Final report

P.PSH.1290 Review of Advanced (Livestock and Carcase) Imaging Technologies

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Abstract

A global scan of existing and emerging visioning and sensing technologies was undertaken to understand the types of capability that are becoming accessible and could support the industry's strategic goals to increase the value created from every animal by 3-fold.

A design led approach was taken to understand the problems worth solving, in contrast to technology scans that often list tools and inventions but don't apply them to innovations that require a wide range of enabling capabilities to create real commercial value.

An overview of the functions, tasks and processes currently undertaken along the red-meat supply chain were then assessed and mapped to identify problem areas (opportunities) that could increase industry value. Value lenses included labour saving, staffing attraction and retention, improved alignment of supply chain outputs to consumer needs to increase value, and enhanced decision making to increase productivity and return on inputs.

Opportunity areas were then prioritised considering value of impact along the supply chain. Factors impacting adoption were also considered in consultation with industry participants.

Project observations demonstrated that commercial engagement in research and development with a focus on extension (adoption) requires a clear vision at the outset. Bigger, bolder problem spaces that communicate a step change in capability and value are more likely to engage the right mix of participants for wider adoption. These bold solutions usually require integration of a broad range of technologies and enabling capabilities. A parallel project has also been undertaken to assess Assistive Technologies. This report heavily integrates the findings from that project in the recommendations.

The development recommendations for Visioning and Sensing, in conjunction with Assistive technologies and other enabling capabilities outline priority development programs for extensive and intensive livestock production.

Executive summary

Background

The Australian red-meat industry is a global leader in meat exports in terms of food safety, eating quality and product value. As a net exporter of beef, sheep, and goat meats and one of the largest meat exporters with greater than 70% of production consumed overseas, the need to be globally competitive is paramount.

Technology and 'widgets' are continuously being developed and refined to improve efficiency, worker longevity and safety, quality of products and ultimately business profitability. Technology adoption is not necessarily aligned with its potential benefits as it may not fit into current infrastructure available or the implications and benefits on the whole system may not be understood or well-articulated. A range of assistive technologies and visioning systems were reviewed for the beef and sheep supply chains from the perspective of research, application and adoption.

In the past five to ten years a range of technology has been deployed on farm and in processing plants. This has led to the collection of large quantities of data. The focus now needs to be on analysis of data and creating information which informs operational and strategic decisions to optimise business processes. The results of this research are presented to identify business processes and decisions – what's not available now and what is required for this to be commercially available based on availability of existing products and their ability to provide accurate and reliable data. This report provides insight into areas where research, development and extension will assist the red meat industry to enhance continuous improvement and adoption of R & D initiatives.

There is a shortage of skilled staff at the processing plants, on properties and industry service providers (large animal veterinarians, nutritionists) as well as a general labour shortage in meat processing facilities. Future research and development activities related to application of technology need to assume high staff turnover and lower inherent skill levels.

Of note, despite being one of the leading meat export countries, Australia has the highest cost of processing, predominately driven by high per unit labour costs and very high energy costs. Specifically, when compared to major competitors, processing costs in Australia were 24% higher than the United States, 75% more than Argentina and 100% higher than Brazil. Labour-related charges are the biggest area of disparity (Cost to Operate and Processing Cost Effectiveness reports "AMPC 2017-1062"). Research and development that clearly translates into commercial solutions to these challenges is paramount.

Objectives

The objectives of the project were to:

- Identify, assess, prioritise for commercial application
    - Relevant technologies from outside the industry
    - Potential service providers
- Determine solution desirability within industry
    - Readiness for value propositions from visioning-driven solutions
- Build a progressive adoption strategy for red meat companies throughout the project
- Define a business model, relevant to solution providers
- Determine the business case and approximate financial value to the industry
- Design pilot projects for implementation outside this project

This report describes the findings from the research undertaken and achieves these objectives.

Methodology

Desk top research was undertaken reviewing previous assistive and visioning technology projects in the red meat industry. A list of technologies currently available or deployable to the red meat industry was developed and each of the companies supporting the deployment and development of these technologies was reviewed. Interviews were conducted along the supply chain with large commercial companies to understand what technology has been trialled and or is in use, and where the current gaps are regarding commercially available and viable solutions. Analysis was undertaken from a whole of value chain perspective to prioritise areas requiring RD&E which offer potentially the greatest gains from yield improvements and labour efficiency perspective.

Results/key findings

Suppliers of technology often focus on their technology. Before deployment of a technology questions need to be asked:

- What decision or process is this supporting?
- Does it fit into culture, strategy and value proposition for the target markets?
- What additional value does the widget create over current processes?
- If data is created from the widget, how and who is analysing the data in a timely manner to support the decision process?

From an RD&E perspective, questions include:

- Does the technology work in the existing system?
- If system changes are required, is this a completely new system or can it be adapted?
- Does the technology offer opportunity, however exact deployment of where and how it will work needs further investigation (this is taken as needing ‘development’)
- Does the technology work, but companies are unsure if they will invest? What is the reason behind the hesitancy?

Benefits to industry

The project has reviewed an extensive number of existing technologies from cobotics to automation to robotics and identified key areas and technologies which have the ability to improve profitability and productivity for the entire red meat value chain in Australia. Labour availability and cost of labour is and will continue to be, a major resource constraint. This report identifies pathways and areas to focus future RD&E funds to maximise benefits.

Future research and recommendations

Bigger bolder innovation projects are required to seize the value opportunities industry is identifying. This requires implementation of RD&E in a way that enables bigger bolder inputs to create significantly greater return for the Australian red-meat industry. Avoiding a shotgun approach to R&D innovation is required and needs very structured guidance to ensure transformational change. A more integrated approach to integrating visioning and assistive technologies in the following areas is recommended:

- Integration of Objective Measurement (OM) technologies along the entire supply chain
- Integration of decisioning support for supply chain alignment
- Development and adoption of technologies to enable supply chain alignment
- Development and adoption of technologies that create productivity gains

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1. Background

1.1 Strategic considerations

The Australian red-meat industry is a global leader in meat exports in terms of food safety, eating quality and product value. As a net exporter of beef, sheep, and goat meats and one of the largest meat exporters with greater than 70% of our production consumed overseas, the need to be globally competitive is paramount. Research and development investment in the red meat industry has enhanced the effectiveness, competitiveness and sustainability of the industry supply chains while meeting consumer needs. Meat Standards Australia's eating quality system and lamb processing automation are two examples of commercial successes.

The red meat industry strategic targets are for the supply chain to be carbon neutral by 2030 and to double the value of sales of red meat. On a farm production side, increases in kilograms of meat gained per animal over a timespan on a rangeland grazing system correlates to decreased carbon emissions. Understanding which animals to select to match market specifications, which paddocks to graze and rest, and which animal are providing a calf every year assists producers to improve profitability. This report will consider the different levels of sophistication in which data can be collected to assist in decision making.

For data to be useful it needs to be analysed and converted to information in a timely manner which then assists producers and technical advisors to make decisions. The cost of obtaining this data (the initial outlay, ongoing fees, staff hours required and maintenance of infrastructure) needs to be outweighed by the additional benefits in accuracy and previous unrealised insights.

When reviewing advanced technologies an underpinning factor is a labour force which is diminishing in terms of people interested and willing to undertake manual work, as well as highly skilled professionals such as butchers and station managers. In addition to a small labour pool from which to draw staff, labour costs are relatively high compared to Australia's competitors on a global scale.

1.2 Emerging capability inventions

Technology and 'widgets' are continuously being developed and refined to improve efficiency, worker longevity and safety, quality of products and ultimately business profitability. Technology adoption is not necessarily aligned with its potential benefits as it may not fit into current infrastructure available or the implications and benefits on the whole system may not be understood or well-articulated. A range of assistive technologies and visioning systems were reviewed for the beef and sheep supply chains from the perspective of research, application and adoption.

In the past five to ten years a range of technology has been deployed on farm and in processing plants. This has led to the collection of large quantities of data. The focus now needs to be on analysis data and creating information which informs decisions to optimises business processes.

1.3 Converting inventions into industry innovation

The results of this research are presented to identify business processes and decisions – what's not available now and what is required for this to be commercially available based on availability of existing products and their ability to provide accurate and reliable data. This report provides insight into areas where research, development and extension will assist the red meat industry to enhance continuous improvement and adoption of R&D initiatives.

Learnings from commercial technology developments over the past few years has highlighted the importance of collaboration in problem solving and the impact that right company fit has on successful technology integration across multiple disciplines. For this reason, non-technology drivers of capability and adoption with whole of supply chain considerations has been included in the assessment matrix.

1.4 Assistive Technologies Introduction

Complexity requires human intervention

Compared to pork, lamb or chicken, the beef industry stands to gain the most from 'cobotic' technology. The human factor is integral to the processing of beef. Larger primal cuts are removed by knife from the skeleton and each other, rather than straight saw cuts through meat and bone. This involves dynamic adaptation of knife to cutting line on a cut-by-cut basis. This requires more complex vision and sensing than is currently possible to fully automate. Full automation of these tasks is estimated at 10 – 20 years away.

The industry trend is toward more detailed sub-primal breakdown, increasing the complexity of visioning. One processor stated that carcase breakdown has moved from 25 to 100+ knife cuts per carcase over the last 30 years (personal communication). So, the need for dynamic manual assist skills will at least remain the same if not increase over time.

Benefits of cobotics over automation

Changing market conditions and consumer demands are a consequence of the world we now live in. Global market perceptions, demands and agility to respond in the face of increased worker expectations impact on a business's competitiveness. The cobotics approach is more flexible to respond than the automated approach where fewer cuts are done more accurately and at higher speeds.

A number of other considerations should be taken into account including the following:

- Cobotics would provide the plant with an increased labour pool by including workers who may have knife skills but less physical strength.
- Younger generations are likely to engage quickly with the technology and see it as a positive work experience in what has not been an attractive environment for them.
- The capability of the technology to work with human intuitive movement means that it can adapt to change as quickly as the operator can.
- If further developed as a technology platform (per the commercialiser's original objectives), the device would have a number of end effectors with only limited reengineering and retraining of staff before it is able to be effective and productive. This has advantages over multiple unrelated cobotics solutions in terms of maintenance, parts and R&D extension on base technology.
- The larger and more automated technology systems come at a much greater capital cost and can require more floor space than cobotics that impact less on existing processes.
- Fully automated systems have a greater business impact with any system failure. For example, workers using Hook Assist could simply continue with manual operations if a breakdown occurred.

- Boning skills are highly valued by operators and the Hook Assist allows these skills to be amplified as a benefit to the plant rather than removed and replaced by a tool which at present don't have the visioning and sensing capability to replace some of the harder manual jobs.
- Small and large company needs: large capital projects will not be suitable for all plants due to space, capital budget and other constraints.

2. Objectives

The projects objectives were to:

- Identify, assess, prioritise for commercial application
    - Relevant technologies from outside the industry
    - Potential service providers
- Determine solution desirability within industry
    - Readiness for value propositions from visioning-driven solutions
- Build a progressive adoption strategy for red meat companies throughout the project
- Define a business model, relevant to solution providers
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- Design pilot projects for implementation outside this project

Relevant technologies and potential service providers from an entire value chain perspective were reviewed to understand application and use of technology needs to consider company and supply chain strategy, company culture, resource constraints including existing infrastructure and labour.

All objectives were achieved with the results, findings and recommendations provided in this report and associated annexes. Travel restrictions due to COVID were a barrier to engaging some companies and meeting to unpack detailed solution findings. The approach was adjusted from the original technology led focus to a problem-solving methodology. This inadvertently reduced the need for field visits and provided a more robust set of future development recommendations as a result.

3. Methodology

3.1 Integrated technology approach

Industry solutions require the integration of technologies for most commercial solutions.

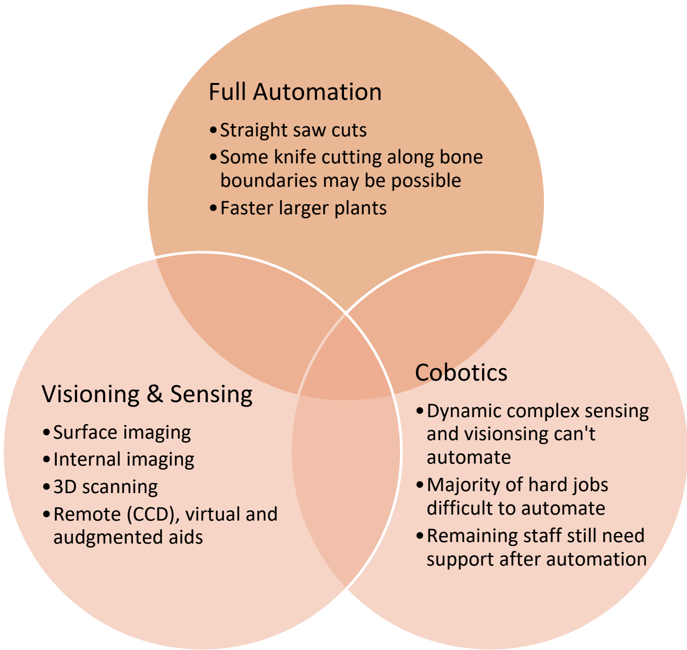


Figure 1: Integration of solutions is required

3.2 Overarching Methodology

The researchers started with an extensive search of the technology available in assistive technologies and visioning systems. The next step was to review the literature on research, development and application of the technology available. Technologies were then categorised based on their commercial viability, likelihood of value creation and willingness to be adopted in the red meat industry. Interviews were conducted with industry and project staff working in beef and lamb automation and large commercial on-farm operators on their experiences with technology.

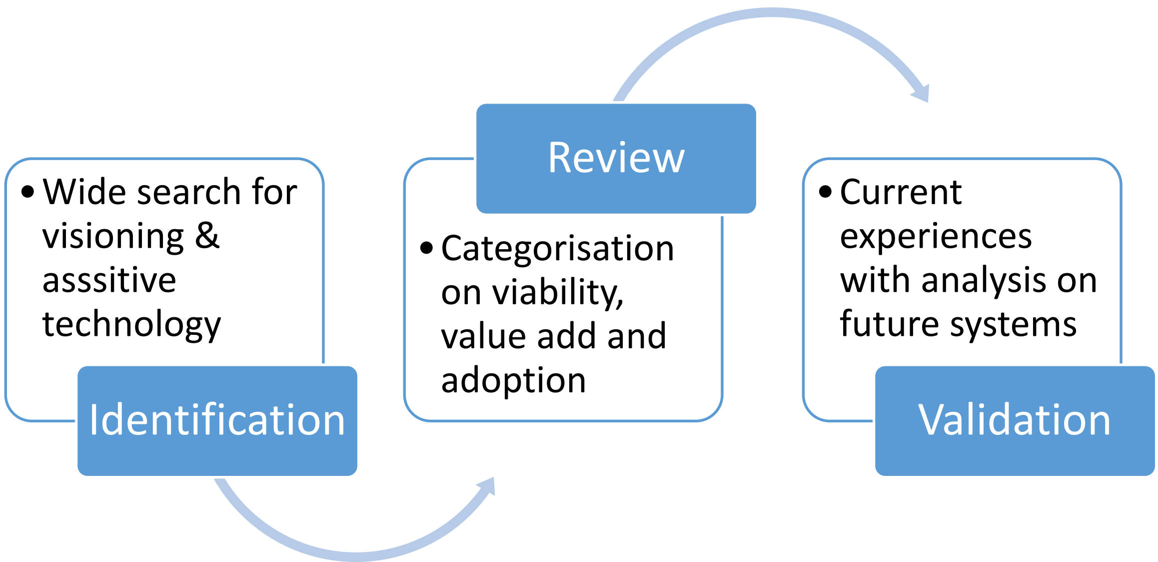


Figure 2: Overarching Methodology

The researchers started with the technology and reviewed to identifying what will add value. When conducting the final analysis to identify findings and recommendations the focus switched from the technology itself to the purpose, issue or decision it was addressing. Consideration was given to how the technology fits into the value chain, integrates with other technology and addresses future challenges, resource constraints and opportunities with value-based pricing and marketing.

3.3 Identification

3.3.1 Identification of technology

Technologies were identified from several sources:

- Desktop research: initially focusing on current state industry operations, then expanding focus to research leading technology across all industries for both visioning/imaging & robotics/assistive
- Previous MLA project work (providing an indication of technology types based on R&D into current technology)
- Leverage of existing Greenleaf work around technology applications and their relevancy to industry jobs

- Identification of the technologies that could potentially contribute to solving each job (either in full or as part of a broader multi-technology solution) based on interviews with industry experts.

Refer to Appendix A for the list of technology identified along with firms' details.

The list of companies was compiled in several phases:

- Phase 1: research into leading edge solutions that fall under 'visioning/imaging' or 'robotics/assistive'
- Phase 2: specific research into companies that would address individual jobs, i.e. single-purpose automation systems that could be developed into a fit-for-purpose solution for the single job

The list of companies in Annex C is not a comprehensive list of all companies operating in the visioning/imaging and robotics/assistive technology industry. The list was compiled with the intent of evaluating each individual technology category, the capabilities within each category and representing this with a set of companies of varying size and maturity. Where a technology category was under-represented, further research was carried out to identify companies that could fill the void.

3.3.2 Identification of processes and tasks

At its core, the industry has a set of discrete processes and tasks; for example, a tag scan in the production sector aims to build traceability, a certain knife cut produces an outcome. In undertaking this research, the focus was questioning what the optimal method for scribing is and cutting, which results in an end product that meets product specifications and results in a high value product.

To communicate the industry vision for a process to prospective partners, they need to be equipped with the detail of what the industry process entails. With that in view, the research team aimed to develop process breakdowns with associated questions to focus partners on the automation direction for that process. A list of On-farm, Feedlot and Processing / Abattoir processes can be found in Appendix B.

The list of key processes and tasks was built using several sources including:

- Internal workshopping with stakeholders: high-level process mapping of industry operations and breaking the operation into individual components and processes.
- Industry case studies that have sought to illustrate what a fully optimised operation looks like for on-farm, feedlot & processing operations.
- Previous project work in which Greenleaf Enterprises were engaged in where key pain points which could be solved through the development of commercially viable technology applications.

3.3.3 Review of Solution Providers

The review of solution providers was undertaken using a list of companies and criteria to assess the feasibility of the companies for prospective partnership with the red meat industry. Further validation of company viability occurred through direct contact with companies of interest (based on the initial criteria and value proposition assessment) to gauge their interest in developing solutions in collaboration with red meat industry stakeholders.

The list of criteria used to determine viability of each company was subject to repeated revision and fine-tuning. Several criteria were initially used that did not yield additional value for example:

- Quick to innovate and develop solutions - while a useful criterion in theory, it is not feasible to determine this consistently through desktop research due to the lack of publicly available data on this matter. This can only be accurately uncovered through direct contact with companies - asking questions around their delivery history, standard project timeframes for technology updates of different sizes, etc.

- ‘Leaders in innovation’ status - due to the nature of the research, most companies were found to be leading innovators, based on independent reviews: e.g. Fast Company ‘Most Innovative Company’ status, industry innovation awards, patent portfolios and ‘breakthrough technology advancements’ delivered.

Therefore, the criteria scoring transitioned from being the ‘single source of truth’ regarding company viability to a contributing input into the overall value proposition of each company.

3.4 Review

3.4.1 Technology Adoption

Historically, industry research and development of technologies which have a potential to add value have taken a technology focused lens. Where technology has delivered results success is underpinned by both technology capability and application. However, commercial adoption of that technology involves many other aspects which are often overlooked. This indicates to some degree why commercialisation (commercial adoption) of technologies in the meat industry has room for improvement.

The traditional approach has seen innovation as:

- Observe a new technology outside industry
- Testing the technology [ZZZZ] (assuming a technology provider, [YYYY] provides it) to see if it can perform
- Asking ‘Can we <u>*now*</u> apply this to [XXXX] process?’
- Assuming “Yes” to the above, “We’d like a *solution* output”.

Although this is an important component of success, and what we will refer to in this methodology as “Feasibility”, this research focused on solutions that were likely to be adopted considering other required factors in conjunction with assessing the technologies themselves. The methodology utilised addressed the desirability, feasibility and viability.

1. Determine *desirability*
    a. ‘How keen is industry to see [XXXX] process revamped/replaced/integrated?’
    b. What is the value proposition for each solution? For example, do people desire this solution and how much do they desire it, relative to other solutions?
2. Determine *feasibility*
    a. ‘Is there a combination of technologies (of which [ZZZZ] is only one; e.g. CT-Scan + Robotic Arm = 2 technologies) which can address [XXXX]?’, noting this is not about a technology, but the integration of technologies to create a commercial solution.
    b. What impact does this solution have on other processes?
3. Determine *viability*
    a. ‘Is there a provider ($[YYYY]_1$ or $[YYYY]_2$) who, irrespective of present capability, is willing to go the distance in commercialising this solution (not just the core

technology), and developing, or integrating other providers capabilities as necessary?

b. Is the provider (s) willing to push and pull with MLA and industry recipients (producers and processors) over re-configuration of deliverable specifications required for a commercially viable solution?
c. Is there a processor/producer who is willing to act as a test-site to support development?
d. Can the solution be delivered in a way that incentivises the provider to develop, invest and support appropriately, and in line with a business' expected return on investment?

The idea is that a provider $[YYYY]_1$ is not special and can be replaced by a sufficiently eager competitor $[YYYY]_2$ who is willing to develop their expertise and business model to support the solution. Furthermore, if the client is willing to provide enough direction, instruction and correction, the growing pains of such an evolving venture will result in a successful product, fit-for-purpose. Such a product will directly solve the issue presented in the *desirability* phase, streamlining adoption to traditionally conservative processors and producers.

3.4.2 Assessment Tools

When assessing technologies, it is important to consider the aspects of desirability, feasibility and viability requires integration of a wider range of factors. These factors all interact and impact in varying ways on the best approaches to progress after this project. A number of assessment methods were designed to support identification and capture of new value, and decision-making in this project. A tool utilised to support decision making when designing and apply research and development is the Figure 8 test, learn, reapply process as described in Figure 3.

Design & Test Process

The Design and Test process is an iterative design-led development process, summarised in Figure 3. This model enables R&D projects to acknowledge unknowns while moving forward by holding the project in a rigorous, manoeuvrable test and learn process allowing the program to adapt and pivot as required. Although this method is used in much longer projects it can be equally adapted to short projects and design sprints and will generally guide this project.

A targeted set of outcomes must be agreed upon for the Design, Test and Learn (and if required, Pivot) process to be effective. They enable the project team to remain focused on project outcomes whilst remaining flexible in design. This flexibility is necessary to achieve commercial deliverables fit-for-purpose, not fit-for-design.

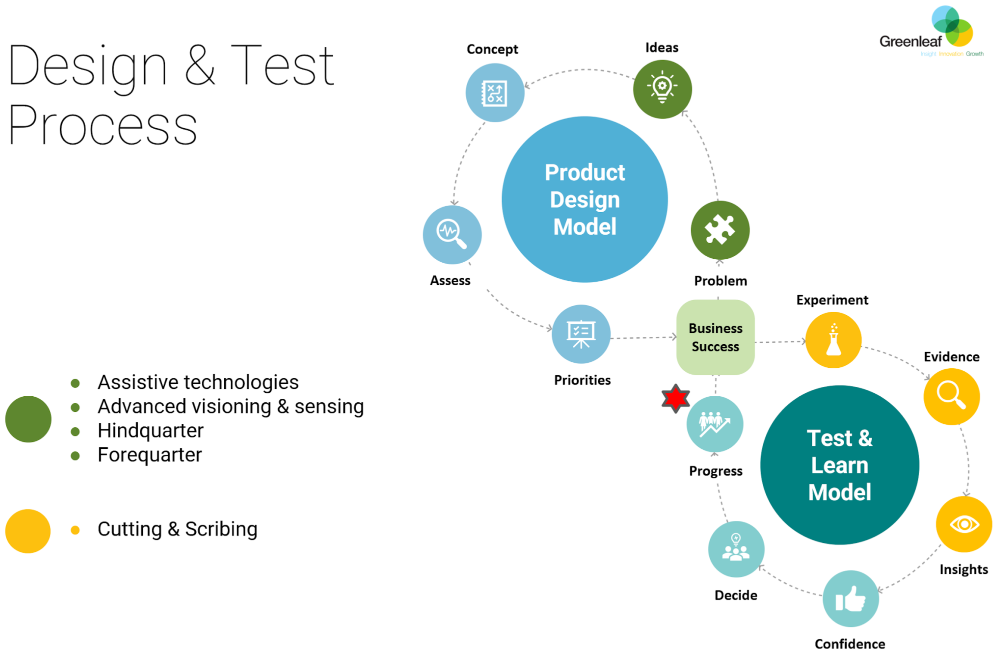


Figure 3: Design & Test process

3.5 Validation

The data collected for quantifying the value propositions for robotics, co-biotics and automation of beef and lamb cutting, boning and scribing in this project has been collected through site visits and using previously completed projects on value proposition in the industry for each processing theme. The references used are shown in Table 1. These references were mainly used to populate the yield benefits for specific cutting lines. In addition to these references two site visits were undertaken, at a beef and sheep/lamb processing facility. The labour requirements for these plants were collected for all the processing themes included in the model.

Table 1: Review of cost benefit reports used to support value proposition development

Report title	Reference
P.PSH.0888 - Lamb and Beef X-Ray Data Extended OCM Benefits and Transportability for Cutting Beef	Brickell, et al., 2018
P.PIP.0443 - RFID Traceability of Lamb Carcase from Slaughter to Boning	Bryan, et al., 2015
Cost Benefit Analysis for Combined Splitting and Spinal Cord Removal	Fanning & Green, 2017
A.CIS.0034 - Ex-ante scoping options for LEAP V	Green & Bryan, 2014
P.PIP.0327 - LEAP IV lamb middle cutting, Ex-Post Review	Green & Bryan, 2014
P.PSH.0629 - Lamb middle cutting system, Ex-Post Review	Green & Bryan, 2015
PSH.0579 - Ovine Robotic Kidney Fat Removal System	Green, 2013

P.PIP.0387 - Ex-Ante CBA for Automated Goat Cutting,	Green, 2013
P.PSH.0579 - (Milestone 5) - Ovine Robotic Brisket Cutter, Ex-post Review	Green, 2013
P.PSH.0579 - Ovine Robotic Dual Sani Vac, Ex-post Review	Green, 2014
P.PIP.0320 - Commercial Evaluation and Viability of Lamb Water Frenching	Green, et al., 2013)
A.TEC.0093 - Picking, Packing and Materials Handling Review	Green, et al., 2013
LEAP III Ovine X-ray Primal Cutting System	Green, et al., 2013
P.PIP.0327 - LEAP III Ovine X-ray Primal Cutting System	Green, et al., 2015
A.PIA.0124 - Cost Benefit analysis of customised manual assist equipment installed in two plants for aitch bone removal and knuckle pulling	Greenleaf Enterprises, 2009
P.PSH.0335 - Beef Aitchbone and Knuckle Puller	Greenleaf Enterprises, 2009
P.PSH.0557 - The potential value of individual carcase identification and automated chiller sortation for an Australian lamb processor	Greenleaf Enterprises, 2010
Beef Loin Deboning Manual Saw Semi-Automation	Greenleaf Enterprises, 201)
P.PSH.0361 - Chine machine	Khodabandehloo, 2011
A.SCT.0047 - 2D, 3D & CT x-ray based scanning for measuring meat parameters	Meat and Livestock Australia, 2019
P.PIP.0470 - Beef Trim Management & Blending System,	Nicolaou, 2018
V.TEC.1704 - DEXA System estimations for red meat industry	Shirazi, et al., 2019

High level business case analyses was conducted on priority areas identified from the processor site visits and in conjunction with solution providers. The review considered issues, gaps, risks, solutions and recommendations that are applicable to a range of plant size, throughput, speeds of operation, configuration and products.

Processors in each of the following categories were consulted within the project, as well as site visits to five processors within these categories.

Plant	Plant Type	Species	Notes
1.	Medium Volume	Beef /Lamb	Mixed species
2.	Medium Volume	Beef	High number of product Stock Keeping Units (SKUs)
3.	Medium Volume	Beef	Relatively low number of product SKUs
4.	High Volume	Beef	
5.	High Volume	Lamb/Goat	

Based on the review and analysis of technology and widgets combined with the value proposition, feasibility, desirability and validity, a number were identified and then reviewed based on where they sit on the research, development and adoption spectrum. In summary, the results and key findings identified (1) technology exists but doesn't add value if used in isolation from business processes and decisions, and, (2) existing technology requires adaptation to operate at speed in extreme environmental conditions such as cold and heat. In some cases, to obtain the full benefit from advanced imaging and sensing technologies remodelling of infrastructure is required; for example, within processing plants and in cattle yards. A detailed description of the results and findings are presented in the next section.

4. Results

4.1 Key findings

Reviewing advanced imaging technologies from the perspective of the entire red meat chain identified technology in the form of imaging in the processing plant supported robotics and co-biotics. If not directly involved in supporting other technology, the advance imaging technologies such as satellite images of vegetative biomass purely creates data which then needs to be ground-truthed, adjusted to reflect actuals and then utilised as part of the decision process with regards to feed budgets and stocking rates. The utilisation and adoption of technology will vary based on the investment required, ease of which it can be incorporated into the existing process flow and the return on investment which can be generated.

Research identified adding a measuring tool which gathered additional data was of little value to the overall system. Management and staff questioning why the technology was deployed as the data is not often analysed. For successful adoption of imaging technologies the tool needs to be part of a change management program which views the system in its entirety which creates value through improved decision making, improved productivity and or an increase in value realised.

The key strategic issues to consider in the adoption of advance imaging technology and co-biotics is:

1. How to better meet the needs of the consumer in areas they are willing to pay for by increasing the value of the product through more precise cutting and scribing
2. How to remain competitive in the global marketplace through differentiating products and utilising technology to optimise labour use

The issues with labour are multi-faceted. Some manual tasks create repeated physical strain on the body. It is important these tasks are re-engineered and reconfigured, with assistive technologies and robotics having a role to play in this space. There is a diminished labour pool, particularly in the meat processing industry with skilled boners and processors in short supply. Skilled head stockpersons and managers required for feedlots and on-farm are available, however, the talent pool is diminishing. Imaging technologies have a role to assist in data collection, however, additional work is required to ensure the data is analysed and available in a user-friendly format to assist staff with a range of skill levels working outdoors in all weather, often without mobile phone network coverage.

4.1.1 Key problem spaces

Key problem spaces where visioning and sensing technology can assist were identified. These include:

On Farm

- Infrastructure, technology, hardware and software currently utilised does not necessarily support decision making.
- Skilled labour shortages and high staff turnover make it difficult to implement best management practices and maintain efficient operations. Most crews are now skeleton staff with one senior and several juniors therefore measurements like weight and body condition score for breeders may not be collected as the focus is on branding and weaning operations.

- Natural resource management isn't optimised, for example measuring, monitoring and predicting pasture growth combined with pasture palatability, quality and quantity often does not occur per land type, pasture species and paddock.
- Livestock Inventory Management is a challenge for large herds, particularly current and future numbers of livestock per class (age/weight/sex/breed/status).

Feedlot

- Livestock are not managed as individuals despite the fact they do not gain weight and marble consistently which impacts performance and profitability.

Processing plants

- The limited and reducing number of skilled boners.
- Shortage of labour which is restricting the ability of plants to collect and pack offal and value add.

Visioning and sensing technology was considered as part of the supply chain and reviewed in how it can address the current issues and assist to create value along the entire chain as shown in Figure 4.

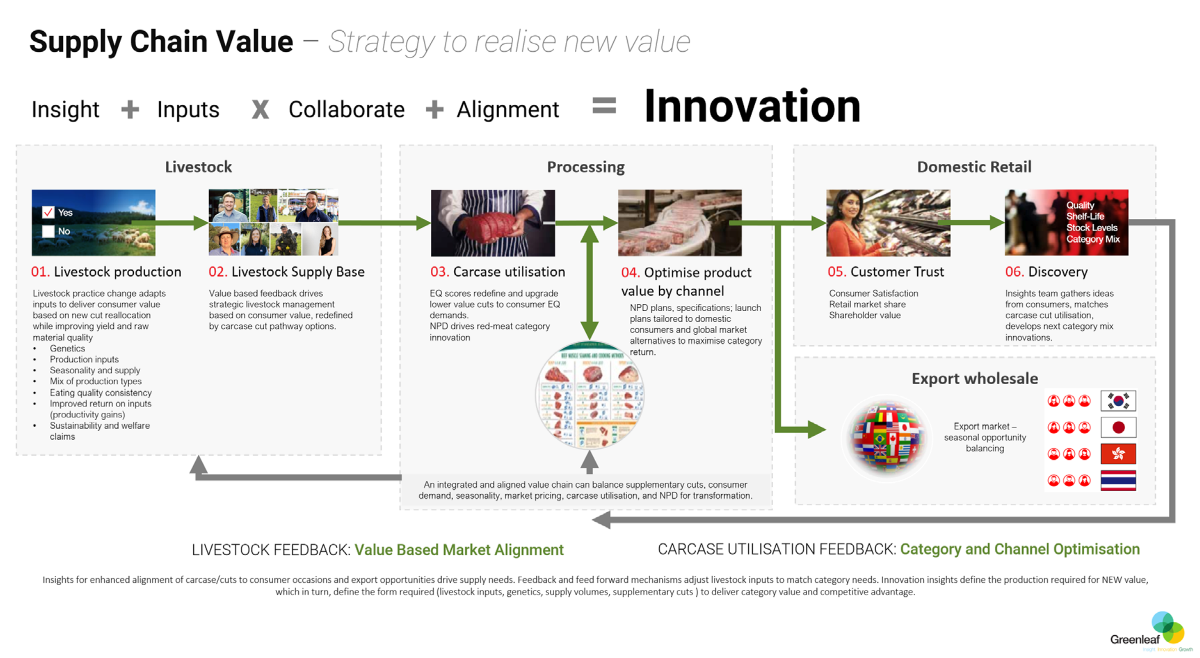


Figure 4: Defining each problem space as part of the interconnected supply chain

4.1.2 Key success factors

This section summarises key factors beyond the technologies themselves that are critical to developing a development roadmap. The project started with a very clear focus on reviewing technologies and technology readiness. The purpose was very clearly to aid in solving industry challenges with the help of new and emerging technologies. However, the project very quickly broadened to consider the translation of technology capability into value and factors like commercial adoption, competitive advantage for adopters, commercial readiness, adopter confidence and engagement to name a few factors, all impacted on the likelihood of properly addressing challenges. Observations were made around previous successes and failures, effectiveness of technology transfer, proportion of innovation driven by technology relative to other success factors.

Assistive technologies

Assistive technology Research and Development (R&D) success has occurred in circumstances where stress on manual operators is significant and the task is simple enough to execute without hindering the persons efforts. Hydraulic pulling and lifting devices, like the Proman and RTL pullers, hinder the operator's free physical movement but relieve physical stress just enough for operators to accept the physical restriction imposed by the technology, but therefore haven't been fully embraced by operators. It was identified these types of assistive technologies have limited long term application across industry. More advanced technologies are required to support people in roles where full automation will not be achievable in the foreseeable future.

Major adoption requires gains to significantly outweigh new limitations – This is an obvious statement but often overlooked. Complimentary technologies that enhance the operators' capabilities to perform the tasks more than the introduced limitations are required to develop commercial solutions, a good example of this is cobotic surgeries in human medicine. These solutions are becoming mainstream because the loss in the surgeon's manual dexterity is compensated by delivering far greater visibility of the anatomy being operated on through enhanced visioning and sensing systems.

Integrating multiple technologies are required for successful adoption – It was identified a combination of technological solutions is often required. For example, a combination of assistive technologies and visioning systems, combined by a technology integrator, has enabled addressing more complex manual processes with cobotic surgeries a good example of this.

Technology specialists or Integration solution providers

Companies with technology specialities are usually not able to, or don't want to broaden their narrow focus to develop a commercial solution. This is often because of business strategy or capability constraints. Integrators that can pull multiple skills together into a solution which addresses the system in which it operates are more likely to create value and provide commercial industry solutions than specialist providers of a single technology. For example, in MLA's beef automation program, Rapiscan is the visioning provider developing the visioning for Scott Automation & Robotics which has the robotic scribing and cutting systems. Companies like Marel and Scott Automation & Robotics combine visioning, sensing, mechatronics, and assistive technology engineering to deliver these solutions. Scott Automation & Robotics, originally a whitegoods manufacturing Automator, has had to become an expert in x-ray technology, waterproofing harsh environments, visioning and complex image analysis.

Many of the industry's R&D projects have had a focus on visioning for collection of data for better decisions. However, this only addresses one of the priority problem areas referred to above.

Solution adoption requires other enablers

Observations throughout the project have highlighted the importance of factors outside the technology capabilities that can limit adoption. The broad development roadmap recommended in Section 6 of this report considers these barriers to adoption. Adoption of proven technologies and R&D recommendations is a very low in northern Australia.

Reasons for this low adoption include:

- Technology delivers data points which need to be integrated into analysis for decision making. Applications which collect and analyse data often rely on mains power, internet connectivity, reliable laptops which don't overheat, modern yard design and highly skilled operators, all of which is a rarity when handling cattle in the yards in Northern Australia.
    - Existing hardware solutions needs to be "ruggedised" so it works reliably in the yards and paddocks with the extreme environmental conditions of hot, cold, contaminants, etc.
    - Existing software solutions need to be able to work off-line (without internet connectivity), delivering analysis and feedback as required.
    - Existing software solutions need to be designed to cope with thousands of animals and multiple staff across a number of properties. This means templates are 'locked down', free text fields are minimised, analysis and back up of data is a simple process.
    - Blue tooth technology which connects technology, for example weighing scales and EID scanners, to a laptop does not work very well due to:
        - multiple connection points, and
        - steel yards and crush interfere with or block electromagnetic fields impacting the blue tooth connectivity, meaning the devices cannot detect or connect.
- Clear return on investment propositions combined with activities to support the change management processes.
    - Where technology can demonstrate value and can be presented as part of a wider company initiative, there is likely to be more support for development and adoption.
    - More effort is required to get engagement, but the adoption issues faced with siloed implementation are likely to be addressed as part of the broader implementation.

Enablers of adoption

A range of additional factors beyond the technologies themselves contribute to adoption barriers and to the defining of the problem space. These enablers include a company vision and strategy which aligns with the use of technology, the value proposition of the new technology is clearly understood, and the product is fit for purpose.

1. Company strategy and vision alignment with benefits from technology applications

Research and development are more likely to be supported and technology is more likely to be adopted when the benefits of the technology align with the firm's strategy and vision. When firms choose to innovate with a long-term vision knowing it will be disruptive, this ultimately can lead to the higher long term gain, as shown in Figure 5.

Company A identified a diminishing labour resource as a constraint. The company strategy focused on optimising the business through improving technology, equipment and processes to make tasks easier and more enjoyable. Staff were asked what jobs they didn't enjoy doing and what areas could be streamlined to reduce manual handling. The company purchased equipment which wrapped pallets, stacked boxes, made boxes and labelled boxes.

On the flip side to the example of Company A, Company B invested in some technologies but did not have a solid company-wide approach. The technology was considered the solution but was not supported by an integrated strategy and value was not created. Company C installed robotic equipment but did not have the technical skills to support with outcomes being worse than pre-installation.

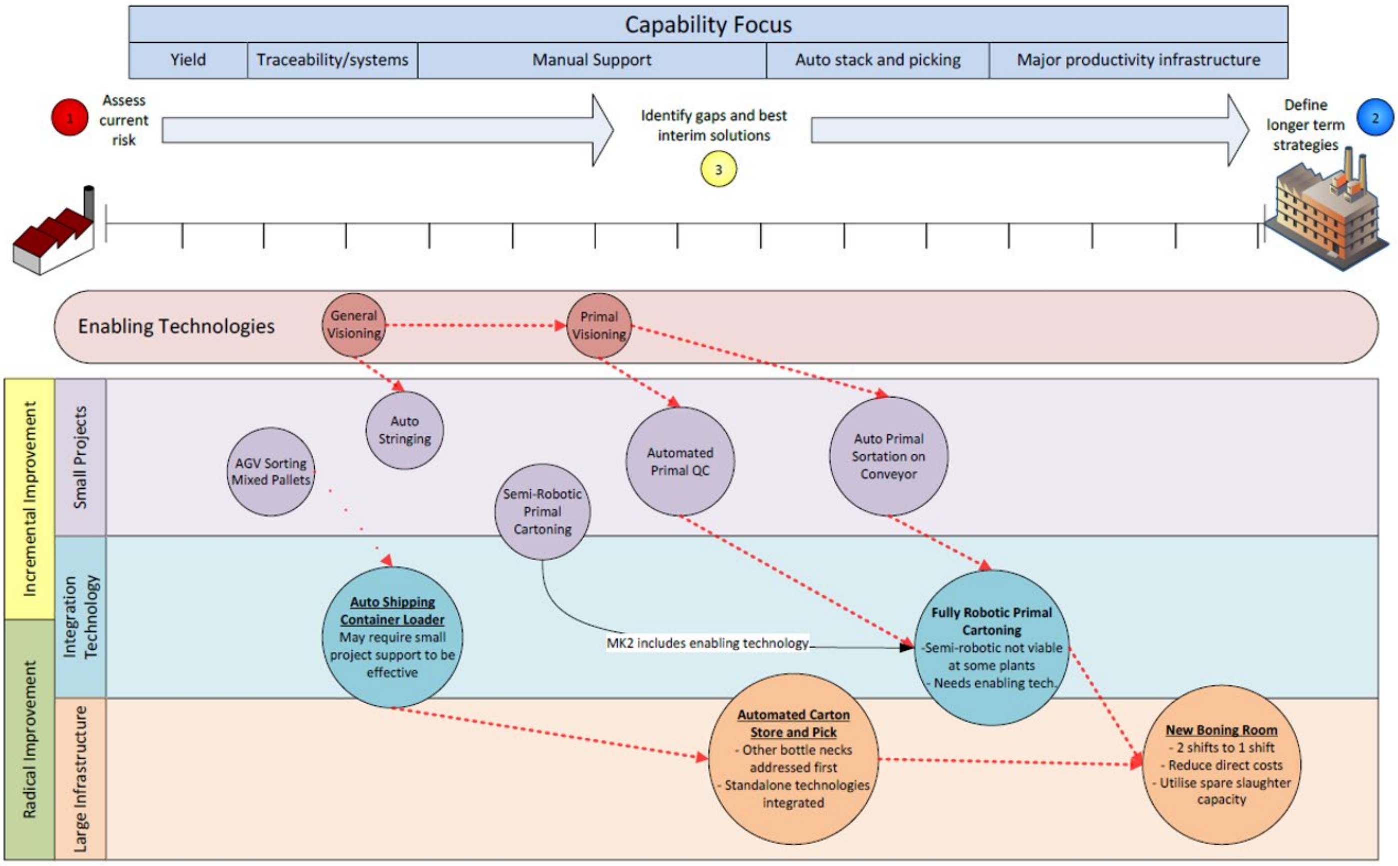


Figure 5: Progressive development of capability adoption as enablers to next stage innovation

2. Value proposition is well understood

Adoption requires change management, time and cost. For some technologies the value proposition (cost verses benefits / increase uplift) is not well understood, articulated or isn't available and therefore the technology isn't adopted. Providers of technology, researchers and industry should ensure that transparent business case studies are provided to enable firms to understand the costs, inputs, staff capabilities required and the potential benefits of adoption.

Confidence in value proposition and the pathways for development requires a number of aspects for delivery and connects the end vision and value. Through this project it was identified there was a gap between research and development, where development of a product means the product requires testing, feedback, further development and adaptation to be commercially viable. Automating lamb processing was regarded as interesting, however, investment was not undertaken until clear business cases were available on the economic benefits.

To promote adoption, it requires support for commercial users to be part of the development phase to ensure the products meet the requirements of commercial operators in real time processing environments (be it in the yards or plant). Based on commercial real-world experiences the actual economic benefits and costs of adopting the technology and changing the system as required will help firms in the red meat value chain make informed decisions in regard to investment in advanced imaging, visioning and cobotics.

3. Product is fit for purpose

As mentioned in Point 2 in this section, for on farm devices there are examples where technology requires mobile phone reception, reliable power sources and Bluetooth connections. In many places there is limited to no mobile phone reception, no to intermittent power and Bluetooth struggles to connect due metal yards/crush and environmental factors (dust, etc). An example provided during an interview when conducting research was the use of drones. Given the longest battery life for a drone is currently 40 minutes and when flown it needs to remain in the line of site of the operator a drone isn't currently suitable for use in areas which cover large distances or require hours of flight time.

In the case of processor equipment there is an example of an assistive boning system which supports the breakdown of a carcase which was trialled, however, the circuitry was not built in a way which was waterproof, so could not be easily washed down at the end of every shift. Initial research was undertaken for the Kinea design system which is further elaborated in the next section. This research suggested it would be highly beneficial however, further development was required to make the product fit for purpose. Commercial firms have not been willing to work in the development space. Commercial firms need to be sensitised in the research and design cycle and that new R&D requires time and input from them to be successful. For technology to be successfully adopted it requires proper engagement between industry and solution providers who both understand and are committed to the journey and commercialisation process.

Learnings from the Kinea Design System

'Cobotics' or Intelligent Assist Devices (IADs) provide a potential solution to some of the inherent challenges of manual meat processing tasks. Its primary capability is the support and amplification of the human sensory capacity, intuitive to the skilled operators in the boning room. Application of this technology to support operators in physically challenging tasks like aitchbone removal could improve operator longevity in the job and quality of life.

IADs take advantage of progress in digital power and digital logic state-of-the-art sensor, actuator and controller technologies. These devices are improving human productivity by replacing traditional mechanical, pneumatic and electro-mechanical material handling devices, and by providing power-assistance to humans in industrial and non-industrial applications, that so far have not been addressable by traditional devices.

4.2 On farm technologies

As part of the analysis, rather than document what currently exists, the researchers sought to understand what research, development, adaptation and adoption is required. In essence this section highlights what the current limitations in the existing systems and technology being used by commercial operators.

On-farm assistive technologies

Generally, assistive technologies have little current relevance to the work being undertaken on-farm. Technology to date is seen as a chore and often irrelevant, with data being collected for no apparent reason or use. Current technologies are also not designed to function optimally in the outdoor conditions, but also in general when having to deal with large numbers of animals, for example scanning, drafting, weighing, 1,000+ a day. While the technology may work well in a clean office environment (even in an on-farm office environment), when taken to the crush, various technology components may not connect or work together. Cables can be used but cannot be permanent as they often get eaten by the birds. Hence the need for ruggedising existing technology stacks in order to drive technology adoption on-farm is essential.

Existing farm infrastructure is not designed for the digital age. Often paddock and yards were designed and built 30 to 80 years ago and are not suited to the requirements related to scanning EID's, weighing, drafting into separate mobs with the increased numbers of animals being processed in a day.

Complicating factors include changes in animals' weight while held in the yards. For example, assistive technology which could automatically draft animals based on weight would need to account for the fact that they may lose up to 50kgs over the days they are in the yards. Technology also needs to account for the multiple drafting sessions to accommodate target weights and numbers needed to load trucks.

The flow of animals around the farm could be automated but it would require significant investment to rebuild paddocks, gates, yards and install walk over weighing, scanning equipment and monitoring equipment which all needs to be connected (within the current constraints of no mobile or internet coverage) so a signal would need to get back to the farm house using additional repeater towers and other such networking technologies.

Livestock inventory management

Accurate livestock inventory management is a key requirement for most on-farm decision making. Stock numbers by class, body condition, weight and managing the available feed quality and quantity with the nutritional requirements of the herd are key drivers of decisions.

Key livestock management concerns are:

1. Management and up to date knowledge of livestock numbers per class:
    a. Identifying animals which are in calf verses empty helps to evaluate overall herd performance.
    b. Identifying when breeders are falling in calf and linking this to season, feed availability, lick blocks, etc., is essential to help maintain appropriate body condition.
    c. Estimating numbers and timing of weaners next year based on pregnancy testing to assist with herd planning, number for sale, number of breeders to cull, quantity and timing of staff needed, quantity of animal health products needed.
    d. Being able to split the herd into stage of pregnancy allows older calves to be mustered first and females supplemented according to nutritional requirements.

e. Integrating session, livestock and pregnancy testing data is the first step to understanding the calves to be born providing future expectations of what stock will be available when for further on-farm decisions. Some applications provide session information but not at a herd level.
f. Using assistive technologies to manage animal movements, location identification, presence and activity may help with managing inventory numbers but may not assist with other key elements of herd management.

2. Linking animal metrics including body condition score, weight, carcase feedback, genetics (EBVs, DNA) and breed at an individual level and a mob level to analyse past performance and understand did the animal(s) meet target market specifications. If they didn't meet target markets specifications, can the reason why they didn't meet specifications be identified? Currently carcase feedback is not frequently linked to live animal data in large herds.

3. Herd inventory management is an activity that is undertaken over time and not just a point in time approach. That is decisions regarding choice of sire and genetics will take 2 to 3 years to materialise and meet a point in time market demand. It is necessary to include longitudinal market drivers and trends and future market expectations in the current animal selection processes together with the current inventory supply management challenges. Visioning and imaging information from kill information, need to be overlayed with live animal EBV's and viewed in light of future market requirements.

Individual animal management and recording liveweight

On farm technologies with regards to individual animal management based on the RFID tag exist. In discussions with large operators, they have identified the current systems to manage the animals at an individual level has functionality issues. Larger operators have multiple properties and 20,000+ animals, and find the systems are unable to manage the scale and provide information on individual animals in the yards without the systems freezing.

Hardware, for example laptops, tablets and weighing scales, are also not without their issues. Computers overheat in Northern Australian conditions; weigh scales and associated systems may not connect or may not take readings quickly as they are waiting for the animal to stand still to take an accurate reading. This may be suitable when working a few hundred quiet stock through the yards in a day, however, when processing thousands of animal who may have never had contact with humans or a set of yards before creates issues.

The yards and crush infrastructure impact the technology solution. For example, steel yards will impact wireless connectivity. In some yards there are separate weighing scales before the crush and EID reader at the crush to record animal husbandry processes. It is nigh impossible to connect the devices by Bluetooth due to multiple items being present in a 5 metre radius.

Labour

Current labour market for on-farm is very much hands on, base line secondary education, with minimal administrative IT and technical skills (e.g. cannot update links in an Excel workbook). There is anecdotal evidence that there is significant interest in itinerant working for minimally skilled staff, however, there is a lack of specialist staff such as leading stock hands and bore runners. High turnover means that young people are not given enough interest in potential career opportunities and in the beef industry there appears to be a lack of career path visibility.

From a technology perspective, having an established career path with broad job descriptions which include the required technology capabilities to fulfill the role, would provide reason for candidates to improve data literacy and technology usage capabilities. With current labour force culture and minimal career path options, there is little incentive to upskill to a more sophisticated work capability.

System connectivity, data integration and whole of supply chain analysis

There is limited system connectivity and whole of supply chain data and analyses when dealing with the larger herds. The animals shift between properties, with some applications keeping the data from the previous properties and adding to previous data while other applications are not set up to follow the animals across different properties. Different livestock and pasture management applications are at different levels of maturity, with some applications not having API access allowing data integration. Whole of supply chain analysis where animals are analysed using their DNA, average daily gains and carcase results is currently lacking, as shown in Figure 6.

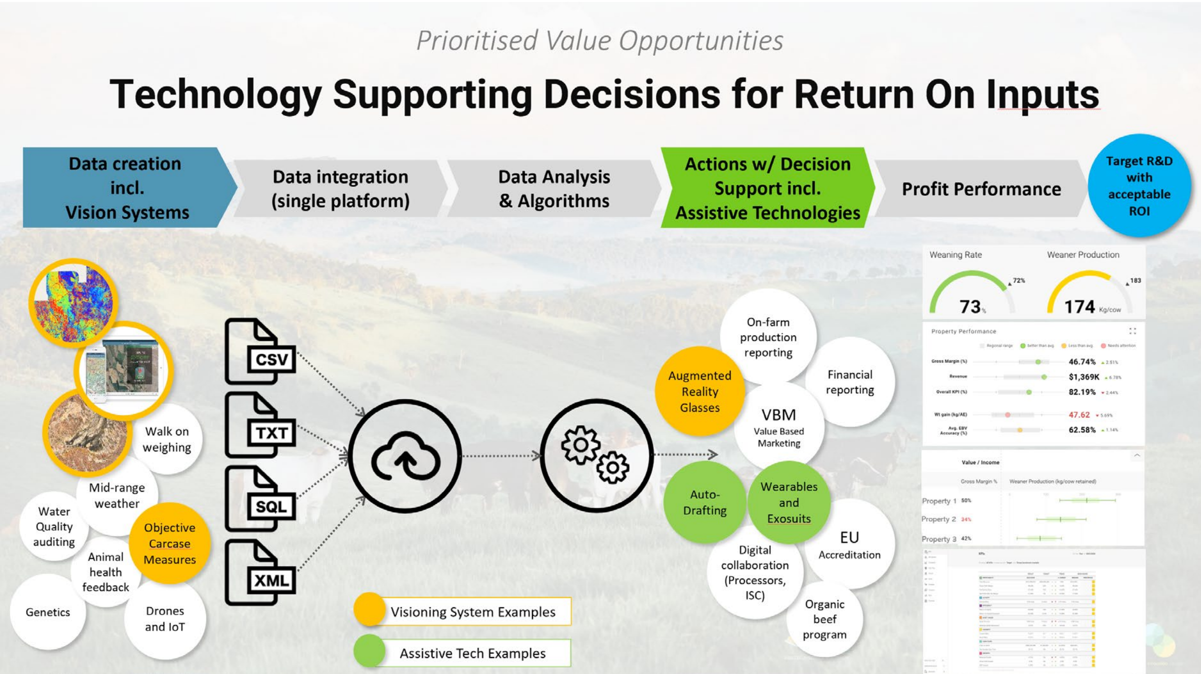


Figure 6: An integrated approach to visioning and sensing and applicable assistive technologies helps prioritise opportunity areas.

Applications as shown in Figure 7 connecting decisions and scenario modelling from a wholistic perspective are in their infancy. Best practice inventory management is associated with planning and managing pastures, food on offer, supplements, licks (quantity, placement, frequency) and ground truthing satellite and other remote sensing imaging data; integrated with session weight, body condition score and weather data. Remote sensing and ground truthing are relatively easy activities for southern intensive farming areas. More remote and extensive pastural properties are challenged by the distances and size of paddock to help align imaging with on-ground reality on a regular basis.

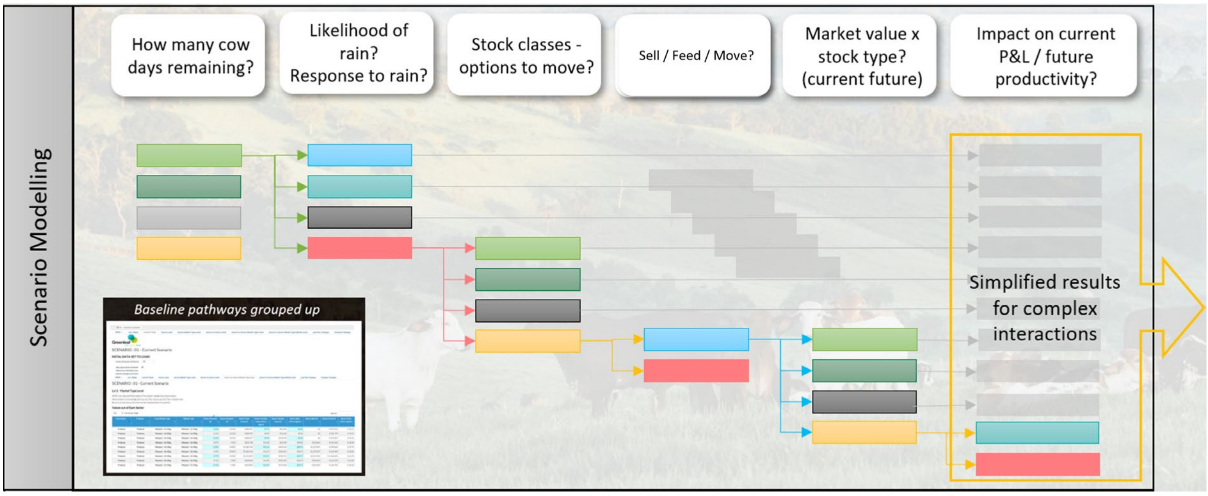


Figure 7: Decision processes impacting profitability that require information such as visioning data or assistive technology interventions to enact the resultant decisions

Use of farm assistive and visioning technologies

Fixing internet and mobile phone coverage is pivotal for future advancement in the use of technology and applications. Building industry or locally funded repeater station network may be an appealing way of improving this technology challenge in rural and remote areas of Australia. For extensive northern properties, where farms are extremely large, automation and assistive technologies do not always deliver a perceived benefit and they are not a big winner from a Return on Investment (ROI) perspective.

As an example, currently CiboLabs data is very “course” and must be consistently and persistently ground truthed. This is a challenge when vast distances need to be covered to achieve this outcome. Ground truthing could be done remotely using visual, technological monitoring or other such technology, however, there is an underlying need for connecting these systems back to a central location for assessment. This is very challenging in an area where there is no mobile phone coverage and next to no internet connectivity. Cables will get eaten by birds and pests. Setting up a private repeater network could be a solution, however, it may be cost prohibitive for the level of density and extensive distances needing to be covered.

Satellite options could be appropriate, however, the ongoing maintenance and support of such systems may be prohibitive, especially in the context of the challenges of getting suitably skilled bore runners to maintain watering points. A whole new industry of sensor runners might be generated to go out and periodically maintain, fix and upgrade remote sensing technologies.

To increase on farm adoption of technology and drive data based decisions (1) the existing technology needs to be ruggedized; (2) applications need to be designed to work away from internet connections; (3) handle thousands of head of animals; (4) software and hardware need to easily integrate and connect; (5) data points need to be obtained at speed (for example weighing scales need to generate a reading in seconds), (6) data needs to be analysed to provide immediate feedback on the session data and the individual animal if required; and (7) information provided should link to management decisions and strategic planning.

Research and development support is required to work with technology providers to ruggedise existing technology stacks so they can work in a range of field conditions. For example, Panasonic no longer produces Toughbooks. Decisions are often needed to be made immediately crush-side or at the end of the day which requires data analysis or feedback to occur in the field and immediately, with applications being designed to be used on a computer which is connected to the internet, thus not helping immediate decisions in the yards.

For producers to invest in technology the question is what value will it add across the entire business, does it fit with existing infrastructure, staff skill sets, business processes and "What will it cost me to buy and maintain?"

Priority opportunity areas

In summary, the question is how best to connect, utilise and maintain the technology available to provide accurate data to make decisions based on environmental conditions in which it operates, rather than focusing on new technology.

When reviewing the use of imaging and visioning technology in the live animal the constraints restricting adoption were:

- On Farm data is collected but much of it is not analysed and used
- Lack of internet connectivity and slow data download speeds
- Data is poorly integrated for on-farm and supply chain decision making and information sharing. For example, linking weather data with weather predictions and available pasture biomass, livestock on hand and predicted calving rates to review the impact of droughts, floods and temperature extremes.
- The equipment is not designed to operate in the environment (outdoors, heat, cold, moisture and contaminants) which compromises data systems which require repeatable processes.
- High staff turnover due to lack of clear career path with employment on rural and remote properties seen as a short-term adventure, which again impedes the ability to manage repeatable processes.

The tasks and processes along the production chain are included in the Appendix A. The highest value opportunities helped form up the prioritised recommendations. Further to this projects research, IoT studies conducted by MLA in 2020 were also considered as part of an integrated solutions as shown in Figure 6.

Visioning systems for Objective Measurement

Sophisticated visioning and measurement devices are unlikely to be adopted due to cost. While there is the potential for progressive development of capability, adoption should be a core focus of these programs. Many producers don't weigh livestock or if they do, use broad weight categories for drafting and decision making. A range of easier to measure systems like visioning for BCS can add value quickly. Whereas sophisticated visioning and measurement devices are unlikely to be adopted at this stage due to cost, limited supporting capabilities to integrate, and downstream payment systems that will reward for more precise livestock descriptions. Transitioning pricing signals are also required to reward for more accurate livestock descriptions. Lack of these signals is a barrier to adopting more advanced live animal objective measurement systems.

Genetic tests are becoming more affordable and are likely to be more practical than visioning systems. They provide information of a predictive nature about how an animal may perform into the future. This is potentially more valuable than point in time measures and more accurately could forecast future livestock value.

Visioning Systems for enhanced decision making

Fundamentally, visioning systems are technologies that present data that should enable decision making of some sort. A range of visioning (decisioning enabling) technology areas are outlined here.

The key data capture points include:

- Production inputs
    - Pasture and biomass production
    - Input capture
- Livestock measurement data
    - Weights
    - Condition scores
    - Growth rates
    - Genetics
    - Individual ID and traceability
    - Body composition
        - Ultrasound, 3D camera, NIR
- Livestock decision pathways
    - Drafting
    - Sales
    - Decision implications

Assistive Technologies

Assistive technologies in the on-farm space were not considered a major focus area of R&D investment for a number of reasons:

- Adoption rates will be slow and unlikely to generate a definitive benefit compared to costs and expenses incurred
- Technologies tend to be less sophisticated, meaning they have less development need, or are readily available such as walk-over weighing and drafting systems.
- Drones have been included in previous value proposition work
- Someone willing to invest in technology is more likely to be strategic, with a focus on enhanced decision making.

Wearable technology, remote weather and water monitoring, drones and other devices are all helpful, however, need to be reviewed from a whole of business value addition perspective. Generally improving infrastructure in conjunction with more accurate data collection and labour saving devices will generate improved returns for the business. IoT devices have not been considered directly in this report. Another program of work was completed in 2020 that identified opportunities for IoT systems. It has been mentioned given integration of visioning systems will require integration support from IoT devices in many cases.

Technology capability versus Value Chain Capability

The degree to which a supply chain creates value is impacted by the capabilities developed that help leverage available resources for maximum value across the entire supply chain from production to end consumer. Part of this project considered the range of capabilities required to make improvements. Identifying gaps in enabling capability required to support new technology capability (or existing but poorly adopted technology) is just as important in underpinning new value.

Figure 8 summarises the groups of capabilities that impact on realising value and the framework used to assess supply chain capability. Resource capabilities include tangible physical resources such as genetics, land assets, infrastructure and processing facilities. Assistive and visioning technologies fall into the infrastructure section and help create the best value from the natural resources. In addition, less obvious, but in some ways more important capabilities (S.C. - signals and connectedness) describe the way in which information and market signals are communicated along the supply chain. This is where visioning and sensing systems can provide additional data to support strategic and market channel decisioning making about how best to realise the value of the natural resource.

These information-sharing and market signal activities help leverage physical capabilities to align with markets to realise value. The third tier Figure 8 describes is the wider market forces in which the value chain operates. These include external competition such as other value chains (Eastern states beef, international competition, other protein sources) and political and regulatory forces such as market access, exchange rates and economic policy. Although this last section has an impact, it exerts the same force across all supply chains and as it is difficult to influence, it does not have any focus in this study.

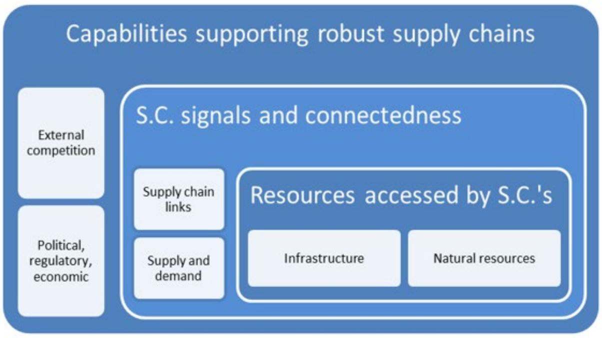


Figure 8: Capability groups used to assess value chain effectiveness

Well-developed capabilities help more accurately identify, align with, and access maximum market opportunity for the natural resources. These effectively minimise risk and increase confidence to invest in further capability development. A lack of capability along the value chain has two major impacts:

- Limits the ability to realise potential value
- Limits in severe cases the development of new capability due to high risk created by capability gaps. This lack of opportunity results in a catch-22 situation that requires specific intervention to overcome barriers to growth.

Enabling capabilities for decision making

Using the framework described in Figure 8, consultation was undertaken with a number of properties including on-farm visits. Due to COVID the site visits were in Queensland and the Northern Territory. Existing technologies are readily available but there is a wider range of enabling capabilities required to get the best use from existing technologies. The extent to which these capabilities are developed will impact on the ability to engage in development and commercial installation of more advanced technologies.

To enable decisions to be made, the data collected by the tool (imaging, visioning technology) needs to be (1) Captured, (2) Downloaded from the device and usually uploaded to a cloud-based program, (3) Cleansed, (4) Analysed, (5) Findings identified, (6) Review of findings and scenarios and (7) Decision formulated which aligns with operational and strategic plans.

Challenges are often encountered including:

- Difficulty in capturing the data due to equipment failure and existing infrastructure
- Downloading and uploading from the device into the cloud using intermittent internet. if available at all (as satellites usually don't work on a cloudy day or with heavy traffic)
- Cleansing the data requires dealing with duplicates, errors and missing data. When dealing with large herds, hundreds of data points and staff inexperienced with data collection, data cleansing can be a laborious task if it is unable to be automated. Ideally the data collection should be as automated as possible and data points 'locked down' with minimal free text areas. Some programs allow this, while others don't have the function to lock down cells.
- Understanding how to analyse the data to provide the information required to make decisions. On several occasions the researchers observed that data was collected, for example weights of animals, however the data was recorded in separate sessions (over several days) and the application was only able to analyse individual sessions, rather than all the sessions which related to a certain group of animals, data was difficult to export into other programs due to size of files or limited functionality of programs.
- Generation of findings and meaning is often limited by the programs associated with the data collection tools. The researcher observed large amounts of data when 'analysed' generated tables which was actually summarised or aggregated data. There was little analysis to help identify findings, built scenarios and 'what if' models to help with decisions built into applications. Several applications working with livestock management and biomass measurement identified this as functionality they will work on in the future, although no definitive timelines were provided.

Analysing data for insights is the single goal when implementing visioning and decision support technologies. One set of challenges in increasing the management interventions in an extensive bioeconomic system is integration of all the related drivers and enablers, coupled with the right management controls. An ad hoc, or piece-meal, approach to enhanced decision support won't account for the interaction of all the parts (economic, biological, environmental, seasonal and cultural) and may not provide the same benefits if implemented from a systems perspective.

Forecasting, predictive analytics, optimisation, AI, machine learning are terms the production sector is becoming familiar with. However, generation of commercial value above status quo requires solid foundational capabilities to be developed.

Data Management and Integration

Within data management and integration there are a number of factors which need to be considered including:

- There are different levels of modernisation and sophistication, for example not all applications have API end points and accessibility.
- Specialised systems are hard coded or securely coded which won't share underlying source information with other systems without substantial development costs.

- Data governance becomes increasingly important as the sophistication of data collection increases and operations become cloud based. Observations from the beef industry identified development, extension and training was required to assist firms to establish policies, procedures, hardware and software solutions which reflect the increased vulnerability due to operations being conducted online, and with technology was required.

Data ownership – who owns the data – the person who collected the data or the firm which provides the software which collects the data or the firm which stores the data on the client's behalf.

Manage technology – people who don't have a background in technology (hardware and software) are required to manage technology in a sophisticated way. For example, when a system changes staff may not be able to do a range of tasks.

Figure 9 summarises the interconnectedness of data capture and decisioning making points in a diverse livestock production system. Scoping of the value-chain demonstrated large gaps in decision making that, if supported with more accurate information, could manage resources more effectively, and could inform better alignment with markets. The value opportunities were significant. Work undertaken in determining the best technologies to implement indicated the challenge is more in connecting all parts in the bioeconomic system than in installation of one or two advanced technologies.

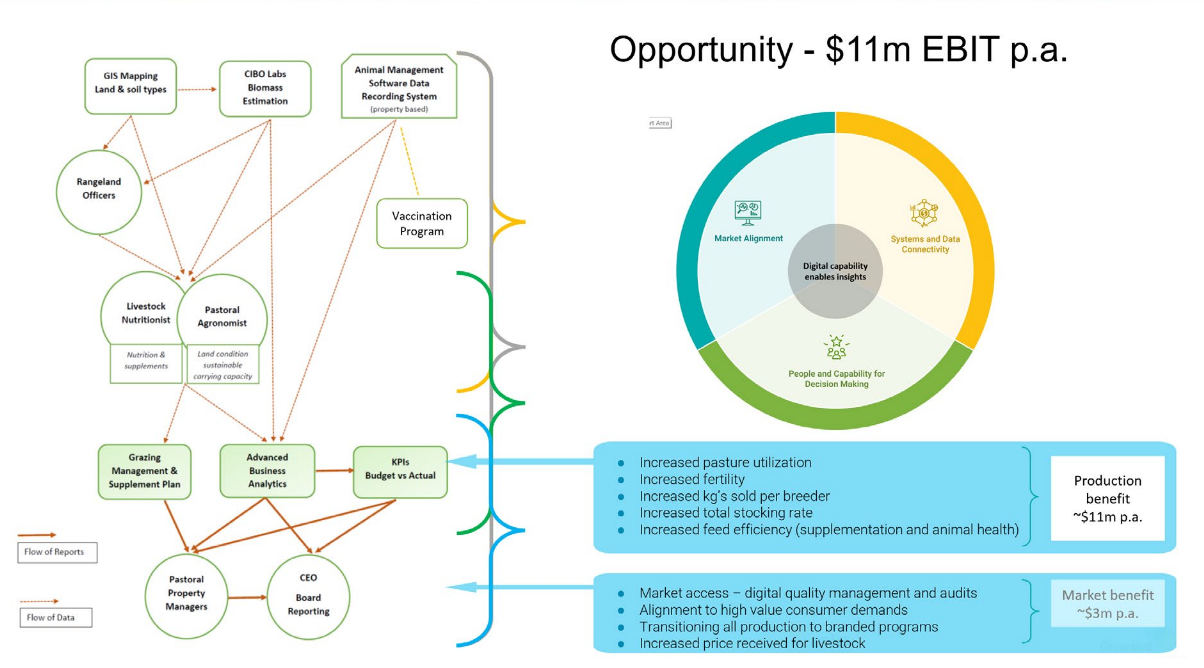


Figure 9: Example of integrated processes in a bioeconomic livestock system with associated value propositions

4.3 Feedlot and backgrounding technology

To maximise value creation, animals need to meet specifications. Linking the carcase attributes to the live animal has the ability to create additional value to ensure animals are within target market specifications. At the producer level DNA testing, Estimated Breeding Values, height and weight measurements can be used to select animals to meet target markets. At the level of backgrounding, animals may be weighed regularly to draft off animals as they hit target weight. Some of the larger operators may split into weight drafts and assume the animals are growing at a similar pace, rather than weigh and redraft.

At the level of the feedlot animals are managed as a ‘pen’ with a pen of animals out together. At a production and backgrounding level animals are being managed as individuals and at a feedlot they are aggregated potentially losing value as they may be outside the specifications. Future technology which identifies which animals are within specifications and animals which require additional days on feed would provide additional value back to industry. Within the pork industry, animals which are one to three weeks away from meeting target market specifications are weighed and fat depth is checked using an ultrasound. Technology exists to scan live beef animals using an ultrasound to check fat depth and marbling. Combined with automatic drafting animals could enter a crush, be weighed and scanned then auto-drafted based on meeting market specifications or requiring additional time on feed.

Changing from a pen-based management system to an individual management system requires additional handling, infrastructure and a culture change. The potential to ensure animals meet market specifications in the higher value animals warrants an investigation into the costs and potential benefits which could be gained. As with any change to shift to managing at an individual animal level rather than at a pen level this requires a culture of innovation and a strategy which focuses on value and meeting customers and consumer’s needs.

4.4 Beef and Sheep Processing

Priority opportunity areas

The tasks and processes along the production chain are included in the Appendix B. The highest value opportunities informed the prioritised recommendations. Further to this projects research, IoT studies conducted by MLA in 2020 were also considered as part of an integrated solutions. AMPC found labour-related charges make up nearly 60% of total operating costs in Australian facilities, compared with less than 50% in the other countries examined.

Key value propositions identified to improve efficiency and optimise yield and quality to increase profitability. The two primary areas of need include:

- Enhanced decision making
- Productivity gains focused on labour saving

On average, operating costs across Australia approximated $360.62 per head of throughput or $1.22 per kg HSCW. Labour-related costs in Australia make up just over 58 percent of total operating costs, excluding livestock purchases. A significant proportion of labour-related costs in Australia are subject to either Federal or State government legislation, estimated to account for approximately 85 percent of total labour-related costs in the beef processing sector.

MLA has successfully developed lamb processing sensing and automation technologies in collaboration with commercial suppliers and industry partners. These technologies transform the cost basis for processing. Their increasing commercial robustness has fuelled in part industry awareness, acceptance, and now a confidence to invest in automation that is resulting in continued adoption. Digital data collection and analysis from these automation systems is also providing objective measures for improved decision making along the entire chain and are beginning to enable whole of chain transformations.

Beef processing is more difficult to automate than lamb processing for many reasons. Although beef DEXA scanning is driving some level of pre-boning room automation, the opportunities are yet to be explored properly. Given the significantly greater size, value and complexity of the Australian beef industry relative to lamb, the opportunities and potential value from these investments is significant.

Visioning Systems for Objective Measure

Visioning for value based marketing is well advanced in terms of capability. Eight potential new objective measurement technologies are in the process, or close to being certified for commercial use in Australia. A number of other systems like NIR have been trialled over many years and recent collaboration between Australian and New Zealand companies is progressing towards a commercial prototype. Given the proliferation of new technologies it is unlikely the market is big enough to support all of them. Due to the broad and well advanced focus on these types of technologies, the project focused in other areas of greater need. It should be noted however, that the findings and recommendations in this report (focusing on enabling capabilities) are at least as relevant to these OM technologies as they are to less developed solution spaces.

The focus of this project has been on the prioritisation of visioning technology developments. But the common theme throughout the research has been the integration of multiple technologies and or capabilities, and as parts of a larger vision for commercial value creation.

As an example, challenges around the adoption of VIAScan occurred due to lack of enabling technologies to help support the real value propositions. VIAScan was just another tool to gather data to help make decisions. Those decisions around pricing, purchasing strategies and feedback of livestock information in a way that created value and competitive advantage required a range of enabling capabilities, many of which required involvement up and down the supply chain to create value. The technology itself was advanced for its time, but the supporting systems and communication capabilities required to realise value needed a lot more focus.

Enabling capabilities required to support OM visioning adoption

Data capture and analysis – is only the first step in commercial application of OM visioning systems. Many of the emerging vision grading systems are providing more accurate measures of existing attributes. Some are creating new measures like the lamb IMF reading. It is one thing to obtain more information about a carcase, but another to manage that to create commercial value and over time, increased supply chain value. Some of these other enablers are included here.

Plant infrastructure – is required to manage the sortation, ordering and flow of product in new ways that are required to extract the additional value. Grading and sortation of carcases into right grades and then into the right cut groupings to be managed through the boning and packaging rooms is then required to act on the results of OM visioning results. The location of cameras in the processing facility is critical, with additional development required to fully understand the implications of measuring hot, cooling and chilled carcasses.

Product breakdown decisions - need to be made through robust data analysis to optimise yield and value including allocating the right product to the optimal market.

Feedback - information from these systems is an important enabler of industry improvements. However, there most likely needs to be an increased processor confidence that they will be able to extract the new value they are measuring. The enabling capabilities above are a minimum in doing this.

Pricing Signals – will have a big impact on driving better alignment of production practices to market needs which equates to supply chain productivity. It is one thing to send feedback, but another thing to pay on new measures. There are two key risks to processors in changing payment methods:

- Incentivising some attributes while disincentivising others will change their supply base and possibly reduce volume supplied
- If premiums are paid, this will increase the supply of livestock with those attributes.

In both cases, if the processor is unable to monetise the full value of these livestock cost shifts, or reduces their volume, this represents a significant value loss.

Visioning and Assistive technologies for labour saving automation and cost saving

MLA's sheep automation programs have been very successful over the past 20 years in managing some of the higher OH&S risks and yield losses resulting from manual boning and cutting tasks. The beef automation program is at the start of this same journey and looks to be generating the same level of engagement and future success. Not withstanding these successes, there is still a significant portion of tasks in the meat processing sector requiring direct manual labour. These tasks are very difficult and there is an increasing shortage of labour globally to fill these roles.

Further to this, the cost of Australian processing, with labour being a significant part of the total cost, is the most expensive in the world, being 50% more than the USA and 75% more than South America, who are our main export competitors.

The jobs that have not yet been automated are much harder to do than those replaced by current automation. This is where visioning, sensing and assistive technologies are required to support people in current roles, and over time as technology advances, enhance and replace assistive technology with full automation.

The research mapped all the tasks in the process and described the required capabilities using a lens that considered integration of assistive technologies in conjunction with visioning solutions. The research considered all tasks along the supply chain, giving attention to what can't we do now and what we don't do very well, and broken into the following parts:

1. Defined each step and its associated processes
2. Assessed what value each creates or doesn't create
3. Pulled out the themes
4. Considered drivers, capabilities, applicable technology and readiness
5. Barriers to technology adoption and associated enabling requirements

Value Proposition Priorities

Table 2 shows the grouped benefits for each area of processing facilities. For example, lamb boning in the table summarises a number of different boning technologies including, but not limited to, visioning and assistive technologies. The individual solutions are described and quantified in the detailed worksheets, then grouped up here to the 'Summary Results':

- This shows 'Total Opportunity' and 'Total RRP' (recommended retail price) for beef, and small stock applications.
    - The total opportunity is calculated using the total benefit for each processing theme. This is the maximum potential value increase that could occur.
    - The RRP includes a discounted benefit for each automation solutions where 80% of the full opportunity is realised, then integrated with a 24-month payback to calculate the upper RRP that could be afforded. This indicative price creates a baseline on willingness to pay or adopt technology solutions. Even before starting an R&D project, this provides a guide to developers on the type of solutions that will be viable (profitable for all stakeholders) regardless of how technologically innovative and impressive they may be.
- The value of each sub-group is then totalled, summarising the full opportunity across all opportunity areas. Some technologies will be able to deliver a greater portion of the full opportunity when commercialised, while others will deliver accuracy below the 80% once commercialised.

Each group of opportunity areas was worked through with each processor for easy comparison of benefits.

Table 2: Opportunity analysis within the processing sector for Beef and Small stock

Summary Results

Processing Themes	Beef		Smalls	
	Annual Opportunity	Average RRP*	Annual Opportunity	Average RRP*
Slaughter (Bovine, Ovine, Caprine, All)	$4,488,965	$8,071,321	$4,235,328	$6,972,860
Boning - Beef	$7,478,391	$10,578,104	$0	$0
Boning - Lamb	$0	$0	$11,430,723	$15,063,084
Boning - Goat (& Mutton)	$0	$0	$413,683	$827,366
Carcase Chilling	$344,736	$689,472	$355,680	$711,360
Pick and Pack (and primal bagging)	$2,137,363	$4,274,726	$2,393,321	$4,786,643
Carton Handling	$1,654,733	$3,309,466	$1,747,655	$3,495,310
Product and Material Handling	$606,311	$1,212,622	$275,789	$551,578
Traceability & Integrity (A Boning Room focus)	$413,683	$827,366	$275,789	$551,578
Co-Product Processing	$418,163	$836,327	$896,314	$1,792,627
People Safety	$0	$0	$689,472	$1,378,944
Food Safety	$0	$0	$0	$0
Total Benefit	**$17,542,345**	**$29,799,404**	**$22,713,754**	**$36,131,350**
Per Head Benefit	**$104**		**$21**	

** Based on assumed % of benefit realised & modelled plant size & payback period*

A review of the Hook Assist technology

The Kinea design assistive technology was mentioned earlier. It is a helpful case study to introduce the proposed development areas in the key findings and recommendations section. The researchers were aware and involved in this project intermittently through its development journey, while it was being tested on site with processors and boning staff. The researchers also had meetings with the technology providers and have been very impressed with technology capability, solution provider commitment, user engagement in the system and general optimism about the future potential. During this current project the ideas around next generation of this technology have been very positive. As we began to unpack what the future solution pathways could be (discussed later in this document), a range of different perspectives and options have evolved. This section unpacks the Kinea value. Later sections consider an assistive technology development pathway that brings in new insights and perspective.

Table 3: Primary benefit areas for Hook Assist technology platform

Benefit	Description
Yield increases	Increased saleable meat yield results from reducing boner effort (and fatigue) allowing greater focus on knife work and precision. Aitchbone pulling enables additional yield benefits due to extra available pulling power, freeing the boner to focus on knife work.
Increased throughput	Improvement in rate of processing where multiple systems make the hardest jobs easier. (This is dependent on plant manning and assumes hardest jobs are the limiting tasks).
OH&S	Reduced physical exertion will reduce fatigue and occurrence of musculo-skeletal and associated injuries. This will improve operator safety and lengthen worker years.
Labour savings	Reduction in labour units required to complete heavy jobs in some plant configurations.
Reduction in staff training costs	Making these higher paying jobs easier will lengthen operator life, reduce turnover caused by fatigue and increase retention rate.

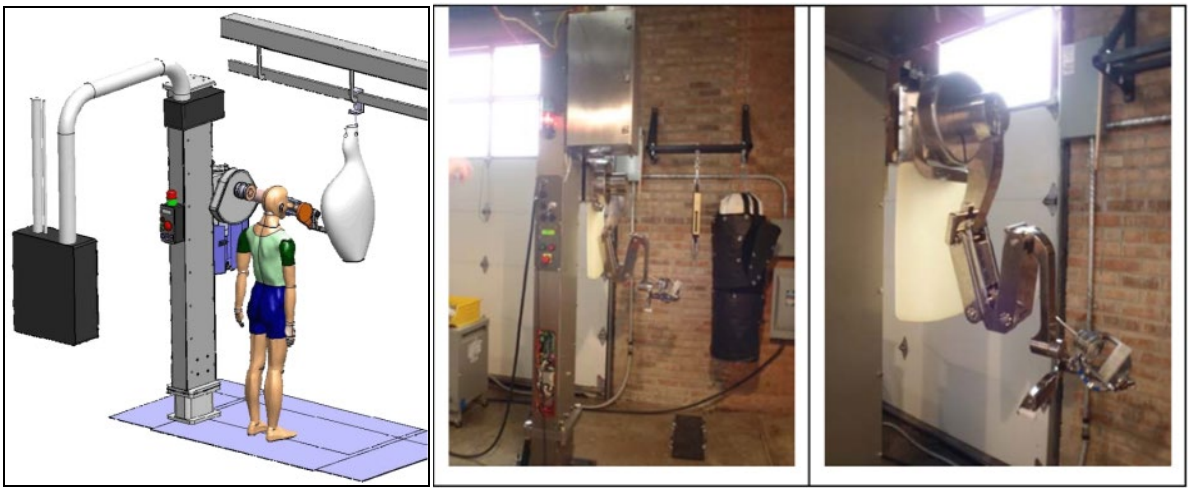


Figure 10: Hook Assist prototype technology

Figure 11: Hook Assist prototype system in industry trial sites

4.5 Solution areas proposed

4.5.1 Meat Processing Assistive Technologies

Meat Processing Assistive Technologies compliment MLA's Beef Automation program (outside Scott Automation & Robotics field – less automation and more assistive cobotics)

a. Wider adoption of MLA's beef automation system will cut across some traditional beef boning processes.
b. Barriers to adoption will be the significant adaptation of existing boning infrastructure while still requiring existing labour to process the forequarter and hindquarter.
c. Changes in boning room layout without improving forequarter and hindquarter boning may limit adoption of middle machine automation.
d. MLA has undertaken some work in assistive technologies as early as 1994 and through until late 2015. Industry R&D and commercial pilots have had a mechanical focus with rudimentary devices that ineffectively carried some of the force in manual jobs.
e. Advances in robotic surgery in human medicine researched during milestones 2-5 have occurred as integrated providers have adapted technology advances across multiple disciplines.
f. Broader adoption barriers are already being considered in the MLA Beef Automation program and are beginning to be addressed as part of the next stages of R&D towards a commercial prototype.

Figure 12: Da Vinci Vision system integrates assistive technologies to enhance doctors' capabilities

Across the many different assistive technologies, there are lots of emerging solutions that could help with specific jobs. But many of these are horizon 1 solutions, still require a lot of investment to make them industry ready, and don't solve the longer term challenges.

The example in Figure 13 shows that some development paths are not going to end up with the best outcomes for industry. This level of strategic and planned R&D enables more specific selection of development pathways that have a greater chance of solving the core challenge. Creating a process that defines, scopes and guides R&D, with robust reality checks along the way provides a vision for commercial companies to engage in. A visible development path that enables test and learn towards a well-defined commercial outcome also helps guide a dynamic process while instilling confidence and engagement.

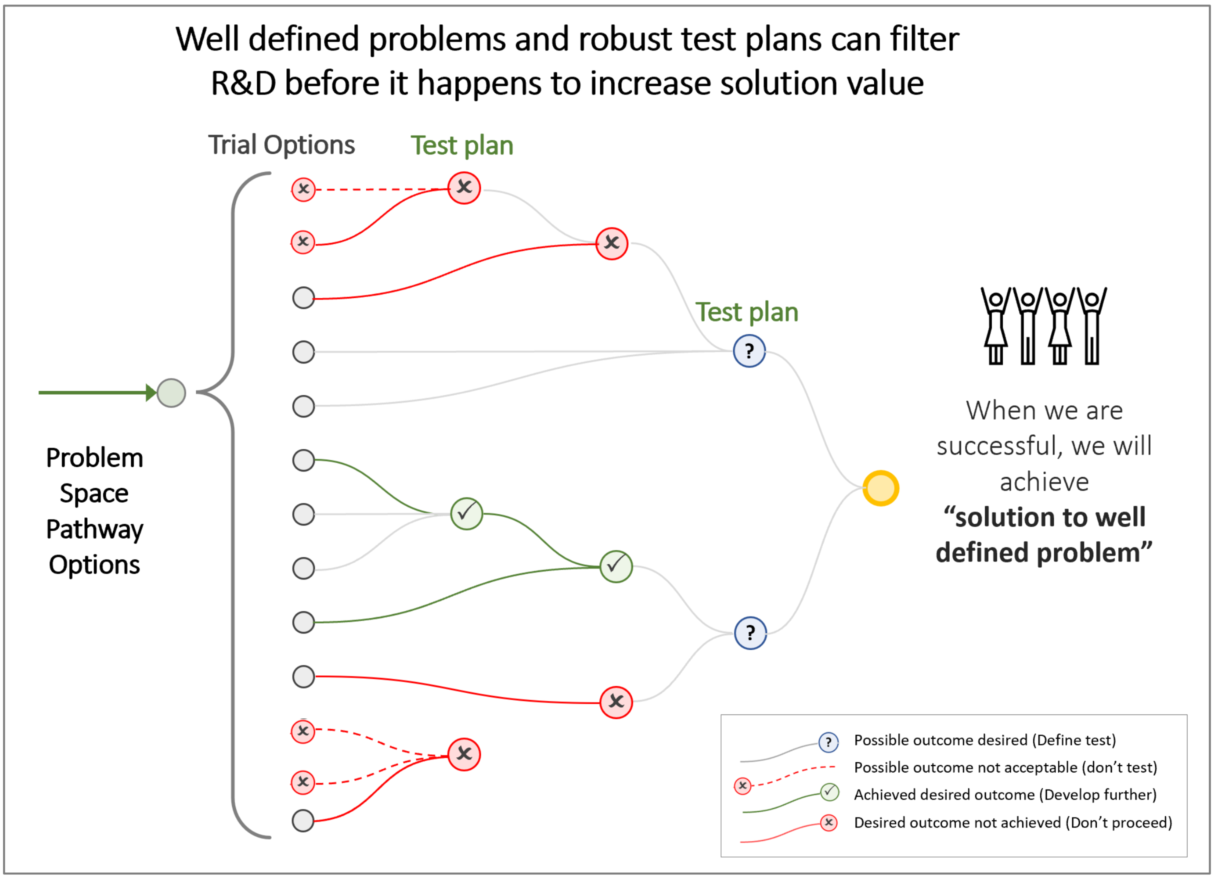


Figure 13: Multiple pathways, but many can deliver an outcome that does not solve the real problem

Using the methodology above, a traditional approach that builds 100% on existing R&D in the form of Kinea Design (horizon 1 – incremental innovation) type technologies require labour on the processing line and only increases the labour pool available by a small amount. This is represented by Option 1 in the table. However, new alternative pathways 2 thru 5 increase labour pool significantly, along with other benefits. Furthermore, these other pathways lead more seamlessly into other technologies that could enable fully automation over time.

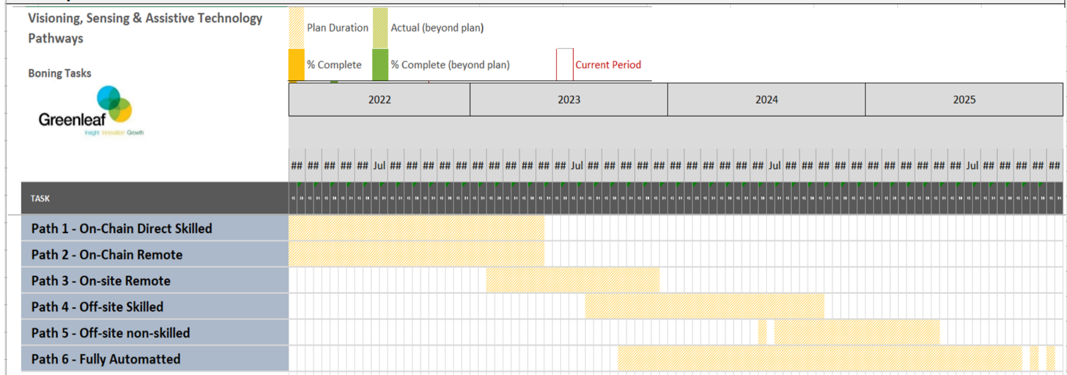
The business case estimates in the scoping indicate immediate value from horizon 1 innovations. However, this will not lead to horizon 2 and 3 radical innovations that then enable much larger changes in supply chain value and competitiveness.

Development Pathway Options – Meat Processing

Table 4: Development opportunities – Meat Processing (Integrated Assistive and Visioning and Sensing solutions)

	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	Path 7
Problem Space							
Limited and reducing availability of skilled boners and at pay rates making Australia uncompetitive.							
Shortage of labour is preventing other tasks such as offal collection and value-adding enhancements							
Processor Pains							
Boners don't show up for work							
Only the strongest people can do the tasks, limiting available work pool							
Salaries increasing but low skilled jobs in other industries are attracting these people and at much higher pay rates							
Females don't have the physical strength to do the jobs but have much better dexterity and attention to detail.							
Solutions	**Path 1**	**Path 2**	**Path 3**	**Path 4**	**Path 5**	**Path 6**	**Path 7**
Gains	On-Chain Direct Skilled	On-Chain Remote	On-site Remote	Off-site Skilled	Off-site non-skilled	Fully Automated	
Labour pool available							
Workers not strong enough to do heavy boning	1	1	1	1	1		
Extend working years for existing boners	1	1	1	1	1		
Part-time workers - school hours etc.				1	1		
Students - the new McDonalds (after school for a few hours before dinner)					1		
Off-shore lower pay rates					1		
No labour required						1	

Development timeline to commercialisation



	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
Capability						
Technical						
Direct operator driven Assistive ergonomic power	1					
Human visioning	1	1	1	1	1	
External visioning CCD to inform human			1	1	1	
Augmented visioning (Assist operations & training)			1	1	1	
Remote controlled power		1	1	1	1	
Flexible motor controlled arms		1	1	1	1	1
Feed-back sensing to support accuracy		1	1	1	1	1
Real-time data transfer speeds		1	1	1	1	
Internet bandwidth speeds				1	1	
Sophisticated real-time image analysis						1
Internal visioning for muscle seams						?
Enabling						
Training required						
Virtual Training to be developed			1	1	1	
Learning Algorithms collect data for full automation		1	1	1	1	
Confidence / Engagement						
Product damage risk - system						
Product damage - negligence / malic				1	1	
Solution Complexity						
Commercially available components	1					
Proven Prototype	1	1	1	1	1	1
Prototype under development	1	1	1	1	1	1
Concept	1					1
Rugged industrial application						1
System Costs						
Value Created ($/hd)						
Labour Jobs saved						$ 1.05
Labour cost / job	$ 0.32	$ 0.32	$ 0.32	$ 0.32	$ 0.53	
Yield Benefit	$ 2.64	$ 1.32	$ 1.32	$ 1.32	$ 1.32	$ 1.32
Value Increase (better alignment)						
Throughput	$ 7.13	$ 7.13	$ 7.13	$ 17.11	$ 17.11	$ 17.11
Other						
Total $/hd	**$ 10.09**	**$ 8.77**	**$ 8.77**	**$ 18.75**	**$ 18.95**	**$ 19.48**

4.5.2 On-farm – visioning and sensing

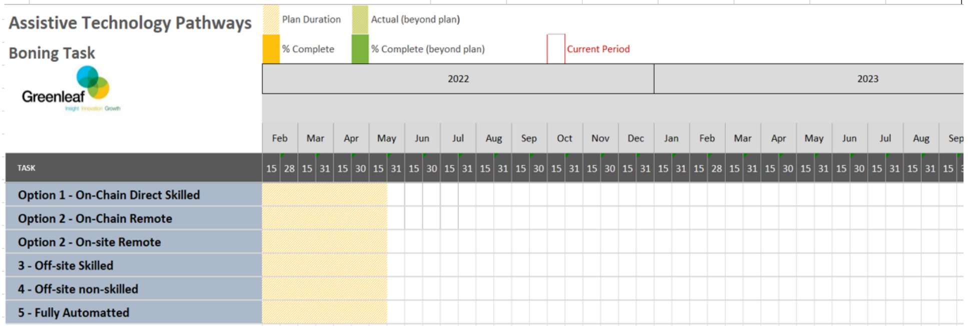
a. Data capture within current standard practices provides limited incentive to adopt in northern Australia as standalone technologies. Unless methods for additional data capture can be automated such as body condition score (BCS), there is unlikely to be an increase in adoption of basic practices and associated technologies.
b. Advancement in satellite imagery for biomass production, coupled with visioning for pasture scanning for ground truthing of this base data, can provide information to improve live animal management practices. However, other information like BCS, more frequent weight gain data among other measures, are all inputs required to generate the extra value.
c. There is evidence from a number of pastoral companies where lots of time and effort has been exerted in collection of data but for limited benefit. Lack of systems and processes, or awareness of what is required to deliver physical change has limited benefit created and has slowed or stopped these initiatives.
d. Barriers to adoption have not been with the technologies themselves, but how they have been integrated into systems, supported by efficient and effective processes, that make it easy for people to repeat.
e. Where a combination of new technologies can address the broader barriers, there is more chance of success and broader adoption. A series of integrated solutions have been proposed that prioritise value opportunities, then consider how to integrate these technologies into systems and processes. Opportunity for more integrated solutions that will address multiple barriers to adoption were prioritised. Priority development areas include:
    i. Satellite biomass prediction, pasture scanning, BCS, weight gain, data integration, staff training in technology support
    ii. Management decision making based on new value propositions based on emerging technologies can enable greater return on assets

The framework and methodology outlined in Table 4 for processing solutions has been applied to the on-farm section in Table 5 below. The template has initial concepts populated which could be used in scoping up future projects outlined in the recommendations section.

Development Pathway Options – Extensive Livestock

Table 5: Development opportunities for extensive livestock production

	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	Path 7
Problem Space							
Natural resources are not used for best value							
Infrastructure and technoloiges don't support decision making around natural resources as well as they could							
Alignment of resource outputs (livestock) to best markets is difficult to identify, and difficult to align due to lack of infromation to support de							
Labour shortages and high turnover make it difficult to maintain efficient operations							
Stakeholder Pains							
Work in remote areas is not appealing for staff retention due to limited amenities and services							
Rugged environments can compromise repeatible data systems							
It is hard to retain staff that have thorough knowledge of best practice systems and can make processes repeatible							
Lots of data but much of it is not actionable							
Solutions	**Path 1**	**Path 2**	**Path 3**	**Path 4**	**Path 5**	**Path 6**	**Path 7**
Gains	Actionable Biomass Estimation	Crush-side livestock OM	Remote livestock OM	Remote drafting	Automatted drafting		
Automation for labour saving					1		
Remote operation to enable labour attraction			1	1			
Higher value decisions from early knowledge (pre-muster)			1				
Higher value decisions from real-time data integration	1	1	1	1	1		
Refined decision/environment interactions (Feedback loops)							
Aligning livestock to highest value markets							
Labour pool available							
Development timeline to commercialisation							



Capability							
Technical							
Improved Satelite imagery for Bimoass estimation	1						
Integrated data for real-time decisioning	1						
Remote - drafting controls				1			
Real-time visioning for remote operators				1			
Automatted drafting controls							
Visioning to support remote drafting							
Automated Body Conditon Score visioning							
Data integration to access visioning outputs							
Enabling							
Integrated metrics customised to bioeconomic conditions							
Confidence / Engagement							
Size of property and labour challenges will limit intervention							
Options that support smaller propertys							
Solution Complexity							
System Costs							
Value Created ($/hd)							
Labour Jobs saved							
Labour cost / job							
Yield Benefit							
Value Increase (better alignment)							
Throughput							
Other							
Total $/hd	$ -	$ -	$ -	$ -	$ -	$ -	

4.5.3 Live-animal pre-slaughter

Live-animal pre-slaughter - focused on labour saving and the use of visioning and sensing for enhanced decisions, coupled with assistive technologies to guide livestock through alternative growth paths.

a. Address challenges in identifying the best growth pathways for feedlot livestock
b. Facilitate the redrafting of livestock in ways that overcome current barriers to do this, in order to increase productivity and end market returns for individual livestock
c. Knowing which animals will marble at 100d, 400d – which animals give ROI – on feed to give right marbling score for investment in feed
d. Contracting methods that support realisation of increased value

5 Conclusion

5.1 Key findings

Technology has been developed which provides improves data accuracy and or provides additional data points. To add value and enhance decision making it requires data to be analysed and interpreted in a timely manner to support decisions, at operational, tactical and strategic levels. Firms have developed technology, with summary of data for their specific technology. Future development should focus on whole of enterprise and whole of supply chain analysis taking data from different 'widgets' and bringing this together to match individual animals to market specifications.

Utilisation of assistive technologies requires an understanding of how the technology fits within the business processes and tasks of the firm and providing explicit returns on investment in improved productivity, yield, efficiency and profitability.

These key elements are summarised in Figure 14 as:

1. A development team that involves researchers through to end commercialisers. A clear definition of the problem space, which is require for engagement in the vision.
2. Validated commercial value proposition that becomes an anchor for stakeholders during iterative and pivoting development processes.
3. Confidence in a development process that encourages multiple options to be tested.
4. Awareness that multiple technologies may be required to achieve the solution.
5. Enabling capabilities will be required to take the solution from invention to commercial value creation. These enabling capabilities will be more important than the specific technologies in some instances in achieving the targeted value.
6. A supportive process of change management was required in many examples reviewed. Where this was done well, confidence in the R&D process was increased. Where this process was started well before implementation, and the commercial users were engaged in the process adoption was more successful.

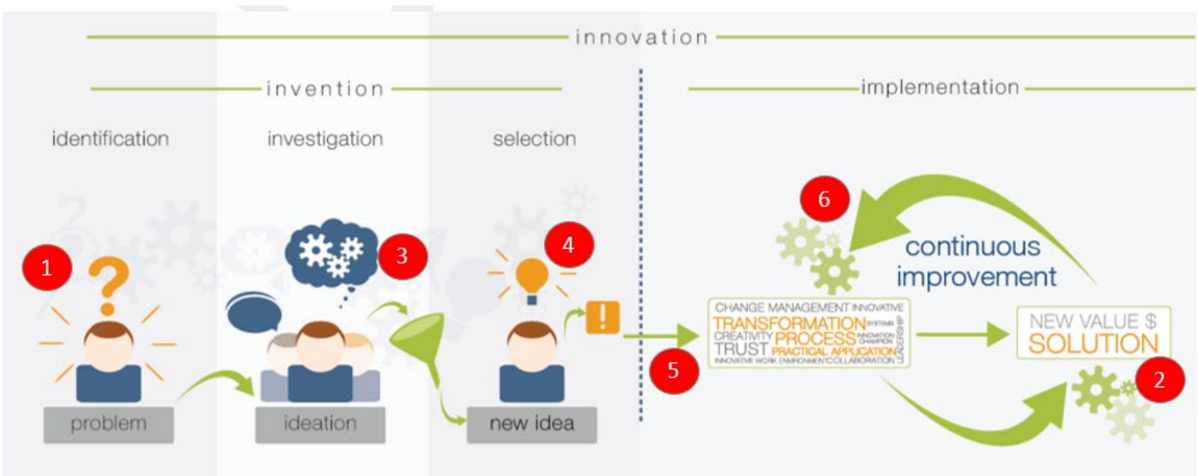


Figure 14: Innovation is much more than technology invention

Technology Specialists versus Integration providers - Companies with a technology speciality are usually not able to, or don't want to broaden their narrow focus to develop solutions as part of a commercial solution. This is often a result of business strategy or capability constraints. Integrators that can pull multiple skills together into a solution are more likely to create value and provide commercial industry solutions than specialist providers. Companies like Marel and Scott Automation and Robotics combine visioning, sensing, mechatronics, and assistive technology engineering to deliver these solutions.

Observations throughout the project have highlighted the importance of factors outside the technology capabilities that can limit adoption.

- Innovation has a better likelihood of adoption when there is a clear path of progressive development towards a commercial outcome.
- Commercial engagement.
- A clear vision of the longer term benefits is required to underpin bigger bolder innovation
- Solving narrow problem spaces does not seem to get the same level of commercial engagement unless the solutions are very simple turnkey.
- The value created by smaller innovations is often minimised until a number of solutions or new capabilities can be cobbled together to realise the value. .Benefits are often larger than the sum of the parts but less likely to be understood through lack of a common awareness.
- Innovations on the horizon that will be possible as a result of integration of existing cobotic and visioning technologies will be quite disruptive. .To move on these quickly will require a clear roadmap that:
    - Engages all sectors
    - Enables creativity and innovation within a framework
    - Has a very clear focus on problems being addressed
    - Has enough flexibility around the problem space that test and learn methods are free to test and fail quickly without losing focus
    - Focus on the interaction of problem spaces enables big bolder disruption if commercial entities can be engaged
    - Multiple pathways need to be tested but a method for cutting them off early is required. This requires focus on the problem space that creates the greatest value.

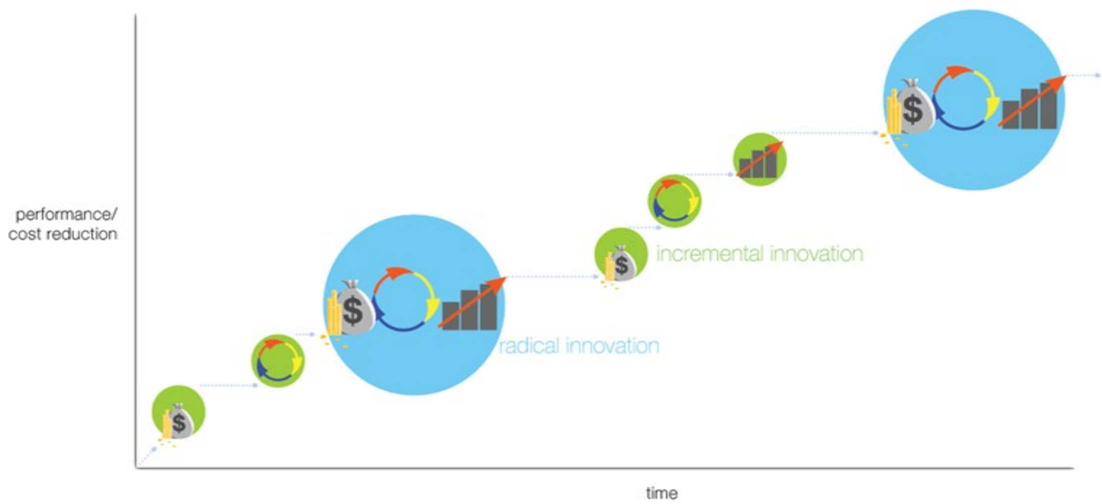


Figure 15: Radical innovation is usually preceded enabling incremental innovations

Being able to package up a range of incremental innovations with a view to achieving a larger radical innovation is able to be more focused and targeted towards solving a much larger problem. The R&D at each incremental level can then be targeted with more likelihood of achieving the bigger goal.

R&D program areas should continue to support incremental innovations that build capability. But where possible, there needs to be an overriding vision and strategy that can form up and guide the incremental innovations towards radical or transformational step changes. Ideally, single programs of work that support incremental development towards a radical commercial outcome are ideal. A specific approach to this type of program is required and outlined in the recommendations in section 6.3.

5.2 Benefits to industry

The red-meat industry has set a bold but achievable target to double the value created by 2030. Bigger, bolder projects which link development to adoption and value creation are required to achieve this target. Visioning, sensing and assistive technologies have specific parts to play in meeting these objectives. The many technologies and problem spaces reviewed in this project were passed through a whole of supply chain lens, considering the longer-term benefits bigger bolder projects could achieve for industry. Three key development areas were prioritised in on-farm and processing sectors. The development of enabling capabilities required for success in these areas were also considered, and if successful, will underpin successful commercialisation of other future development areas.

Program areas for value creation will require development of capability to realise that value, including:

1. Value based transactions
2. Enhanced operational decision making to increase supply chain alignment to customer needs to improve return on inputs
3. Improved productivity through enhanced capability to address product cost
4. Increased value realised through enhanced capability to supply the highest paying customer with that product

The core benefits in adoptive whole of supply chain imaging, visioning and cobotic technologies includes enhanced decision making, improved capability and the ability to reduce the strength required to undertake physically demanding tasks.

6 Future research and recommendations

The project was briefed with identifying visioning, sensing and assistive technology development opportunities. Three development areas or problem spaces have been recommended. Specific technologies have not been recommended although visioning, sensing and assistive technologies are required to address all three development areas. Based on the conclusion and key findings from this project, a holistic approach to solving the specific problem spaces has been proposed. It is likely that multiple projects could be undertaken in each R&D area. A clear definition of the problems and vision of the commercial outcomes, along with the other success criteria summarised in the following sections.

6.1 Future R&D Areas

Meat Processing Assistive Technologies

This project area should address the following immediate industry needs:

- Significant labour shortages across processing plants
- High cost of labour relative to major country competitors
- Inability to automate due to lagging capability in visioning and cutting controls
- Loss in processing productivity and ability to pack and process offal as a result of these labour shortages.

Industry value propositions, if addressed effectively, could:

- Increase access to labour via remote login
- Create a development pathway to fully automated boning for 2/3 of the beef carcase
- Reduce boning room labour requirement by 40%
- Create a positive communication and awareness of the industry in the global community
- Increase Australian processing productivity against our largest competitors

On-Farm Visioning and Sensing for integrated decisioning

This project area should address the following immediate industry needs:

- Increase the return on inputs and therefore profitability of farming enterprises
- Reduce management risks associated with intensification of extensive livestock production
- Increase the quality of livestock feedback for enhanced management decisions and livestock selection for genetic improvement
- Increase the decision-making capability of livestock handlers and managers and the confidence of investors in adopting value adding technologies (including advanced carcase visioning and measurement technologies in future)
- Assist in development of capabilities required for the evolving of value-based transactions
- Automation of some farm practices that have existing technology but lack of confidence or access to the data required to automate

Industry value propositions, if addressed effectively, could:

- Create an agreed vision of how adoption of on-farm technologies can enhance livestock profitability
- Awareness of the strategic decisions to improve pathways to different market channels and value opportunities

- Increased confidence in on-farm technology value propositions
- Create a push-environment where on-farm controls and information systems can place pressure on buyers around longer term sell and buy contracting

Feedlot Decisioning Concepts

This project area is quite innovative and will provoke many concerns relative to status quo processes. Projects that scope the problem spaces in more detail should consider a design led approach to identifying the opportunities worth solving.

In brief, the project area should consider immediate industry needs, but take a longer-term view of how the problem could be addressed. Immediate problems include:

- Livestock are fed on a fixed ration plan and number of days while performance is variable and impacts profitability in two ways:
    - Variable growth performance
    - Variable quality and yield performance
- Decision data is required to optimise pathways and days on feed for individual animals
- Embrace individual animal management
- Provide alternative growth pathways to increase return on inputs
- Address the barriers to optimised production pathways with the use of assistive technologies
- Address the decisioning limitations to optimised pathways to market using enhanced data from visioning systems
- Explore alternative methods of value-based transactions with the use of objective visioning and sensing systems for pricing and value assessment

Benefits to industry could include:

- More efficient feedlot industry
    - Less feed inputs per kilogram of finished product
    - Greater consumer value for each kilogram of inputs
- Lighter environmental footprint while enabling higher value markets to be expanded
- Potential change agent in the establishment of new value-based transactions
- Support on-farm initiatives for value-based decision making

6.2 Project Methodology – Success Criteria

The findings from this project identified criteria that increase the likelihood that adoption will occur, and that commercial value will be delivered. The project areas recommended for further development should include the following aspects:

- Development of collaborative commercialisation projects that begin with the R&D and finish with commercial adoption. This requires an integrated technology approach, coupled with development of supporting or enabling capabilities.

- Engage commercial companies that understand the commercial value proposition and are committed to commercial success of the whole solution (not just the immediate technology).

- Projects should not be specifically technology centric but have a problem space lens that allows adaptation where one technology may need to be replaced or adapted to achieve the commercial objective.

- Develop clear programs of work that have very tight success objectives, but with well-defined frameworks that support agile design and pivoting as required, in a way that provides confidence and accountability to the participating stakeholders.

- Ensure the combination of skills and capabilities required for commercial success are accessible by the project teams. This requires a robust scoping of the capabilities required and genuine commitment to continuous review and reality checking processes throughout the project.

6.3 Proposed next steps

1. Development of scoping briefs that define the specific problem spaces,
2. Validate at a high level the value propositions and
3. Determine the specific projects that could be developed to support these Program areas.

7. Appendix

7.1 Annex A - List of Technologies

The list of technologies that would be researched was initially scripted as the below.

Phase 1 Technology Category List

- Exo-skeleton
- Cobots / Robots
- Manual Assist / Teleoperated
- Full / Semi Automatic Slaughter Line
- Augmented Vision
- Visioning & Sensing- CT
- Visioning & Sensing- X-ray
- Visioning & sensing- MRI
- Visioning & Sensing- Sonic
- Visioning & Sensing- Radio Scan
- Visioning & Sensing- Camera Technology
- Visioning & Sensing- Other
- VR / AR

The above list was formulated upon the original research mandate to consider assistive technologies as a category, and visioning & imaging/sensing technologies as another category. However, after Phase 1 of the research was completed, it became apparent that the research was both too broad (not applied enough to focus on the commercial application of solving industry jobs) and too limited (many of the industry-leading technologies that are prevalent in the above technology categories are too niche and focused in application to be applied to the industry jobs). As a result, an internal review of technology categories was conducted in parallel with a return review on the 'problem (or in this case problems) worth solving), and resulted in the list evolving into the below:

Phase 2 Technology Category List

- Internal AGVs (Automated Guided Vehicle)
- External AGVs
- AGV with robotic arm(s)
- Pneumatic conveying
- CT (small and large bore – boning and quality solution enabler)
- X-ray / DEXA (small footprint)
- NMR/MRI
- Ultrasound
- Hyperspectral
- Microwave
- High Powered Microwave (aka Pain Ray)
- Ultrasonic / laser cutting / CO2 / Water / Ice / Wire
- IoT Device development and evaluation
- Robotics, Cobotics and Manual Assist

- Augmented / Virtual Reality
- Haptic and Remote Control (including Gaming approaches)
- Artificial Intelligence / Deep Learning / Machine Learning
- Isolated/single-purpose automation system (only addresses 1 job type)
- Multi-purpose automation system (addresses multiple job types)
- Camera monitoring & evaluation system
- ID application (e.g. QR code, facial recognition etc.)
- Pneumatics- General (something needs to happen in single place)
- Visioning- General
- Other (details provided where applicable)

Many of the industry jobs could be solved by multiple technologies from the above categories (in the sense of multiple technologies being feasible as stand-alone solutions, or multiple technologies required to form an integrated solution). This analysis was done through internal workshopping, with a spreadsheet output identifying which technologies are relevant for each job, and detail recorded regarding what the solution could look like based on the problem the solution solves.

	On farm tasks and activities
Water to stock	
	Solar pumps to feeder tank so don't need to go out and start bore pumps
	Wind mill to feeder tank
	Manually starting diesel powered bore pump
Checking stock water	
	live camera feed from water trough
	live alert message via SMS limited inflow into tank and or trough
	delayed picture / msg several times a day
	Highly visible flag on tank which is raised when water level in tank is low (can see by flying over or from a distance away in smaller properties)
	Manually checking water troughs every second day
Feeding lick blocks	
In R&D	Lick requirements in water supply
	Live camera feed of lick block (in same line of sight as watering point)
	Lick requirements / supplements in loose form in bins which are topped up every couple of days & covered
	Licks are hard blocks on the ground in the open, checked every month or every week if near a watering point
Pregnancy testing	
In R&D	Breath / Urine sample
	Ultrasound wand used by station staff
	Ultrasound wand used by vet
	Vet - palpation
	No pregnancy testing / visual guess from 6mths plus
Body Condition Scoring	
Future	Photograph analysis / scan analysis from tail head and pins
	By Vet
	By experienced station staff
ADG	
	Walk over weigh scales in paddock connected to watering point
	Weigh scales at crush and animals weighed each time in the yards
Weight for turnoff	
	Walk over weigh scales in paddock connected to watering point with auto drafting feature
	Weigh scales at crush
R&D	Weight plates at individual supplement stalls (not suitable for large scale enterprises)
Scanning EID	
	Multiple readers in a crush / race to capture all animals and smallers animals
	Fixed reader
	Wand reader
Issues:	Smaller animals in the race don't get read properly, need multiple readers which adds cost
	Blue tooth from readers to computer doesn't work very well
Drafting stock in yards	
	Yard design which faciliates drafting from a distance and or autodrafting
	For example automatic backing gates moving stock forward in the mob which then feeds into a race with one person observing the animal and potentially drafting at the same time (separating wet cows, dry cows, small calves, weaner size - have the weight quickly flashed up from scales or height measure on the race)
	Yard design which has two crushes.
	The first crush scans and weighs the animal, the second crush has the veterinary producedures so quantity of dose etc can be calculated on weight. This allows animal to stand still and record the weight.
	Yard design and infrastructure that facilitates weighing & branding/marking
	Yard design and infrastructure that facilitates the use of technology - power,
Issues	maximum of 300 head of cattle. QDPI has a booklet - last published in 2006 and discusses placement and issues of weighing scales (no other tech mentioned)
Tracking stock	
	Radio collars
	Ear tag transmitters
R&D	Currently expensive and aren't retained by stock, need repeaters or mobile phone coverage
	Producers struggle with benefit gain - potentially useful for very valuable animals
NLIS transfers	
	EID reader on race and scanned as walk off the truck and recorded in a system which automatically updates NLIS database
	In an area with mobile reception and EID reader scans into a program and instantly updates NLIS database
	EID reader somewhere - walk animals through a separate race and record in a system which manually need to upload
	Hand wand and manually need to scan each animal
Monitoring pasture availability to adjust stocking rates or add supplements	
Measuring tools	
R&D	Satellite images - no people input required once calibrated and ground truthed
R&D	Wide angle sonar - needs vehicle / robot to measure. Suitable for smaller properties
	Drones - suitable smaller properties
	Time lapse on the ground photographs - larger properties
	Manual plate reader - smaller properties
	Manual biomass samples- quandrants - larger properties

7.2 Annex B - List of Processes and Tasks

1. Processing Tasks

- Slaughter (Bovine, Ovine, Caprine, All)
    i. Lairage livestock movement (automated – aka pigs)
    ii. Stunning
    iii. Head grading station
    iv. Rinse and Chill Validation
    v. Extremity removal (head, hock and tail)
    vi. Shackling
    vii. Y-Cutting
    viii. De-dagging (lairage and processing)
    ix. Bung Removal (and cleaning)
    x. Hide removal (What parts can we do here)
    xi. Brisket cutting and opening
    xii. Tipping (automated or alternative approach)
    xiii. Evisceration
    xiv. Splitting
    xv. Spinal cord removal
    xvi. Kidney fat removal
    xvii. Hot feather bone separation (and removal)
    xviii. Sterilisation
    xix. Skin on Bovine Processing (dirty side slaughter floor
    xx. Hot carcase grading
    xxi. Hot Grading station
- Boning - Beef
    i. Primal Cutting/Scribing (Treat as 3-4 carcase parts aka lamb)
    ii. Middle Processing (Parts 2 & 3)
    iii. FQ Processing (Part 1)
    iv. HQ processing (Part 4)
    v. Bone Belt Monitoring product loss minimisation
    vi. Trim Sortation (CL) Hot/Chilled
- Boning - Lamb
    i. Primal Cutting (small footprint)
    ii. Aitchbone removal
    iii. Tunnel boning
    iv. Frenching
    v. Fat cap removal
    vi. FQ deboning
- Boning - Goat (& Mutton)
    i. Six/Eight way cutting
    ii. Cubing
- Carcase Chilling
    i. Automated sorting
    ii. Hot boning plant – Middle chilling (i.e. FQ/HQ boned hot)

- Pick and Pack (and primal bagging)
    i. Primal identification – naked and bagged (enabler)
    ii. Auto Primal bagging outcomes (auto bagging / wrapping)
    iii. Automated carton packing (and validation)
    iv. Carton packing validation (primal ID and fill/voids)
    v. Vacuum bag leak detection
    vi. Lamb & Mutton Carcase Bagging (and Beef Quarter)
    vii. Carton Handling
    viii. Depalletising and Port marking
    ix. Container loading
    x. Case Buffer, sequencing, mixed case palletising
    xi. Meat lumping (internal and external to plant)
    xii. Label to Product to Carton Integrity
    xiii. Benchmarking (and further evaluating if required) roller/gambrel RFID (or equivalent) slaughter traceability
    xiv. Head processing
    xv. Transmissible Disease protection and monitoring
    xvi. Transmissible Disease protection and monitoring
    xvii. Co-Product Processing
    xviii. Beef feet processing
    xix. Assisted and Automated offal inspection
    xx. Hide grading, sorting and palletising
    xxi. Rendering alternatives
    xxii. Carcase Inspection & Trimming
- Carton Handling
- Product and Material Handling
- Traceability & Integrity (A Boning Room focus)
- Co-Product Processing
- People Safety

2. Feedlot Tasks

- Feed production & Delivery
    i. Receival of grain
    ii. Silage production
    iii. Ration batching/mixing
    iv. Ration delivery
    v. Bunk calling
- Animal receival & induction
    i. Unloading trucks
    ii. Placing hay in holding yards
    iii. Pushing cattle up in the race
    iv. Catching in the crush
    v. Animal health treatments

   vi. Drafting animals
   vii. Delivery of animals to the pen
   viii. OM data collection to better drafting of animals for feeding programs

- Animal health identification & treatment
   i. Identification of sick animals in the pen
   ii. Movement of animals to the hospital
   iii. Animal health treatments at hospital
   iv. Heat Stress management
   v. Relocation of animals back home.
   vi. Deaths & burial management
   vii. WHS & ESI identification of animals in the feedlot
- Animal movements
   i. To and from receival and exit yards
   ii. Weighing of animals at entry and exit
   iii. Animals lost in the feedlot (going to wrong place)
- Water management
   i. Cleaning troughs
   ii. Leaks identification
- Pen floor improvements
   i. Cleaning out pens
   ii. Processing of manure for fertiliser
- Data collection opportunities
   i. In pen weight gains for feed conversion & intake data
   ii. OM data
   iii. Animal health in pen data

3. On Farm Tasks

- Cattle Yards
   i. Animal movement through yards
   ii. Automated dehorning
   iii. Castration
   iv. Branding (for animal ID)
   v. Ear tags (for animal ID)
- Sheep yards
   i. Crutching
   ii. Shearing
   iii. Marking
   iv. Fodder management
- Operations
   i. Biomass monitoring
   ii. Vegetation management
   iii. Carbon sequestration processors
   iv. Irrigation
   v. Moisture management
   vi. Nutrient management

vii. Animal movement between paddocks
viii. Selection of animals for sale
ix. Pest management
x. Feed monitoring
xi. Water monitoring

- Heavy lifting operations
  i. Fencing

7.3 Annex C - List of Companies

List of Assistive / Cobotics Companies:

1. 6River- a mid-sized company operating globally, focusing on high-load exo-skeleton technology with an industrial, warehouse & logistical industry focus. Strong revenue growth and partnerships indicative of the optimism surrounding start-ups.
2. Lyro – a small local company from Australia, focusing on robotic automated packaging solutions utilizing visioning for a retail and industrial focus. A market-leader in research and technology for logistics and warehousing solutions for agricultural industry. Award winning team and research/technology/business advisors with globally recognized experience.
3. Ocado Group – is a large innovative, one-of-a-kind company with presence in a couple countries so far; 10 partners so far. They have created a system/chain for mass, online grocery shopping and ordering focusing on retail. Is the world's 2nd largest retail platform as a globally present innovator.
4. Dematic – World's 2nd largest materials handling systems supplier with a focus on AGV's in warehouses that are collaborative. Their focus is in retail, industrial, mining, aviation and logistics, agriculture and automotive industry.
5. Direct Industry – a B2B marketplace for industrial equipment, not a product manufacturer.
6. Ebn Online – an industry expert on key industry questions, not a product manufacturer.
7. Kawasaki – a large global leading robotics company with growth and engagement across multiple industries: public interface, retail, industrial, aviation and logistics, agriculture, automotive, mobility. Dabbles in cobotics. Humanoid robots focused on automated factories and collaborative arms.
8. Universal Robot – a large global leading cobotic arm company with a developed business approach. A market-leading company in cobotics with a focus on workflow enhancement of companies in retail, artisan and industrial.
9. Fanuc – one of the largest global leading robotics companies with growth and engagement across multiple industries. Focus on robot arms, plus manufacturing machines. Moving into the cobotics industry, mainly an innovator in large payload robots.
10. Easy Robotics – a small niche independent company that works on robotic stations for machine tending in the robotic industry and has their foot in the pharmaceutical, aviation and logistics, agriculture, automotive and mobility industries.
11. Doosan – similar to universal robot and is a competitor in the cobotics industry, but with a focus on R&D and sustainable growth of company. An industry focus in construction, industrial and mining.
12. ABB – a very large company with a leading approach to many industries in automation: Retail, Construction, Mining, Security, Automation. They specialize in cobotic arms for assistive workflows and support small businesses and pharmaceutical workflows. They also provide solutions for many other non-automotive industries. Possess a large body of knowledge in the tech solutions industry.
13. Akon – a very small company in Europe who specialize in egg palettizing automation. One of many companies who utilize existing robotic arm solutions from leading solutions providers to integrate into commercial ready specific automotive solutions in the agricultural industry.
14. Nachi – a medium sized global company in the robotics industry providing robotic arm solutions for automation. Strong performer with a focus in construction, retail, industrial, agriculture.

15. Kuka – is a leading global innovator in the robotics industry with a focus towards assistive and cobotic arms. They are a large company with a focus towards the medical, construction, retail, industrial, mining, aviation and logistics, agriculture, automotive and mobility.
16. Yaskawa – is a leading global innovator in the robotic arm industry with a focus for every robotic application in the industry. Their smart series have rolled out with 4 designs.
17. OCRobotics – is a small global leading company in visioning and robotics to assist with inspection and maintenance of remote access sites. They are an R&D company with a working product and a focus in construction, artisan, industrial, mining, aviation and logistics, automotive and mobility.
18. RoboWorld – provides suits & protective equipment for robots to prevent wear & tear.
19. Staubli – No.7 in world's top ten industrial robot manufacturers and is a large global leader. A very focused product range with collaborative and AGVs and general robot arms targeted at all automated industries.
20. DanskRobotTeknik – not a product manufacturer- distributes & integrates market-leading robots into an integrated solution + installs solution for clients.
21. Intuitive Surgical – The most dominant medical robotics company with global reach and increasingly utilized systems for surgeries. 20 years of software development capabilities.
22. Auris – a small-medium starting up US company focused on medical robotic assisted surgery. Partnered with Johnson & Johnson and focusing on user interface and experience for physicians.
23. Medtronic – Largest medical company that is in the robotic assisted surgery space as well as many other forms of healthcare. Focus is more so on healthcare than technology development. Similar products to intuitive and Auris.
24. Stryker – provides the vast majority of medical equipment used by physicians and is a global leader in the space. They have a system for robotically assisted surgery.
25. Corindus – is a small technology centred siemens healthcare company working on robotic assisted surgery for specific type of surgical application in the US. Leader in niche technology.
26. Asensus – a small starting company with a robotic assisted surgical system looking to boost its business with its similar approach to Auris and Intuitive Surgical. Specific global locations.
27. Titan Medical – a small US company start-up with a high focus on its technology rather than healthcare applications. Looking to increase popularity through design. Is partnered with Medtronic.
28. Stereotaxis – is a small/medium company focused on visioning technology and robotically controlled imaging. Is a global leader in its industry niche
29. Smith & nephew – a large global leading company in the healthcare industry with a focus on injuries and patient care. Developed a smart AI/robotic assisted technology for surgery; focused on healthcare.
30. ZimmerBiomet – a competitor to Smith & Nephew with the same focus, utilizing real robotic/collaborative arms for assistance in surgery.
31. Vicarious Surgical – Boston-based company focused on research and development of highly flexible robotic assisted surgery. A small niche company, not yet public
32. Vicarious AI – A small niche Canada-based company focused on providing automated solutions for companies in the picking industry. Utilizing robots for automation.
33. Monteris – a small US company providing solutions for minimally invasive technology utilizing robotics and MRIs. 2 0 years in the healthcare industry.
34. Marel – A leading global provider for advanced food processing and scanning. Very large company with a focus in public interface, retail, agriculture and cold chain.

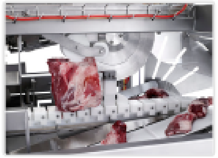
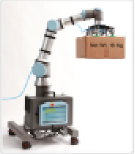
35. Ekso Bionics – a small company with a presence in the automotive industry as an injury-prevention provider via their bionic suits. One of the leading R&D companies in the space.

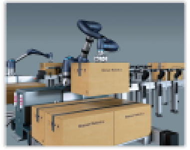
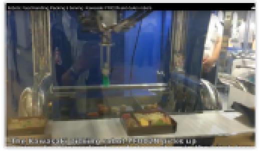
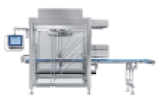
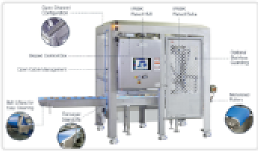
List of Visioning / Imaging Companies

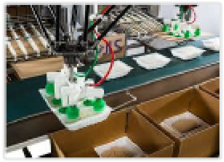
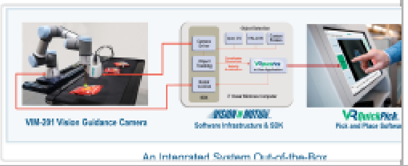
1. VSight UAB
2. ThirdEye
3. Toshiba
4. Vuzix
5. Teamviewer Frontline
6. Epson
7. Analogic
8. Rapiscan
9. Smiths Detection
10. L3Harris
11. IDSS
12. Inutitive Surgical
13. Esaote
14. Carestream
15. Frontmatec
16. ScopeAR
17. EverySight
18. Solos
19. Spatial
20. Liminal VR
21. Teslasuit
22. HTC Vive
23. Oculus
24. Fujifilm Holdings
25. GE Healthcare
26. Siemens Helthcare
27. Minfound
28. NeuroLogic
29. Neusoft
30. Epica
31. 4DDI
32. Eagle x-ray
33. Nutech
34. GIG XR
35. Engage
36. C360
37. SLAMcore
38. Sonic Healthcare
39. iTechArt
40. Shimadzu Corporation

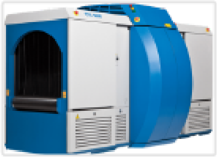
7.4 Annex D - Database of technologies applicable to processors

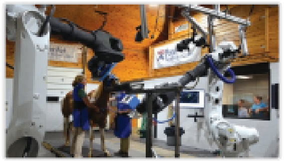
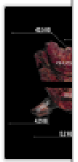
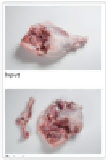
#	Name	Category	Images	Vendor	Description	Commercial ready
Category: Exo-Skeletons						
1	Sarcos Guardian® XO® Full-Body Powered Exoskeleton	Exo-Skeletons		Sarcos Robotics	The Sarcos Guardian XO full-body, powered exoskeleton is a first-of-its-kind wearable robot that enhances human productivity while keeping workers safe from strain or injury. Set to transform the way work gets done, the Guardian XO exoskeleton ...	✔
2	backX by suitX	Exo-Skeletons		suitX		✔
3	legX by suitX	Exo-Skeletons		suitX		✔
4	shoulderX	Exo-Skeletons		suitX		✔
5	PERCRO Body Extender - whole body exoskeleton for human power augmentation	Exo-Skeletons	 	PERCRO	[2012] An advanced wearable robot expressly conceived for augmenting the human strength for handling of heavy materials in unstructured environment. The system is composed by four robotic limbs with anthropomorphic kinematics and has a tota...	
Category: Cobots / Robots						
6	UNIVERSAL ROBOT UR3e	Cobots / Robots		Universal Robots	The UR3e collaborative robot is a smaller collaborative table-top robot, perfect for light assembly tasks and automated workbench scenarios. The compact table-top cobot weighs only 24.3 lbs (11 kg), but has a payload of 6.6 lbs (3 kg), ±360-degree ...	✔

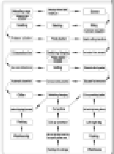
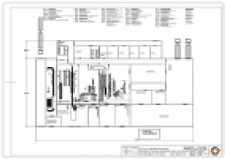
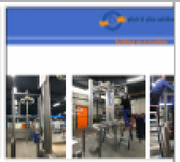
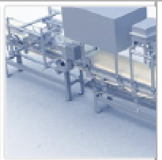
#	Name	Category	Images	Vendor	Description	Commercial ready
7	UNIVERSAL ROBOT UR5e	Cobots / Robots		Universal Robots	THE UR5e - A FLEXIBLE COLLABORATIVE ROBOT ARM Built with the future in mind, the UR5e is designed to grow in capability alongside your business, a spring board to improved product quality and productivity, so you wil...	✔
8	UNIVERSAL ROBOT UR10e	Cobots / Robots		Universal Robots	The Universal Robots UR10e is an extremely versatile collaborative industrial robot arm with its high payload (10kg) and long reach capability. Its 1300mm reach spans wide workspaces without compromising precision or payload performance. UR10e addresses ...	✔
9	Frontmatec automatic lamb shoulder machine	Cobots / Robots		Frontmatec	Processes complete lamb shoulders (double). After the shoulder has been positioned in the machine, it automatically cuts off the two front shanks. The circular knives are automatically adjustable in height. ...	
10	Frontmatec AiRA Robotics	Cobots / Robots		Frontmatec	Frontmatec offers a complete program of AiRA dressing line robots. The AiRA robots is a concept based on more than 20 years of R&D in engineering of automated processing and is regarded as the world's unrivaled leader in dressing line robotics. T...	✔
11	UNIVERSAL ROBOT UR16e [NEW]	Cobots / Robots		Universal Robots	The Universal Robots UR16e delivers an impressive 16kg (35.3 lbs.) of payload within a small footprint, and is ideal for use in heavy machine tending, material handling, packaging, and screw and nut driving applications. This powerhouse robot allows ...	✔
12	DOOSAN M-SERIES (M0609 · M0617 · M1013 · M1509) [Masterpiece]	Cobots / Robots		Doosan	M-SERIES is the highest quality premium cobot! 6 high-tech torque sensors provide the highest dexterity for highly sophisticated tasks and ensure the upmost safety...	✔
13	DOOSAN A-SERIES (A0509 · A0509s · A0912 · A0912s) [Almighty]	Cobots / Robots		Doosan	A-SERIES can go anywhere! With its superior speed and cost-effectiveness, A-SERIES promises a simple solution and a satisfaction to whom may be hesitant to get a cobot	✔

#	Name	Category	Images	Vendor	Description	Commercial ready
14	DOOSAN H-SERIES (H2017 • H2515) [High-Power]	Cobots / Robots		Doosan	H-SERIES is the most powerful cobot in the market. Outstanding 25kg payload and 6 torque sensors brings safe work environment for any kind of application	✔
15	YF002N - Kawasaki Robotics for food processing	Cobots / Robots		Kawasaki Robotics	The YF002N pick & place robot is the compact model of the Y series and it can be installed in narrow spaces. The high-speed Y series Robots can be used for material handling and assembly applications in a variety of industries, including food, ...	✔
16	duAro2 - Kawasaki Robotics for food processing	Cobots / Robots		Kawasaki Robotics	The Dual-Arm SCARA Robot "duAro": A brand new offering that realizes the concept of an innovative dual-arm SCARA robot which can safely collaborate with humans in work operations. The duAro2 has the deeper vertical stroke ...	✔
17	FANUC - food and beverage robots	Cobots / Robots		Fanuc	We have the largest offering of standard and collaborative robot models with payload capabilities from 0.5 - 2,300 kg. In addition, we provide application software for packaging and palletizing, integrated iRVision® and tracking features, ROBOGUI...	✔
18	PickRobot (single, double, triple, quadruple, SmartPicker	Cobots / Robots		weber	The Weber PickRobot stands for the uncompromising automation of slicing applications. Specifically adapted to your application area, it can be used flexibly for all insertion tasks and is available in five different executions: SmartPicker, single, ...	✔
Category: Manual Assist / Teleoperated						
19	Guardian® XT	Manual Assist / Teleoper...		Sarcos Robotics	The Guardian XT teleoperated dexterous robot performs intricate, and even dangerous, tasks that require human-like skill, all while keeping the operator at a safe distance. The robot is platform-agnostic and attaches to various mobile bases, including ...	✔
20	Talon® Series Pick-and-Place Robots Packing System	Manual Assist / Teleoper...		JLS Automation	Hygienic Robotic Packaging Solutions	✔

#	Name	Category	Images	Vendor	Description	Commercial ready
21	Osprey® Robotic Case Packers	Manual Assist / Teleoper...		JLS Automation	Osprey® Robotic Case Packers are designed for washdown applications such as meat, poultry, fresh produce, frozen (IQF) foods and cheese.	✔
22	QuickPick 201 3D Vision Guidance System	Manual Assist / Teleoper...		Visual Robotics	Visual Robotics' QuickPick 201 3D Vision Guidance System is a transformational offering. With our patent-pending Vision-in-Motion™ technology, a robot can track and handle moving objects as easily as static. No conveyor instrumentation. No gantry ...	✔
Category: Augmented vision						
23	[Headset] VUZIX M series Smart Glasses	Augmented vision		Vuzix		✔
24	[Software] xPick - Vision Picking solution	Augmented vision		Teamviewer Frontline	xPick is a patented and award-winning "pick-by-vision" solution. It supports manual order picking, incoming, outgoing, and sorting of goods, inventory control, sequencing, and many more processes in logistics and warehousing.	✔
25	[Headset] Moverio BT-200 Smart Glasses (Developer Version Only) CLOSEOUT	Augmented vision		EPSON	Enhanced features in accessories, lens and controllers; works out-of the-box with most Android apps	✔
Category: Visioning & Sensing - CT, X-ray						
26	eXaminer® XLB - CT-based ultra-high-speed explosives detection system	Visioning & Sensing - CT...		Analogic L3Harris	High-Speed Explosives Threat Detection for Large, Heavily Travelled Airports Key Features of the eXaminer XLB: Innovative PowerLink™ brushless power ...	✔

#	Name	Category	Images	Vendor	Description	Commercial ready
27	Analogic ConneCT	Visioning & Sensing - CT...	 	Analogic	ConneCT features a new modular imaging system based on advanced medical imaging technology and an interoperable network architecture designed to maximize reliability and achieve the lowest total cost of ownership.	✔
28	RTT110	Visioning & Sensing - CT...	 	Rapiscan	The RTT® is designed to allow screening to the highest levels of security at the first point of screening. The versatility of RTT allows it to be used as a high speed in-line system at the first level of screening or as a level 3 ...	✔
29	CTX 5800	Visioning & Sensing - CT...	 	Smiths Detection	CT explosives detection system A compact explosives detection system (EDS), the CTX 5800 identifies threats in checked baggage and cargo packages. ...	✔
30	CTX 9800 DSi	Visioning & Sensing - CT...		Smiths Detection	High speed CT explosives detection system The CTX 9800 DSi explosive detection system (EDS) uses a proprietary single X-ray source, dual energy design that provides high-resolution 3D images along with 2D and 3D...	✔
31	L3 ClearScan® Checkpoint CT	Visioning & Sensing - CT...		L3Harris	The L3 ClearScan® cabin baggage screener uses CT technology and advanced algorithms to deliver the highest level of explosives threat detection at an unprecedented false alarm rate. The aviation security system is designed to detect solid and liquid ...	✔
32	DETECT™ 1000	Visioning & Sensing - CT...		IDSS	Based on medical computed tomography (CT) imaging technology, the DETECT™ 1000 is a powerful lens with which to see and identify smaller and more advanced threats than ever before. ...	✔
33	Da Vinci Vision – Iris (part of Da Vinci Surgical Systems)	Visioning & Sensing - CT...		Intuitive	Iris is an anatomical visualization service that makes it possible for you to bring your surgical plans into the operating room. Using data from diagnostic CT imaging, a segmented 3D model of your patient's anatomy is created. Iris then enables you to...	✔

#	Name	Category	Images	Vendor	Description	Commercial ready
34	EquImagine – 4D true sterro-Dynamic 4D scanning	Visioning & Sensing - CT...		Universal Medical Syster	High accuracy, shows where bones are and a couple other things too, they also have a large CT animal scanner (http://www.veterinary-imaging.com/multi-slice-ct.php)	✔
35	[X-ray] DRX-Revolution Mobile X-ray System	Visioning & Sensing - CT...	 	Carestream Health	A mobile X-ray system on wheels powered by a wireless DRX detector. Ultra-manoeuvrable, automatic, collapsible column mobile imaging system.	✔
36	[X-ray] CPS-X 400 X-ray Scanner	Visioning & Sensing - CT...			The products get transferred in a continuous-flow process. Products go through the scanner where the mass allocation of each product is determined using X-ray technology. The products are then weighed on the integrated weighing ...	✔
37	[X-ray] Multitom Rax – robotic arm x-ray	Visioning & Sensing - CT...			It is particularly suited for difficult exams such as trauma or orthopaedic cases. Benefit from unique insights, efficient workflows, as well as comprehensive diagnosis on a single system – and set new standards in advanced musculoskeletal and trauma imaging. Preci...	✔
Category: Visioning & Sensing - Other						
38	Beef Classification Center, BCC-3™ (Advanced multi-view stereo imaging)	Visioning & Sensing - Ot...	  	Frontmatec		
Category: Full / Semi Automatic Slaughter Line						
39	HAMDAS-RX Automatic Ham Boning Robot	Full / Semi Automatic Sla...	 	Mayekawa (MYCOM)	The world's first automated ham deboning robotic machine. HAMDAS-RX automatically debones pork ham after pre-cutting is performed. The auto measuring feature allows precision cuts to the correct specifications of each ham and provides ...	✔

#	Name	Category	Images	Vendor	Description	Commercial ready
40	WANDAS-RX Automatic Pork Shoulder Deboning Machine	Full / Semi Automatic Sla...	 	Mayekawa (MYCOM)	An automated pork shoulder deboning robotic machine, the WANDAS-RX. It utilizes the technology of the HAMDAS-RX. Our image processing and auto measuring features with a vertical multi jointed robotic arm allows WANDAS-RX to process precisio...	✔
41	FALCON smartline by TREIF and Meral	Full / Semi Automatic Sla...		TREIF Marel	Less personnel — More flexibility — All from one source Simply faster to the finish line — with Smartline Your products are processed with nearly 10...	
42	OSAINT Chicken Slaughtering Line	Full / Semi Automatic Sla...	 	Shandong Osaint Machi	Complete Chicken Slaughtering Line for chicken killing, scalding, plucker, visceral and cut up	✔
43	LEAP (Low investment, Expandable, (semi) Automatic Processing) Concept - Chicken Slaughtering Line	Full / Semi Automatic Sla...		Meyn (subsidiary of CTB	The Leap concept incorporates Meyn's top-of-the-line technology at all stages. Expand from 500/1,300 to 15,000 bph.	✔
44	Poultry processing line 6000 birds per hour with auto Evisceration	Full / Semi Automatic Sla...	 	Dutch Poultry Tech	6000 birds per hour poultry processing line. Based on proven technology and 30 years of poultry processing experience. Lean engineering, manufacturing and overhead enable a cost-effective processing solution. Low initial investment, low cost of ownershi...	✔
45	Danish Crown Pork Processing Plant	Full / Semi Automatic Sla...	 	Frontmatec	• Automatic bung cutter, throat cutter and ham divider (APOLLO) • Automatic carcass opener (OMEGA) • Automatic evisceration (ORION) • Automatic back finning (pre-cutting of loins) (SATURN)...	✔
46	Cattle Slaughterhouse Systems & Equipments (HALAL)	Full / Semi Automatic Sla...		CEMSAN Slaughterhous		

#	Name	Category	Images	Vendor	Description	Commercial ready
47	Sheep Slaughterhouse Systems & Equipments (HALAL)	Full / Semi Automatic Sla...		CEMSAN Slaughterhous		

7.5 Annex D – Database of companies with advanced technology applicable to meat processing.

Companies are most likely to align themselves with the Australian red-meat industry for development of horizon 2 and 3 technologies, related to meat processing were identified.

#	Name	Logo	website	Headquarter	Countries have office	AU Office	Contact	Distributor / Position
1	Analogic	analogic	https://www.analogic.com/	US			LeeAnn Levesque	Security CT Sales and Media Inquiries
2	Avante Health Solutions	Avante Health Solutions	https://avantehs.com/c/ct-scanner-machine/1113	US			Jasen Hargrove	International Sales for Southeast Asia, Canada, Europe
3	Carestream Health	Carestream	https://www.carestream.com/en/us/	US		Level 3 176 Wellington Pde East Melbourne, 3002 Australia		
4	CEMSAN Slaughterhouse Systems	CEMSAN Slaughterhouse Systems	http://www.cemsanmakina.com/en/	Turkey				
5	Doosan	DOOSAN	https://www.doosanrobotics.com/en/Index	Korea		11A Columbia Way, Baulkham Hills, New South Wales 2153		Doosan Bobcat Doosan International Australia Pty Ltd.
6	Dutch Poultry Tech	Dutch Poultry Technology pluck & play solutions.	https://www.dutch-poultry-tech.com/	Netherlands				
7	Easy Robotics	EasyRobotics - we move your parts	https://www.easyrobotics.biz/	Denmark				
8	EPSON	EPSON EXCEED YOUR VISION	https://epson.com/usa	US		Unit 4C, 305 Montague Rd, West End, Qld 4101		
9	Fanuc	FANUC	https://www.fanuc.com/product/index.html	Japan		Unit 6, 29 Cinderella Dr, Springwood, QLD4127, ...		FANUC Oceania
10	Frontmatec	FRONTMATEC	https://www.frontmatec.com/en/front-page	Germany				

#	Name	Logo	website	Headquarter	Countries have office	AU Office	Contact	Distributor / Position
11	IDSS	IDSS Integrated Defence & Security Solutions	https://www.idsscorp.net/en/airport-security	US				
12	Intuitive	INTUITIVE	https://www.intuitive.com/en-us	US		Garigal Road, Belrose, NSW-2085, Australia		Distributor - Device Technologies Australia Pty Ltd.
13	JLS Automation	JLS	https://www.jlsautomation.com/	US				
14	Kawasaki Robotics	Kawasaki Robotics	https://robotics.kawasaki.com/en1/industries/robots-for-beverage-automation/	Japan				Distributor - Diverseco Brisbane South Branch
15	L3Harris	L3HARRIS	https://www.l3harris.com/en-au/australia?regional_redirect=en-au	US		Level 1, 97 Northbourne Avenue, Turner ACT 2612		L3Harris Australia
16	LYRO	LYRO	https://lyro.io/	AU		6 Electronics St, Eight Mile Plains QLD 4113		
17	Marel	marel	https://marel.com/en	Iceland		42 Borthwick Ave, Murarrie QLD 4172		Marel Food Systems Pty Ltd. AU
18	Mayekawa (MYCOM)	MAYEKAWA MYCOM	https://www.mayekawa.com/	Japan		Unit 2, 44 McCauley Street, Matraville, NSW 2036		MAYEKAWA Australia Pty Ltd
19	Meyn (subsidiary of CTB Inc.)	meyn	https://www.meyn.com/	Netherlands				
20	PERCRO	PERCRO Perceptual Robotics Laboratory	https://www.santannapisa.it/en/institute/tecip/perceptual-robotics-percro-lab	Italy				
21	Rapiscan	Rapiscan systems An OSI Systems Company	https://www.rapiscansystems.com/en/	US		6-8 Herbert Street, Unit 27, St. Leonards, NSW 2065		Rapiscan Systems Pty Ltd

#	Name	Logo	website	Headquarter	Countries have office	AU Office	Contact	Distributor / Position
22	Sarcos Robotics		https://www.sarcos.com/	US				
23	Shandong Osaint Machine Co., Ltd		https://www.osaintequipment.com/	China				
24	Siemens Healthineers		https://www.siemens-healthineers.com/en-au#05664149	Germany		885 Mountain Highway, Bayswater, VIC 3153		
25	Smiths Detection		https://www.smithsdetection.com/	UK		Unit 5 Botany Grove Estate, 14A Baker St, Botany, NSW ...		Smiths Detection (Australia) Pty Ltd
26	suitX		https://www.suitx.com/	US		117B Great Eastern Hwy, Rivervale WA 6103	Ruth Lennon	Distributor - Biosymm https://www.lifereadybiosymm.com/
27	Teamviewer Frontline		https://www.teamviewer.com/en-us/solutions/frontline/	Germany				
28	TREIF		https://treifusa.com/	Germany		2/7 Jubilee Ave, Warriewood, NSW 2102		Distributor - CBS Foodtech Pty Ltd https://cbsfoodtech.com.au/brands/treif/
29	Universal Medical Systems		https://www.universalmedsystems.com/	US				
30	Universal Robots		https://www.universal-robots.com/	Denmark			Oceania sales rep. in Singapore	https://www.universal-robots.com/distributors/#/map/2514/26086/-/-
31	Visual Robotics		https://www.visualrobotics.com/	US				https://www.visualrobotics.com/contact-1
32	Vuzix		https://www.vuzix.com/	US				https://www.vuzix.com/Contact/Sales

#	Name	Logo	website	Headquarter	Countries have office	AU Office	Contact	Distributor / Position
33	weber		https://www.weberweb.com/	Germany				
						FILLED 14		

7.6 Annex F – Concept Testing in a commercial environment

Commercial application scoping and ideation is the gap between desktop scoping and commercialisation. At the later end of the feasibility stage practical application of solutions into commercial environments is to be assessed. Given the limited time in the project, this was done as 1 to 2 site visits with processors and producers to consider the barriers and challenges involved in integrating technologies into commercial environments. The findings from the concept testing are summarised into an assessment matrix and reported in findings.

Review process flows

The process flow review looks to outline the specific applications and process flow options using the current as a baseline and looking and methods to change the current process flow for future benefits. Process flows presented will be accompanied by product photo's, value metrics, challenges and risks at each stage that need to be addressed. This detail will support tests that feed into work plans.

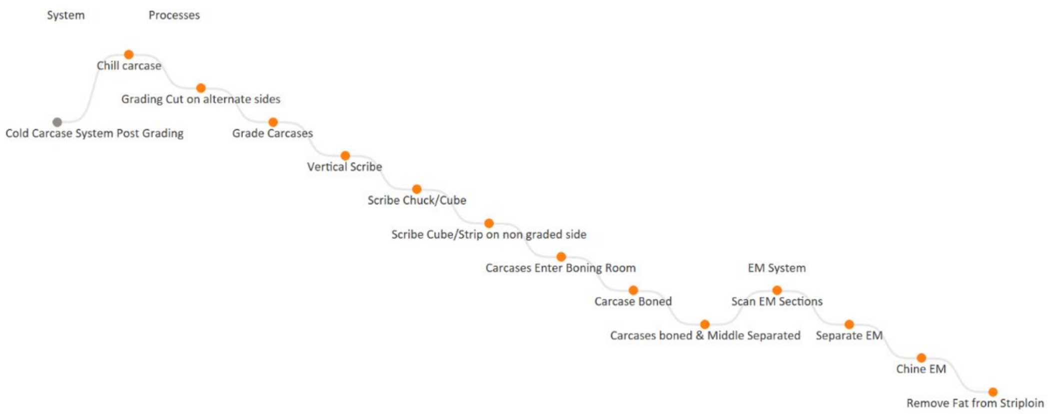


Figure 9: Example process flow

Note – there will not be one single process flow. Multiple prioritised flows/cutting approaches will be maintained as pivot options for service providers depending on ease of engineering of deliverables.

Technology Capabilities

The objective of this activity is to imagine how technology could deliver the solutions from step 2. Technologies will be presented for each cutting line or combination of boning processes with examples of capability.

A number of questions will be pre-prepared to be answered during product brainstorming on-site in the next step.

Although the focus is on technology the groups skill sets are still operational and task focused rather than engineering service provider focused. This is to:

- prevent narrowing of focus to one particular service providers skill sets
- pressure test the physical process flows for further refinement
- develop workplan of activities as blocks of design work – this will be prepared to then engage technology service providers.

An automation expert and an assistive technology (cobotics) expert will be attending (Yet to be confirmed – potentially via video link subject to travel restrictions) and will lead parts of this section in censoring what is possible/commercially realistic. They will bring alternative approaches that stimulate operational solutions to align with existing technology capabilities.

The discussion may prompt further ideas on carcase breakdown, integration, or other risks not yet thought of. This will aid the hands-on boning room breakdown session in the next step. Technology examples will be presented for each of the following areas:

a. Cobotic assistive technologies
b. Automated cutting capabilities
c. Visioning technologies
d. Clamping capabilities

Figure 10: Example visioning systems and assistive technology integrations for discussion

Product inspection

A range of different engineering designs will be investigated. The intention is to show how each application could be done, and how a combination of cuts could be integrated. Different applications of technology/cutting outputs will have different impacts on capital cost, integration with existing boning layouts, performance (yield, throughput, labour, ROI).

Workflows and outputs will be broken down, disassembled, then reassembled to support the discussion process.

The impact of technologies on each process flow will be discussed as the task components and the flow in the boning chain are used to pressure test the options for automation.

Minimum levels of improvement that warrant development will be agreed. For example, a small improvement in shoulder boning using cobotics will be assessed in relation to overall process integration as worthy or not for development. Manually assisted lifting on pastoral properties or visioning of crush side activities may or may not benefit the overall processes required of people. Pros and cons of each automation scenario within the whole process flow will be considered.

7.7 Annex G - Business case analysis modelling

The following outlines the 5-step approach Greenleaf has used to calculate the value created through increased accuracy of cutting lines through automation.

1. Accuracy standards (mm = grams meat)

The models utilise the standard assumption of 1.033 g/cm3 of meat density to volume. This provides the conversion of meat volume calculations to a kilogram weight from which a dollar ($) value can be determined using adjusted yields from each application.

2. Cutting line accuracy (Manual, CT & DEXA)

A cutting line accuracy measurement of will be assumed for each application throughout the calculations process for the new automated process.

3. Carcase variables (EMA, fat depth, etc.)

Eye Muscle Area (EMA) assumptions and models were used to determine appropriate meat areas for product volume calculations. This data was obtained from the MSA carcase grading data.

4. Price differentials ($)

Differential prices based on historical yields for each plant were determined using industry reporting data. The price differentials were calculated for different product cuts as well as different animal feed types. The final model provides the ability to undertake scenario modelling for different animal process composition and volumes (with automatically adjusted yields), to help stress test the investments for the automation processes.

5. Impact on value opportunity (IRR%)

The full marginal impact of the investment, for each plant, was modelled using the accuracy model inputs previously described as well as assumptions regarding volume and percentage of animal feed types processed through the three plants.

It is important to note that a reasonable expectation from automation would be an increase in throughput and so the modelled scenarios allow for a once off increase in plant production volumes, for each plant, because of investing in an assumed automation process.

To maintain the integrity of the investment decisioning, the models permit “switching off” the automation benefits of each or all the cuts modelled. This can be different for each plant being modelled.

To determine the payback period, marginal cashflow and IRR for each plant, 10-year assumptions regarding additional capital investment, upgrade and support costs were included. Assumptions regarding savings from labour, WH&S and throughput were also captured. All can be adjusted based on the investment appetite and expectations to determine a complete marginal position from the investment.

7.8 Annex H – Analysis of visioning technology

Computer Tomography (CT)

eXaminer® XLB - CT-based ultra-high-speed explosives detection system EC

Category

CT, commercial continuous throughput

Brief description

High-Speed Explosives Threat Detection for Large, Heavily Travelled Airports

Key Features of the eXaminer XLB:

- Innovative PowerLink™ brushless power transmission system
- Dual-energy system
- Throughput of up to 1,200 bags per hour in Continuous-Flow mode
- One-meter-wide tunnel
- TSA certified EDS

Industry

Aviation, already been used in some airports

Company

Analogic and L3harris

System specifications

(Product brochure)

- Throughput speed: 1,200 bags per hour
- Weight:
  - Scanner: Approx. 5,035 kg (11,100 lbs)

- Inline Entry/Exit Tunnel: Approx. 771 kg (1,700 lbs)

- Dimensions:
  - System Dimensions: 528 cm (208") L x 224 cm (88.2") H x 228 cm (90") W
  - Conveyor Belt Height: 947.7 mm (37.3")
  - Conveyor Speed: 34 cm/sec (13.4 in/sec)
  - Conveyor Capacity: 136 kg (300 Ibs)
- Image resolution:
  - Video Resolution: Dual 1600 x 1200 high-resolution, flat panel LCD monitors
  - Image Display: High-resolution 2-D and 3-D images Enhanced 3-D full bag scan in a single pass Full 3-D bag/threat object views 3-D full image and threat object rotation
- Tunnel Opening: 1000 mm (39.4") W x 592 mm (23.3") H
- Operating Temperature: 0°C to 40 °C
- Storage Temperature: -20°C to 70 °C Relative Humidity: 10 to 90%, non-condensing

Radiation safety

All L-3 Communication Security & Detection Systems’ X-ray systems comply with all international standards for radiation safety requirements and external emissions limits including the United States Code of Federal Regulations, Title 21, Section 1020.40 (21 CFR1 020.40) that apply to our products.

Analogic ConneCT EC

Category

CT, Dual Energy Patented Computed Tomography (CT) Technology, commercial continuous throughput

Brief description

ConneCT features a new modular imaging system based on advanced medical imaging technology and an interoperable network architecture designed to maximize reliability and achieve the lowest total cost of ownership.

Brochure

Video featured on CBS, CNBC, NBC

Industry

Aviation, already been used in some airports

Company

Analogic

System specifications

Data sheet

- Throughput speed: > 600 Bags Per Hour
- Weight: 1,990 kg
- Dimensions: 2.69 m x 1.44 m x 1.75 m
- Image resolution: to be tested
- Tunnel size: 62 cm x 42 cm
- Operating Temperature: 0°C to 40 °C
- Transport / Storage Temperature: 7°C to 49°C
- Relative Humidity: - 10 – 90%, non-condensing
- Additional Cooling (Internal / External): Ambient Fan Cooled

Radiation safety

All Analogic X-ray systems are in full compliance with all international radiation safety requirements and external emission limits.

RTT110

System specifications

- Throughput speed: 0.5m/sec (good)
- Weight: 7 tonnes
- Dimensions: 6m L x 2m W x 2 m H
- Image resolution: to be tested
- Tunnel size: 1020 x 756 mm

CTX 5800 EC

Category

CT, commercial continuous throughput

Brief description

CT explosives detection system

A compact explosives detection system (EDS), the CTX 5800 identifies threats in checked baggage and cargo packages.

1. Threat detection in a small footprint
2. Belt speed 0.14m/s (400-450BPH)
3. Unlimited bag length (with curtain extensions)
4. Stand-alone and in-line configurations
5. Customized networking solutions
6. High resolution 3D images from a single X-ray source

Data sheet

Industry

Aviation

Company

Smith's Detection

System specifications

- Throughput speed: up to 400-450BPH; Belt speed: 0.14m/s
- Weight: 2041kg (4,500lbs.)
- Dimensions: 1570 (W) x 1550 (H) x 2610mm (L) (59.0 x 57.8 x 102.8in)
- Image resolution: High resolution 3D images from a single X-ray source
- Tunnel opening (max. width at conveyor edge): 750 mm (29.5in)
- Conveyor height from floor: 616 mm (24")
- Operating temperature: 0° to 35°C (32 to 95°F) [up to 0° to 45°C (32 to 113°F) with air conditioning]
- Storage temperature: –7 to 49°C (20 to 120°F)
- Humidity: 10 to 95% noncondensing

Radiation safety

Meets all applicable laws and regulations with respect to X-ray emitting devices

CTX 9800 DSi EC


Category

CT, commercial continuous throughput

Brief description

High speed CT explosives detection system

The CTX 9800 DSi explosive detection system (EDS) uses a proprietary single X-ray source, dual energy design that provides high-resolution 3D images along with 2D and 3D organic/inorganic material discrimination.

These imaging tools enhance the analysis of details and specific structures of suspected threats, allowing for efficient security decisions on all checked bags and cargo packages.

7. Customized networking solutions
8. Intuitive user interface
9. Efficient power consumption
10. High resolution 3D images from a single X-ray source
11. Level-1 decision and Level-2 image made before bag exits the machine

Data sheet

Industry

Aviation

Company

Smith's Detection

System specifications

- Throughput speed: up to 1,800 BPH; Belt speed: 0.2, 0.3 or 0.5 m/s
- Weight: 6713 kg (14,800 lbs.)
- Dimensions: 2400 (W) × 2177 (H) × 4803 mm (L) (94.5 × 85.5 × 189.0 in.)
- Image resolution: High resolution 3D images from a single X-ray source, 3D Volumetric Rendering
- Tunnel opening (max. width at conveyor edge): 1020mm (40.2in)
- Operating temperature: 5° to 38°C (40 to 100°F)
- Storage temperature: –7 to 49°C (20 to 120°F)
- Humidity: 10 to 95% noncondensing

Radiation safety

Meets all applicable laws and regulations with respect to X-ray emitting devices

Capabilities – extras

IT and AI, imaging capabilities of some kind

L3 ClearScan® Checkpoint CT EC

Category

CT

Brief description

The L3 ClearScan® cabin baggage screener uses CT technology and advanced algorithms to deliver the highest level of explosives threat detection at an unprecedented false alarm rate. The aviation security system is designed to detect solid and liquid explosives, as well as HMEs, to the latest regulatory requirements without the need for any divestment. This offers the highest level of passenger convenience, allowing for liquids and electronics to be screened while remaining in cabin baggage.

- Combines dual-energy CT technology and advanced explosives detection
- High throughput/low false alarm rate
- Optional integration with automated tray return system (TRS)

Video demo, video demo 2

Industry

aviation

Company

L3Harris

System specifications

- Throughput speed: over 500 bags per hour
- Weight: 7 tonnes
- Dimensions: 6m L x 2m W x 2 m H
- Image resolution: to be tested
- Tunnel size: 1020 x 756 mm

DETECT™ 1000

Category

CT

Brief description

Based on medical computed tomography (CT) imaging technology, the DETECT™ 1000 is a powerful lens with which to see and identify smaller and more advanced threats than ever before.

The system's modern open platform design leverages High-Resolution Imaging combined with Artificial Intelligence (IA) technology to automate the threat detection and provide superior imaging to allow screeners to quickly identify prohibited items without divestiture of electronics or liquids. Soon this technology will be applied to both checked baggage and cargo.

- Artificial Intelligence and deep learning capabilities allow for optimized Automated Threat Detection
- Patent-pending "Dynamic Flow Throughput" ™ technology provides high throughput while maintaining radiation safety
- Elimination of divestiture of electronics and liquids

Industry

Aviation

Company

IDSS

System specifications

- Throughput speed:
- Weight: 3,300lbs
- Dimensions: m (L) x m (W) x 2m (H)
- Image resolution: to be tested
- Tunnel size: mm

Da Vinci Vision – part of Da Vinci Surgical Systems EC

Category

CT, 3DHD with endoscope

Company

Intuitive | Robotic-Assisted Surgery | Da Vinci Surgical System

Equimagine – 4D true sterro-Dynamic 4D scanning

Category
CT, Stereo-Dynamic 4D scanning, robotic, digital radiography, tomosynthesis

Brief description
High accuracy, shows where bones are and a couple other things too, they also have a large CT animal scanner

Industry
Veterinary industry for scanning horses

Company
Universal Medical Systems

System specifications
Has 6 different types of available scans all in one. 0.03mm accuracy

Radiation safety
Unsure

Washdown ready
Not so much

Common Medical CT scanners

Companies

- Avante
- GE Healthcare
- Epica Medical Innovations – Large horse scanner
- Minfound,Anike,SinoVision,SternMed,NeuroLogic,Neusoft,Arineta – Medical

X-Ray

DRX-Revolution Mobile X-ray System EC

Category

X-ray

Brief description

A mobile X-ray system on wheels powered by a wireless DRX detector.
Ultra-manoeuvrable, automatic, collapsible column mobile imaging system.

Brochure
Video demo

Industry

Medical

Company

Carestream

System specifications

- Throughput speed: n/a

- Weight: 575 kg, (1,268 pound)
- Dimensions: [129.5-195.6] x 57.6 x 121.9 ([51-77] x 22.7 x 47.9)
- Image resolution: to be tested
- Tube arm reach of 135.1 cm; tube tilt of -10 to +90 degrees.

Radiation safety

The System is manufactured with radiation protection in accordance with IEC/EN 60601-1-3:1994.

Although exposure to high levels of X-radiation may pose a health risk, System X-ray equipment does not pose any danger when properly used. Be certain all operating personnel are properly educated concerning the hazards of radiation. Persons responsible for the System must understand the safety requirements and special warnings for X-ray operation. Review this manual and the manuals for each component in the System to become aware of all safety and operation requirements.

X-ray Scanner CPS-X 400 EC

Category

X-ray

Brief description

The products get transferred in a continuous-flow process. Products go through the scanner where the mass allocation of each product is determined using X-ray technology. The products are then weighed on the integrated weighing station according to their individual track. The system features a two-stage safety guarding for its radiation source. The CPS-X 400 is specifically designed for weight-accurate slicing of speciality products like Swiss Cheese and those which vary in density, e.g. fat to lean ratio.

Video demo
Brochure

Industry

Food processing

Company

Weber

System specifications

- Throughput speed:
- Weight:
- Dimensions: 2,794mm (L) x 1,062mm (W) x 2,091 mm (H)
- Image resolution: to be tested
- Max. product length (mm): 2,560
- Max. product width (mm): 1,000/1,200

Multitom Rax – robotic arm x-ray

Category
Twin robotic x-ray system

Brief description
It is particularly suited for difficult exams such as trauma or orthopaedic cases. Benefit from unique insights, efficient workflows, as well as comprehensive diagnosis on a single system – and set new standards in advanced musculoskeletal and trauma imaging. Precise insights through unique automation. Efficient workflows around your patients. Comprehensive diagnosis with multiple procedures

Industry
Medical diagnosis

Company
Siemen's healthcare

System Specification
Ceiling mounted, multifunctional wireless footswitch, for extended anatomical coverage

These are the ways it is used

Radiation safety
Doesn't say

Washdown ready
Probably not.

3D Cameras

Libra 165C EC

Category

3D imaging/scanning

Brief description

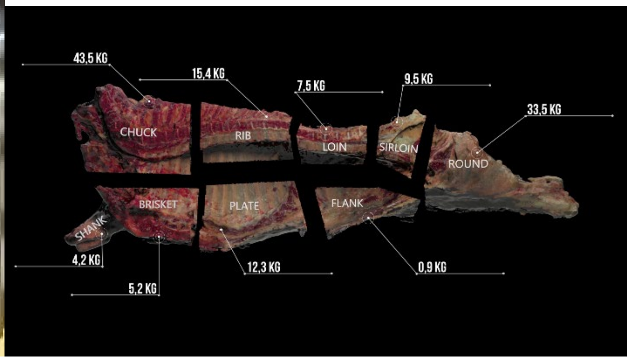
Catalogue
Video demo

Company

Nantsune Japan

Others

Beef Classification Center, BCC-3™ EC

Category

Advanced multi-view stereo imaging

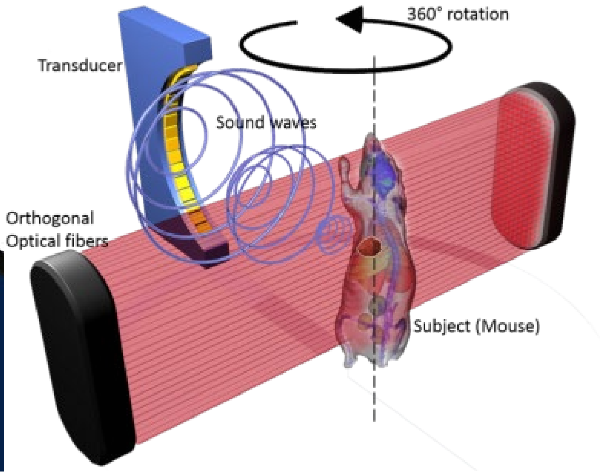
Brief description

Brochure
Video demo

Company

Frontmatec

LOIS 3D Pre-clinical System EC



Category

Optoacoustic(photoacoustic) Tomography

Optoacoustic (OA) imaging is a method of acquisition and reconstruction of visual representation of biological tissue based on time-resolved detection of acoustic pressure profiles induced in tissue through absorption of optical pulses under irradiation conditions of temporal pressure confinement during optical energy deposition

Brief description

LOIS 3D combines light and sound to produce a three-dimensional image of tissue-simulating phantoms, small animals, and other types of tissue submerged in the imaging module.

LOIS-3D is the first system of its kind to produce comprehensive information based upon volumetric optoacoustic tomography depicting the absorbed optical energy (blood distribution and its oxygenation). This provides an extremely rich set of complementary anatomical and functional 3D images.

Industry

biomedical research

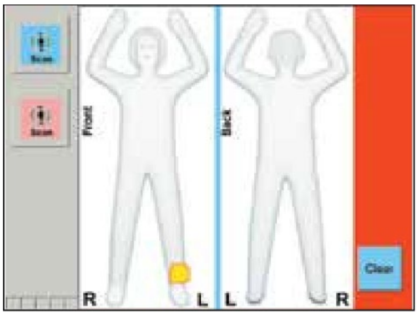
Company

Tomowave

System specifications

- Throughput speed:
- Weight:
- Dimensions: m L x m W x 2 m H
- Image resolution:
- Tunnel size:

ProVision® 2 EC



Concealed items are highlighted on a generic mannequin

Category

millimetre wave (MMW) imaging technology

The active millimetre-wave holographic imaging technology produces the image mainly by using the penetrability of MMW to clothes. The system emits millimetre waves of certain frequency to human body and the waves will penetrate clothes and be reflected back after striking human body or other hidden objects.

Brief description

The ProVision 2 is the most widely deployed advanced personnel screener in the world. It quickly screens passengers using safe millimetre wave (MMW) technology to automatically detect concealed objects made of a broad variety of concealed materials – both metallic and non-metallic.

Brochure by Leidos
Brochure by L3Harris
Video demo

Industry

Aviation, people scan

Company

Leidos & L3harris

System specifications

- Throughput speed: Less than six second total processing time for the scan and decision. Processes up to 200-300 people per hour depending on application.
- Weight: 698.5kg (1,540lbs)
- Dimensions: 2.27m (L) x 1.5m (W) x 2.36 m (H)
- Image resolution:
- Tunnel size:
- Operating temperature: 0° to 35°C (32 to 95°F)
- Humidity: 10-90% non-condensing

Radiation safety

The ProVision 2 does not use X-rays or ionizing radiation.