Final Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

Small Footprint DEXA

Small Footprint DEXA – Stage 2

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1.0 Executive Summary

The Australian red meat processing sector (bovine, ovine, and caprine) has always looked towards the European pork industry for automation and technology advancement insights. Those of us that have worked in the Australian red meat R&D areas (either as investors or developers) have always been challenged as to why we are perceived to be lagging behind the slaughter floor and boning room automation solutions that we have seen in the European pork processing sector.

One technology that has been developed for the industry that has substantially enabled the development of some processing automation and information solutions (such as those noted above), has been full lamb carcase or full beef side continuous x-ray (Single Energy and Dual Energy) systems.

AMPC issued an innovation challenge asking providers to rethink x-ray design for the smaller footprint required for greater uptake in the Australian red meat processing sector. In approaching AMPC's innovation challenge through this project, Intelligent Robotics have developed a design for a carcase x-ray scanning machine to address the inspirations of the AMPC innovation challenge. In relating back to the objectives that were established for the project:

1) **Develop a carcase DEXA concept and assess its alignment with the following aspirations: modular (applicable to a range of processing plants from an ROI perspective), with scalability assessed for increasing units in series and in parallel in terms of throughput rates and cost; smaller footprint; and simpler installation**

   The concept has been designed with these aspirations as key design criteria.

2) **Perform design and equipment selection tasks to provide accurate costing for the cell concept in terms of commercial price and cost of further development**

   The designs of the concept have been progressed to the point of allowing reasonable estimates to be made of target commercial pricing, as well as the work required for development. A scope of supply and costing has been provided for the initial systems reflecting this, which would form the structure for a sales proposal in the future.

3) **Detail accurate layout designs to enable costing for site works requirements for processors**

   During this project, the designs were progressed enough to provide an accurate layout of the system. In this report, the scope of site works required was then outlined, with the primary components being railworks and any required building modifications (if needed). The exact scope of these will be site-dependent.

4) **Perform detailed cycle time analysis with concept for different cut configurations, including simulations**

   Simulations of the concept throughout its design were built and used to evaluate the system as well as factors such as positioning of cell walls and sensors.

5) **Investigate Hot vs Cold carcase processing by the system**

   The system maintains the same design for hot or cold carcase processing. Depending on the application (e.g. lean meat yield measurement vs cutting), and the type of cattle produced by the plant, the side stabilisation time may vary slightly which will need to be accounted for in the system throughput rate. The machine itself however will remain unchanged.

In this project, the commercial aspects of the Small Footprint DEXA concept were investigated. The concept was also reviewed against the initial inspirations for the project as well as the project objectives. The concept has been developed to the point where the next step would be customer engagement for a project, the structure of which has been outlined.

The project has produced a detailed concept for a Small Footprint DEXA system. Processor feedback was sought on the concept as a mechanism for driving scribing automation. While the concept was viewed positively, and is significantly smaller and simpler than existing solutions, the footprint and cost required were still too large to proceed with the processors that were approached. Currently alternative sensing technologies are being evaluated for the purposes of driving cutting automation. As these assessments progress and the realisable benefits of these alternative sensing technologies to x-ray become known in the context of scribing, the next steps for the Small Footprint DEXA concept developed in this report may be to explore other areas such as performing cuts which can't be sensed alternatively (e.g. requiring sub-surface features), focussing on lean meat yield evaluation, quarter-processing (which requires a smaller machine), or specifically targeting customers wanting scribing yield gains above and beyond what the alternative sensing technologies can provide and have sufficient space in their plant.

2.0 Introduction

AMPC's 2020-2025 Strategic Plan identifies both within the Advance Manufacturing (pages 5 & 6) and People and Culture (pages 10 & 11) programs that address:

1. Removing staff from dangerous operations, via Hands-Off processing (Adv. Mft.),
2. Carcase Primal Profitability Optimisation, via accurate processing (Adv. Mft.)
3. Digitisation, via acquiring product information and leveraging data insights (Adv. Mft.),
4. Retention, via improving working conditions and making tasks exciting (People & Culture),
5. Development, via developing tasks that require higher skills and intellect – operational & technical (People & Culture),
6. Safety and Wellbeing, via reducing the high-risk nature of processing operations (People & Culture),

are all foci of AMPC, and that this (Small Footprint DEXA) is one innovation theme will aim to make a significant impact upon all six.

Current Solutions

The current solutions on the market specifically developed for both beef and lamb automation, are considerably large in footprint (to accommodate x-ray shielding requirements designed by the commercial companies), are not able to be 'walked-in' to a meat processing facility over a weekend, and do not afford a scalable design for smaller portions of a carcase or side to be scanned for smaller part processing automation cells.

Existing x-ray solutions provided for metal detection and or fat/lean trimming blending/QA have not been evolved and demonstrated (to date to the best knowledge of AMPC) to then be leveraged for automation of carcase or primal processing.

Innovation Competition

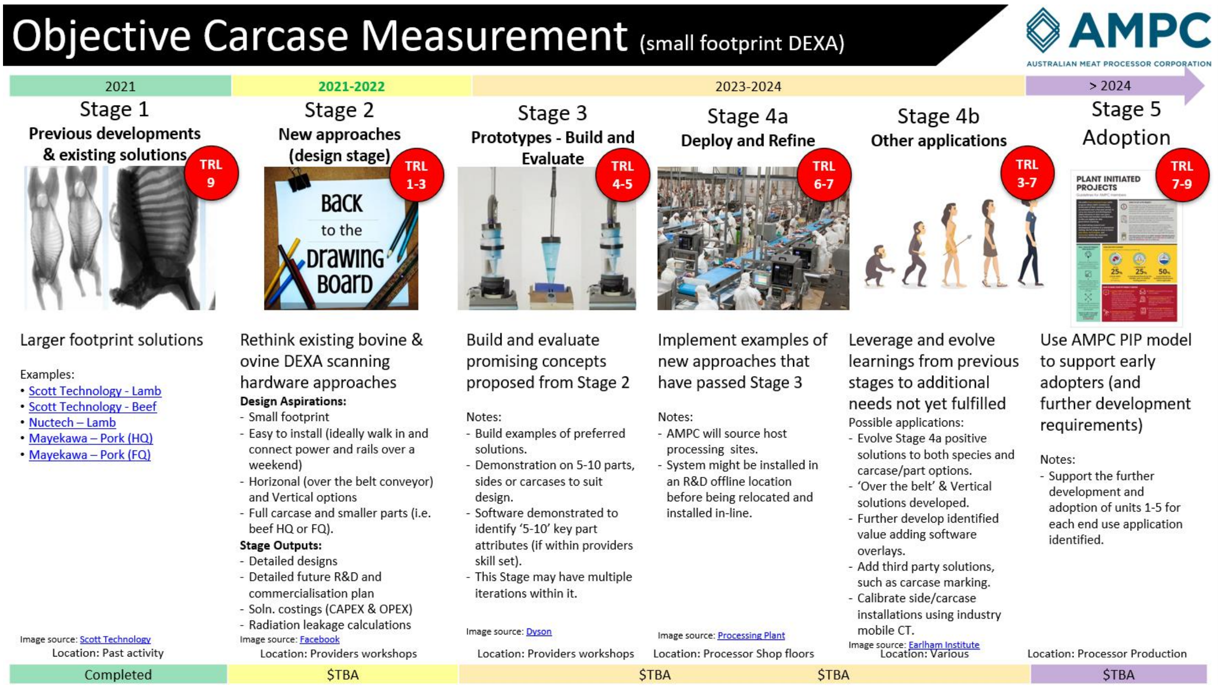
AMPC is anticipating operating an innovation competition with this (and other) innovation themes. Following a widely practiced approach of other innovation investors (such as DARPA), AMPC where possible will support a number of providers with unique approaches during Stage 1 (and 2). As the stages progress the number of providers supported to the subsequent stages will be reduced.

Development Path (and adoption / path to market)

To provide guidance in the AMPC proposed stages of development for this area of innovation, AMPC has drafted the following Theme on a Page. Note: this is a suggestion only, and providers can ignore this approach and or provide an alternative. However, for any provider who proposes a different approach, AMPC will only consider an application if an equivalent development and path to market strategy (similar to the one below) has also been provided.

Additional information can be found at these links:

- https://www.linkedin.com/pulse/small-footprint-x-raydexa-pork-industry-has-one-red-sean-starling
- https://www.linkedin.com/pulse/small-footprint-x-raydexa-pork-industry-has-one-red-sean-starling-1f
- https://www.linkedin.com/pulse/small-footprint-x-raydexa-pork-industry-has-one-red-sean-starling-1c/



Stage 2 – Rethinking X-ray design for small footprint needs of Australian red meat processing sector.

Stage 2 will enable supply companies/integrators/researchers to work with AMPC to conceptualise, design and price x-ray solutions that address the following aspirations of this AMPC Innovation Challenge:

1. Take up along the chain no more than 3 times the width of a beef carcase or four times the width of a lamb carcase.
2. Be 'walked' in and 'plumbed' to the carcase rails (with x-ray shielding incorporated into the solution walked-in to the site facility.
3. Be vertically scalable as a solution (but as different product offerings) to full carcase lamb/full side beef, and part thereof, i.e. HQ of beef, or beef butt.
4. Optional solution designs are requested also for integrated 'over a conveyor belt' solution in addition to scanners being developed for product hanging vertically from a meat rail and hook/gambrel.

The output of Stage 2 is a detailed design, sufficient to (1) demonstrate to AMPC staff the working functionality of the concept(s), (2) develop indicative targeted $RRP, (3) demonstrate theoretical x-ray shielding calculations, and (4) draft a Stage 3 application submission, which includes an indicative indication of Stage 4+ and commercialisation plan.

3.0 Project Objectives

The Australian red meat processing sector (bovine, ovine, and caprine) has always looked towards the European pork industry for automation and technology advancement insights. Those of us that have worked in the Australian red meat R&D areas (either as investors or developers) have always been challenged as to why we are perceived to be lagging behind the slaughter floor and boning room automation solutions that we have seen in the European pork processing sector.

One technology that has been developed for the industry that has substantially enabled the development of some processing automation and information solutions (such as those noted above), has been full lamb carcase or full beef side continuous x-ray (Single Energy and Dual Energy) systems.

This project looks to rethink x-ray design for the smaller footprint required for greater uptake in the Australian red meat processing sector. The objectives of the project are to:

1. Develop a carcase DEXA concept and assess its alignment with the following aspirations:
    - Modular (applicable to a range of processing plants from an ROI perspective), with scalability assessed for increasing units in series and in parallel in terms of throughput rates and cost
    - Smaller footprint
    - Simpler installation.
2. Perform design and equipment selection tasks to provide accurate costing for the cell concept in terms of commercial price and cost of further development
3. Detail accurate layout designs to enable costing for site works requirements for processors
4. Perform detailed cycle time analysis with concept for different cut configurations, including simulations
5. Investigate Hot vs Cold carcase processing by the system

4.0 Methodology

The methodology for conducting the project was as follows:

1. Perform initial x-ray design – engagement with suppliers and selection of suitable equipment for the concept, design of scanning geometry required
2. Draft initial layout
3. Mechanical design for all mechanical components, including quoting
4. Sensing design for all sensing requirements, supplier engagement and selection, and quoting
5. Electrical design for all controls and electrical equipment required, supplier engagement and selection, and quoting
6. Detailed cycle time analysis and simulations
7. X-ray shielding and safety design
8. Finalise layout and determine scope required for site works
9. Develop schedule and costings for development, initial systems, and repeat systems, including commercialisation plan

5.0 Project Outcomes

Throughout this project a modular beef x-ray scanning system was developed which was smaller in footprint that existing solutions. Its modular design allows for simpler scaling of throughput, as well as simpler installation when compared to existing beef x-ray systems.

5.1 Smaller Footprint

The concept developed by Intelligent Robotics requires approximately 4m wide x 4.6m deep in footprint for the scanning module itself. When considering the infeed and outfeed stations, the total required width increases to 7.4m. This is the smallest footprint that was able to be achieved for the system while scanning a beef carcase, maintaining the required distance between the x-ray scanning hardware and the carcase to obtain the required field of view. In terms of the core scanning unit itself, this represents a 54% reduction in footprint compared to currently available commercial options for beef x-ray scanning (see section 6.1).

Some potential further developments in the future that may further reduce once the original concept is proven, including revisiting the sensing design and setup, and carcase stabilisation.

5.2 Modularity / Scalability

The system has been designed to be modular in design. It can be positioned independently of a cutting cell as best suits an individual plant. The module itself is estimated to be capable of running up to 150 head per hour when performing a scan of a beef carcase side. This cycle time consists of stabilisation actuation, indexing, and scanning time.

The scanning time is the most variable aspect of the system and will depend on the use case for the system. A number of mechanisms exist to optimise this scanning time throughout production.

Another aspect which will impact cycle time is the side stabilisation time. From work done on other projects investigating hot cutting (AMPC project 2021-1200), it is known that a hot carcase will take slightly longer than a cold carcase to settle. Depending on the application, this may or may not be an issue – for performing DEXA scanning for lean meat yield, a perfectly still carcase is not called for, however when scanning to perform cuts the carcase should be as stable as possible to maximise accuracy.

In order to scale cycle time, modules can be placed in parallel to achieve higher throughput rates. The concept can also be scaled with two systems in series. These concepts have been examined in the project.

5.3 Simpler Installation

A key advantage to the current concept is the simpler installation of the system – it does not require new rooms to be built where lead is sandwiched in between panels as part of the building works. Although the original goal of being able to walk it in over a weekend is still not quite achievable, the system has a much more optimised assembly process with the cell able to be transported in parts and built up while on-site. This optimised assembly process was developed in the project.

5.4 Layout and Indicative Commercial $RRP

A standard layout installation has been developed in the project. The customer would provide the required railworks to drop the carcase sides at the infeed station, and pick-up the carcase sides from the outfeed station.

The indicative $RRP for this concept was costed per module. This would scale approximately linearly with additional modules. It should be noted that the expected installation and building costs and time would be significantly lower than currently existing systems in the market due to the smaller size and the optimised assembly procedure (rather than having to build a custom shielded room).

5.5 Hot vs Cold Processing

The system has been designed to be able to process hot as well as cold carcases, with the implications relevant to hot carcase processing examined and analysed. The DEXA system remains essentially unchanged for hot or cold carcase processing.

6.0 Discussion

6.1 Existing Commercial Systems

There are currently two commercial beef x-ray scanning installations in Australia – one which is used to drive automated rib cutting, and one which is used to calculate the lean meat yield percentage of beef carcases.

6.1.1 Beef Rib Cutting System

The only currently operating commercial beef cutting system requires approximately 7m x 12.5m for X-ray Scanning and one cutting robot as per Figure 1 below (Trieu, et al., 2016). This system integrates the x-ray scanning upstream of the cutting and cannot currently split the x-ray component from the cutting component. Thus, this footprint is required in one contiguous space. It is currently only commercially available for performing 2 rib cuts, from rib 2 to 8. It is capable of operating at line speeds of up to 260 head/hr for performing these two rib cuts on cold carcases. There are no current commercial installations performing any spine cuts, or any cuts on hot carcases.

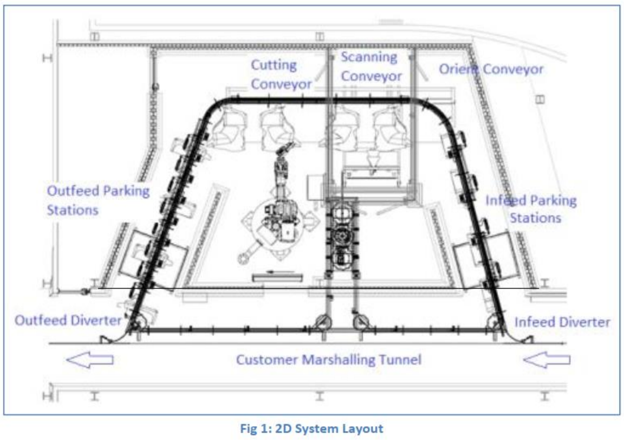


Figure 1 - Existing commercial x-ray cutting system (Trieu, et al., 2016)

6.1.2 Beef DEXA Scanning System

A beef x-ray scanning system was also developed and is currently in production. This system performs x-ray scanning only of a full beef side (without any cutting). The footprint is approximately 8m x 6m.

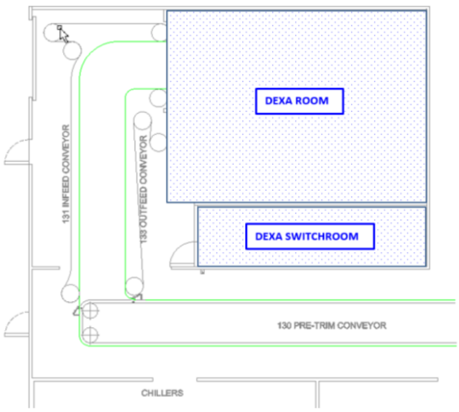


Figure 2 - Existing commercial beef x-ray scanning system (Coatsworth & Kennedy, 2018)

6.2 Simulations

A simulation was built for the Small Footprint DEXA concept examining x-ray scans required to span the largest and smallest beef carcase sizes.

In terms of cycle time, the limiting factor is primarily the scanning speed of the x-ray which will produce images able to be reliably processed by the vision software. Optimisations were explored within the project to maximise scanning speeds to keep cycle times minimised.

6.3 Shielding Design

Intelligent Robotics consulted with a third-party radiation protection consultant, as well as Queensland Health to discuss the concept that was being proposed. The necessary standards the system needed to comply with were then outlined which is what the shielding calculations were produced to.

From the shielding calculations, and using the dimensions from the concept drawing, the amount of shielding required in various areas of the system were calculated:

- The amount of lead required in the primary beam stop, walls, doors, and ceiling
- The amount of lead required in the x-ray tube and collimator enclosure

A shielding plan was then generated.

6.4 Electrical Design and Equipment Selection

The electrical design of the system and equipment selection was performed during the project. There are three main components to the Small Footprint DEXA, are three main components: the control system, the motion system, and the sensing system.

6.4.1 Control System

PLC

The external control system of the Small Footprint DEXA system contains the PLC and the control of the chains that feed carcases in and out of the DEXA X-ray Cell. The chosen controls platform was selected due to its flexibility in controls and the advanced algorithms included within their libraries.

Chain Drives and Motors

The next component to be chosen was the chain drive and motors, to control the chains on which the beef sides are transported to, and away from the X-ray Cell. These were matched with the PLC to allows its powerful motion libraries to be fully utilised. Motors capable of withstanding abattoir conditions were chosen to control the conveyors.

6.4.2 Motion System

Linear Axis Drives and Motors

Drives and motors were selected based on the motion profiles required to be achieved. Drive were selected with a CAN connection and use the DS402 protocol for communications across the system. Motors capable of withstanding the harsh meat industry conditions were coupled with appropriate drives with the required motion features.

Safety PLC

A safety PLC had to also be chosen to control the system's safety circuits. Through analysis of a range of different safety control systems, the selected safety PLC was chosen due to the:

1) The ability for decentralised control (each remote IO header is a safety PLC)
2) The scalability of the PLC
3) The ability to use an EFI Bus to talk between all safety nodes, and to use CIP Safety communications protocol to communicate to safety nodes from other providers

IO

The last components to be chosen for the system, is the IO. There are pneumatic cylinders designed into the system to protect the vision cameras, and as a result the primary IO system was selected as a fieldbus-based system capable of natively controlling pneumatic directional control valves.

6.4.3 Sensing System

The final part of the machine is the sensing system. This comprises the required circuitry and components to generate, and emit the X-rays required for the scanning process, as well as the imaging required to complement the x-ray imaging to enable the cut paths to be specified.

X-ray Subsystem

The X-ray subsystem consists of:

- an X-ray tube
- an X-ray generator which powers the x-ray tube
- the high-voltage cable
- a water chiller, for cooling of the x-ray tube

X-ray Detector

A dual-energy detector was chosen for the system's detector. This has proven capabilities when it comes to x-ray beef carcases.

Imaging

Additional sensors have been designed and selected to complement the x-ray imaging hardware to allow the system to generate the required cut profiles to perform scribing. This additional imaging may not be required if the system is used for performing DEXA-only operations such as Lean Meat Yield Calculations.

6.4.4 System Architecture

Based on the system design, the system architecture for the Small Footprint DEXA was developed. Both the controls topology and the power topology were developed, to confirm the way in which the components interacted and how the safety components worked.

6.5 Mechanical Design and Equipment Selection

6.5.1 Design Constraints

There were a few design constraints which needed to be met for our modular system to be deemed acceptable across a wide variety of processor applications. It was critical for us to stick close to these requirements since a failure to do so could create potential barriers to acceptance. These constraints include: -

- **System Dimensional Restrictions**: Approximate internal dimensions 2.4 x 4.0 x 4.2m high would be desirable as it suits a majority of site layouts whilst giving us enough space to fit our X-Ray system assembly.
- **X-Ray Safety**: In order to limit radiation leakage, the enclosure must be suitably shielded.
- **Hygiene Requirements**: Since we will be working in a meat processing environment, all assemblies need to be suitable for washdown and drip trays are required below mechanisms requiring grease or oil. All surfaces need to be suitable for typical cleaning procedures in an abattoir. Additionally, the floor needs to be free draining, either sloping or with grating, and needs to be non-slip but easy to clean.
- **Portability**: For transport the enclosure needs to be split into sections which can be transported easily. This will give us the ability to construct most of the system in advance leaving only the assembly work to be conducted during site installation. The main benefit of this method is the reduction in construction/installation time on site.
- **Cycle Times**: The cycle time for indexing, scanning & cutting each carcass
- **System Operational Constraints**: In order to ensure we can move the carcase through our X-Ray system whilst shielding from the X-Ray radiation, we will need appropriate management of the carcase flow and required mechanical components.

6.5.2 Design Features

Once our design constraints were compiled with consideration to the customers' needs and requirements, we needed to ensure each design feature we conceptualised would need to meet these requirements so as to ensure the design is widely accepted as fit for the industry. Below are the various design features we needed to conceptualise with respect to the constraints mentioned in section 6.5.1.

X-Ray Shielding – Panel Design & Assembly

Various methods of constructing the system to ensure proper shielding of x-ray radiation were explored throughout the project before settling on the final design which allowed the design constraints to be met.

System structural members

The structural members within the system were design and analysed to ensure they were capable of meeting the mechanical and operational requirements for the system.

Keeping to our portability and transport requirements, the structural members were designed in 6 sections to facilitate ease of transport.

Carcase transport mechanisms

The mechanisms required to facilitate carcase movement through the system were examined and designed, ensuring they complied with the relevant design constraints.

Carcase stabilisation

The means for stabilising the carcase is a critical part of the X-Ray cell. Some of the design constraints and requirements considered during the conceptualisation of this design include: -

- **Operational Requirement:** Most importantly, it will need to effectively stabilise the carcase for the X-Ray scan.
- **Cycle Time:** The system needs to operate as quickly as possible.
- **Hygiene**: Needs to be wash down rated and compatible with site cleaning protocols (chemicals etc.).

A number of concepts were examined before a final concept was selected and designed.

Maintenance

From a system maintenance perspective, we needed to meet a few critical design requirements to ensure the system was easy to work with over the course of its service life. Some critical requirements include: -

- Ease of Cleaning.
- Access to key components.
- Key components can be replaced.
- Needs to be wash down rated and compatible with site cleaning protocols (chemicals etc.).

The system has been designed to enable access for equipment like a scissor lift to ensure access to key components for inspection, maintenance and cleaning. Future options would be to incorporate a Clean in place (CIP) system.

6.5.3 Assembly

Sticking to our goal of creating a modular and portable system, the intent of the design is that the system can be tested and verified before leaving the factory. This ensures quality standards can be maintained in a factory environment and the time spent on site carrying out the installation phase can be significantly minimised.

In addition to this, assembly on site should be safe and efficient. The significant reduction in downtime for the customer during the installation phase can increase uptake with industry processors.

The assembly process was carefully designed within the project.

6.6 Site Concept (Initial System) – Layout, Site Works Scope, Development

As part of the project, Intelligent Robotics examined and detailed what would be required for the first DEXA project completed including development and with an installation at a processor site. This included providing a detailed scope of supply, as well as outlining what the customer's scope of supply might include. A detailed overview of the development activities required was outlined and a prospective timeline was developed.

6.7 Commercialisation Plan

It is anticipated that the first few installations will require varying levels of development in order to transition to the commercial phase of the technology roll-out. These will involve working through any issues encountered with the first installations and improving upon the concept, including design and programming aspects. Further optimisations to the design are also expected as the learnings of how the system is operated are distilled from the first installations. This will allow optimisations to be developed to further decrease the footprint and decrease the cost of the system.

Another potential opportunity area is adapting the technology to work with small-stock such as lamb, acknowledging that a significant portion of the lamb kill in Australia is now going through some form of a DEXA for grading. This technology could be leveraged to improve the uptake by lamb processors, and further generate the data to drive valuable breeding decisions together with the new eating quality measurement technologies that have recently become available.

With market acceptance, reducing the cost of key items such as the x-ray hardware may become more feasible with suppliers.

As the first installation(s) come online, mechanisms such as industry open days, articles with industry news sources, and webinars would be explored to inform the industry of the technology and drive market uptake.

Once the initial key development of the technology has been achieved and commercial sales are being generated, the focus will shift to incremental and continual improvement initiatives to ensure the technology keeps up to date with the industry's needs and ahead of the curve, and to further drive value.

While the project was successful in reducing the footprint and size significantly compared to other available systems, the DEXA unit still adds considerable space and cost when considering it in the context of a robotic cutting system. The latest version of the small footprint DEXA concept has been presented to three processors to date for the purposes of driving cutting automation. The concept was viewed positively, but the footprint required, as well as the total cost for the system, even for this amended small footprint DEXA concept, have prevented those projects from moving forward.

In light of this industry feedback, other sensing technologies are being investigated as an alternative to x-ray sensing for the purposes of driving scribing cut automation. These assessments have progressed rapidly and will impact what the next steps are for the Small Footprint DEXA technology with respect to scribing. As the realisable benefits of alternative sensing become known in the context of scribing, it may be that the Small Footprint DEXA technology may proceed under the following potential application streams:

- For customers wanting yield gains in scribing which exceed what can be achieved with alternative technologies
- For performing cuts or other processing operations which can't be sensed with the alternative technologies (e.g. requiring the accurate location of sub-surface features)
- Lean meat yield calculations
- Cutting/scribing on quarters, which can reduce the size of the machine substantially

7.0 Conclusions / Recommendations

A viable concept for smaller footprint, simpler installation x-ray scanning for the red meat industry has been developed. Throughout the course of the project, an x-ray design has been developed to a significant level aiming to address the inspirations of the AMPC innovation challenge:

1) **Take up along the chain no more than 3 times the width of a beef carcase.**

   The scanning concept itself currently takes up one "position" for the actual scanning. When including the "infeed" and "outfeed" positions this increases to three "positions". These positions also allow for the necessary safety distance from any safety hazards.

   It should be noted that this is larger than "3 times the width of a beef carcase", but great effort was made to keep the pitch of these positions as small as possible. With future iterations of the design, it is expected that the width of the scanning cell may be further reduced by a further ~500mm.

2) **Be 'walked' in and 'plumbed' to the carcase rails (with x-ray shielding incorporated into the solution walked-in to the site facility).**

   This goal was the most challenging. Given the sheer size of a beef carcase (up to 1.5m in width including its foreleg, and operating on overhead chains 4m+ from the floor), and the amount of lead required to shield the system, the ability to develop something that could be "walked in" was extremely limited. The concept was able to be designed in a modular fashion however with a clear assembly procedure to build to cell up relatively simply in stages. This installation is far simpler than requiring lead nibbing to be installed in the ground, and a new room to be built with lead sandwiched between refrigerator panel.

3) **Be vertically scalable as a solution (but as different product offerings) to full carcase lamb/full side beef, and part thereof, i.e. HQ of beef, or beef butt**

   The solution itself is able to be scaled down in size to accommodate lamb carcases or beef quarters – anything driven by overhead rail would be well suited to the concept.

In relating back to the objectives of the project:

1) **Develop a carcase DEXA concept and assess its alignment with the following aspirations: modular (applicable to a range of processing plants from an ROI perspective), with scalability assessed for increasing units in series and in parallel in terms of throughput rates and cost; smaller footprint; and simpler installation**

   The concept has been designed with these aspirations as key design criteria.

2) **Perform design and equipment selection tasks to provide accurate costing for the cell concept in terms of commercial price and cost of further development**

   The designs of the concept have been progressed to the point of allowing reasonable estimates to be made of target commercial pricing, as well as the work required for development. A scope of supply and costing has been provided for the initial systems reflecting this, which would form the structure for a sales proposal in the future.

3) **Detail accurate layout designs to enable costing for site works requirements for processors**

   As aforementioned, during this project the designs were progressed enough to provide an accurate layout of the system. In this report, the scope of site works required was then outlined, with the primary components being railworks and any required building modifications (if needed) – the exact scope of these will be site-dependent.

4) **Perform detailed cycle time analysis with concept for different cut configurations, including simulations**
   Simulations of the concept throughout its design were built and used to evaluate the system as well as factors such as positioning of cell walls and sensors.
5) **Investigate Hot vs Cold carcase processing by the system**
   As outlined previously in the report, the system maintains the same design for hot or cold carcase processing. Depending on the application (e.g. LMY measurement vs cutting), and the type of cattle produced by the plant, the side stabilisation time may vary slightly which will need to be accounted for in the system throughput rate. The machine itself however will remain unchanged.

In this project, the commercial aspects of the Small Footprint DEXA concept were investigated. The concept was also reviewed against the initial inspirations for the project as well as the project objectives. The concept has been developed to the point where the next step would be customer engagement for a project, the structure of which has been outlined.

The project has produced a detailed concept for a Small Footprint DEXA system. Processor feedback was sought on the concept as a mechanism for driving scribing automation. While the concept was viewed positively, and is significantly smaller and simpler than existing solutions, the footprint and cost required were still too large to proceed with the processors that were approached. Currently alternative sensing technologies are being evaluated for the purposes of driving cutting automation. As these assessments progress and the realisable benefits of these alternative sensing technologies to x-ray become known in the context of scribing, the next steps for the Small Footprint DEXA concept developed in this report may be to explore other areas such as performing cuts which can't be sensed alternatively (e.g. requiring sub-surface features), focussing on lean meat yield evaluation, quarter-processing (which requires a smaller machine), or specifically targeting customers wanting scribing yield gains above and beyond what the alternative sensing technologies can provide and have sufficient space in their plant.

8.0 Bibliography

Coatsworth, R. & Kennedy, G., 2018. *V.TEC.1701 Beef DEXA Supply Chain Grading – LMY (TEYS Rockhampton - Construction scanning Platform),* s.l.: MLA.

Trieu, W., Ford, M. & Shirazi, M., 2016. *P.PIP.0288 JBS Dinmore Beef Rib Cutting MLA Public Report,* s.l.: MLA.