necessitated by the future imposition of a greater regulatory burden. In this case any companies operating a traceability system are likely to be ahead of their competitors and in a strong position to guide and inform policy development in a more advantageous way. As has been noted, Australia's use of the National Livestock Identification System (NLIS) offers a fairly effective means of tracing a meat cut's history to a general source location such as a feedlot and possibly even the farm the animal originated from (Thomason 2007; PwC 2011). The NLIS works well in cases where the meat cut was processed from animals sourced from one or two locations, which was observed for the ACC and may be more common for large scale processors given the number of animals needed for a single day. This is supported in the case of ACC by a well-developed electronic database systems and barcode tagging which enabled a link between an animal's ear tag and carcase to be established.

The NLIS was introduced specifically to improve the speed and reliability of any trace back requirements should any issues occur with any red meat products. This system has undoubtedly improved the red meat industry's capacity to respond to potential disease outbreaks and contamination concerns. However, it still relies entirely on batch level traceability given the situation in the boning room. A blockchain enabled traceability system based on the one-to-one scenario as outlined by the project team would enable a meat cut's full history to be determined with certainty in a very short amount of time. This in turn would enable a quicker response to an emerging health-related situation, and more importantly also limit the extent of damage arising from the incident to farmers, processors and retailers who are not affected or involved (e.g. loss of brand reputation, dramatic price drops), as a result of the ability to pinpoint the related parties through one-to-one traceability.

6.3. Uses of Data Collected along Supply Chain

Marketing uses

Currently many of the cases in which blockchain is used in food supply chains are based on batch level traceability or are focussed on completed items, rather than tracing the individual components used to create the finished item. The primary reason for the batch level approach is that, in many cases, the required changes to production processes to trace an individual item adds excessively to the overall complexity and cost base for the companies across the supply chain. This is the central reason why BeefLedger opted for batch rather than one-to-one level traceability within their system (BeefLedger 2019a, 2019b, n.d., 2019c). This can also be observed from the first ROI analysis demonstrated in this report.

Related to traceability and product provenance is also a consideration of what information consumers are looking for when making their purchasing decisions. If consumers are satisfied with provenance details at a national level, batch level traceability might be sufficient to meet their requirements and provide the assurance they seek. On the other hand, if a more focussed 'origin' of products (such as at a state or regional level), can provide a differentiation in terms of marking value, then one-to-one traceability would become an essential requirement for meat processors and the red meat industry.

The digitisation of supply chains opens up a number of options for companies to engage in both the management of their processes and engagement with consumers. As indicated above, a blockchain enabled supply chain presents an opportunity for reinforcing consumer confidence in a product's authenticity. This offers companies avenues to develop marketing campaigns centred on the origin of the food underpinned by a blockchain record. This particularly applies to markets where digital platforms are becoming popular for consumers because the ability to highlight the provenance of a product is greatly enhanced when compared with a store centred retail experience. For the Australian domestic market, the online sales channel for groceries is not as developed as it is in countries such as China so the initial focus of meat traceability would, arguably, need to be centred primarily on the export market.

This observation highlights the need for a dual marketing strategy for the domestic and international markets. The current NLIS system within the Australian red meat sector offers a fairly detailed traceability history as was communicated by ACC and participants during the training hosted by MINTRAC. However, it is likely that domestic consumers are unaware of the food traceability capabilities within the domestic red meat market. The absence of major food contamination risks within the domestic red meat market is in all likelihood the underlying reason for this situation. That said, recent issues around food contamination in rock melons and the purposeful contamination of fruit within Australia have raised consumer consciousness on having verifiable and secure supply chains.

Process and sales tracking

Aside from offering value from a consumer-focused perspective, a blockchain enabled traceability system also offers value to implementing companies. They will be able to get a detailed and timely picture of their supply chain flows. In the case of the one-to-one traceability scenario, the information from the supply chain flows, such as the type of cuts, the 'origins' of meat, and the meat consumption regions, could be used by processors to determine how to best optimise their processes to produce products with the attributes that the market is currently demanding and market the products accordingly. If the blockchain system is integrated with the retail stage, it could also enable processors to determine consumers purchasing behaviour and enable them to analyse trends within the retail market over time. The data harvested could be used to derive knowledge and facilitate decision making in respect of product mix, improve the industry's understanding of consumer behaviour, and allow the development of improved marketing strategies.

6.4. Existing Gaps

Understanding consumer attitude towards traceability

A blockchain enabled meat supply chain would offer enhanced transparency, accountability, coordination, traceability, and customer confidence with improved customer-oriented decision making for the industry. However, there exists a clear knowledge gap on consumer preferences in terms of food provenance at both domestic and international levels. This gap makes it difficult for meat processors and the industry to understand the potential benefits of providing the product provenance history to consumers. To address this gap, the first question that needs to be answered is what level of provenance detail do consumers want in their purchasing decisions? Ascertaining this is a significant step towards establishing the likely cost base of implementing a traceability system, given that costs would increase with the need for finer provenance information.

The second question that needs to be determined is how consumers want to be presented with a product's history and interact with the traceability record (e.g. whether it is on the packaging or through scanning a QR code or NFC chip)? As is noted above there is also a need to consider the preferences in retail experiences (i.e. store based or online transactions) as this is likely to impact the response to the above points.

Implementation in the red meat processing facilities

After establishing the knowledge base for provenance information around red meat in the market, the next step would to be determine a standard approach towards implementing the blockchain traceability system. While the boning room redesign has been discussed in this report, a practical implementation of one-to-one traceability may still encounter some technical challenges. These would centre on the adopted technology's ability to withstand the environment, such as temperature, humidity, and hygienic requirements. In this sense, a pilot implementation would need to be tested to understand the preferred approach from the perspective of the red meat processors, as well as in the granularity of information that it will provide to the customer. Furthermore, a blockchain system needs to be implemented from the first record to the exit of the traced product in order to offer the most secure system. In line with this, extensive industry engagement would need to be conducted and coordinated through AMPC and its partners in other industries to first detail the vision for such a system and gauge feedback on the technical specifications being examined.

7.0 CONCLUSIONS/RECOMMENDATIONS

7.1. Project Summary

This project investigated the use of blockchain technology within the Australian red meat industry. More specifically, the project team examined how the blockchain technology could be used to establish meat product traceability, and in order to achieve that, what types of information should be collected and at what places along the meat supply chain should such information be collected.

The project team started by understanding the operations in the current red meat supply chain and developed a base scenario. Following on from this base scenario, two further scenarios which incorporated traceability were proposed: one focussed on traceability at the batch level; and the other focussed on one-to-one traceability. The batch level traceability tracks all the products leaving meat processing facilities and therefore has little impact on the current processing practices of meat processors. The one-to-one traceability, however, needs to address the challenge of primal cuts mixing at the boning room. A redesign to the boning room was proposed to address this challenge. The redesign relies on breaking the current continuous flow of primal cuts into small batches and utilises RFID technology to automatically pass the traceability information from one work station to the next in the boning room.

As the one-to-one traceability requires operational changes to the current meat processing practices, and hence requires additional investment, two ROI analyses were conducted to assess the feasibility of such an investment. The first ROI analysis focused on understanding the broad cost of one-to-one traceability, and thus only considered the fixed costs. With the assumed throughput and carcase weight, the cost of establishing one-to-one traceability would be 1.19 cents per kilogram in Year 1, and 0.04 cent per kilogram from Year 2 and onwards. The second ROI analysis considered a number of benefits that reflect one-to-one traceability. With an assumed price increase of 5 cents per kilogram, and annual labour cost savings of $60,000, the ROI analysis results indicated that there would be a positive cashflow of 0.7 cent per kilogram in Year 1 and this number rises to 1.85 cents per kilogram after Year 2.

While there will unquestionably be upfront investment required to establish one-to-one traceability, this project found that with some modest benefits considered, the ROI would be positive for the meat processors. Moreover, as discussed earlier, the existence of one-to-one traceability would open up opportunities for marketing, the types of products on offer, regulatory compliance, risk mitigation, and eventually allow the harvesting of data to analyse customer preference and assist in production decision making for meat processors in Australia.

7.2. Recommendations

Recommendations for understanding the market

The role of consumer preferences is central to industries such as the red meat sector as this will define the actions by companies aiming to secure sales and target niche markets. This highlights the importance of the need for further research into the attributes that are essential in driving consumers' selection of red meat products. Closing these knowledge gaps would best be achieved through direct engagement with consumers and retailers in the target markets using structured interviews and surveys. Specifically, it is recommended that:

- Further research is undertaken to understand the value that Australian domestic consumers place on the ability to trace a red meat product's full history (i.e. paddock to plate). Key to this would be an examination at the level of particular products/meat cuts, as the majority of studies in this area focussed on too broad a range of products such as beef and lamb in general.

- // Similarly, the international market for Australian red meat needs further definition and analysis to understand the reasons why international consumers are choosing Australian red meat over that from other source countries.
- // To ascertain how customers would want to have traceability data presented, and their preferred means of interacting with such traceability information.

Recommendations for understanding the technology

A pilot implementation across the red meat supply chain, which incorporates the proposed approach for traceability, would allow AMPC to better understand how a blockchain based traceability system might operate. Many use cases involving blockchain had pilot demonstrations as a key step in showcasing the ability of the various traceability systems, and at the same time as a means of problem solving for any implementation barriers and challenges. Therefore, it is recommended that AMPC:

- // Examines the suitability of the proposed technologies and equipment for one-to-one traceability, and how they could be implemented in a meat processor's facility;
- // Analyses, based on the data harvested from the proposed one-to-one traceability pilot system, how business decisions could be improved to deliver better returns for farmers, meat processors, and partners along the meat supply chains.

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9.0 APPENDICES

9.1. Appendix 1 – Acronyms

ACC – Australian Country Choice

AMPC – Australian Meat Processor Corporation

EAN – European Article Number

MINTRAC – National Meat Industry Training Advisory Council

MLA – Meat and Livestock Australia

MSA – Meat Standards Australia

NLIS – National Livestock Identification System

NPV – Net Present Value

PV – Present Value

QR Code – Quick Response Code

RFID – Radio Frequency Identification

ROI – Return on Investment

SCC – Supply Chain Council

9.2. Appendix 2 – Process Maps

The SCOR model is a process reference model, developed and endorsed by the Supply Chain Council (SCC) as the cross-industry, standard diagnostic tool for supply chain management. The SCOR model describes the business activities along the supply chain under the six headings of: plan, source, make, deliver, return and enable (SCC, 2012). The model is inherently capable of including all players along a supply chain – a core requirement for this research project. The SCOR reference framework is a hierarchical reference model which provides three levels of activities, as shown in Figure 7.

The three levels of process detail in the SCOR model define the process types, process categories and process elements. Specifically, Level 1 provides the overall definition of the six processes; Level 2 defines the core process elements of the basic processes; and Level 3 consists of the tasks, input measures, parameters and output metrics of the process elements (SCC, 2012). Further process decomposition, which is beyond the scope of the SCOR model, will be required if more detailed information about the activities performed within the supply chain is needed.

Figure 8 illustrates the hierarchical decomposition of the SCOR model, using the 'Deliver' management process as an example. It can be observed that on top of the basic management processes defined in the SCOR model, an additional level, Level 4, is utilised to represent the activities associated with the Level 3 process. When necessary, the Level 4 activities could be further decomposed to allow greater granularity to be incorporated into the process modelling and ensure all the required data are properly collected.

	Level #	Level Description	Examples	Comments
Within scope of SCOR	1	Process Types (Scope)	Plan, Source, Make, Deliver, Return and Enable	Level-1 defines scope and content of a supply chain. At level-1 the basis-of-competition performance targets for a supply chain are set.
	2	Process Categories (Configuration)	Make-to-Stock, Make-to-Order, Engineer-to-Order Defective Products, MRO Products, Excess Products	Level-2 defines the operations strategy. At level-2 the process capabilities for a supply chain are set. (Make-to-Stock, Make-to-Order)
	3	Process Elements (Steps)	• Schedule Deliveries • Receive Product • Verify Product • Transfer Product • Authorize Payment	Level-3 defines the configuration of individual processes. At level-3 the ability to execute is set. At level-3 the focus is on the right: • Processes • Inputs and Outputs • Process performance • Practices • Technology capabilities • Skills of staff
Not in scope	4	Activities (Implementation)	Industry-, company-, location- and/or technology specific steps	Level-4 describes the activities performed within the supply chain. Companies implement industry-, company-, and/or location-specific processes and practices to achieve required performance

Figure 7: SCOR as a hierarchical process model (Source: SCC 2012).

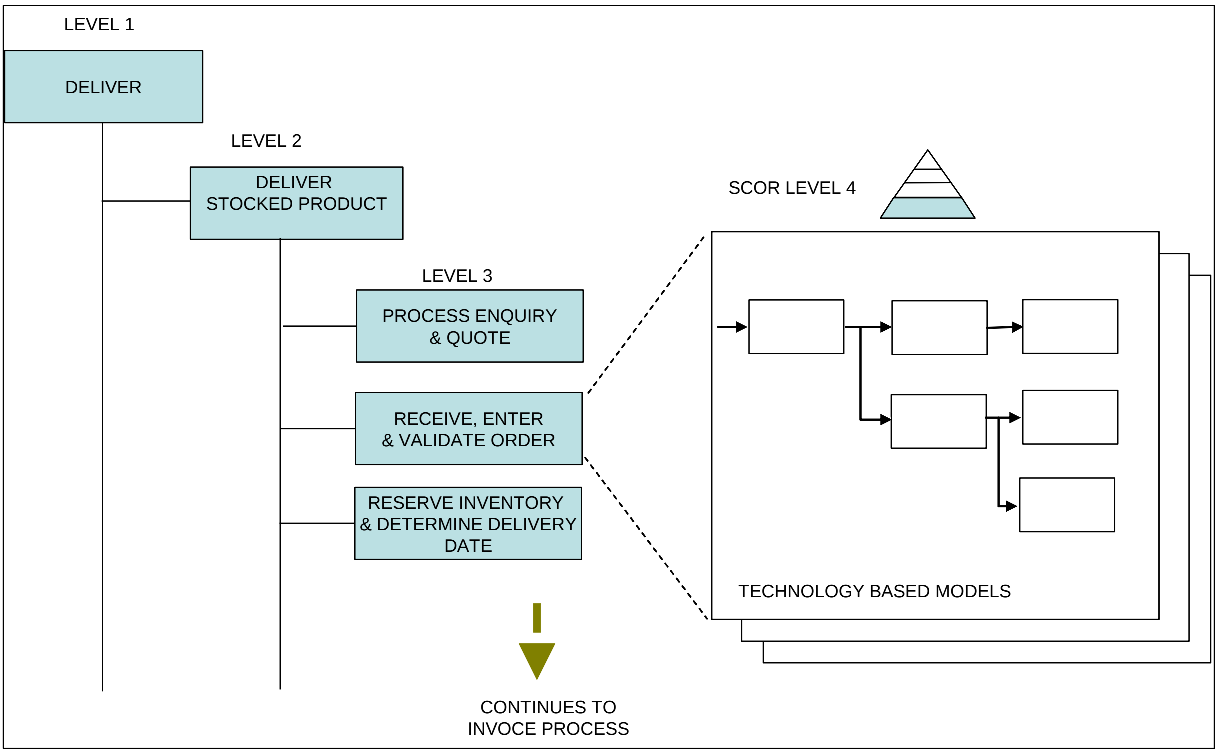

Figure 8: Modelling of specific business processes at different levels (Source: de Souza et al., 2011).

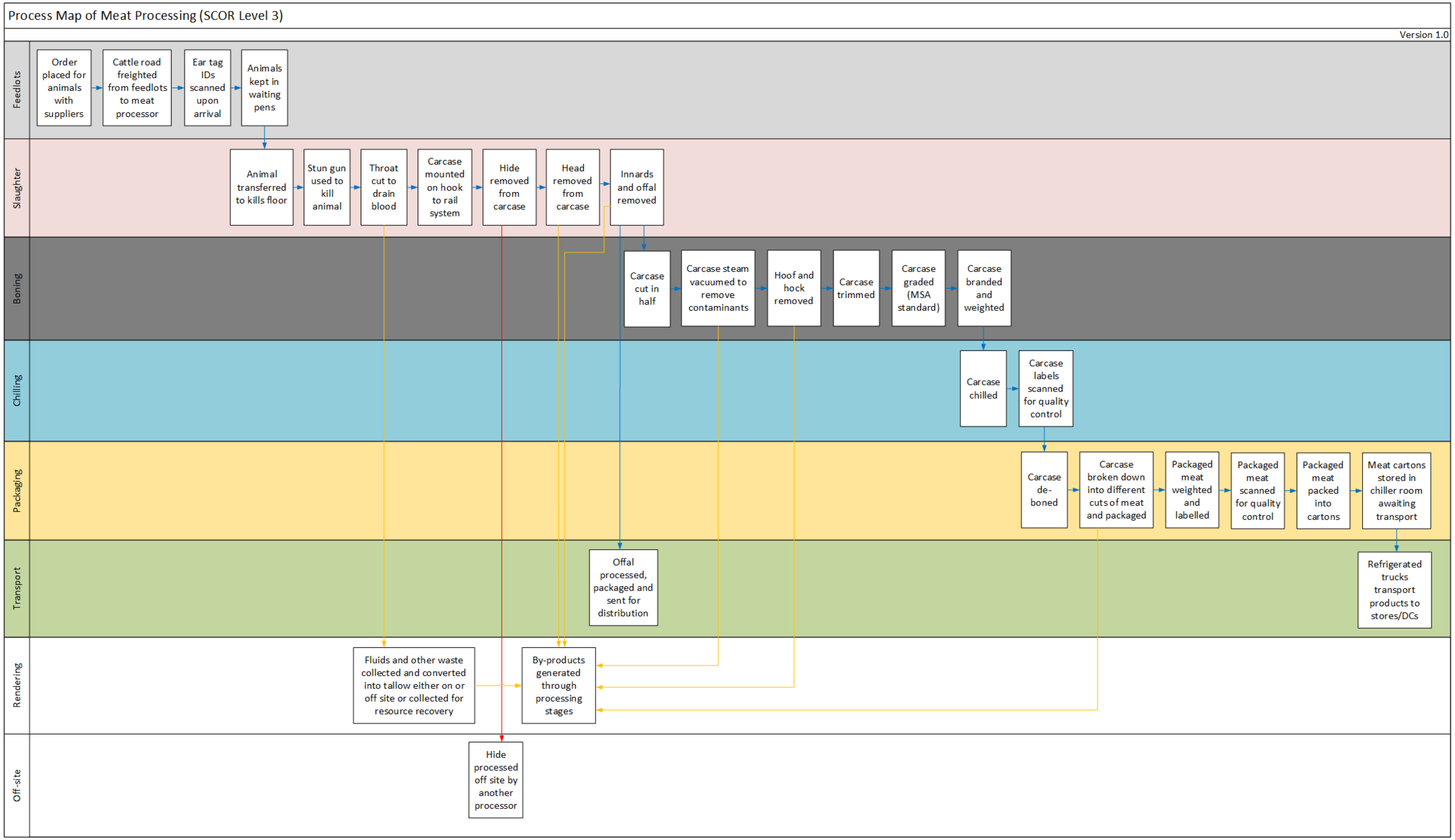

Figure 9: Process map for the “as-is” model.

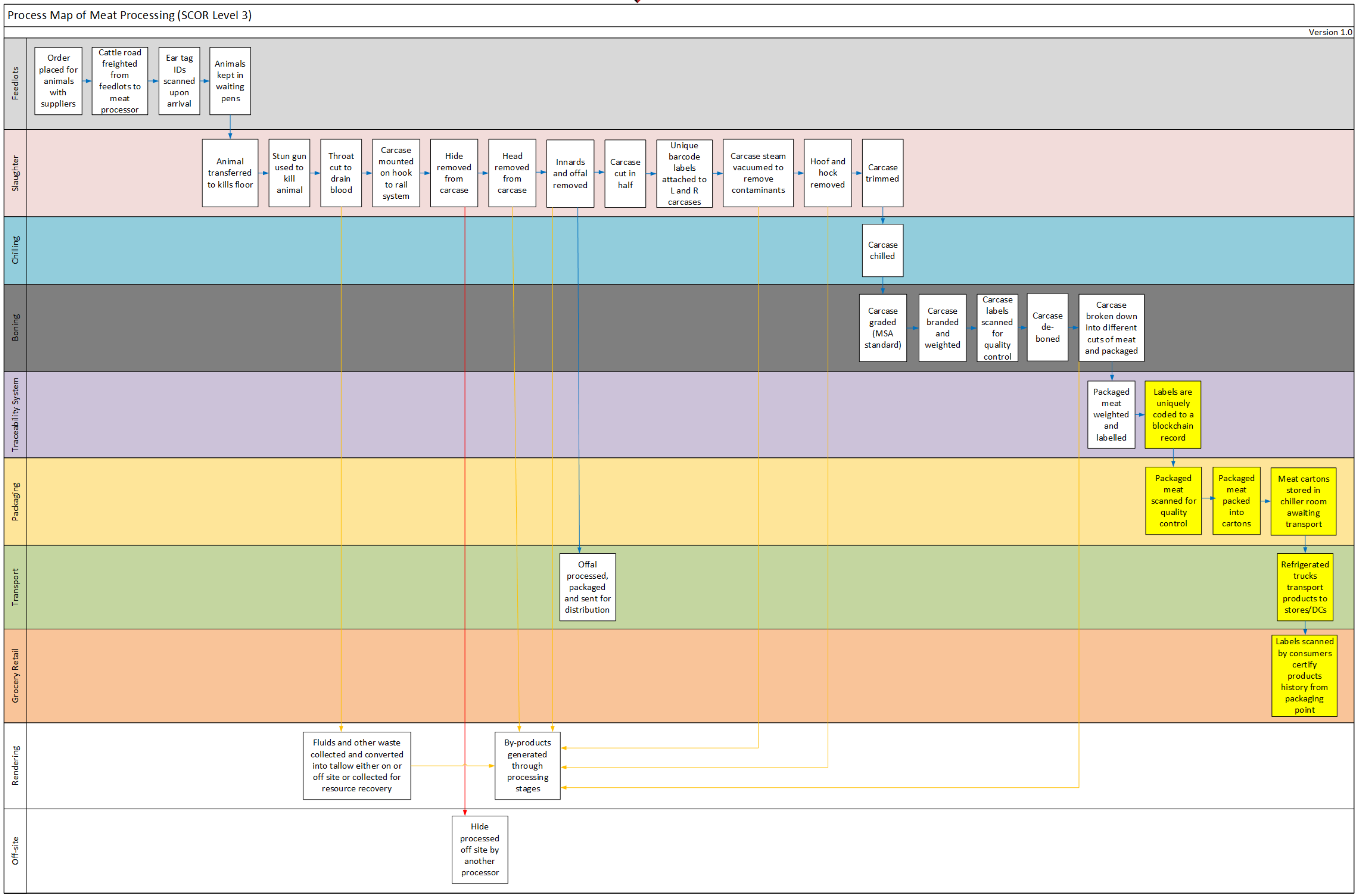

Figure 10: Process map for the "to-be" model with batch level traceability.

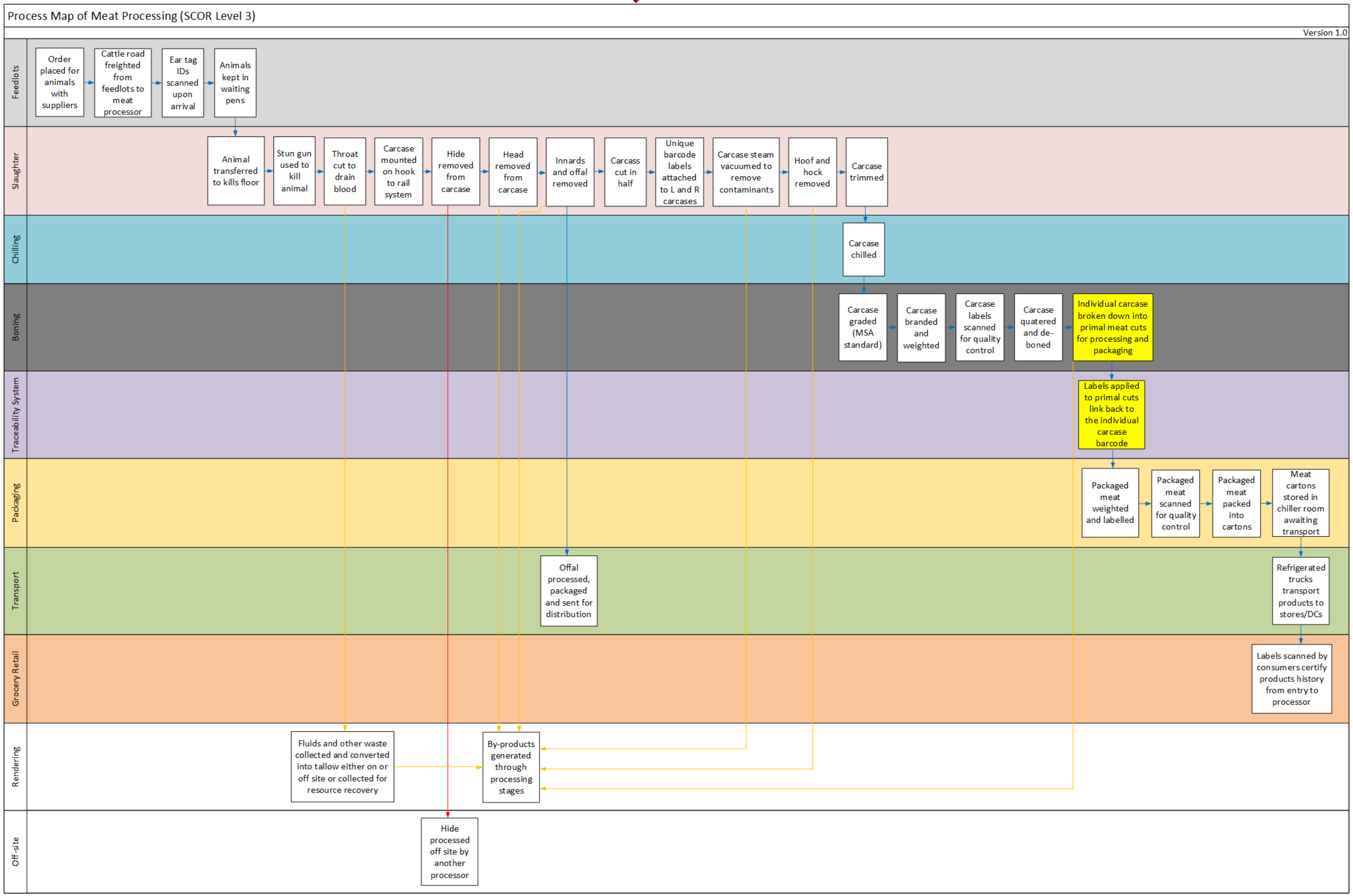

Figure 11: Process map for the “to-be” model with one-to-one traceability.

9.3. Appendix 3 – Cost Parameters and Benefit Components in the ROI Analyses

Cost parameters included in the ROI calculation included a few sections where the cost and benefits of similar nature are grouped together. Using Table 3 as one example, which provides one output from the ROI analyses where RFID technology was used to enable one-to-one traceability while barcodes were applied at the primal cuts' level. Specifically, these sections include:

- Plant parameters:
  - Cost of labour as hourly rate. The cost of labour will be relevant when there are differences in processing time between the "as-is" and "to-be" scenarios. Here an hourly rate of $25 is assumed, based on the information provided at https://www.payscale.com/research/AU/Industry=Meat_Processing/Hourly_Rate. As there is no processing time difference in the ROI samples discussed, this cost information has no impact on the ROI results.
  - Cost of capital in percentage. Based on IPART (2018) and KPMG (2018), the cost of capital is assumed to be 10% in this calculation.
  - Plant annual throughput as the number of animals processed per year. The number of animals processed per year will directly affect the average fixed cost per kilogram of processed meat. Here an annual throughput of 150,000 animals is assumed. A sensitivity analysis of annual processing throughput from 20,000 to 300,000 animals is presented later in this report.
  - Carcase weight in kilograms. The carcase weight is another parameter this is similar to the plant throughput, as it also has a direct impact on the average fixed cost per kilogram of processed meat. Here the carcase weight is assumed to be 180 kilograms, based on information acquired during visits to ACC.
- Per head differences: The per head differences summarise the cost and processing time differences between the "as-is" and "to-be" scenarios. Depending on the results, there are two items related to the per head differences. If there is less cost (and similarly for time) incurred for the 'to-be' scenario, the difference will be treated as benefits; otherwise, it will be counted as additional cost (or time).
- Expected system wide benefits: The expected system wide benefits include the potential sell price increase per kilogram, and potential labour cost savings per year that are not captured in the boning room. These benefits are listed here to allow the meat processors to include such benefits when planning for their investment. In the two ROI analyses, one of them considers the potential labour cost savings.
- Fixed costs:
  - System integration. The system integration costs include the installation of equipment, as well as the one-to-one traceability information integration into existing information systems. It should be noted that the training to boning room operators could also be incorporated in this cost entry. Obviously, these costs represent a high percentage in terms of the fixed costs. In the two ROI analyses, a baseline figure of $300,000 was assumed (incurred in year 1). The

technology is assumed to have a functional life of 5 years (which is the reason for the 5-year analysis period) in the ROI analyses conducted in this report. Longer functional life could be easily established. Given the high sensitivity of this cost component, a sensitivity analysis is conducted for fixed costs in the range of $100,000 to $1,000,000.

- System maintenance. System maintenance costs include both hardware and software maintenance that are needed to ensure the proper operations of the one-to-one tracing system. An annual cost of $10,000 is assumed for Years 2 to 5.
- Reader/writer to transfer data from barcodes. Cost data was sourced from https://www.atlasrfidstore.com for one reader/writer at $2,385 (US$1,600). This reader/writer will be deployed when the quarter carcases enter the boning room.
- Tags attached to trays. Data was sourced from https://www.atlasrfidstore.com. Here we assume there will be 180 RFID tags with a unit price of $2.23 required to be attached to the trays. The number of RFID tags required will be dependent on the number of animals processed and how quickly the processed products are circulated in the boning room. A quick circulation will enable prompt reuse of trays (once emptied) and therefore require fewer tags.
- Readers/writers at workstations. Data was sourced from https://www.atlasrfidstore.com. Here we assume there will be six workstations, with each workstation equipped with one RFID reader/writer at unit cost of $2,385. In total, they cost $14,307 as Year 1 fixed cost. Again the number of readers/writers required in this part of the process will depend on how many workstations are to be set up.
- Tags for workstation trays. Data was sourced from https://www.atlasrfidstore.com. Here we assume there will be 100 tags required at a unit price of $1.77 (incurred in Year 1).
- Reader to transfer data from tags to system. Data was sourced from https://www.atlasrfidstore.com. Here we assume one RFID reader is required with a unit cost of $2,385.
- Tags on conveyor into vacuum steamer. Data was sourced from https://www.atlasrfidstore.com. Here we assume there will be 100 tags required with a unit cost of $1.77 (incurred in Year 1). The number of tags required in this case will depend on the length of the conveyor and the frequency of trays from workstations being transferred to the vacuum steamer.
- Reader to transfer data to barcodes. Data was sourced from https://www.atlasrfidstore.com. Assuming one reader/writer is needed at a unit price of $2,385 (incurred in Year 1).

- Variable costs: The variable costs summarise the total additional cost (if the one-to-one traceability system requires additional cost per head) and the total additional processing time (in dollars). As these costs are based on the per head cost and processing time differences, the throughput will play a key role in determining these numbers.
- Benefits: The potential benefits will be explored further in Milestone 7.

- Total expected price increases. The total expected price increases assume that there will be a possible price increase to absorb the investment incurred by the meat processing industry. They are controlled by the sell price increase per kilogram, the throughput, and the carcase weight.
- Total expected labour cost savings. This entry refers to potential labour cost savings as a result of using the one-to-one traceability system. For example, if RFID tags are attached to primal cuts, the efficiency of sorting and packing of products might be improved and thus create cost saving opportunities.
- The last two entries in the benefits section summarise the total cost savings (if the one-to-one traceability system saves operational cost per head) and the total processing time saving (in dollars) per head. As these benefits are based on the per head cost and processing time savings, the higher the throughput, the more the benefits.

It should be noted while the above cost parameters and benefits try to cover all the aspects for the ROI analyses, there might be areas that the research team have not considered, or the cost estimations are not accurately reflecting actual implementation costs. To address this issue, sensitivity analyses have been conducted on some of the key parameters to cover a wider spectrum of the ROI analyses. It should also be noted that the total costs of RFID readers/writers and tags in the fixed cost category will be dependent on the size and layout of the processing facility. That said, given the relatively low percentage of such costs in the fixed cost component, they, though pivotal in establishing the one-to-one traceability, would not have a significant impact on the ROI analyses.