final report

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P.PSH.0911 - LEAP 4 BEEF – Detailed Design Stage 2 – Develop high level design and layout concepts

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Abstract

This project is an extension of the initial Scott/ MLA "Leap 4 Beef" scoping and conceptual design project, with the aim to further detail the high level concepts and technologies required to deliver the conceptual automated beef boning room.

The beef boning process in a sample of Australian processing plants was studied, including an industry consultation meeting, and automation solutions are created and developed into 3D CAD layouts. Appropriate vision technologies are reviewed and evaluated, highlighting development opportunities and decision points including application of DEXA X-ray or computed tomography (CT) scanning, grading without the grading cut, chiller sorting location in the process and optimised chuck/cube roll and cube roll/loin cut locations.

It is estimated that there will be a $13.06 per head benefit, given the proposed systems have a cutting accuracy of ± 5 mm. The payback is most significantly attributed to additional value due to cutting accuracy, yield and then labour and health and safety savings.

Executive summary

The goal is to develop stages of an automated beef boning room for Australasian processors. The objective is to propose systems that are likely to achieve +/-5mm accuracy, yield, labour and health and safety savings as anticipated in the earlier report, *Feasiblity Review - Automated X - Ray Beef Boning Solution*[1], where a $13.06 per head possible benefit has been measured. An industry representative steering committee was to be constructed and engaged.

The concept design was to detail key vision, cutting and materials handling enabling technologies. And key process integration considerations, including staged adoption options. Evaluation of where benefit can be maximised through perusing specific arrangements and automation concepts.

There was a review of current Australian processing plants where a Scott team visited four beef processor plants and captured the process. In combination with the visits, interviews, industry consultation and online research, production rates, existing process and value opportunities were collated. Background research was performed and included; input product and cut specifications, incorporation of key learnings from lamb automation experience and patent searches and review.

Creation of Automation Options and development of 3D Cad Layouts included:

- Review and development of carcass process diagrams to suit the proposed automated beef processing systems, including pre-trim considerations.
- Research of suitable clamping and cutting devices, and evaluatation.
- Development of the automated beef processing concepts and associated three dimensional geometry considerations, and 3D CAD layout development.
- An investigation into current and potential vision and sensing technologies.
- Consideration of the issues for the implementation of the proposed automated beef processing systems and the staged adoption options.

Australian processing rates range from 150 – 447 sides per hour. Single rail and Dual rail systems have process rates of 180 and 360 sides per hour respectively. Rates above the proposed system rates will require duplication.
It is considered that the existing grading cut will create significant handling and re-referencing problems and therefore grading without the cut is a significant enabling technology.

Regarding the process review, with respect to automation, it is proposed that tenderloin removal and “fore leg bone” removal is moved to the prim- trim area – as not suitable for automation at this point.

The following automation systems have been proposed:

1. The single rail system (**Error! Reference source not found.**) process consists of a either Dexa or CT scanning, potentially sorting, re-referencing means for each downstream station and then various robotic sawing and cutting operations.

[1] P.Green,K Bryan,S.Fischer, 2014. *P.PIP.0361 Final Report - Feasiblity Review - Automated X - Ray Beef Boning Solution,* Sydney: Greenleaf Enterprises.

2. Additionally the dual rail system has been proposed, which is a duplication of the robotic sawing and cutting stations.

Ultrasound or CT scanning could be suitable for fat trimming applications. Identifying muscle seams could be attempted with CT scanning. The outcomes of the steering committee meeting on the 30th April 2018 were generally supportive of the developed automated cutting concepts. The ability to perform stepped seperations between fore and the rack and between the rack and the loin is crucial.

The potential for CT scanning to offer a complete carcase analysis system is exciting, however the limitations of most commercial systems requires further development. There is a significant value opportunity to make the cuts either side of the cube roll after the grading, as opposed to current practice where it is performed before the grading.

An important step in the development of the linear systems would be to prototype one or more systems for re-referencing carcasses between cutting stations. This will be an enabling technology for the linear proposals. Validation that CT scanning of racks and loins gives the accuracy required for chining, fat trimming and button bone removal, combined with economic and cycle time considerations will further suggest the suitability of CT technology.

The current DEXA systems could be used to validate the feature finding accuracy and establish the geometry limits of the carcasses that are expected to be processed. In future stages of beef automated cutting development, it is proposed that Scott Automation should work individually with participants of the smaller steering committee in order to protect their particular process innovations.

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1 Background

This project was an extension of the initial Scott/ MLA "Leap 4 Beef" scoping and conceptual design project ((Mark Seaton, 2017). Where a vertical and/or horizontal automation concept was proposed. And the middle primal piece was proposed as highest value primal and likely to have the highest value proposition.

The purpose was to further detail the high level concepts and technologies required to deliver the conceptual beef boning room.

The project is to involve understanding key vision and sensing cutting and materials handling technologies required for an automated beef solution. Additionally issues for integration of the technologies into Australian processing plants were to be considered.

2 Project objectives

It is intended that at the conclusion of this project the following outcomes will be delivered:

1. An industry representative steering committee will be constructed and engaged on a periodic basis to both drive and evaluate the Beef automation strategic development vision
2. Concept design will be completed to detail the following:
    a. Key vision and sensing enabling technologies and how they integrate into a solution
    b. Key cutting and materials handling concepts that will underpin the main automation modules
    c. Key process integration considerations for Australian processing plants including how a staged adoption is possible and
    d. Identify what options exist for different arrangements of the above technologies and concepts

It is also anticipated that evaluation of where benefit can be maximised through perusing specific arrangements and automation concepts will eventuate from this level of detail.

3 Methodology

3.1 Current Australian Processing Plant Review

Four beef processor plants in Australia were visited by a Scott team of one vision engineer and two mechanical designers. Photographs, video and interviews results were collated to capture production rates, existing process and consult on value opportunities.

Additionally online research was performed to include production rates for the majority of the Australian beef processors and the proposed automation system options compared.

3.2 Background Research

Background research included:

- Input product and cut specifications review.
- Online Literature research.
- Key Learnings from lamb processing experience review.
- Patent searches and review

3.3 Creation of Automation Options and 3D Cad Layouts

3.3.1 Develop Proposed Carcass Breakdown

- Review and develop carcass process diagrams to suit the proposed automated beef processing systems, including pre-trim considerations.

3.3.2 Review of Clamping and Cutting

- Research of suitable clamping and cutting devices & evaluatation.

3.3.3 Layout Creation

- Development of the automated beef processing concepts and associated three dimensional geometry considerations.
- Three dimensional CAD layouts are developed.
- Consideration of current processing facility space constraints.

3.4 Proposal and Evaluation of Vision and Sensing Technologies

- An investigation into current and potential vision and sensing technologies was undertaken to determine suitable candidates for the proposed automated processing systems.

3.5 Key processor integration considerations

- Consideration of the issues for the implementation of the proposed automated beef processing systems and the staged adoption options.

3.6 Payback Calculations

- Payback calculations for each of the three concept options.

3.7 Beef Steering Committee Consultation

The beef automation system concepts were present to the beef industry representative group in Brisbane on Australia 30th April 2018. The feedback has been collated and captured.

4 Results

4.1 Current Australian Processing Plant Review

4.1.1 Site Visits, Meetings and Interviews

Several beef processors in Australia were visited to look at how the manual carcass breakdown was achieved, similarity between processors and the products that are produced. Four processor sites were reviewed; one performed table boning, one quarter boning and two processed beef sides on a rail.

4.1.2 Processor Production rates

From the visits, online research and interviews, an assessment has been made of the beef production rates for the majority of Australian beef processors.

The production rate varied from a maximum recorded rate of 3350 head per day down to a minimum recorded rate of 150 head per day with a mean of 1643.

Most Australian processors are less than 1500 head per shift.

4.2 Background Research

4.2.1 Input product and cut specifications review.

The inputs and outputs to the process were studied, using the AUS-MEAT handbook (refer (AUS-MEAT, 2005), and used to formulate the process diagrams.

4.2.2 Patent search and review

There several patents related to primal cutting which are of particular interest to us, they include:

AU2010202154A1- Automated Meat Breaking System and Method by Cargill INC
US2017049116A1 - Robotic Carcass Processing Method and System by Jarvis Products
US2016037787A1 - System and Method for processing slaughtered animals and or parts by Marel

Because our concepts are based on robotic rail processing rather than table boning, it is judged that concepts proposed here are unlikely to infringe with the existing patents.

Refer to paragraph 9.2 Patent Review.

4.3 Creation of Automation Options and 3D Cad Layouts

4.3.1 Development of Proposed Carcass Breakdown

The proposed carcass process for automation has been developed and diagrams created. Figure 1 Proposed Carcass Breakdown

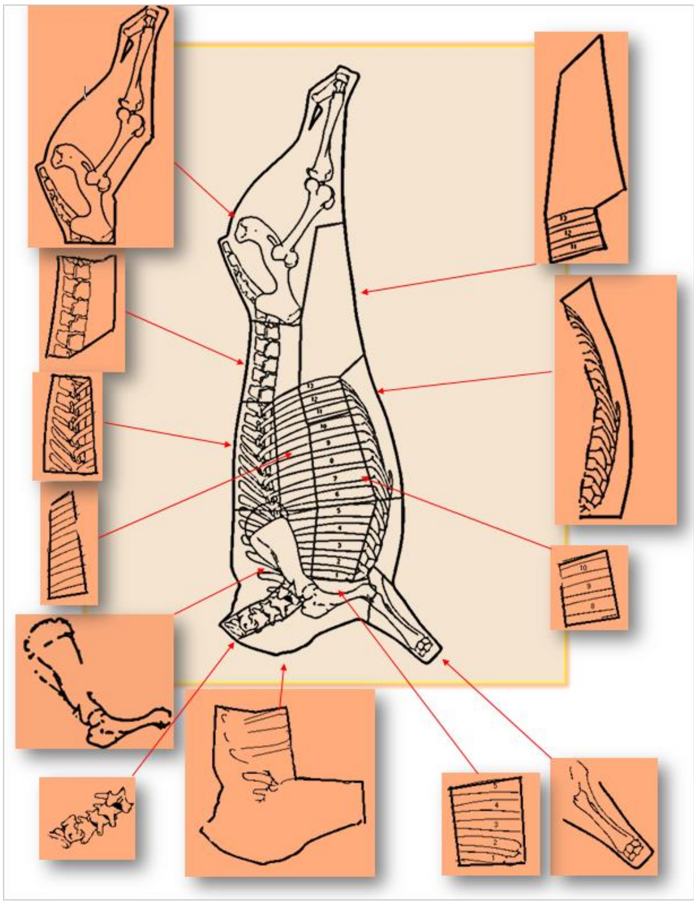

Figure 1 Proposed Carcass BreakdownBeef Product Processing Diagram

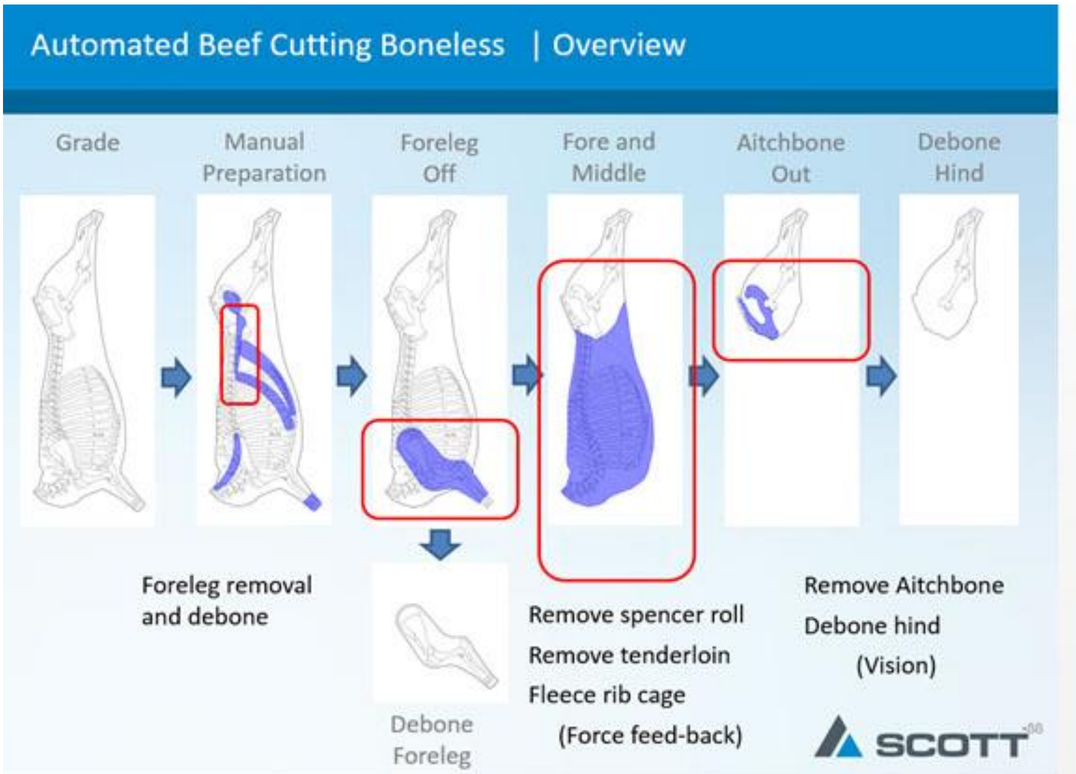

Figure 2 : Overview of beef side products from the automated line

4.3.1.1 Pre-trim operations

The typical pre-trim operations would be retained:

1. Neck bones cleared and left hanging
2. Featherbones cleared
3. Diaphragm removed
4. Inside skirt dropped
5. Paddywack removed
6. Neck chain removed
7. Head of tenderloin dropped or tenderloin removed

Where grading cut needs to be deleted and rib cage scribing would not be necessary.
And tenderloin removal is proposed, subject to further work
Additionally at least the “fore leg bone” would need to be removed from the foreleg to enable subsequent robotic operations

4.3.2 Process detail considerations

4.3.2.1 Tenderloin Removal

It is believed that leaving the tenderloin in during the automation process is going create handling and damage to the tenderloin issues. Therefore it is proposed that the tenderloin is removed in the pre-trim. The top of tenderloin is already typically released from the hindquarter section in the current process. It is recommended that the tenderloin is release by cutting both sides from the forequarter end to the hindquarter end. To perform this operation in the pre-trim there are issues around the tenderloin tearing away under gravity as normally it is removed horizontally on a table. Also leaving the tenderloins in to enable the production of “T” bone steaks is an issue. This is an area for further development.

4.3.2.2 Fore Leg Removal

Automation of foreleg removal has been reviewed but considered difficult and therefore of a lower priority.

This foreleg process would be broken up into the various steps, with dedicated clamping and require several stations. The operations include; removal of clod meat, chuck tender, severing tendons and removal of the scapula bone.

Therefore it is proposed to remain a manual operation in the Pre-Trim area.

4.3.2.3 Brisket Removal

After several reviews it was decided to look at removing the Brisket as one piece in the proposed automation system with further processing downstream into the PEB and NEB pieces.

4.3.2.4 Thin Flank Removal

To aid loin processing we are proposing the removal of the thin flank from the loin section prior to loin removal. This may include 1, 2 or 3 ribs in the thin Flank, which may have the meat fleeced off the outer rib section.

4.3.2.5 Hind Leg Processing

At this stage we are not considering hind leg fleecing or boning out operations, based on our agreed direction, but it could be considered in the future.

4.3.3 Review of Clamping and Cutting

4.3.3.1 Carcase presentation

The ability to present the carcase consistently from scanning through each subsequent cutting station will impact heavily on the overall cut accuracy. It is known that the inclined belt approach in a scanning station suffers from movement.

Additionally, it is known that the shape will change through each cutting station. Therefore the loss of "reference" and "carcass deformation" are issues that need to be addressed. Either the carcass could be "jigged" throughout the process or the carcass needs to be 3D scanned throughout the process and corrections performed – referred to as re-referencing.

This an area for further development, to establish additional opportunities, and select the optimum.

4.3.3.2 Clamping Devices Summary

Various clamping options have been considered and evaluated in Figure 3.

It is proposed that the clamping should clamp each section of Forequarter, Rack and Loin such that clamping of each remaining section, after primal separation, is achieved. The stepped cut option would need to be considered for this development.

There are significant issues with any grading cuts which sever the spine, for transporting and re-referencing of the beef side. Grading without severing the spine is a key enabling technology.

	keeps product referenced	Size Changeability	Can avoid Cutting head	Damages product	Stops Product moving from datum
End Effector Gripper	🟢	🟢	🟢	🟡	🟡
Angled Belt	🟡	🔴	🟢	🟢	🔴
Flat belt	🔴	🔴	🟢	🟢	🔴
Fixtured Belts	🟡	🟡	🟢	🟢	🟡
Overhead Chains	🔴	🔴	🟢	🟢	🟡
Linear Clamping Head (Mass transfer)	🟢	🟡	🟡	🟢	🟢

Legend		
	🟢	feasible
	🟡	feasible with restrictions
	🔴	not feasible

Figure 3: Clamping devices

4.3.3.3 Cutting Devices Summary

Cutting devices have been researched and an evaluation performed in Figure 4. Further details are documented in paragraph 9.12D-JD649 Cutting and Clamping.

	Pasteing	bone chips	Quality of Cut	Scribing Cuts	Meat Cutting	Button Removal	Cutting Bone/ Ribs	Cutting Cartiledge	maneuvering around product	Speed of Cutting	Needs blade changes
Rotary Saw	feasible	feasible	feasible	feasible	feasible	not feasible	feasible	feasible	feasible	feasible	feasible
Reciprocating Circular Saw	feasible	feasible with restrictions	feasible with restrictions	not feasible	feasible with restrictions	not feasible	feasible with restrictions	feasible with restrictions	feasible	not feasible	feasible
Bandsaw	feasible	feasible	feasible with restrictions	feasible	feasible with restrictions	not feasible	feasible with restrictions	feasible	feasible with restrictions	feasible	feasible
Buster saw	feasible	feasible	feasible with restrictions	feasible	feasible with restrictions	not feasible	feasible with restrictions	feasible	not feasible	feasible	feasible
Knife	feasible	feasible	feasible	feasible	feasible	not feasible	not feasible	feasible with restrictions	feasible	feasible with restrictions	feasible
Powered Knife	feasible	feasible	feasible	feasible	feasible with restrictions	not feasible	feasible	feasible	feasible	feasible with restrictions	feasible
Whizz Knife	feasible with restrictions	feasible	feasible	not feasible	not feasible	feasible	not feasible	feasible	feasible	feasible with restrictions	feasible

Legend: feasible (green); feasible with restrictions (yellow); not feasible (red)

Figure 4: Cutting Devices comparison

4.3.4 Layout Creation

4.3.4.1 Proposed Single Rail Option

In the proposed single rail system the Beef Side is graded in the chiller prior to entering the boning Room and then travels through the Pre – trim area.

The proposed automation system consists of a DEXA X Ray scanning Room and Clamping and Cutting Robots, which separate the foreleg, racks and loins.
In detail;

- PEB & NEB Brisket would be removed and placed on the Brisket Line
- Forelegs (bone in) are placed onto the foreleg processing line. They could be rehung.
- Rack & Loin (bone in) cuts are subsequently placed on the rack line for automated processing.
- Hindquarters (bone in) would continue on the rail for, for example, semi-automated processing using Scott Beef Puller arms.

4.3.4.2 Proposed Dual Rail Option

In the proposed Dual Rail system the cuts removal area, clamping and cutting robots, is duplicated to achieve the cycle time requirements.

4.3.4.3 Grading

It has been identified that if grading is developed that does not require the grading cut, then there is a value opportunity to use the grading information to perform the rack/loin separation (and/or chuck/cube roll cut position).

It is considered an objective carcass measurement system, equivalent to the current MSA grading results, is required.

Additionally this path, may enable sorting (in the chiller) prior to processing.

4.3.4.4 Scribing

It is proposed that DEXA scanning in combination with robotic scribing, followed with manual boning, can offer a significant value proposition. And DEXA can provide lean meat yield data. The issue of movement between scanning and robotic processing has been identified as needing further work (outside this scope). It is anticipated that results from re-referencing work will assist with decision around means of maintaining reference from the scanning to robotic processing and even potentially extended to allowing scanning to be upstream of sorting (and chilling).

4.3.4.5 Rack and Loin Downstream Machine

For the linear systems, Dual and Single Rail Proposals, a downstream rack and loin machine is proposed.
Separate Racks and Loins would be automatically or manually loaded into a rack and loin machine. In which the loins would have the fat removed, spinal section chinned and then the spinal buttons removed. The rack could also be processed through the same machine to remove the spinal section chine.

4.4 Proposal and Evaluation of Vision and Sensing Technologies

An integral part of the automation process will be detecting the key features of a carcase (bone locations, fat depth, muscle seams etc.). These will be used to determine specific cut paths for robotic/mechanical cutting tools.

Cut paths will need to be generated relative to the position and orientation of the carcase at a given cutting station.

4.4.1 Summary

DEXA X Ray and CT scanning seem to be the best options for rib geometry. Dexa X ray may have issues scanning thick meat sections.

Ultrasound or CT scanning could be suitable for fat trimming applications. Identifying muscle seams could be attempted with CT scanning.

The potential for CT scanning to offer a complete carcase analysis system is exciting, however the limitations of most commercial systems might present problems for early adoption. It would seem that some type of X-ray analysis (DEXA) would be a minimum requirement for successfully generating cut-paths. It is likely that a combination of a number of different technologies will offer the best outcomes.

4.5 Key processor integration considerations

4.5.1 Staged Introduction Options

Processors could consider a several options for a staged introduction

- DEXA X Ray Room with Beef scribing robot.
- Standalone Robotic Cutting Cell.
- Standalone Rack/ Loin machine which could be manually loaded.

4.5.2 Proposals for a staged adoption of layouts

The linear systems would better suited for staged adoption, as they would have a number of stand-alone stations connected by overhead conveyors. A staged integration would still require a scanning station (DEXA or CT) as part of the initial installation. It follows that more stations could be added to the linear system as the technology is developed and in a flexible arrangement to suit processors. It would be important to prototype and test the re-referencing technology before committing to this style of layout.

4.6 Payback Calculations

4.6.1 Payback based on number of head

Payback calculations for the proposed systems were based on $13.06/head benefit as an average on 5 mm accuracy improvement as described in the independent report by Greenleaf enterprises - MLA P.PIP.0361 (P.Green,K Bryan,S.Fischer, 2014).

4.7 Steering Committee Consultation

In developing concepts to automatically produce bone in beef cuts, it became clear that decisions were required that could have a significant impact on the complexity and configuration of an automated beef cutting system.

1) Can required preparatory work be completed before automatic cutting?
2) Are stepped separations necessary?
3) Can the foreleg be removed before automated cutting?
4) Is X-Ray required to make grading and sorting decisions?
5) Can we get rid of a full grading cut?
6) If the size and weight of severed parts was not an issue would we cut differently?

To ensure that the system is as widely applicable to the Australian beef processing industry as possible, it was important that as much of the industry as possible had input into the decisions.

The issues requiring decisions were explained and discussed at the beef processing industry steering committee meeting organised by MLA on the 30th April 2018.

4.7.1 Preparatory Work

The ideal automation scenario is that the automatic equipment is all within one area that is entirely fenced off from manual tasks. Mixing manual and automatic tasks will require a larger foot print and introduces cycle time uncertainties.

To facilitate complete manual / automatic separation, some tasks that are performed during current manual processes would need to be performed before the automated cutting system. Those tasks are:

1) Pope's eye removal
2) Tenderloin removal
3) Inside skirt removal

Removal of the Pope's eye is only necessary if the aitchbone is automatically removed. As this is beyond current automation scope, the task was not discussed.

The general consensus of the steering committee was that:

> Tenderloin removal or dropping of the tenderloin head may have to be preceded by removal of the thin flank.
>
> Removal of the inside skirt at the start of the process is a change from current practice, but is possible.

4.7.2 Stepped Cut Necessity

Stepped separation of the fore from the rack and of the rack from the loin complicate automation. Compared to a separation system that simply follows a rib from spine to brisket, a system capable of delivering stepped separations will be larger, more complex and more costly.

The general consensus of the steering committee was that the ability to make stepped separations with as shown in fig. 4 with cut position flexibility is essential.

4.7.3 Foreleg Removal

The foreleg can be removed manually before automatic cutting in the same way as it is currently in a manual side boning process. In future it could be removed automatically to be processed in an automatic deboning system.

The general consensus of the steering committee was that manual or automatic removal of the foreleg at the start of the cutting sequence will have no effect on cuts produced and therefore will not be a problem.

4.7.4 Grading Cut

The grading cut is required to assess marbling (intra muscular fat distribution) and colour within the longissimus dorsi muscle.

The grading cut significantly alters the shape of a beef side, reduces rigidity, reduces cutting flexibility and will increase automation complexity. From an automation point of view the cut needs to be replaced with non-invasive assessment methods.

The steering committee agreed that the grading cut needs to be replaced with non-invasive assessment methods. Work is under way by MLA to find non-invasive alternatives. In the event that these are not successful, or take longer to develop than automated cutting equipment, the consensus of the steering committee was that the grading cut will need to be accommodated.

4.7.5 Alternative Cut Lines

Current cutting processes are manual and must conform to what is ergonomically possible. An automated system doesn't have this restriction.

The steering committee were left to ponder the alternatives that automation could facilitate and invited to raise them at future meetings.

4.8 Future Steering Committee Meetings

While no further meetings are necessary for this project, other current and future projects focused on beef processing automation will require industry participation.

Processors at the steering committee meeting were invited to register interest in a smaller steering committee to assist Scott Automation in future stages of automatic beef cutting system development.

It was generally felt by the steering committee that more would be achieved if Scott Automation engaged with participants of the smaller steering committee individually, instead of as a group, with periodic group or industry meetings to keep everyone abreast of development progress

5 Discussion

Limitations in using pararells from the lamb LEAP developments have been identified, due to lamb end products being bone in end and beef being boneless products (with the exception of the spare ribs and prepared ribs products).

Additionally limiting issues of the horizontal system, identified in the LEAP 4 beef report , have been further considered and therefore not further developed in this work.

5.1 Maximising benefits of automation

The major benefits of an automated processing line are yield and value due to accurate cutting and more meat in the high value cuts versus the lower value cuts.

A reduction in labour and health and safety costs would be obtained.

The introduction of CT scanning would allow grading options and greater accuracy around muscle seams and bone structure for cutting processes.

The value proposition is in optimisation of the cut location either end of the cube roll and optimising the width of the short ribs cuts.

Additionally CT scanning would enable chinning racks (if adds value for the particular processor) and loins.

It is considered that the proposed automation would be able to provide the required flexibility to cater for the majority of the various cut specifications that processors perform.

5.2 Beef Automation Process - Options

Comparison of beef scribing options and an automated system.

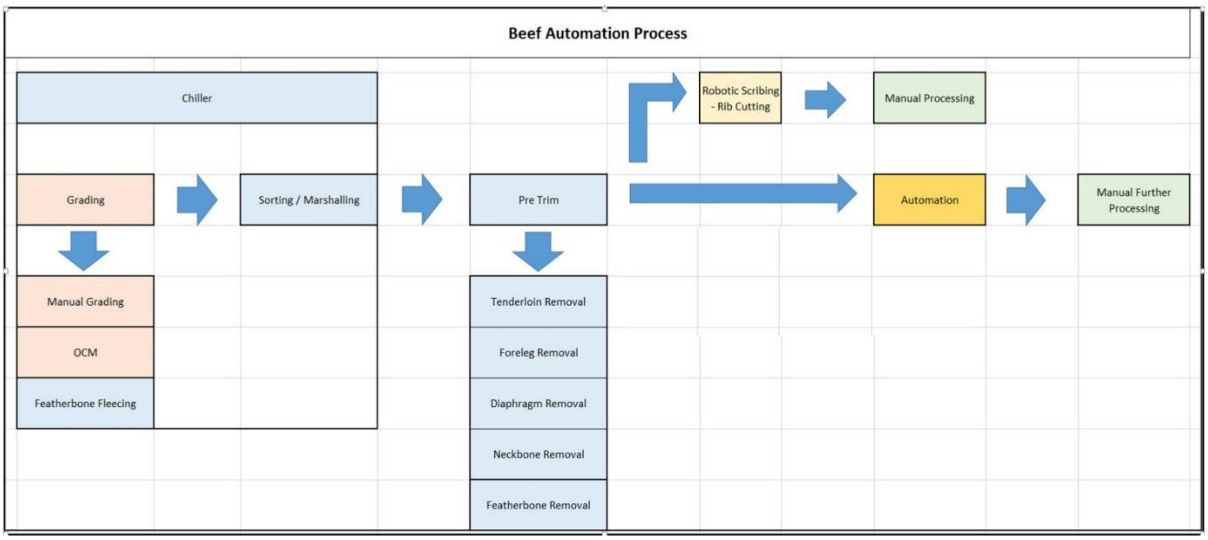

Figure 5: Beef Automation Process

5.3 Proposed automation systems comparison

The single rail system has a production rate of up to 675 head per shift, over this the dual rail system is required. For a production over 1350 head per shift, two complete cells would be required.

The output product conveyors may need to be split into several outfeed belts to minimise the amount of product on each belt and suit the processor layout.

5.4 Evaluation Chart

Payback is based on 2 shifts, 240 days per year. The overall cost for each option is only an approximation at this stage.
Evaluation criteria used for all the concept options.

- **Quality** = Finish of Cut ,Pasting, Chips, Saw Marks, Bone sharps
- **Yield** = Amount of Saleable meat per carcass. Bone, Fat , trimmings , Lean Meat
- **Value** (Processor) = Difference in value from amount of Meat which is in Lower value cuts. Cut Accuracy including Cut Tolerance.
- **Labour** + **Health & Safety** = Labour unit cost + safety around saws

Evaluation Matrix

Quality = Finish of Cut Pasting, Chips, Saw Marks, Bone sharps	**Yield** = Amount of Saleable meat per carcass. Bone, Fat ,trimings, Lean Meat.
Value (Processor) = Difference in value from amount of Meat which is in Lower value cuts.Cut Accuracy including Cut Tolerance.	**Labour** + **Health & Safety** = Labour unit cost + safety around saws.

Figure 6 - Evaluation matrix for considering option

6 Conclusions/recommendations

The scope of this project was to provide an automated solution for processing of beef sides. The systems are to have an accuracy of ± 5 mm to achieve the payback, proposed by others, of around $13.06 per head[2]. The payback is most significantly attributed to additional value due to cutting accuracy, yield and then labour and health and safety savings.

The two linear options (Single Rail and Dual Rail) have the advantage of staging the install of separate stations but do have re- referencing issues as the carcass moves from scanning and between stations.

Either of these options are larger than the current process and will present retrofitting challenges.

DEXA X Ray and CT scanning seem to be the best options for establishing rib geometry. DEXA X ray may have issues scanning thick meat sections.

Ultrasound or CT scanning could be suitable for fat trimming applications. Identifying muscle seams could be attempted with CT scanning.

The potential for CT scanning to offer a complete carcase analysis system is exciting, however the limitations of most commercial systems might present problems for early adoption. It would seem that some type of X-ray analysis (DEXA) would be a minimum requirement for successfully generating cut-paths. It is likely that a combination of a number of different technologies will offer the best outcomes.

These automation proposals rely on performing grading without the grading cut and associated carcass handling issues.

And there is a significant value opportunity to make the cuts either side of the cube roll after the grading, as opposed to current practice where it is performed before the grading.

The proposed concepts are inclusive of processing a beef side from neck up to the hind leg as the hind leg would be manually processed at this stage.

The overall process has required some rearrangement to enable automation, particularly fore leg and tenderloin removal moved to the pre-trim area.

The outcomes of the steering committee meeting on the 30th April 2018 were generally supportive of the developed automated cutting concepts:

- Removal of the foreleg in parts before automated cutting is OK.
- Removal of the inside skirt before automated cutting is OK.
- The ability to make stepped separations between the fore and the rack and between the rack and the loin is crucial.
- The need for a side clamping system that travels through the cutting system is understood by industry and accepted, but the system should be expandable and have layout flexibility.
- If the grading cut can be eliminated, it will be. If it can't be eliminated, the automatic cutting system will have to accommodate it – somehow?.

[2] *P.PIP.0361 Final Report - Feasiblity Review - Automated X - Ray Beef Boning Solution*

Some decisions that will affect the configuration of an automated beef cutting system can't be made until work that is currently in progress is complete.

- Location of X-Ray with regard to the carcass sorting can't be determined until DEXA at Rockhampton is providing useable carcass data.
- The effect that moving and cutting a side has on its shape and the ability to accurately reapply X-Ray data is unknown. Trials at Rockhampton are planned as part of the DEXA image refixing project.

In future stages of beef automated cutting development, Scott Automation will work individually with participants of the smaller steering committee in order to protect their particular process innovations.

6.1 Future research

An important step in the development of the linear systems would be to prototype one or more systems for re-referencing carcasses between cutting stations. This will be an enabling technology for the linear proposals.

Validation that CT scanning of racks and loins gives the accuracy required for chining, fat trimming and button bone removal, combined with economic and cycle time considerations will further suggest the suitability of CT technology.

The current DEXA systems could be used to validate the feature finding accuracy and establish the geometry limits of the carcasses that are expected to be processed.

Other decisions that will affect the configuration of an automated beef cutting system will need trials and development that is beyond the scope of current projects.

- Tenderloin removal or partial removal may require the thin flank to be dropped or removed.
- Dropping or removing the thin flank before rack removal may reduce side stiffness to an unworkable level.
- If the thin flank is not dropped or removed as preparatory work, finding the correct cut path for a robot to follow could be difficult.
- The benefits of upstream scribing for cuts that will be made automatically needs to be assessed.

7 Key messages

CT scanning, as applicable to boning room rates, capital cost, environment, product sizes and potentially including fixturing has an exciting potential but is a significant development challenge.

The beef process outputs are largely boneless products (except prepared-rib and spare ribs) as opposed to the lamb process. The dropped portions in the beef process have evolved to output sized portions that the manual process can cope with. And the orientation is constrained to suit the manual operator. Automation solutions typically aim to hold the product and “don't let go”. Whereas cutting the side into numerous primals introduces referencing and adaptive clamping expensive infrastructure – without adding value. The opportunity is for the alternative constraints of a mechanised solution to enable an improved solution given a mechanised process.

Robotic fleecing and boning, whether it be fore-leg removal, tenderloin removal or fleecing rib cages, is a demanding new technology that requires development work.

8 Bibliography

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Johnathon Cook, Fiona Anderson, 2017. *A.TEC.0123 Beef and Lamb OCM with CT in situ further development,* Sydney: MLA.

Mark Seaton, 2017. *P.PSH.0741 Final Report - Leap 4 Beef - Vision Development and preliminary Concepts,* KV , Dunedin: Scott technology.

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9 Appendix

9.1 2D-JD649 Cutting and Clamping

9.1.1 Rotary Saw

Applications:

- Scribing
- Cutting
- Marking

9.1.2 Reciprocating Circular Saw

Applications:

- Banjo Leg (Foreleg) removal

9.1.3 Reciprocating Saw

Applications:

- Cutting through bone
- Primal cuts

9.1.4 Bandsaw

Applications:

- Chine bone cutting
- Cutting shank
- Shorten ribs

9.1.5 Buster Saw

Applications:

- Splitting carcasses
- cutting

9.1.6 Knife

Applications:

- Fleecing ribs in racks
- Remove intercostal meat
- Fleecing transverse/spinous processes loin
- Trimmings
- Prepare meat cuts
- Loin fat trimming
- Deboning

9.1.7 Powered Knife

Applications:

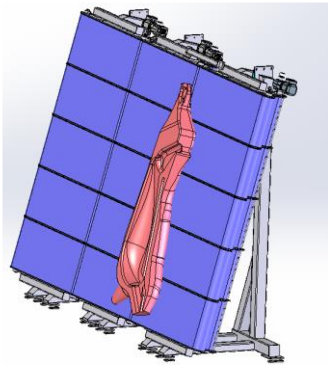
- Cutting ribs
- Deboning

9.1.8 Whizz Knife

Applications:

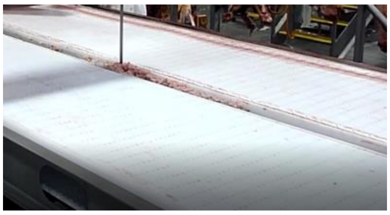
- Fat trimming loin
- Skinning
- Button removal loin
- Cleaning meat cuts

9.1.9 Angled Belt



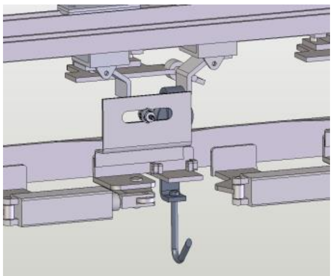
An angled belt can used to support the Beef side while scribing and scanning sides can be used to support the product during these processes. Based on previous experience in Beef Grading or Scribing Rooms.

9.1.10 Flat Belts



Flat conveyors can used in a Table boning application or packaging and transportation of cut products. In addition, flat belts are used for sorting applications.

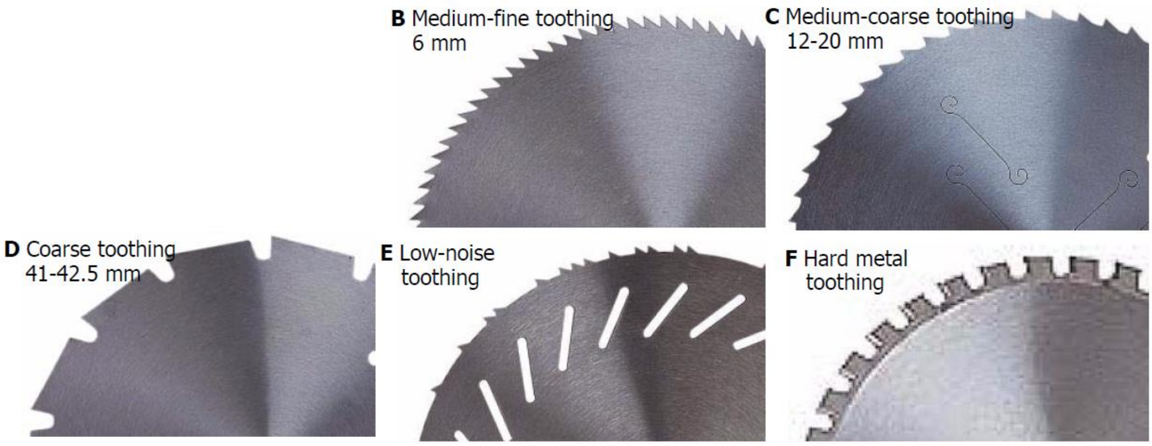
9.1.11 Overhead Chains



Overhead conveyor chains have applications in transporting sides through scanning rooms, fixing sides/hindquarters for manual processing and storing sides/bodies in the chiller.

The Clamping unit is size changeable to move up and down the beef side to clamp the spine against a flat plate. The clamping unit is placed to avoid the horizontal primal cuts.

9.1.12 Types of Blades Available



BEEF PROJECT – JD649 – SCOTT 1 DUAL RAIL – BF1000-001

9.2 Patent Review

9.2.1 Primal Cuts

- U2010202154A1- Automated Meat Breaking System and Method.
- US2004029514A1-Laying-down system and vision-based automatic primal cutting system.
- EP0600755A1 - A butchery process.pdf
- CA2250466 (A1) - Primal Cut System For Animal Carcasses
- FR2940747 -translated-Pig semi carcass cutting method.pdf
- EP0502581B1 Method and device for deboning halves of slaughtered animals.pdf
- US5713787A Device for deboning meat pieces with an articulated bone assembly.
- US3940830A-Apparatus for breaking animal carcasses and handling meat products.pdf
- US5580306A - Loin separation apparatus and method of operating thereof.
- US5407384A - Apparatus for processing an animal half carcass to recover loin and ribs
- US4667371 - Method and apparatus for mechanically excluding the breastbone of livestock carcasses.

- US2016106113 (A1) - A System For Processing Carcass Parts
- WO2007105299 (A1) - Method And Equipment For Removing Backbone Of Carcass
- US5542878A Method and Apparatus for Separating Meat from a Bone of an animal carcass.
- US2017049116A1 - Robotic Carcass Processing Method and System.
- US2016037787A1 - System and Method for processing slaughtered animals and or parts.
- EP0985348A2 Method and apparatus for longitudinal cutting
- WO9620605A1 - Bandsaw for cutting cattle carcasses
- WO2017036458 (A1) - Device For Removing A Backbone

9.2.2 Scribing

- DE102004024077 (A1) - Machine for cutting and carving meat, with rotary cutting blade, has swing arm to support motor gearing at cutting blade with spindle drive adjustment and safety wedge
- EP1228693A1-Apparatus and method for cutting through the ribs of a middle from a carcass.

9.2.3 Scanning Devices

- US2013059513A1 Separation of the Spinal Column from a carcass middle part.
- US7404759 Spinal Column Removing Method & Spinal Column Removing Apparatus.
- US2016106112A1 Automated Scanning and Butchering System.
- US4118777A - Computer directed primal cut indicating device.
- US4688296A - Means for breaking down carcasses.pdf
- US5205779A - Method and apparatus for automatically segmenting animal carcasses.
- EP2946667A1 - x-ray imaging apparatus for determining a cutting path of a carcass.
- US2016029647A1 - Device for measuring a slaughter animal body object.
- From: CSB SYS AG [DE]
- US8500523B1 - Cutting System and method of cutting meat parts using the same.
- US2008200107A1 - Method and facility for automatically determining quality characteristics of a carcass on a slaughterline.

9.2.4 Grading

- CN102854148 (A) - Detection and grading system for tenderness of fresh beef based on multispectral imagery
- US5353796A – Non invasive device and method for grading meat.
- US2011110563A1-Method and system for automatically grading beef quality.
- US5079951A-Ultrasonic carcass inspection.
- US2003072472A1-Image analysis systems for grading of meat
- CN107045013 (A) - Automatic grading detector for beef taste quality and detection method thereof
- CN105651776 (A) - Device and method for automatically grading beef carcass meat yield based on computer vision
- US5944598A-Method and apparatus for using image analysis to determine meat and carcass characteristics.
- US5194036A-Method for grading carcasses of large cattle and device for implementation thereof.