AUSTRALIAN MEAT PROCESSOR CORPORATION

Hook-Assist CBA and feasibility for future modifications

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1 Executive Summary

In 2005 MLA and AMPC embarked on the process of investigating 'cobotics' as a technology that may address some of the OH&S issues faced by the meat processing industry. A 'co-robot' works collaboratively with operators by amplifying human effort, as opposed to conventional automation systems that replace operators.

Industry was engaged throughout the development process that produced the Hook Assist platform prototype. There was great potential for the technology subject to addressing a number of functional refinements during off-line trialing of the prototype system. At completion of the development stage in 2010, Scott Technology won the tender to handle the commercialisation process. Beef scribing was identified as one possible extension of the Hook Assist platform. The proposed solution was considered to have the potential to reduce the OH&S issues associated with manual beef scribing, increase cutting accuracy and provide an improvement in processing speed. It was intended to trial the prototype system at line speeds in commercial boning rooms to familiarize operators with Hook Assist and identify and build additional capabilities and applications from the base technology. One aim of these trial installations was for the industry to work with AMPC, MLA and Scott Technology to identify further applications the platform technology could be extended to address.

The Hook-Assist Prototype has experienced considerable technical faults and component failures indicating the design of the foundational technology is not suitable for harsh boning room conditions. This has halted all trials and development work by Scott Technology as the prototype technology was not ready for the planned commercialization activities.

Prior to moving forward with commercialisation a major re-design of some aspects of the system is required before it could even operate robustly in the environment let alone investigate variants of the base technology. Given more R&D investment is required to re-build the system, a more in-depth evaluation of the processes and outcomes to date as well as pros and cons of further investment need to be considered carefully.

This report intends to facilitate these considerations. Learnings to date and from other cobotics and fully automated initiatives enables industry to determine the best way to leverage these assets to address the industry needs to which the project was originally started and which still exist.

Although the purpose of this project was to evaluate from a financial perspective industry investments and outcomes in relation to the Hook Assist technology, evidence indicates less tangible contributors like human engagement also impact greatly on a company's performance.

On review, this Hook Assist device and the technology platform are unlike any other currently employed or proposed for reducing OH&S risks involved with meat processing. The Hook Assist engaged workers in a totally new way. It improved the existing natural human capability through engagement with the operator's intuitive movements rather than replace the human deficiency with another tool requiring further skill acquisition. In aligning itself with their natural abilities it also engaged with their natural senses. This interaction introduced the emotive responses that trigger commitment, and commitment can have profound impact on engagement and performance level. Findings from this study around adoption indicate the importance more seamless integration of cobotics with human movement could have if cobotics are successfully developed and become more widely adopted.

Skilled boners will continue to be necessary because visioning and sensing will not be good enough for at least 10-20 years to replace these jobs. The flexibility and adaption of humans to ever changing cutting specifications further complicates full automation and highlights the importance of amplifying human capability. When OH&S issues and increasing pressure to reduce risk in the workplace are added to this, a commercial Hook Assist (or alternative cobotic technology) is well positioned as a solution.

Key findings

A number of areas of investigation have been integrated to identify the challenges and opportunities in this section and underpin the recommendations on how to proceed with the technology. The key findings as are as follows:

Project outputs

Two significant capability assets have been developed – The key output developed from the hook assist project are summarised in the top two rows of Table 1. These capabilities combined to work seamlessly (when the prototype worked) resulting unprecedented amplification of human skill in row three of the table delivered. Potential alternative boning processes were intended in the last row of the table before the prototype failed in the harsh commercial environment.

Table 1: Hook Assist capability outputs from the project to date

Capability	Description / outcomes	Benefits
360° range of movement (XYZ axis)	Existing cobotic systems (RTL) only have XY movement. Providing full range of human movements means faster more intuitive support of natural human movements.	- System becomes an extension of the operators arm rather than changing the oppertors process - Quicker adaption by operators - Higher number of applications
Variable power output	The variable output of power allows for greater control of cutting lines and amplifies human movement. Resulting in greater productivity per operator.	- Reduced strain on boners - Larger range of employees able to complete task
Combination of XYZ movement and variable power output	Combination of variable power control AND full human movement provides opportunity for a much wider range of finer motor skill applications.	- Reduced OH & S issues - Larger number of applications
Radical change in boning process	The current boning process has been established as a result of what is physically capable by the boners and product specifications. Refinement of this process could be possible.	- More advanced value adding opportunities - Access to additional markets - Increased ability to meet customer requirements

Project capabilities developed greatly amplify human capacity - Hook Assist delivers a significantly better integration with human capability than any other human assist devices (based on when the system worked). This seamless integration between machine and human is critical for future cobotics success. This is particularly critical where technology has to integrate with a wide range of human sensing and visioning capabilities.

- Operators felt there was a significant improvement (60% more integration with the operator) in the system and were clearly more engaged than with RTL or Proman hook assist devices.
- This increase in engagement is a potential opportunity expanded further below.

No future without further industry R&D - The Hook Assist technology is not commercial ready and requires investment in re-design. This is the minimum investment needed to enable trials prior to undertaking the planned commercialisation activities. Two options to get the prototype to commercial operation are:

- <u>Low cost rewire</u> - Approximately $250,000 will fix waterproofing and maintenance issues but will not address some fundamental shortcomings like too short a swing arm.

- <u>Higher cost redesign</u> – Approximately $550,000 involves a complete rebuild. Although it will address the known issues, twelve months of commercial trials will generate new learnings, most likley requiring a further refinement of the base technology platform.

R&D / Commercialisation path not a failure - Some re-design issues had been identified with the prototype prior to the commercialisation tender. It was decided not to further invest in R&D to re-engineer at the time. Pre-existing issues were not the reason for system failure. A number of new issues only arose during the commercial trials after Scott Technology won the commercialisation tender. If industry money had been spent earlier, these new (yet to be identified) issues would still not have been addressed. The technology would still have been inoperable but with a higher industry investment cost.

- The main disadvantage of this path has been loss of time while the commercialiser and industry decide whether to proceed or not.

- The main positive is a clearer understanding of what is required from commercialiser and industry to develop a successful cobotics technology platform.

- The development path required is not dissimilar to the multi-stage building and refining of the LEAP technology for lamb where a number of trial and error developments were required to find a successful solution.

Commercial viability of project outputs

Traditional approach ("tool for a job") delivers mixed benefits – Hook Assist benefits include yield, OH & S, throughput and labour saving but these vary across the range of jobs (refer to figure 1). Return on investment varies from 6 months to 4 years between jobs as a result. Taking the approach of "a tool for a job" will limit adoption to two to four tasks in the boning room with the most immediate tangible benefits.

Industry cost / opportunity – OH&S and labour related costs are expected to increase by 30% over the next 15 years and will make investment in cobotics more viable. Effective cobotics could address an opportunity cost estimated at $21 million per annum (see Potential Industry Benefit section on page 53).

Simplistic short-term approach limits future opportunity - If hook assist is viewed as a single tool for an existing job without considering potential innovation opportunities redevelopment will be hard to justify.

- Hook assist does not deliver much better financial benefit than other cobotics in a task for task comparison when only considering yield.
- Capital cost needs to reduce from the projected $150,000 to $200,000 per unit to be commercially viable for single task applications.

Cobotics discussions require a fresh approach to innovate

Innovative engagement and adoption strategies - Existing competing cobotics technologies have had limited adoption. The difference between plants that have successfully installed cobotics and those that haven't has been the approach to engaging existing staff. A potential new development and adoption process that focuses on the people should be considered and would be required for Hook Assist if it is further developed. Careful engagement of industry is required to encourage adoption.

New systems approach increases benefits - Hook Assist technology has the potential to seamlessly amplify human capability. A systems approach where 5 to 6 Hook Assists were installed on a line to support all difficult boning jobs could deliver benefits around throughput, not possible when only installing two to three systems for jobs with yield payback. This systems approach would further address absenteeism and staff engagement. Because two to three of the installs don't deliver high payback in isolation from the other installs a different approach to installing equipment is required. This would require significant testing and demonstration to prove the approach.

Options to address OH&S challenges

Full automation cannot replace cobotics - Fully automated solutions could replace straight cutting tasks like scribing. However manual boning tasks have no visible automation development pathway at this point in time. If Hook Assist is not progressed, alternative cobotics will be required to overcome current labour and OH & S challenges around these jobs (approximately 80% of beef boning tasks). Figure 1 summarises the differences between the two technology approaches.

Cobotics and automation deliver similar ROI - More automated solutions come at a greater capital investment and require higher processing volumes to provide an attractive payback period (refer to Table **9**). Although fully automated systems can deliver greater value the capital cost is also much greater. Interestingly, ROI for the automated and cobotics systems compared in the study were not that different.

Small and large processor needs – Plant foot print, volume processed and flexibility of operations influence a plants appetite for full automation. If cobotics modules can be developed they will be more suitable to smaller processors than full automation. Even if fully automated solutions are developed, smaller cobotics solutions (if developed) would better suit many processing plants.

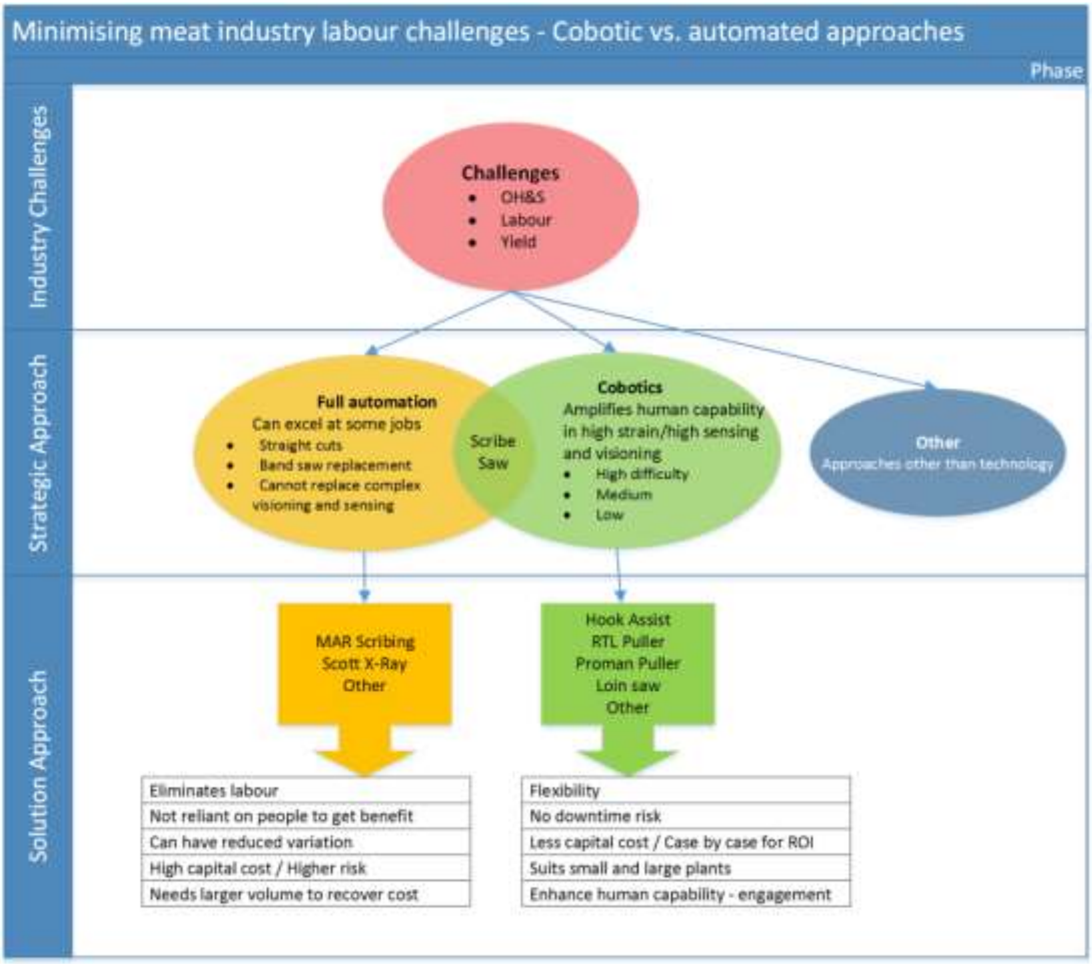

Figure 1: Comparison between cobotics and automated technologies

Industry still requires a cobotic solution - If manual assist technology is not advanced, some other technology approach will be required to address the original labour and OH&S challenges that instigated the project investment to date. Full automation is not an alternative pathway to cobotics in the short to medium term.

1. No other solutions so look harder or develop more strategically with more specific target outcomes but longer term development pathway.
2. Cost of small multiple unit installations versus large single complete overhaul installations – different target audiences.

Industry R&D would "kick start" commercial investment – Further R&D beyond testing of the base technology will be required to build end effectors and adapt the base technology into a range of manual assist applications. The commercialiser had already committed to this ongoing investment in collaboration with interested processors as future funded PIP projects. However, they intended 12 months testing in the production environment which the prototype failed to deliver (less than 6 weeks in fact). If industry want to realise the assets developed to date, investing in a commercially robust prototype would get the technology to a point where the commercialiser would take over R&D.

Recommendations:

The following recommendations require input from industry to step through the best future direction for the Hook Assist technology.

1. **Confirm industry commitment to reduce boning OH&S risks** – Confirm with industry that cobotics is still an important strategic initiative for reducing physical strain and difficulty from the hardest boning tasks as the first step in considering the way forward with Hook Assist. This is important when considering industry adoption.
2. **Double-check alternative cobotic development pathways** - Confirm that no alternative cobotic technologies exist that present a shorter commercialisation path than Hook Assist. This is unlikely given previous industry research. Adapting alternative technology to the meat industry would probably be more expensive than further development of Hook Assist.
3. **Value engineering is absolutely critical to success** - If industry agree to proceed with this technology a value-engineering strategy will be required to reduce the capital cost as current $150-200,000 Hook Assist capital cost will limit adoption. Target capital costs should be agreed with industry as part of this strategy.

If these recommendations can be agreed on between industry and the commercialiser, it is recommended to proceed with redevelopment of Hook Assist in order to:

1. Test whether the significant project learnings can deliver an acceptable cobotic tool – S*uccess seems likely*.
2. Identify how a second stage adaptation could innovate around OH&S and worker engagement. *– Success depends on findings from 1. but could lead to radical innovation*.

If redevelopment proceeds it should be on the following basis:

- **Redesign the prototype** - in order to conduct 12 months of commercial trials as originally planned.
- **Re-design using the more expensive option** - Preference is towards the more involved redesign as a number of physical constraints on the existing prototype (such as redesign of new hook and longer arm to keep up with chain speed) would limit effectiveness of the 12 months of trials. NOTE: discussions with engineers and commercialiser are required to decide on the best redevelopment option.
- **Agree on a target capital cost window with industry** for a range of applications of Hook Assist prior to conducting the redesign. This will guide design requirements and may help uncover a more innovative approach.
- **Improved engagement could occur** - Agree to further investigate the employee engagement component of this equipment. Significant potential could come out of improved engagement.
- **Manage expectations with industry** - This 12 month trial will not produce a commercial product. Further refinement of the redesigned system will be required either to adapt learnings, or to

develop end effectors for specific manual tasks like Scribe Assist. Previously, false expectations arose that the prototype was commercial ready. When it failed some considered the whole project to have been a failure. The capabilities built to date have potential to transform complex manual boning tasks but will require a lot of testing.

2 Glossary

Term	Description
AMPC	Australian Meat Processor Corporation
CBA	Cost Benefit Analysis
Ex-ante	"Before the event". Ex-ante is used most commonly in the commercial world, where results of a particular action, or series of actions, are forecast in advance (or intended).
Ex-post	The opposite of ex-ante is ex-post (actual)
HSCW	Hot Standard Carcase Weight
IAD or 'Cobotics'	Intelligent Assist Device
Manual assist	A system which assists the operators normal natural movements
MLA	Meat and Livestock Australia
NCMC	Northern Co-operative Meat Company
NMIT	North Melbourne Institute of TAFE
OH & S	Occupational Health & Safety
ROI	Return on Investment
FTER & D	Research and Development

3 Introduction

In 2005 MLA and AMPC embarked on the process of investigating 'cobotics' as a technology that may address some of the OH&S issues faced by the meat processing industry. A 'co-robot' works collaboratively with operators by amplifying human effort, as opposed to conventional automation systems that replace operators or provide them with a tool.

MLA and AMPC commissioned US based Kinea Design to develop the Hook Assist platform prototype. Industry was engaged in the development process and saw great potential for the technology subject to addressing a number of functional refinements during off-line trialing of the prototype system. At completion of the development stage Scott Technology won the tender to handle the commercialisation process. Trialing the prototype system at line speeds in commercial boning rooms was intended to familiarize operators with Hook Assist and identify and build additional capabilities and applications from the base technology.

The first industry trail system was installed at JBS Brooklyn in mid-2011 with further trials undertaken at the Northern Co-operative Meat Company, Casino. One aim of these installations was for the industry to work with AMPC, MLA and Scott Technology to determine what else the platform could be used for. From this, beef scribing was identified as one possible extension of the Hook Assist platform. The proposed solution was considered to have the potential to reduce the OH&S issues associated with manual beef scribing, increase cutting accuracy and provided an improvement in processing speed.

Although Scott Technology envisaged having a commercial platform for both Hook Assist and Scribe Assist in 2012, this has not eventuated. The Hook-Assist Prototype has experienced considerable technical faults and component failures indicating the design of the foundational technology is not suitable for harsh boning room conditions and has prevented any further trials.

Prior to moving forward with commercialisation a major re-design of some aspects of the system is required to ensure the system can operate robustly in the environment. Given more R&D investment is required to re-build the system, a more in-depth evaluation of the processes and outcomes to date as well as pros and cons of further investment need to be considered carefully.

It is now necessary to:

- Review industry investment and contributions to Hook Assist (and Scribe Assist) and summarize outcomes, benefits and outputs from these investments.

- Identify industry drivers, current and future gaps, considerations and needs and potential tasks for the successful adaption and commercial implementation of the Hook Assist platform technology and its wider uptake in industry (as a feasibility analysis for future investment).

- Conduct a cost/benefit analysis into the development and adoption of the Hook Assist platform technology (including tasks identified in this project).

This report is not about determining if the Kinea Design prototype system is “almost” ready for commercial use. It clearly is not ready as discussed in the report.

This report is about identifying the learnings from the development to date and from other cobotics and fully automated initiatives and assembling them in a way that enables industry to determine the best way to leverage these assets to address the industry needs to which the project was originally started and that still exist.

4 Objectives

The objectives of this project are to:

1. Engage with red meat processors and the commercialiser Scott Technology, to capture learnings from industry trials of the Hook-assist prototype to date, understanding issues faced with regards to its adoption by processors and confirm industry appetite for delivery of a robust commercial platform.
2. Investigate and determine the nature and extent of technical challenges besetting the existing Hook Assist prototype and understanding what is required to resolve these including specific modifications required to successfully adapt to tasks identified throughout this project.
3. Independently assess the cost benefit of developing and delivery to industry potential applications for Hook Assist by processors.

These objectives were successfully achieved.

5 Methodology

Desktop Study

The desktop study summarised all published information and established a base understanding of the technology platform. It enabled identification of the current and potential applications as well as comparative technology systems available. All available documents were reviewed, along with a number of videos of the prototype system in operation across different boning tasks. References relating to processes or concepts were obtained for inclusion as appropriate. A list of reviewed documents is included in section 14 which helped to:

- Understand research and development conducted to date.
- Identify systems which perform similar operations to which the Hook Assist could be utilised.
- Gain insights into the development process and learnings for any future development.

Industry Review

A framework was developed to address the industry review objectives and to structure and guide site visit investigations. Activities conducted during these site visits included discussions with industry participants and cost benefit analyses required to support recommendations. The primary points of focus were to:

- Identify the specific capabilities of the technology that were different to manual processes and other existing technologies
- Clarify how these capabilities deliver value
- Apply this value to wider industry benefit including likely impact on adoption
- Determine the current limitations of proceeding forward with this technology and the cost of addressing these limitations
- Assess the significance of this technology capability to the industry now and in 10 years considering other known technology development pathways with similar industry benefits
- Determine the risk for industry challenges of not proceeding with the technology

Site visits were conducted, along with discussion and input from industry representatives to test and validate the findings reported.

Modelling

An ex-ante CBA modelling process has been used to quantify the immediate and longer term opportunities for the technology platform. This includes the following activities:

- Quantify the value each capability contributes to a job function over and above manual and other alternative technologies
- Estimate the capital cost that would be required for an installation to achieve a set payback period, based on the estimated value benefits the system would provide
- Consider the number of commercial unit sales required to obtain ROI on the further R&D costs
- Model the likely number of applications for the technology platform and a viable R&D re-configuration cost to adapt the base technology to new applications

The key benefits the system has the potential to deliver are included in Table 1. The magnitude of value these benefits could deliver are estimated in the CBA analysis based on pre-existing data from production and yield trials and from validation conducted during site visits.

Table 2: 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's 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.

6 Description of technology

'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 in Figure 2 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.

Figure 2: Hook Assist prototype technology

Figure 3 demonstrate the prototype system in action and various boning applications for the Hook Assist application.

HookAssist installed in 'spare' boning room at Brooklyn

HookAssist installed and being trial in a chiller at NCMC.

Figure 3: Hook Assist prototype system in industry trial sites

Multi-unit systems approach over single task replacement

A key consideration in assessing this technology is not to view it as a one-off tool with a cost benefit trade-off for a particular job, but to consider the wider applications of the IAD technology as a series of tools supporting all difficult boning jobs as part of a system. This multi-unit approach if the technology is proven may increase throughput and enable future transformation in meat processing beyond what is capable with single stand-alone installs. A more strategic level of thinking than traditional CBA's is required to ascertain the longer term value the technology could provide with this alternative type of approach and has been included as well.

7 Evaluation of Current Hook Assist System

A number of key capabilities of the Hook Assist technology differentiate it from other systems already in the industry. These are described here and summarised in Table 3 & Figure 4:

- 360° range of movement or XYZ-axis unlike the existing RTL aitchbone puller that only has a 2 dimensional movement. This core capability enables the operator to utilise the full range of natural human movement. It supports intuitive movement rather than limiting operator's freedom of movement. This results in quicker adaptation by operators and increased operator speed. If successfully commercialised this attribute is transferable to a number of manual assist applications.
- Greater control of variable power adjusts force applied as the operator adjusts effort through the normal movement required to complete a task. This gives much greater control of cutting lines than existing cobotics systems which have been known to tear the meat on occasion. This intuitive control may result in increased productivity. The power output amplifies the human movement with increased strength. This enables a broader pool of workers to be considered for these more physically demanding positions.
- A new approach to carcase breakdown processes due to the combination of these new capabilities above could enable alternative methods for primal cut breakdown that have not been possible due to limited manual force. Current boning room processes have been designed around the physical capability of the boners and the product specifications.

These capabilities are the most valuable assets and outcome of the investment to date.

Capability benefits comparative to other technologies

Understanding exactly what these capabilities are, relative to current capability, was the first step. Clearly defining these capabilities in Table 3 is important to help differentiate what this technology delivers beyond current alternatives and what benefit can be expected from these additional capabilities. They are significant in terms of the industry's strategic commitment to technology implementation in order to deal with OH&S issues, whilst increasing productivity and yield.

Table 3: Capabilities resulting from initial investment in the Hook Assist concept

Capability	Description / outcomes	Benefits
360° range of movement (XYZ axis)	Existing cobotic systems (RTL) only have XY movement. Providing full range of human movements means faster more intuitive support of natural human movements.	- System becomes an extension of the operators arm rather than changing the oppertors process - Quicker adaption by operators - Higher number of applications
Variable power output	The variable output of power allows for greater control of cutting lines and amplifies human movement. Resulting in greater productivity per operator.	- Reduced strain on boners - Larger range of employees able to complete task
Combination of XYZ movement and variable power output	Combination of variable power control AND full human movement provides opportunity for a much wider range of finer motor skill applications.	- Reduced OH & S issues - Larger number of applications
Radical change in boning process	The current boning process has been established as a result of what is physically capable by the boners and product specifications. Refinement of this process could be possible.	- More advanced value adding opportunities - Access to additional markets - Increased ability to meet customer requirements

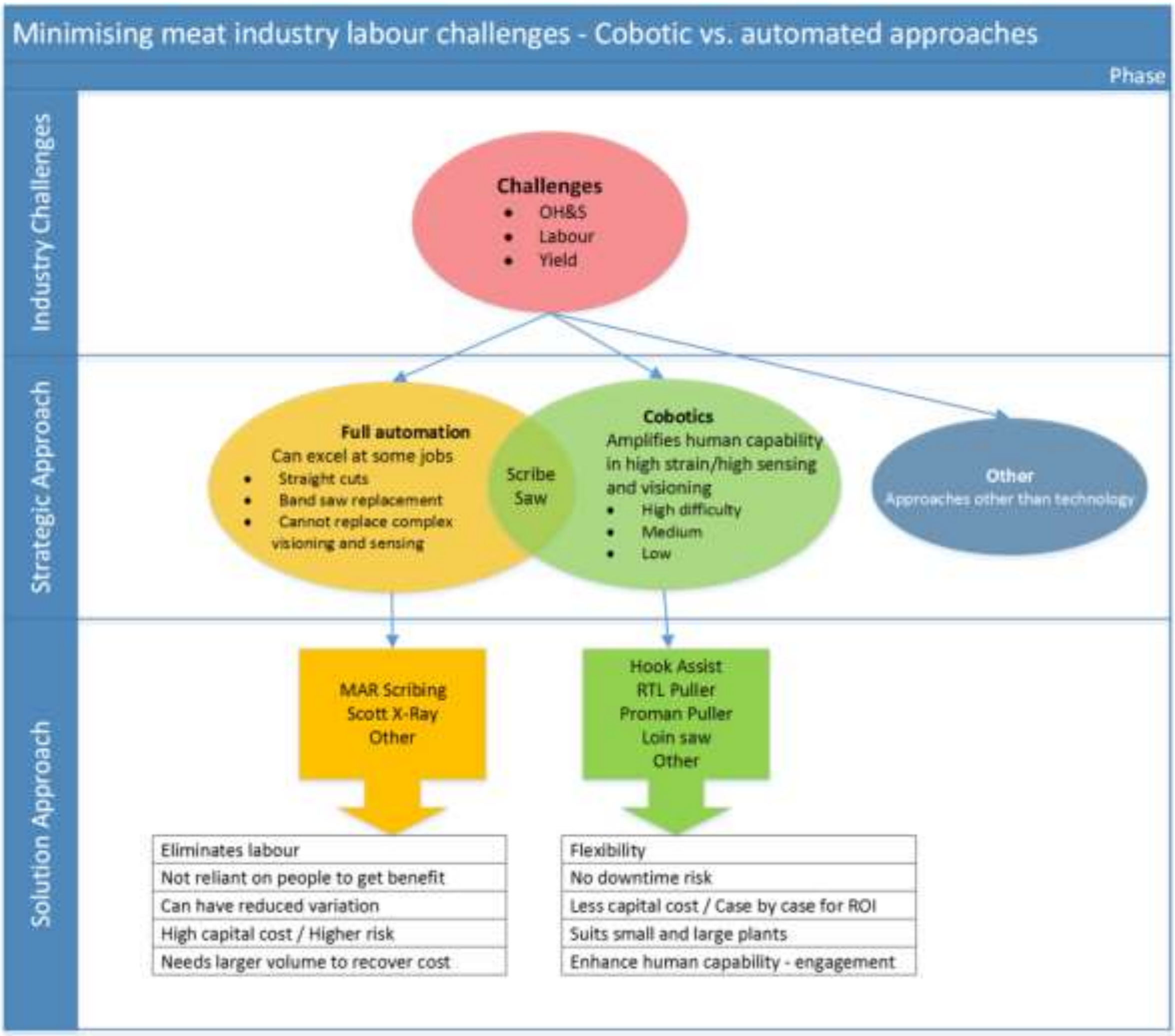

Figure 4: Complementary and differences between cobotic and automated technologies in reducing labour risks

Summary findings from site visit interviews

A number of in-person and phone interviews were conducted with 16 people across 8 beef processing sites and service providers. Not all people had direct exposure to Hook Assist but all had experience with RTL aitchbone pullers. Discussions with this secondary group were around adoption barriers and benefits from that technology. This industry input has been integrated throughout the report and a summary of findings for each group of industry representatives has been included in the following sections.

Uptake of the technology with boners

A summary of findings from boners using the system has been included below:

- Received the concept enthusiastically.

- Boners took a while to adapt to the process but once they adapted their boning style found the system worked well.
- The system breakdowns caused boners to lose faith.
- The reach of the system was too short and limited the boners ability to finalise the process. Increasing arm length is a relatively minor task if the system is re-designed.
- Different boning hooks need to be trialled as well as a detachable boning hook.
- The counterweight at the handpiece applied strain to operator and made hook orientation difficult. This is an ergonomic limitation that needs to be addressed.
- The Handle grip could be improved to reduce slip when holding it.
- Boning room staff and supervisors agreed adaptations of the system could support a wide range of cuts (details are included in Table 5).

Managers, supervisors and boners general perceptions of the system:

- They could see a number of applications that the technology concept could be applied to directly or with minor modification (assuming the base technology was commercially robust).
- Some importance was placed on extending the reach of the arm as a minimum to keep up with chain speed.
- Reliability was the major drawback from their perspective.
- Managers and supervisors were very supportive and felt the technology if commercially robust would reduce boner strain.
- Two senior managers were quite negative about the system in the following ways:
    - The engineering design and particularly the electrical components would never be suitable for the harsh meat industry environment.
    - The physical Hook Assist equipment is not commercial in any way.

  These comments were about the immediate piece of equipment, not about the improvement in capability. There was no tolerance for a non-commercial system operating in a commercial environment.

Responses on functionality compared to commercial aitch bone pullers

- The Hook Assist technology is more advanced than the Scott Aitchbone puller and the Proman puller.
- The technology is driven/controlled both vertically underneath the rail and toward/away from the rail which increases its potential to assist a number of tasks beyond aitchbone and knuckle pulling.
- The Hook Assist technology is able to be controlled with a higher level of accuracy.
- Boners were surprised how intuitive a machine could be and how responsive the Hook Assist was. One boning room trainer commented that “As I thought the next move, it [Hook Assist] was almost moving at the same time”, and another said “It [Hook Assist] is 60% better than the RTL puller”. When asked what he meant he referred to its ability to integrate with human

movement enabling the same or better control of hook pulling and cutting lines than full manual human movement.

- The 'cobotic' Hook Assist device could perform the same tasks as other existing commercial cobotics systems but the performance and impact on operators is far superior.
- This technology was interfacing with what they thought and did intuitively, increasing their capability. Existing systems enhanced strength but limited other human skills like fine motor control, dexterity and manoeuvrability. The prototype system (when it worked well) was a significant improvement on existing systems in terms of worker engagement.

Technology extension opportunities

The following ideas were raised as potential extensions of the base technology:

- The technology can easily be set up to monitor process parameters and provide greater feedback to the boner.
- Data acquisition could be enabled to collect x/y/z coordinates and used as pre-development for automated knife boning.
- The technology is fairly different in a number of ways to the Scott Aitchbone and Knuckle puller giving it potential as a technology platform on which to adapt a range of end effectors.

Trials and constraints limiting commercialisation

Industry has been closely involved in the development pathway from scoping and prototype trials, design iterations and further testing. The 2011 Kinea Design report A.OHS.0050, outlines the development stages that were undertaken to reach prototype and trial stages of the project. Review of the events leading up to commercialisation indicate a number of areas of development still needed to be addressed. In hind-site the actual path taken has probably been the best one for industry as a number of additional design limitations could not have been identified without commercial testing, even if further R&D had been invested in prior to commercialisation.

An account of the development path and course of events is summarised here but explained in more detail in appendix 16.

Prototype development

Phase 1 – made measurements in plants, and mocked-up non-functional assist devices, to determine the range of motion of the assist device that was needed for the required tasks, in order to determine how to integrate it into existing plant structures, and to assure that its geometry would not interfere with work flow or traffic in the plants.

Phase 2 – fabricated a fully functional experience prototype assist device. It was over-designed, so that it could serve as a test-bed, allowing a number of investigations and variations to be explored. The prototype device was used in a non-production testing environment and workshopped to industry in the Melbourne TAFE facility. Although there were a number of operational issues general industry consensus was that the core capabilities of the technology were of value to industry and worth pursuing.

Phase 3 – Kinea Design adapted the design from lessons learned in phase 2 and built an assist device for plant installation and in-production testing.

The Kinea report after the Melbourne TAFE workshop detailed feedback responses and comments on the devices limitations. Some were addressed but many were not completely resolved. A summary of these issues and actions is included in the appendix limitations section.

Commercialisation

This refined system (with some unresolved issues) was tested at the JBS Brooklyn plant. A number of functional design issues were raised and it was removed. The system was then transferred to NCMC at Casino for further trials.

System failure

It was envisaged that the NCMC site trials would be extensive, conducted for 6-12 months to gather further development data. In reality, this period amounted to a few weeks due to system failure as the prototype could not withstand the harsh and wet abattoir environment. These trials showed that the prototype was still going to require substantial development to reach viable commercialisation.

Whilst capabilities and resultant benefits were clearly confirmed during the development, workshop and trial processes, the outcomes were unable to be realised due to the technical failures once it was in commercial operating conditions as shown in Figure 5.


Installed at the NCMC boning room

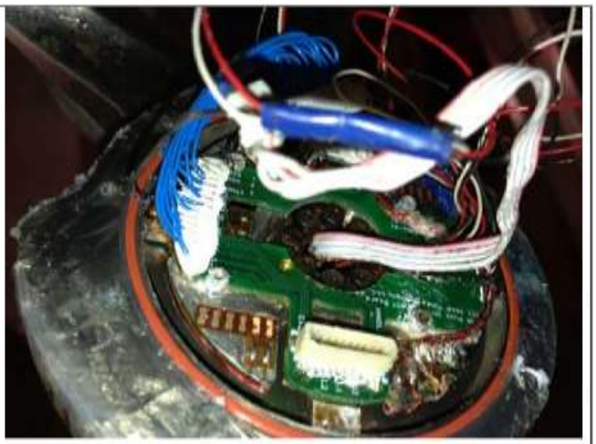
Example of electrical issues

Figure 5: Hook Assist issues when installed in a commercial environment

There were considerable technical faults and component failures with the prototype once it was installed on site. Its inability to operate reliably in the wet environment and difficulty troubleshooting and repairing problems were the main issues. Previous reports have provided extensive evaluation of these limitations which are summarised here in Table 4.

Table 4: Prototype system short-comings resulting in commercial operating failure

Modification	Description
Electronics	The wiring and circuit boards need upgrading to withstand the environmental pressures reducing erratic behaviour.
Software	The software needs additional programing to improve trouble shooting ability .
Water Proofing	The casing and sensors need to be able to withstand being washed down with 95°C water every shift.
Reach	The reach of the system limits the ability of boners to finish the job.
Strength	The system needs an additional 50kgs of force.
Serviceability	Currently the serviceability of the system is low as it is designed with small parts which could be dropped and lodged in meat.
Arm Design	The arm design currently has a number of pinch points and areas which meat get trapped harvesting bacterial growth.
Gimbal Design	The gimbal is the piece which the operator holds and directs the system. This needs redesigning as it currently places pressure on the operators hand.
Home position	The system currently stops where the bone levels the handle. It needs the ability to return to a home position to reduce any chance of staff being stabbed with the hook.

Outcomes of commercial trials

The key observations from investigation of the develop stages and commercialisation process are summarised as follows:

- Design concept and proposed capabilities had industry endorsement.
- Off-line testing of core capability proved impressive with boners claiming a 60% increase in useability over RTL aitchbone puller.
- Core capabilities are hindered by minor but not insignificant design constraints such as length of arm reach.
- These constraints require further refinement and had been acknowledged prior to commercialisation.
- Scott technology intended to redesign minor limitations after 12 months of commercial testing of the existing prototype
- The commercialiser was intending to test capability, scope adaptations to base technology and investigate other end applications for 12 months.

- Fundamental DNA of the system wiring and fabrication materials did not function in the wet commercial environment. This has become the entire projects stumbling block.

Potential development pathways

As the prototype system requires a significant amount of money to re-design a number of potential paths forward have been identified in Figure 6 including estimated costs for re-engineering that were provided by Scott Technology.

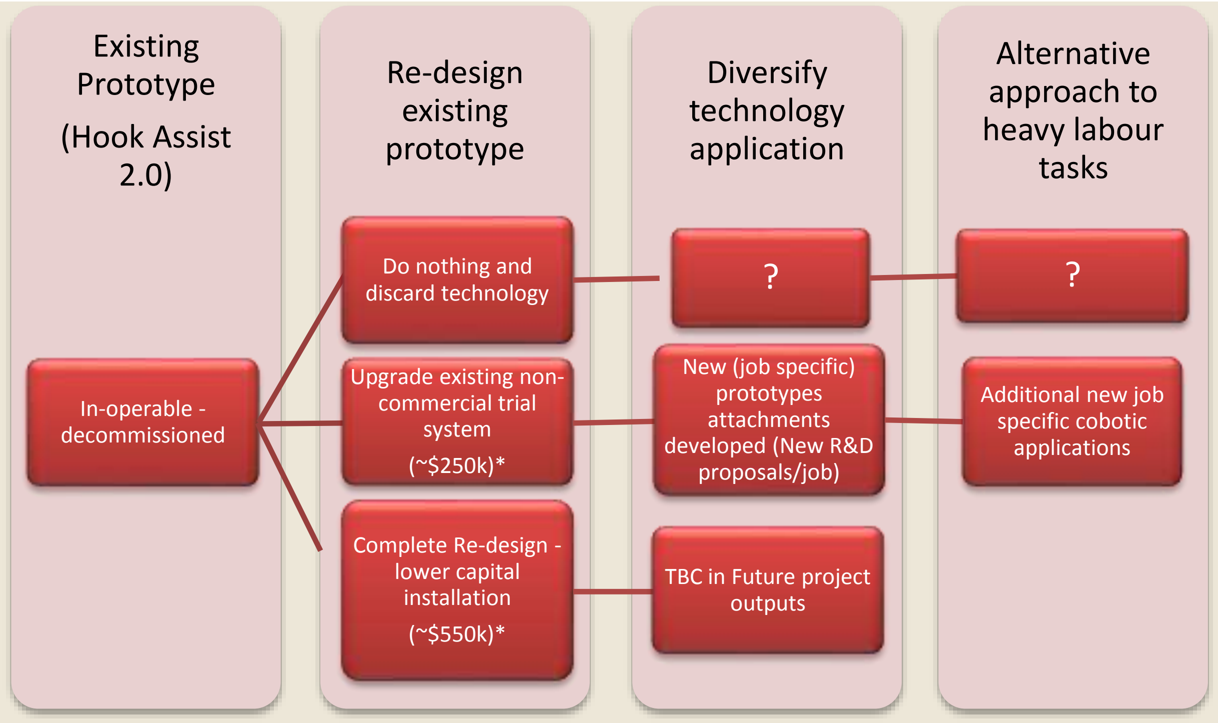

Figure 6: Potential development pathways

**Rough estimate based on preliminary investigation by Scott Technology.*

Working from left to right of Figure 6:

1. The first choice is to discard the technology. But this does not solve the existing industry challenges. Unless an alternative technology has emerged no cheaper alternative options will address the targeted OH&S issues. Moreover, a platform technology to further develop and refine industry solutions will not present itself in the third and fourth generation innovations to the right of the figure.
2. The second option is to spend a minimal amount to upgrade the existing system so it can function in a commercial environment to achieve the original outcomes of 12 months of commercial trials. If this option was progressed further redesign will be required as things like

arm length are already too short. Further R&D would also be required to diversify the application but most likely after a complete redesign between the second and third column.

3. The third option is complete redesign and re-build prior to 12 months of commercial trials. This would address the obvious prototype system limitations like building a longer arm and hook.

Options 3 is likely to require a complete rebuild after commercial trials as there will be other learnings not yet considered such as:

- adaptation to enable multiple end-effectors
- Easier integration at various points along the production line.
- One possibility of improving return on investment is to re-design the system with a lower capital installation cost in mind. Scott Technology would need to investigate potential savings from alternative designs. High level discussions indicate retail capital cost would still be above $100,000 per unit.

Future commercial design considerations

The current focus is on re-design to make the system commercially robust. This will enable Scott's original objectives to test the system commercially for 12 months to explore wider opportunities for adaptation of the technology platform to other jobs.

A number of additional short and medium term design considerations are required around reduction in capital cost but can only be considered after addressing functional limitations.

Value engineering

The system cost under its current design is forecast between $150,000 and $200,000. It is unlikely any plants would consider installing a system at this full cost for any of the tasks discussed in this document. If industry does proceed with development of the technology a process of re-design will be required to reduce the capital cost for commercial systems. A target capital cost would need to be below $100,000 and potentially lower than that. The RTL aitchbone puller costs around $70,000. Although the Hook Assist technology is much more supportive of the operator and easier to use, the tangible benefits of yield will not be that much greater. Based on the mixed adoption rates for RTL with capital cost being a barrier where multiple installations are required, final capital cost appears to be important for the final commercial version of the system.

8 Strategic Considerations

The technology platform was only applied to Hook Assist as an easy way of testing the technology. Capital investment of $150,000 - $200,000 for aitchbone pulling does not deliver a fast enough ROI. This application of the technology is not enough to warrant further R&D support. Boning room staff and supervisors at the trial sites could see a number of applications the concept could be used for but due to its short life in a commercial environment the full potential of the technology has not yet been tested. Given the technology capability is not able to operate in a commercial environment, the challenge is weighing up the value of spending more R&D money to enable commercial trials to further explore the opportunities.

Answering the questions below help determine the value of further investment:

- What other applications is the system most likely to be used for?
- How would these solutions deliver something more than current alternatives?
- What sort of ROI (both direct financial and in-direct benefits) could be delivered? and
- Is this ROI better than alternative and is it likely to encourage adoption?

We considered these questions in collaboration with industry and assessed a range of alternative applications of the technology and likely benefits. We also consider in the following sections what industry considers to be a suitable expectation on ROI when considering this type of technology leap.

The original objective of this technology was to address manual labour challenges faced across the industry. Given the system development is at a cross-road, we considered a number of alternative technology pathways including alternative cobotics as well as full automation This next section includes high level cost-benefit analysis of further hook assist development and in comparison with these alternative cobotics and fully automated paths.

9 Hook Assist Cost Benefit Analysis

Other manual assist solutions are already commercially available for Aitchbone, knuckle and cube roll (RTL, CarneTech, Scott's Loin saw) but there has been limited adoption of these technologies. No fully automated beef boning solutions exist except for an automated Rib Scribing system which is in development but not yet commercial. Comparison of Hook Assist with alternative cobotics and with automated concepts is covered in this section.

A number of business case models have been developed to assess the value opportunity for Hook Assist technology. These models support the strategic comparison with other development pathways in these next 3 sections including:

1. Cost benefit analysis of the Hook Assist system for each of a range of boning room tasks compared with manual operation.
2. Comparison of Hook Assist to competing manual assist technologies.
3. Comparison of cobotics to fully automated solution concepts.

Cobotic Business Case

A range of benefits are expected from an effective IAD. These include increased yield, OH&S savings, improvement in throughput and labour savings (refer to Table 5).

Each boning task requires different degrees of force and different technique so the impact of an IAD on yield and throughput improvement also varies across jobs. More difficult tasks have greater potential value of IAD intervention. Table 5 identifies the hardest tasks for the operator and the hardest to automate.

Yield benefits

Previous detailed yield analysis conducted across 6 plants for aitch bone removal and hind quarter boning using RTL systems (Greenleaf) have underpinned the yield benefit calculation in this Table 5.

Table 5: Yield Benefits

Yield Benefits									
Task	Strength level*	Highly sensory	System Installed	Opportunity (plant size)	Automated system	Increased yield %	Throughput increase (%)	Yield Benefit	Source
Rib Scribing	M	Moderate	Yes	Medium	Yes	1.5%	0.5%	$ 0.21	
Forequarter									
Short Ribs	L				Partial			$ -	
Shirt	L							$ -	
Point Brisket	L				Partial			$ -	
Navel Brisket	H	Yes	Yes	All	Partial	0.5%	0.5%	$ 0.02	P.MDC.0028
Clod	H	Yes	Yes	All	No	0.0%	0.5%	$ -	
Ribs	L				Partial			$ -	
Cube Roll	H	Yes	Yes	All	No	0.1%	0.5%	$ 0.10	Striploin
Chuck Roll	L							$ -	
Shins	L							$ -	
Trim	L							$ -	
Hindquarter									
Flank	L							$ -	
Tender	L							$ -	
Loin	L				Partial			$ -	
Rump	L				Partial			$ -	
Aitchbone	H	Yes	Yes	All	No	1.19%	1.0%	$ 0.85	P.PSH.0335
Inside	L							$ -	
Knuckle	H	Yes	Yes	All	No	0.10%	1.0%	$ 0.04	P.PSH.0335
Eye	L							$ -	
Flat	L							$ -	
Shank	L							$ -	
	Number of systems per line		6			Total	4%	$ 1.02	

* Scott Technology (2010)

These benefits have been extrapolated to other tasks during site visits in consultation with boning managers and included in Figure 7. A wide range in yield benefit is expected between tasks with some having limited yield improvement. This creates a wide range in benefit and financial payback (Figure 7) when applying the technology to different tasks. Aitchbone removal provides the highest value benefit per carcase at $0.85/carcase.

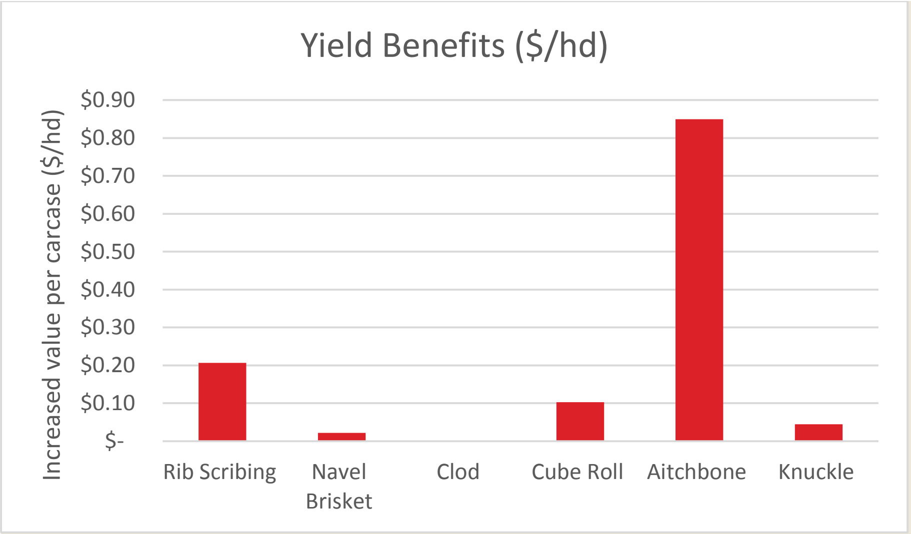

Figure 7: Yield Benefits ($/hd)

Yield improvement is the main direct benefit of Hook Assist that provides a return on investment. But yield benefit is not as significant for some tasks. Plants naturally want to assess equipment merits on a task by task basis. Plants would find it hard investing in a unit as part of a system when its job specific benefits are only small but there could be other throughput benefits by considering installation of a number of systems as a package.

Throughput benefits

Installation of a single unit for a single boning task is unlikely to deliver throughput benefits but installation of multiple systems for all the harder jobs in Table 5 may lift throughput. Although boning manning structure is balanced as much as possible there is still surge capacity in some jobs. As the harder jobs become easier, addition of slicers or packers can allow an increase in productivity of the whole room (kilograms packed per FTE). Each plants configuration, the type of cattle and cutting specifications will impact on the potential benefit.

Discussion with plants indicates this throughput improvement is possible but requires a holistic approach to the difficult boning jobs. This integrated approach to install multiple units to increase production per FTE would require some adjustment to most plants boning process to address other bottle necks (different for each plant).

The benefits of installing multiple systems where yield is not significant but a throughput benefit is achieved is summarised in Table 5 in the third last column. An increase in throughput is assumed based on multiple installations of Hook Assist so all the harder physical tasks becoming easier. An increase in processing speed of 4% or 1-2 carcass per hour is estimated in the modelled example. This transformation would require a change in thinking that focuses more on room improvement than on specific tools for specific jobs.

Labour saving

Hook Assist enables both small and larger plants to manipulate process flow in the room in some cases to make the boning process easier. Depending on plant boning configuration Hook Assist has the potential to save labour. The operations manager at one plant worked with the boning supervisors and estimated that Hook Assist will enable the aitchbone to be removed earlier in the process which then makes the removal of the rump easier reducing the number of cuts required further down the chain resulting in saving of one labour unit. These savings are reflected in the cost benefit analysis in the yield benefit column of Table 5.

Alternative primal breakdown processes may be possible but would require a commercially operational system to trial a range of options.

Technique Benefits

Some companies have well developed hands-on management and daily reporting of yield and have opted for improvements in yield through enhanced staff management. Although this will reduce sloppy workmanship to an extent it will not address technique differences. Scott's RTL system reduced fatigue, and enabled boning technique improvements by mixing operator sensing with system improvements to find new value that was not possibly without assisting operators. Technique improvements are a component of the savings reported under yield benefits in Table 7.

Hook Assist and Competing Cobotic Systems

A number of other manual assist devices have been commercialised for removal of Aitchbones. This section compares the prototype Hook Assist technology with Proman and RTL systems and considers motivations for further development of the Hook Assist platform as an alternative technology.

Extensive yield trials were conducted at commercial speeds for the Proman and RTL systems in the right side of Table 6. Hook Assist performance (Left side of Table) was adapted from RTL yield improvements in conjunction with operators who trailed the Hook Assist system alongside the RTL system during prototype testing. The Hook Assist figures assume the technology is further developed to become commercially robust. The improvement in yield reflects a higher level of operator control and full freedom of movement.

Table 6: Competing system summary performance measures

SUMMARY PERFORMANCE MEASURES						
	Hook Assist		Proman Aitch Bone Puller		RTL Aitch Bone Puller	
Hd / annum	251,712		251,712		251,712	
	From	To	From	To	From	To
Capital cost (pmt option, upfront)	$150,000		$61,000		$60,000	
Gross return Per head	$3.58	$3.58	$2.33	$2.33	$2.67	$2.67
Total costs Per head	$0.14		$0.29		$0.11	
Net Benefit Per head	$3.44	$3.44	$2.04	$2.04	$2.56	$2.56
Annual Net Benefit for the plant	$ 866,316	$ 866,316	$ 513,473	$ 513,473	$ 643,874	$ 643,874
Annual Net Benefit for the ex cap	$ 881,316	$ 881,316	$ 519,573	$ 519,573	$ 649,874	$ 649,874
Pay back (years)	0.17	0.17	0.12	0.12	0.09	0.09
Net Present Value of investment	$6,183,162	$6,183,162	$4,057,125	$4,057,125	$4,665,129	$4,665,129

The first point to note is that payback for all three systems is very good at less than 6 months payback. Secondly, the capital cost of the Hook Assist system is twice as expensive as the other options. There is no difference in chain speeds for each of the systems summarised in Table 7 assuming issues addressed with the Hook Assist prototype are overcome.

Table 7: Performance benefits for competing cobotic aitchbone systems

TOTAL BENEFIT							
		Hook Assist		Proman Aitch bone puller		RTL Aitch Bone puller	
Loss summary		$/hd From	$/hd To	$/hd From	$/hd To	$/hd From	$/hd To
1. Yield Benefit		$3.10	$3.10	$2.13	$2.13	$2.33	$2.33
2. Throughput cost		$0.18	$0.18	$0.00	$0.00	$0.15	$0.15
3. OH&S costs		$0.19	$0.19	$0.78	$0.78	$0.78	$0.78
4. Labour costs		-$0.11	-$0.11	$0.01	$0.01	$0.01	$0.01
Equipment costs	**Maintenanc**	$0.00	$0.00	-$0.02	-$0.02	-$0.07	-$0.07
	Operation	-$0.07	-$0.07	-$0.24	-$0.24	-$0.02	-$0.02
	Risk of	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	$ Benefit per head	$3.30	$3.30	$2.66	$2.66	$3.18	$3.18
$ Annual Benefit overall plant		$831,091	$831,091	$669,546	$669,546	$799,847	$799,847

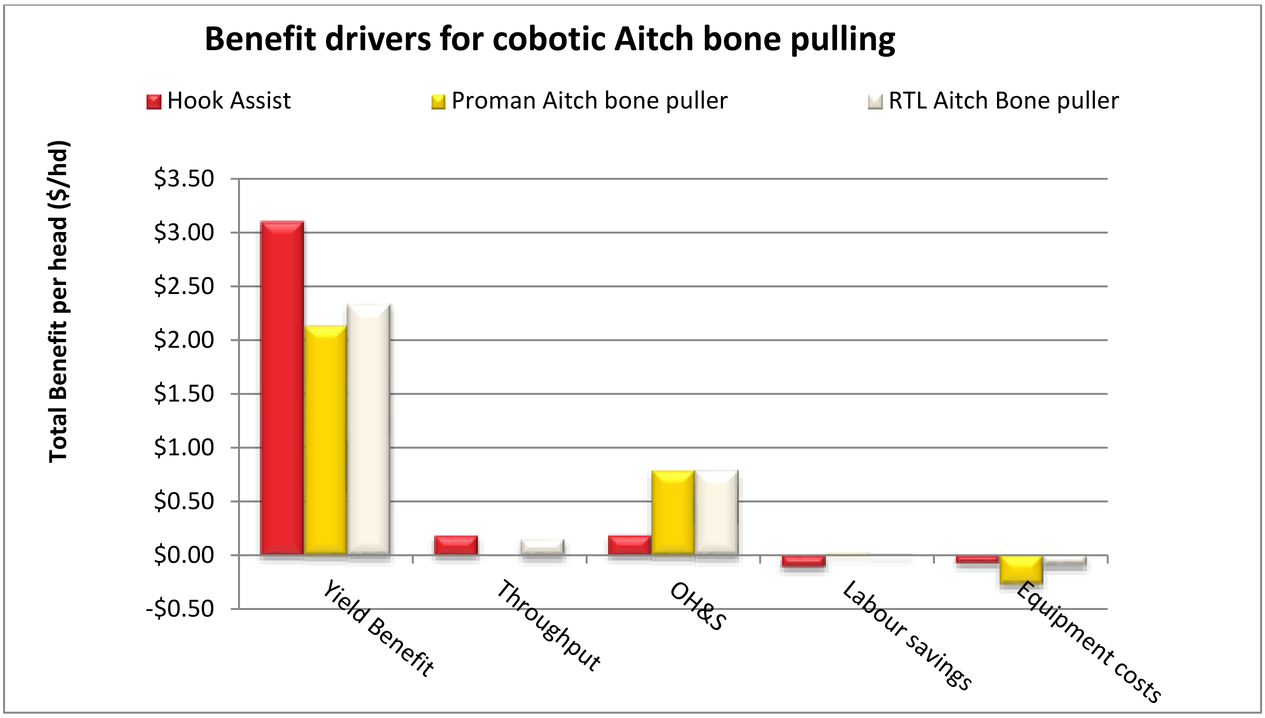

Figure 8: Benefit drivers for cobotic Aitch Bone pulling

Historical adoption barriers

The Tender proposal document prepared by Scott Technology in 2010 referenced ROI similar to the RTL system indicating paybacks of between 5 and 35 months. The documents also referred to a commercialisation strategy following that of the RTL aitchbone and knuckle puller. Since then the level of adoption of the RTL puller has been poor although industry continue to applaud the benefit of the system. Even with a payback of 1 month, there has been limited adoption of the RTL system although effort has been put into plant demonstrations. Given this slow adoption the ROI would not indicate that the Hook Assist has viability as a finished device. This begs a number of questions:

1. If payback is so good why are most companies not investing in existing RTL technology?
2. Some companies have invested in RTL systems and operators cannot do without them. But other companies have installed RTL systems but operators don't use them. Why is there such variation in acceptance?
3. With low adoption to date, why would companies invest in a Hook Assist system at twice the capital cost? Does Hook Assist address any of the current barriers to adoption faced by the current systems?

Possible barriers to cobotic adoption to date

Some of the negative aspects of existing technologies listed below could contribute to the poor adoption rates of these technologies:

- Proman system reported to tear rumps and knuckles due to excessive force and limited control.
- RTL was always intended as a Mark 1 system to be further developed to address limitations such as:
  - Improved power control which is difficult for some operators
  - Improve natural human movement which the current system limits

Operators pride themselves in their agility, dexterity and workmanship. If a machine interferes with these human capabilities a lot of the machines other benefits are masked or lost. It is important to note that although the yield benefits are similar across these systems, trial operators believe Hook Assist could be 60% more functional and useable. Although increased yield benefits could result, the most exciting outcome is enhancement of operator skill without limiting human movement as is the case with current cobotics technologies.

Strategic considerations for further R&D

The original hope for Hook Assist was to support boners in doing their highly skilled job more effective than other commercial solutions, reducing the negative impact on the people. It is clear the current prototype is not yet a suitable commercial tool for a job. The key questions are:

1. **Does the technology's' core components provide the capabilities required to warrant further industry R&D investment (achieve the original industry objective)?**

   The core components (with redesign) do provide these capabilities.

2. **If developed, is industry likely to adopt?**

This second question is less straight forward. As discussed already industry actions to date may provide some deeper learnings:

- The RTL Aitchbone puller delivers returns of around 6 months but there has been limited adoption (see other section in report). Site visit reviews indicated that:
  - ROI is only important if cheaper alternatives are not available.
  - In some cases RTL systems, accepted and proven to work at one site were replaced by cheaper, less effective "in-house" developed systems.
  - Capital cost and ROI are not the only drivers.
- Staff engagement is important for these jobs. Getting functionality and interaction right could improve engagement. Where operators chose not to use the RTL Cobotics:
  - Staff were not engaged in a process of change management, or
  - The system install on the line hindered range of human movement.

The impact of human engagement is expanded more in section 10 "Additional Considerations".

Matching industry expectations to short and longer term R&D innovations

Industry places high demands on capability and commercial reliability. These points must be considered carefully when discussing further strategic development of Hook Assist technology. It is important not to create false expectation of having a fully commercial system after the next round of developments if they do go ahead. There will need to be a number of iterations and refinements of the technology addressing the re-engineering points raised so far.

Industry Solution Still Required

The continued development of a manual assist technology platform as a strategic initiative to address longer term labour challenges is not a straight forward consideration given the further investment required and development risk. Industry still requires solutions to the labour stresses from difficult boning tasks. This next section considers full automation as a completely different alternative.

Automation Compared to Cobotics

There are some views in industry that development of the Hook Assist technology has been unsuccessful and that cobotics presents less opportunity than fully automated approaches (complete removal of operator). This section considers the fully automated approach as an alternative to manual assist and weighs up the short and long term trade-offs between each approach.

A number of fully automated cutting systems have been successfully commissioned in the lamb industry. Beef processing is very different to lamb processing and direct adaptation to beef is not possible. Some preliminary investigation has been done to develop beef automation although none have been commercialised and still present many new development challenges and risks. So discarding the manual assist approach in preference to full automation will not reduce risk or future R&D investment required.

Fully automated beef boning solutions have been scoped by technology providers for single-tasks (Beef scribing) as well as multiple-tasks. An ex-ante CBA model (estimate of concept solutions) has been developed to compare these systems as follows:

1. Cobotics "Scribe Assist" (Beef scribing application of the hook assist platform)
2. MAR x-ray driven automatic beef scriber (Figure 9)
3. Scott Technology x-ray driven multi station concept solution proposes to automate beef scribing, plus perform 12 total cuts to remove 6 bandsaw jobs from the boning room (Figure 10).

Figure 9: MAR Beef Scribing prototype

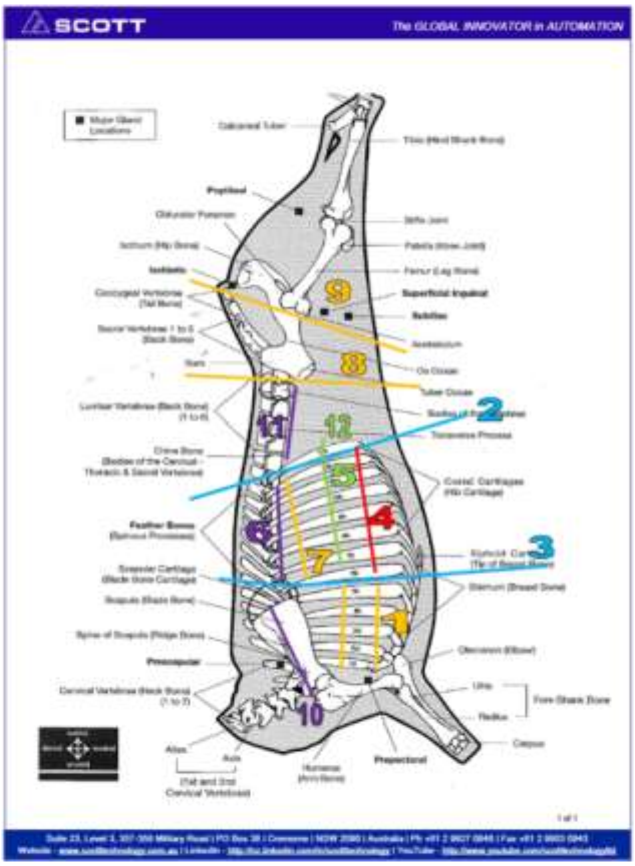

Figure 10: Scott technology integrated system concept for fully automated beef cutting

Financial Drivers

Financial drivers are summarised in Table 8 with the most obvious point being the significant capital investment as solutions become more automated and integrated moving from left to right in the table.

- Production volumes and processing rates are the same for each scenario.
- The Robotic Beef Scribing (MAR) system in the second column does the same tasks as the Cobotic Scribe assist in the first column. The MAR system is 10 times the capital investment but delivers $1.75/head of benefit compared with $0.33/head due to additional yield improvements and labour saving. Interestingly ROI is similar for each system.
- The Scott's system is an ex-ante concept underpinned by detailed production measurements.
- Labour savings increase with more automation and increases in yield over manual variation offset the higher capital cost to varying degrees.
- After straight cuts have been made automatically, difficult manual chain boning tasks still exist to remove the cuts by manual knife and hook.

Table 8: Summary Performance Measures – Automation compared to Cobotics

SUMMARY PERFORMANCE MEASURES						
	Scribe Assist		Robotic Beef Scribing (MAR)		X-Ray Beef (Scott Technology)	
Hd / annum	251,712		251,712		251,712	
Production increase with equipment	0.00%		4.17%		9.89%	
	From	To	From	To	From	To
Capital cost (pmt option, upfront)	$150,000		$1,500,000		$4,712,770	
Gross return Per head	$0.39	$0.39	$1.81	$1.81	$12.57	$17.00
Total costs Per head	$0.13		$0.66		$2.21	
Net Benefit Per head	$0.26	$0.26	$1.15	$1.15	$10.36	$14.80
Annual Net Benefit for the plant	$ 65,010	$ 65,010	$ 290,108	$ 290,108	$ 2,607,927	$ 3,724,340
Annual Net Benefit for the ex cap	$ 80,010	$ 80,010	$ 440,108	$ 440,108	$ 3,079,204	$ 4,195,617
Pay back (years)	1.87	1.87	3.41	3.41	1.53	1.12
Net Present Value of investment	$533,094	$533,094	$1,698,113	$1,698,113	$17,509,483	$25,350,702

The more automated systems come at a greater capital investment and require higher processing volumes to provide an attractive payback period (refer to Table **9**). However they are not going to be able to automate all tasks that the Hook Assist could be utilised for. The Scott's fully integrated system for example, does not replace all difficult boning jobs. The total solution still proposes to use RTL Aitch bone pullers and manual assist loin de-boners as part of its integrated solution.

Table 9: **Total benefit summary**

TOTAL BENEFIT							
		Scribe Assist		Robotic Beef Scribing (MAR)		X-Ray Beef (Scott Technology)	
Benefits summary		$/hd From	$/hd To	$/hd From	$/hd To	$/hd From	$/hd To
1.Yield Benefit		$0.21	$0.21	$1.29	$1.29	$9.94	$14.37
2. Throughput Benefit **		$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
3. OH&S Benefit		$0.18	$0.18	$0.02	$0.02	$0.36	$0.36
4. Labour Benefit		$0.00	$0.00	$0.46	$0.46	$2.27	$2.27
Equipment costs	**Maintenanc**	$0.00	$0.00	$0.00	$0.00	-$0.24	-$0.24
	Operation	-$0.06	-$0.06	-$0.02	-$0.02	-$0.01	-$0.01
	Risk of	$0.00	$0.00	$0.00	$0.00	-$0.09	-$0.09
	$ Benefit per head	**$0.33**	**$0.33**	**$1.75**	**$1.75**	**$12.23**	**$16.67**
$ Annual Benefit overall plant		**$82,054**	**$82,054**	**$439,290**	**$439,290**	**$3,079,204**	**$4,195,617**

The process improvement benefits including increased throughput in the left of Figure 11 are smaller in magnitude than product value (yield) although still significant. Full automation removes operator error by delivering greater yield (product value) benefits in the right of the figure. Accuracy of the cuts is about optimising the placement of the cuts (Figure 12 and Figure 18) to maximise weight on the highest value side of the cutting line. Fixed points can be identified on the skeleton to reference these cuts.

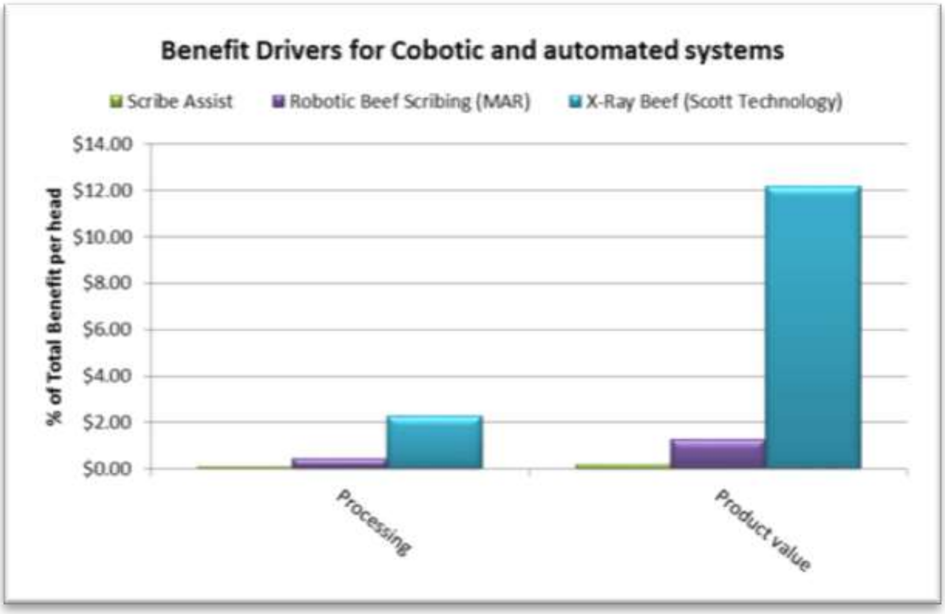

Figure 11: Benefit Drivers for Cobotic and automated systems

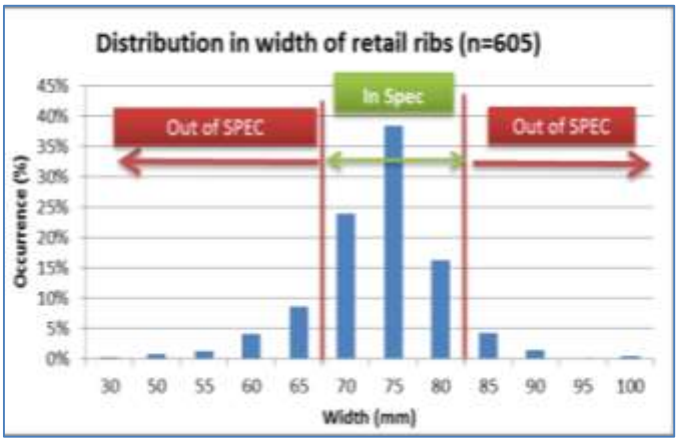

Figure 12: Distribution of rib widths for manual scribing

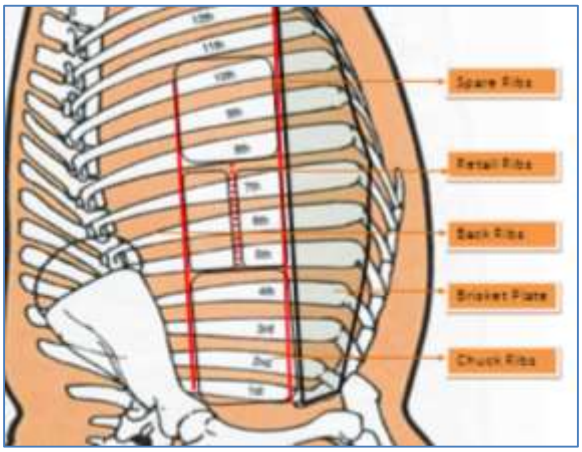

Figure 13: Retail rib scribing lines at one site study

Capability comparisons between cobotics and automation

Boning yield improvements arising from cobotics involve separation of meat from bone and accuracy of seaming between muscle groups to remove foreign muscles without knife scores. Human vision and sensing required to complete these jobs is too difficult to automate at this point.

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. So full automation of these tasks is still at least 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 reference from NCMC). So the need for these 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 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, 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. 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.

Comparison has also been made in Table 10 between fully automated and operator assisted development pathways and differences between beef and lamb that will pose different automation challenges for beef.

Table 10: Development trade-offs between manual assist and fully automated boning technologies

Trade Off	Manual assist (Beef)	Automated (Beef)	Automated (Lamb)
Capital cost	Relatively small with limited interruption of existing layout	Significant cost. Redesign of room layout required.	Significant cost. Redesign of room layout required.
Development risk	Significant but simpler integration of technologies than full automation.	Largely unproven risks around visioning of large carcase mass. Carcase manipulation also difficult.	Much of the risk has been eliminated for straight bandsaw cuts but has taken +10 years of development and confidence building in industry. Have not been able to develop dynamic knife cutting for removing primals from bones or primals from primals.
Labour solutions	Hook Assist is almost suitable from a technical capability.	Nothing has been developed yet.	Eliminates a number of difficult and dangerous bandsaw jobs.
Suits plant size	All plant sizes.	Likely to favour large plants only.	Suits a range of plant sizes but better return for larger sites.
Visioning	Relies on Human sensing.	Nothing to replace human sensing	Nothing to replace human sensing
Application to all jobs	Versatile to apply to most jobs subject to benefits and return on investment.	Nothing has been developed apart from scribing (straight band saw cuts).	Only developed for straight band saw cut jobs.

A number of differences between cobotics and current automation capabilities result in minimal overlap in the application of both technology approaches to the beef industry as summarised in Figure 14.

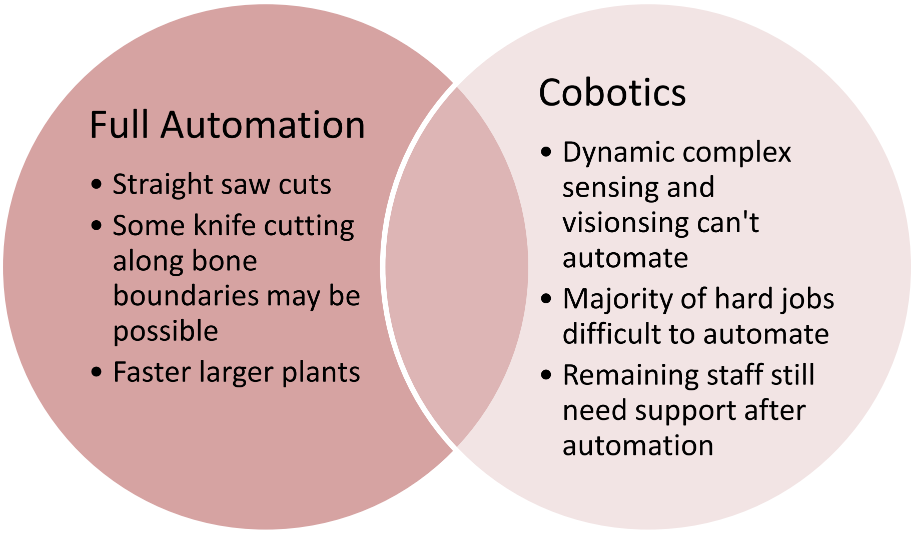

Figure 14: Separate applications of cobotics and automation with minimal overlap

Comparative Development Risk

The Kinea design process has had considerable investment and is not yet commercial. Given the recent successes with full automation of parts of lamb carcase breakdown one could be mistaken for thinking full automation is an easier development path with greater chance of success. This is not true.

Full automation requires integration of a more diverse range of technologies than manual assist. With this comes increased risk. The following examples demonstrate the challenges and progressive iterative development required:

- MAR scribe assist developments failed on the first attempts due to poor visioning to detect ribs.
- Lamb boning automation success has been underpinned by x-ray visioning which has also required a number of attempts.
- Scott's LEAP III primal cutting technology was first installed at Colac 10 years ago. The system was moth-balled and did not have adoption by the plant due to technical and engineering failings. Scott's and industry found other ways to continue development to the point that fully automated MARK III versions of the system have been installed successfully in 2 or 3 plants in Australia in the past two years. Another plant is about to install the Mark III system making it the fourth installation. Cobotics development also takes time to be successful.
- No systems have successfully commercialised knife boning and seaming which requires rapidly adaptive visioning and sensing of a human.

Scott's commercialisation proposal demonstrated an awareness of the need for progressive development and based on the industry achievements in other automation areas further refinement should not be a surprise. The question is whether further investment will deliver an incremental increase large enough to warrant the further investment. This would depend on achieving the commercial outcomes agreed previously by stakeholders.

Short and medium term industry impact

Assuming a Kinea design cobotics system could operate at commercial lines speeds effectively in the harsh work environment the system would not deliver a return any better than 3 years on a 2 shift plant considering yield and OH&S savings alone. Given an RTL system delivers returns of around 6 months payback for the same application and there has been limited adoption of that technology it is unlikely there would be broad adoption of the technology in its current state based purely on return on investment.

However the system reduces OH&S risks and those costs will continue to increase. This benefit will continue to increase in magnitude over time and has been modelled in this next section. Increased staff engagement has been demonstrated at a preliminary level already and will enhance IAD adoption beyond existing cobotics technologies. Benefits arising from increased staff engagement are discussed further in section 0.

Labour cost implications over time

The OH&S and labour issues that prompted the investigation in the first place are still unresolved. If this type of approach is not progressed due to ROI alone, another solution approach will need to be developed and probably with similar ROI’s. Although ROI is not the only driver of adoption, this section considers the future costs to industry and resultant benefits.

Given the technology development path was intended to address longer term industry labour and OH&S challenges, longer term impacts need to be considered beyond a short term “technology for a task”. CBA modelling work considered the impact of these costs into the future to see whether future conditions may deliver a more favourable return on investment. Potential reduction in capital cost due to design improvements and technology advancements were also considered. What may be uneconomical now could become a viable investment in the future if costs continue to increase without an alternative means of addressing these issues.

A range of labour cost trends have been sourced and extrapolated forward over the next 20 years to model future state labour costs. The model in the next section extrapolates out these costs and benefits in 5 year increments. Costs of electricity and technology cost increases have also been allowed for and offset these benefits to a degree.

The cost of labour including direct wages and overheads is forecast from ABS house hold income statistics to increase from $56,000 to almost double that at $105,000 by 2025 as presented in Figure 15 (ABS). The throughput benefit of the Hook Assist platform will be a greater dollar per head saving in the future as a result of increased labour costs and has been reflected in the bottom row of the Table.

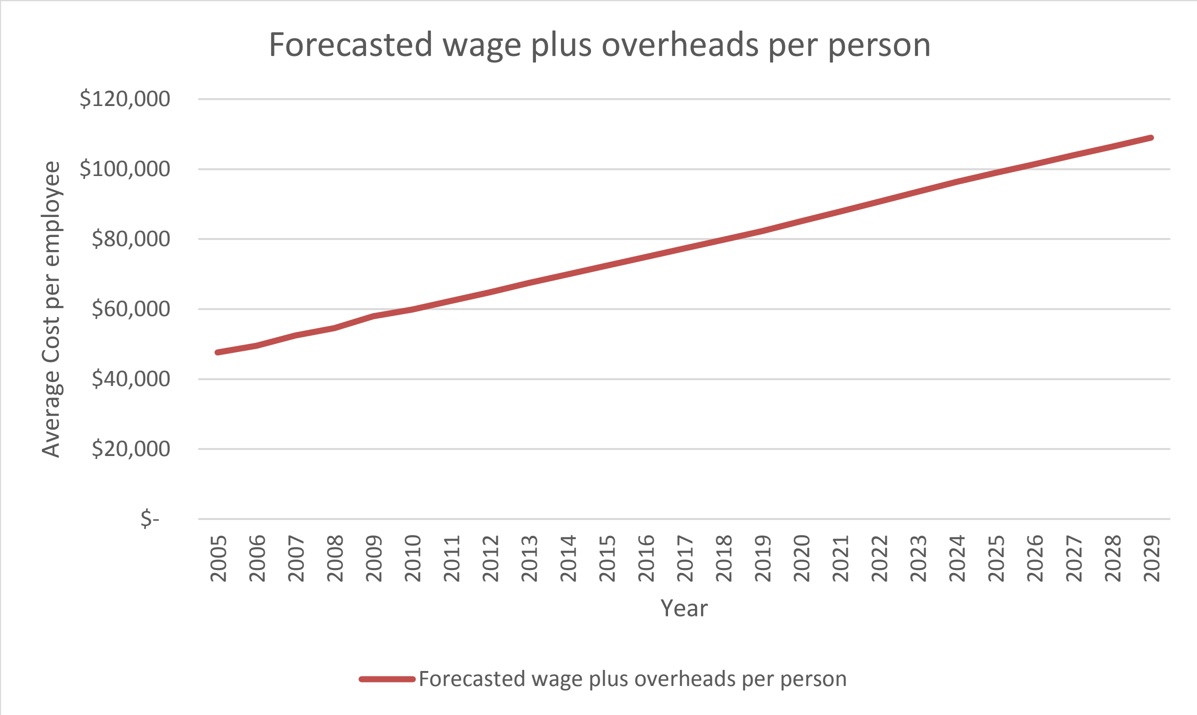

Figure 15: Forecasted wage plus overheads per person

The benefits of throughput increases and reduction in labour positions discussed earlier in sections 6.1.2 and 6.1.3 will become greater as labour costs increase over time and are summarised here in Figure 16.

Table 11: Labour saving impact over time

Labour requirements					
	Manual	2016	2019	2024	2029
Average labour costs	$ 53,657	$ 53,657	$ 59,142	$ 68,284	$ 77,427
Average labour costs with WW loading	$ 72,437	$ 72,437	$ 79,842	$ 93,550	$ 106,461
Labour requirements per boning room line					
Total FTE's required	29	29	29	29	29
Boning room cost per year (without labour savings)	$ 2,100,666	$ 2,100,666	$ 2,315,416	$ 2,712,937	$ 3,087,383
Cost per hd processed	$ 19.19	$ 18.46	$ 20.34	$ 23.84	$ 27.13
Labour requirements after Hook Assist Installation					
Total FTE's required	29	28	28	28	28
Boning room cost per year (with labour savings)	$ 2,100,666	$ 2,028,230	$ 2,235,574	$ 2,619,388	$ 2,980,921
Cost per hd processed	$ 19.19	$ 17.82	$ 19.64	$ 23.01	$ 26.19
Opportunity					
Benefit per year	$ -	$ 72,437	$ 79,842	$ 93,550	$ 106,461
Benefit per hd	$ -	$ 1	$ 1	$ 1	$ 1
Opportunity when compared to manual	$ 19.19	$ 18.56	$ 18.49	$ 18.37	$ 18.26
Productivity					
Annual hours per FTE	1,824	1,824	1,824	1,824	1,824
Total Hd / FTE / Hr	2.07	2.23	2.23	2.23	2.23

Table 12: Throughput processing costs & benefits

Throughput processing costs and benefits					
	Manual	2016	2019	2024	2029
Number of Employees	29	29	29	29	29
Boning room cost per day	$ 8,156	$ 8,753	$ 9,648	$ 11,304	$ 12,864
Number of hd processed per day	456	474	474	474	474
Boning room cost/hd processed	$ 17.89	$ 19.19	$ 21.16	$ 24.79	$ 28.21
Benefit/hd w- Cobotic	$ -	$ 0.74	$ 0.81	$ 0.95	$ 1.09

Table 12 breaks down throughput benefit demonstrating the largest benefit would come from the hardest manual jobs and the impact of rising labour costs on each task over time.

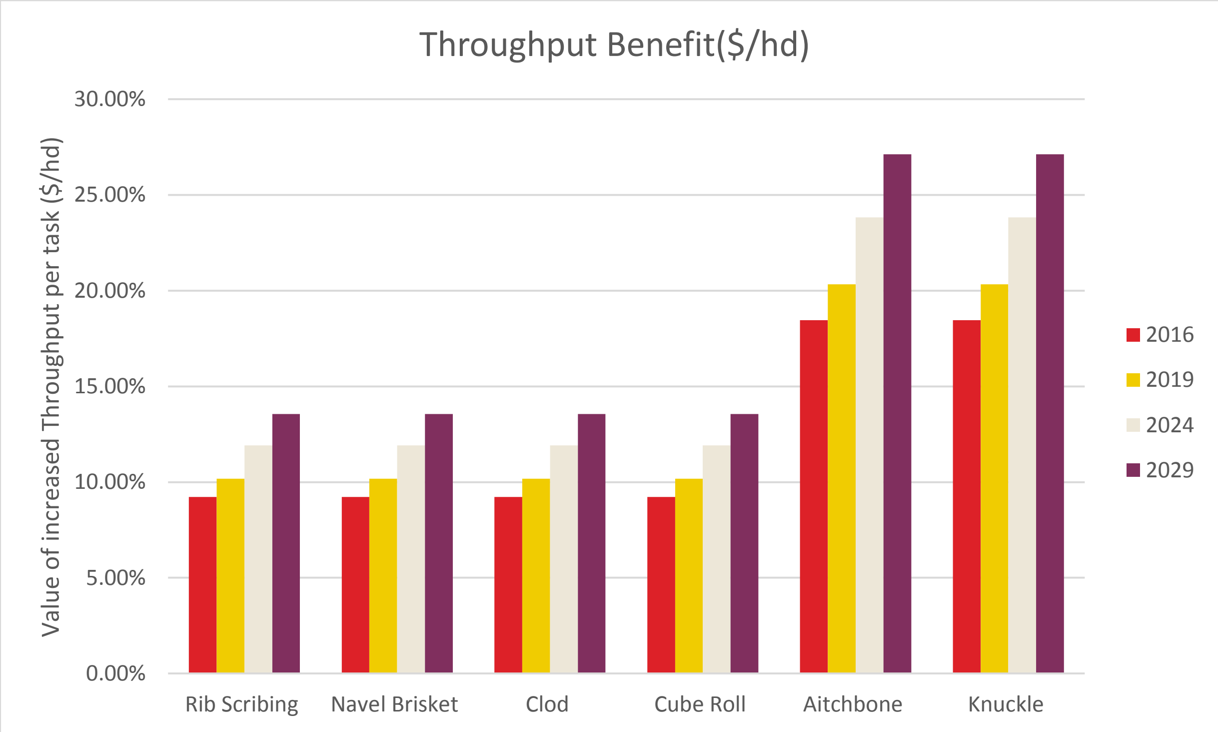

Figure 16: Throughput Benefit ($/hd)

The size of plant used to model the impact of Hook Assist installations is summarised in Table 13.

Table 13: Operation speeds

Operation speeds					
	Manual	2016	2019	2024	2029
Carcases / min	1.00	1.04	1.04	1.04	1.04
Carcases /	60	62	62	62	62
Carcases / day	456	474	474	474	474
Annual days	240	240	240	240	240
Annual # of hd	109,440	113,818	113,818	113,818	113,818

OH&S claims over time

Industry workers compensation data (COMPENDIUM OF WORKERS' COMPENSATION STATISTICS AUSTRALIA) shows in Figure 17 that whilst the number of OHS claims is reducing, the cost per claim is increasing at a faster rate. If current trends continue the net impact is an increase in OH&S costs over time forecasted in Table 14. The benefit from Hook Assist to minimise these claims increases over time in the table.

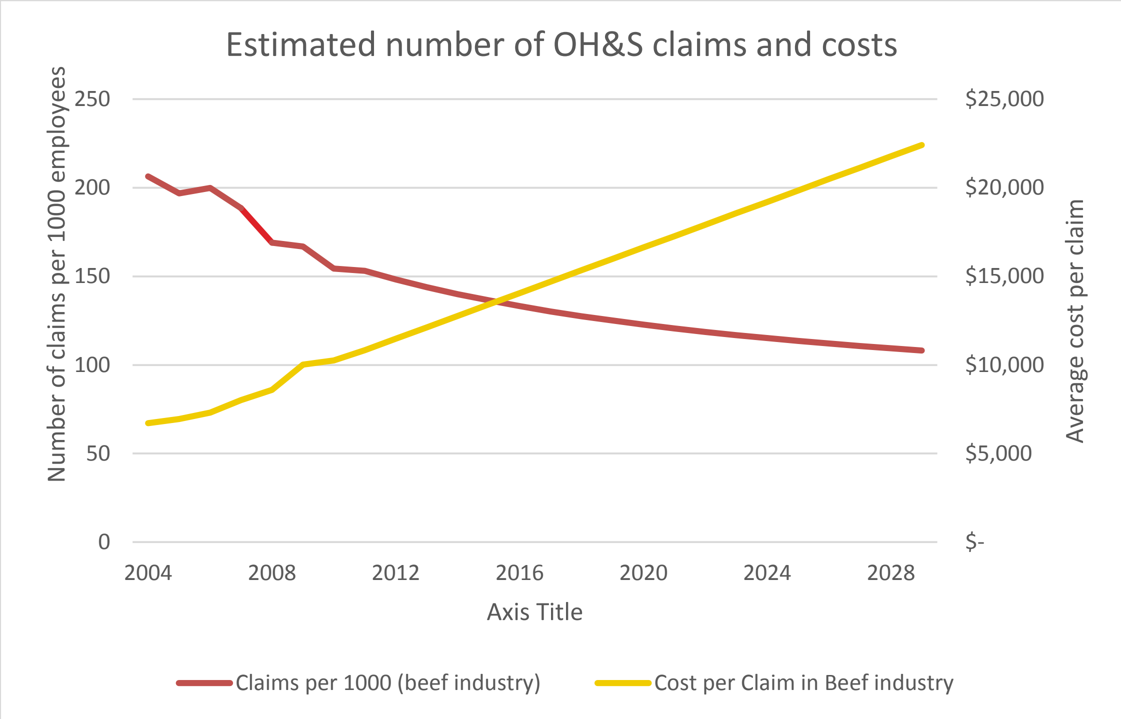

Figure 17: Estimated number of OH&S claims and costs

Table 14: OH&S Processing costs and benefits

OH & S processing costs and benefits					
	Manual	2016	2019	2024	2029
OH & S cost/hd processed	$7.45	$7.80	$8.33	$9.22	$10.10
Benefit/hd w- Cobotic	$0.00	$1.13	$1.21	$1.33	$1.46
New OH & S cost/hd w- Cobotic	$7.45	$6.32	$6.24	$6.11	$5.98

Assumptions

A number of assumptions have been assembled on which to base the calculations and are summarised here and in Table 15:

Operational benefits are based on installation of 6 systems in a boning line with 1 system for each of 6 different boning tasks.

- Throughput increases are assumed at 4% above baseline when 6 systems are installed. The throughput opportunity will decrease if less systems are installed.
- Salaries and forecast increases are based on manufacturing industry figures (ABS) with the meat industry average salary at 83% of this average.
- OH&S costs are based on red-meat industry costs relative to the food manufacturing industry reference.
- Beef industry OH&S costs are 18% higher than other food manufacturing.
- Beef industry has 3 times more claims than other food manufacturing.

- Percentage of tasks completed by Hook A is the percentage of tasks that it can be employed in, in the boning room.
- Last line – percentage of reduction in OH&S claims from positions that can utilise the Hook Assist.
- The proportion of OH&S claims caused by musculoskeletal injuries was provided by one processor as 65% of total claims. Of these claims, 21% came from jobs that would be potential applications for hook assist. Data was not available on claims for these positions being either knife hand or hook hand. An estimate was used assuming injuries in these jobs as a result of hook assist would reduce by 70%.

Table 15: Assumptions

Assumptions	
Operational information	
Number of systems (change to systems per line)	6
Average Carcase Weight	265
Number of lines processing beef	1
Number of cattle processed in Australia per year	8,360,000
Throughput	
Throughput increase - 6 installations	4%
Labour Savings	
Current average salary	$50,000
Average salary ratio	83%
OH & S costs	
Wages costs for average sized plant	$60,000,000
Chance of injury (beef industry)	14%
Premiums percentage	5.5%
Musculoskeletal portion of injuries	65%
Staffing numbers	1,200
Values used for	1,000
Muscular skeletal injuries cost	$ 2,145,000
Cost per 1000 injuries	$ 1,787,500
Number of OH & S claims in Manufacturing during 2013 (per 1000 employed)	45
Beef industry ratio of costs	1.18
Beef industry claims ratio	3.08
Number of hd per year	288,000
Number of staff	1,200
Head processed per 1000 employees	240,000
Percentage of tasks to be completed by Hook Assist	21%
Reduction of Musculoskeletal in positions used by Hook Assist	70%
Operational costs	
Capital cost per systems	$ 150,000
Kilowatts of the HookAssist	1
Maintenance costs per system	$ 14,802

Benefit drivers

A high level summary of the ex-ante financial performance for installation of 6 systems on a boning room chain (for the tasks identified earlier in Table 5) is summarised in Table 16 and Table 17.

Table 16: Summary Performance Measures

SUMMARY PERFORMANCE MEASURES				
	2016	2019	2024	2029
Hd / annum	113,818	113,818	113,818	113,818
Production increase with equipment	7.71%	7.71%	7.71%	7.71%
Number of systems per chain	6	6	6	6
	Avg.	Avg.	Avg.	Avg.
Capital cost (pmt option, upfront)	$900,000	$900,000	$900,000	$900,000
Gross return Per head	$3.52	$3.74	$4.13	$4.50
Total costs Per head	$1.20	$1.20	$1.20	$1.21
Net Benefit Per head	$2.33	$2.54	$2.92	$3.29
Annual Net Benefit for the plant	$ 264,749	$ 289,159	$ 332,793	$ 374,708
Annual Net Benefit for the ex cap	$ 354,749	$ 379,159	$ 422,793	$ 464,708
Pay back (years)	2.54	2.37	2.13	1.94
Net Present Value of investment	$1,916,247	$2,090,042	$2,400,418	$2,698,723

Yield improvements create the greatest value but vary in magnitude between tasks with the most difficult jobs delivering the greatest potential opportunity as discussed earlier.

Table 17: Total benefit summary to plant

TOTAL BENEFIT					
		2016	2019	2024	2029
Benefit summary		$/hd From	$/hd From	$/hd From	$/hd From
1. Yield Benefits		$1.02	$1.02	$1.02	$1.02
2. OH & S Benefit		$1.13	$1.21	$1.33	$1.46
3. Throughput Benefit		$0.74	$0.81	$0.95	$1.09
4. Labour Savings		$0.64	$0.70	$0.82	$0.94
Equipment costs	**Maintenance**	-$0.78	-$0.78	-$0.78	-$0.78
	Operation	-$0.03	-$0.04	-$0.05	-$0.06
	Risk of failure	$0.00	$0.00	$0.00	$0.00
	$ Benefit per head	**$2.71**	**$2.92**	**$3.30**	**$3.66**
$ Annual Benefit overall plant		**$308,527**	**$332,603**	**$375,680**	**$417,038**

Total benefit is currently $308,527 however it is estimated to increase to $417,038 over the next 15 years due to increasing cost of labour and cost per OH&S claim. Note this is only for a small to medium boning room chain processing 30 carcases a minute.

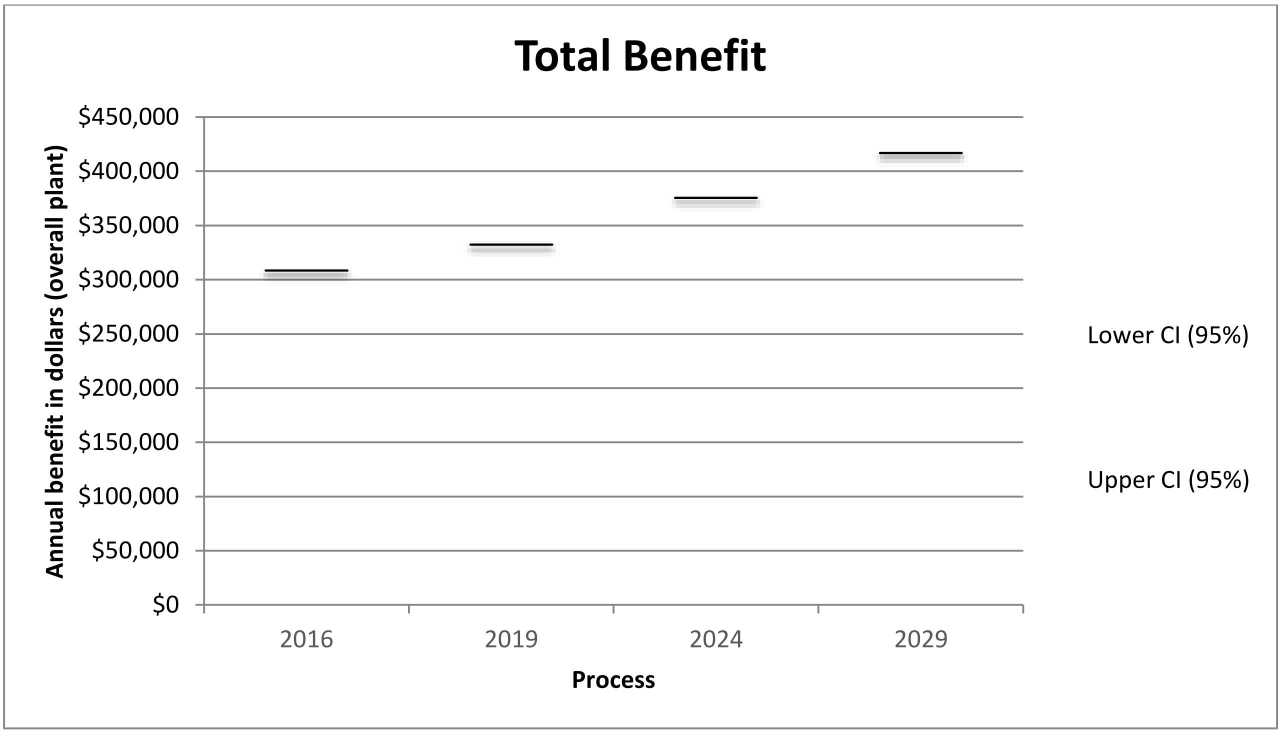

Figure 18: Annual benefit in dollars

OH&S and Labour costs are the main costs increasing over time in Figure 19 and therefore the main drivers of increased technology benefit over time.

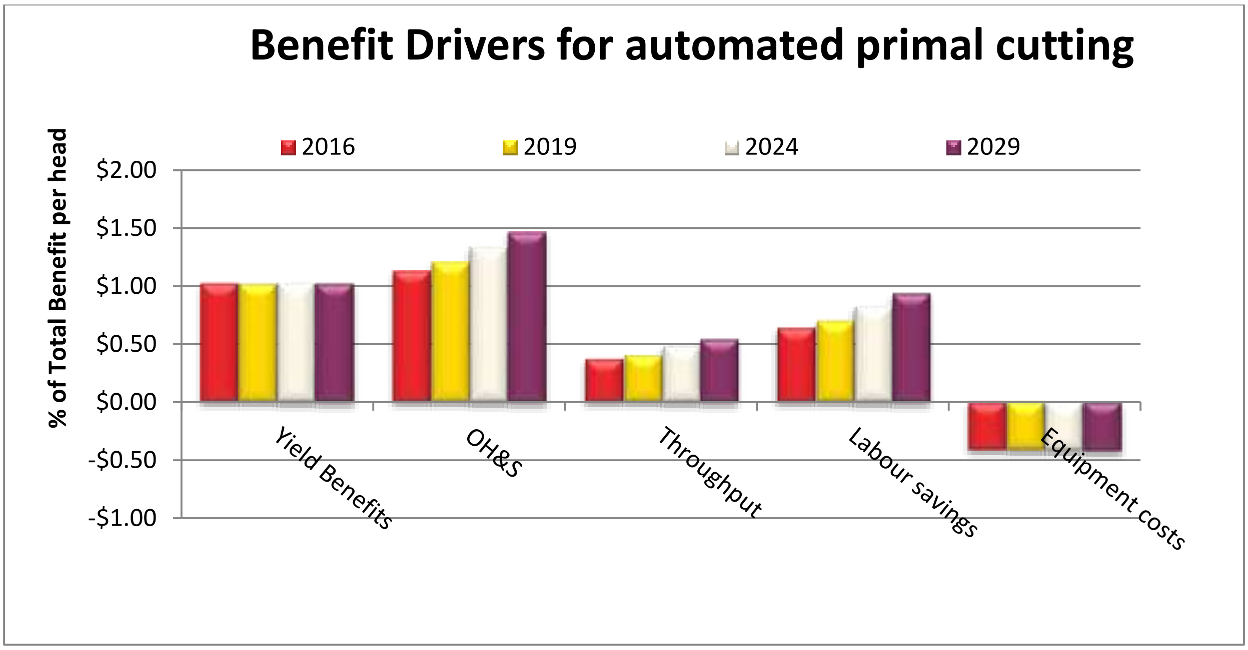

Figure 19: Benefit Drivers

Potential Industry Benefit

The Hook Assist system requires further investment to overcome current limitations. It has not been operated at commercial levels long enough to collect commercial data so extrapolation of benefit is difficult as a result. However, what is known about the improvements in processing performance discussed earlier has been extrapolated out as an estimate of the value opportunity to the Australian beef industry if a technology platform could be developed to address these issues.

Potential industry adoption rates

Industry estimates in Table 18 extrapolate out the benefits discussed earlier in Table 17 and assume a range of adoption rates and resultant value benefits to industry if successful solutions could be developed.

Table 18: Benefit to industry

Benefit to Industry			
Year	Percentage of industry uptake		
	25%	50%	75%
	Net Benefit for Industry		
2016	$ 5,292,947	$ 10,585,894	$ 15,878,840
2019	$ 5,705,985	$ 11,411,970	$ 17,117,955
2024	$ 6,444,989	$ 12,889,979	$ 19,334,968
2029	$ 7,154,508	$ 14,309,015	$ 21,463,523
Number of systems required	102	204	306
Number of carcases processed using system	2,090,000	4,180,000	6,270,000

Benefits by carcase type

Different types of animals require different processing techniques. Veal is small and light with soft bones so Hook Assist will not be of benefit on these types of carcases. Heavy grainfed carcases on the other hand tend to have harder fat, are larger and more difficult to bone so Hook Assist will provide a large benefit to boners.

Potential dollar values for type of carcase across industry have been taken into account and summarised in Table 19.

Table 19: Carcase mix assumptions

Animal type processed	Benefit level for carcase types	Percentage of kill
Veal	0%	7.57%
Average carcases	100%	87%
Heavy carcases	120%	5%

Modelling figures quantify the value to the relevant processing tasks. Veal processing tasks don't receive any value as opposed to heavy carcases that require more effort.

10 Additional Considerations

An industry wide culture of innovation will ensure that the Australian Red Meat Industry continues to be a success in today's complex business environment. Building innovation capability is the key to sustaining productivity and competitive advantage. The fostering of an innovation culture and the implementation of innovation strategies are critical success factors for developing red meat businesses to meet future challenges and opportunities.

Value proposition of staff engagement

The purpose of this project was to evaluate from a financial perspective the Hook Assist technology. There is evidence that human capability and engagement can be significant contributors to company's performance although they are much harder to quantify.

Boners are hard workers who are proud of their strength and physical human capability. If the skills they pride themselves in are not limited but further amplified (unlike the RTL puller which only delivers power but restricts movement), and they are less fatigued the level of worker engagement can be lifted. The Hook Assist has the potential to do this. Discussions with boners that had used Hook Assist and across a range of plants that had successfully installed the RTL aitch bone puller indicated the technology could improve the level of staff engagement in the boning room, increasing value beyond the technical hardware benefit. We have said previously that it has the capacity to interact and amplify the human element and the human element is more than physical strength. These other 'emotive' drivers are important consideration and critical components of any future cobotics solutions. The Hook Assist technology has already demonstrated a significant improvement in integration with human movement as compared to all other existing cobotics solutions.

A robust global survey around drivers of staff engagement and resulting benefits gives insight into the potential impact Hook Assist could have on employee performance. More than 50,000 employees from 59 organizations, 30 countries, and 14 industries participated in an employee engagement survey conducted by The Corporate Leadership Council. Findings indicate that there is an almost linear correlation between improvement in commitment and reduction in departure (CLC 2004).

The research identified a ***"10:6:2 Rule"*** where:

- *Every 10 percent improvement in commitment can increase an employee's effort level by 6 percent.*
- *Every 6 percent improvement in effort can increase an employee's performance by 2 percent.*

A further ***"10:9" Rule"*** was identified where:

- *Every 10 percent improvement in commitment can decrease an employee's probability of leaving by 9 percent.*

Engagement contributes almost half the improvement in company performance attributed to direct employee drivers of rational and emotional commitment summarized in Figure 20, supporting the need for multiple strategies in a range of areas. Companies with above average engagement are significantly more likely to have above average company performance than those with only average staff engagement as summarized in Figure 21.

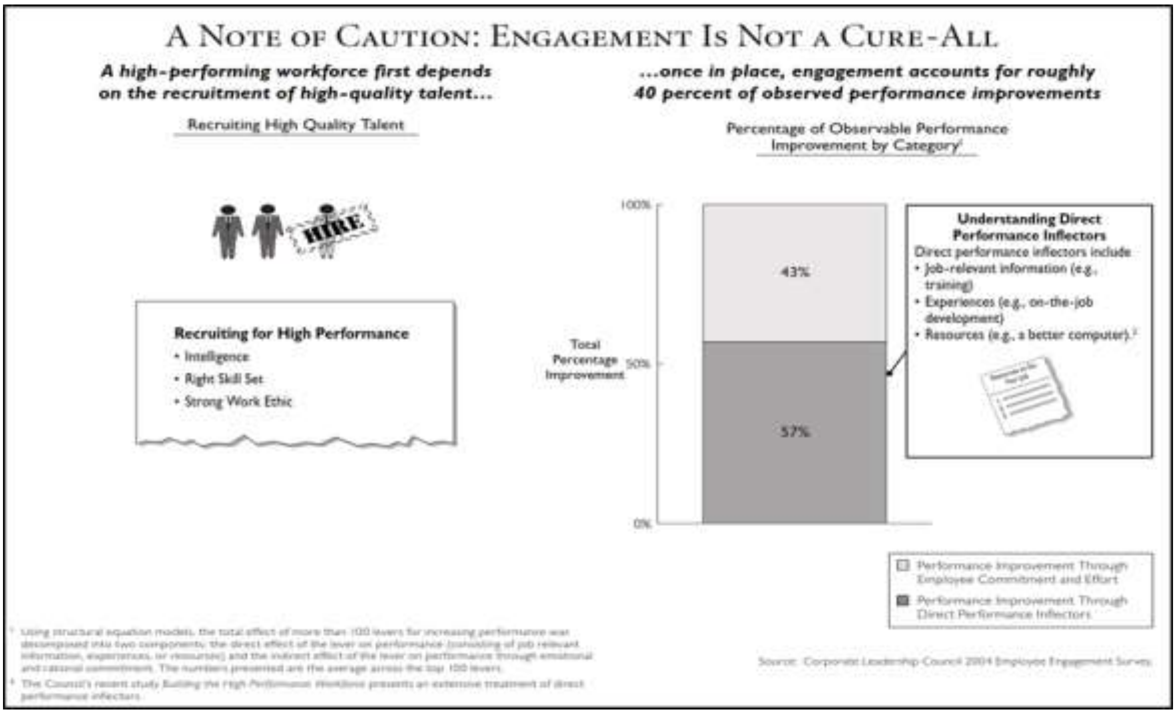

Figure 20: Engagement impact on employee performance (Source: CLC, 2004)

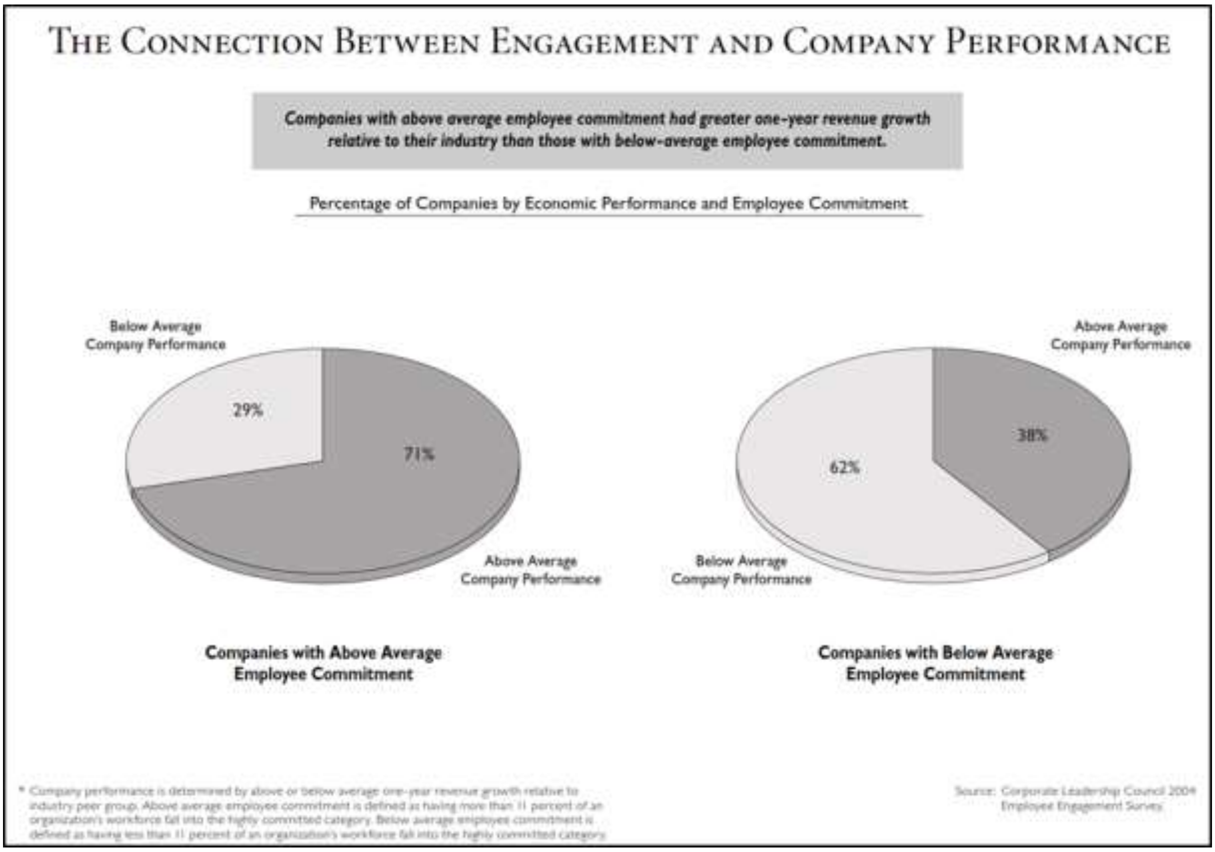

Figure 21: Impact of engagement on company performance (Source: CLC, 2004)

11 Strategic Considerations

Industry still needs a solution

Development pathways for fully automated systems are already occurring in parallel of an IAD platform as are more simplistic traditional systems. Each has trade-off benefits including capital investment, labour saving, ROI and risk of technology success. A longer term positioning of IAD platform needs to be considered in relation to these other pathways. If it were halted in the hope that fully automated systems will be successful, lack of success in 5-8 years will leave the same gap in what by then is now a critical technology advancement. Alternatively full automation may be successful but only viable for the largest plants.

Further development of the technology could have far reaching benefits for labour management in the years to come.

Technology

The original vision of AMPC and MLA toward 'cobotic' technology was a progressive move in the strategy of dealing with OH&S issues threatening the industry. The initial prototype, though clearly needing further development, was viewed by those that had first-hand experience of it, as the next evolution in assisted technology. Its potential capability was described as 'revolutionary' and promised much in terms of useability.

Having confirmed this through the industry workshop and trials, the original plan to proceed to the next iteration seemed to have been replaced with a 'speed to market' approach. This pathway to development wasn't necessarily detrimental in the outcome of the asset in hand today, but it has affected the confidence in industry, and now needs some consideration in going forward. It also had implications to the ongoing vision of the technology platform.

The initial study commissioned by MLA and AMPC was to identify a provider of technology that could bring new capabilities and benefits to the industry. The primary initiative and investment was toward the technology as an enabling platform, in this case - Intelligent Assist Devices (IADs) for a range of "to-be-developed" applications rather than one single product solution. The investment is connected to the vision for the industry and further investment decisions will need to consider the level of ongoing commitment to this vision. Hook Assist in its current format will not be commercially viable in the short term. It needs to be viewed as the long term development of a technology that will have much broader application, and implications for the meat and other industries.

Vision

Despite various documents and communication implying that the Hook Assist could be quickly brought to a robust commercial system, Scott Technology (the commercialiser) viewed it as a technology platform that needed considerable development before being commercially viable. The application and integration of this 'new' technology required much deeper understanding than providing a 'tool for a job'.

Vision became an important ingredient in the mix of this development and commercialisation process. It highlighted the need for change in the approach to 'new' technologies.

Without a defined vision there was the potential to make something 'new' fit into the 'old' and adopt the approach of upgrading something already existing. Although this was the original intent and purpose toward the technology, this quickly became lost in the success of the potential. Instead of holding to the long term view of what the technology had to offer strategically, there was reaction to the immediate pressure from industry for a finished solution to a job.

There is opportunity now to carefully consider and commit to a long term strategic vision that can encompass various technologies and the development processes that will apprehend their potential value. This clarity of vision will help define messaging and manage expectations as industry is engaged through the various processes of development.

Broad and inclusive industry engagement needs to be a constant through the process so that at the point a finished product is delivered to market, there are relationships built and confidence to proceed to purchase.

Innovation Considerations

People often forget that innovation is more than just developing creative inventions. There is an implementation process (shown in Figure 22) that often has to undergo a number of transformations before the invention can create new value (pay for itself). The Hook assist technology is past the invention stage and probably half way through the implementation stage with a number of transformations still required to generate commercial value.

According to industry studies around 90% of enterprises have not created repeatable innovation processes. Yet delivering new innovations is by far the best opportunity for finding new growth.

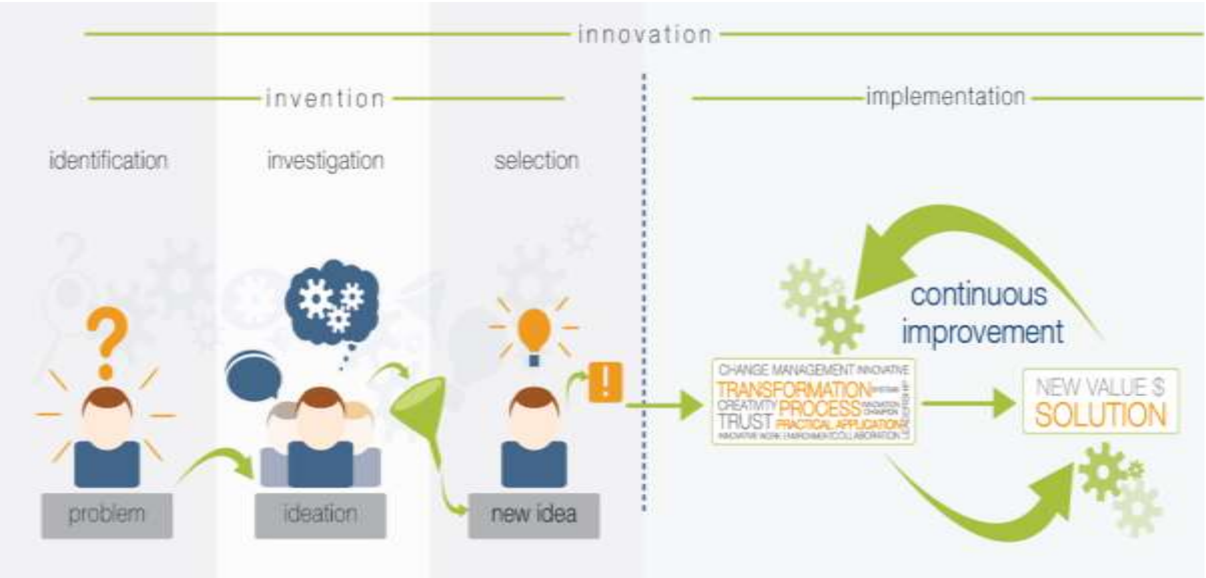

Figure 22: Innovation is much more than invention

The challenge with Hook Assist is determining whether it is worth continuing development of what is a smart invention but not yet capable of delivering any new value. Industry needs to consider the strategic impact of this potential innovation on future transformational change in managing staff work environment. Transformational or radical innovation is usually only possible after a number of incremental innovations have occurred as demonstrated in Figure 23.

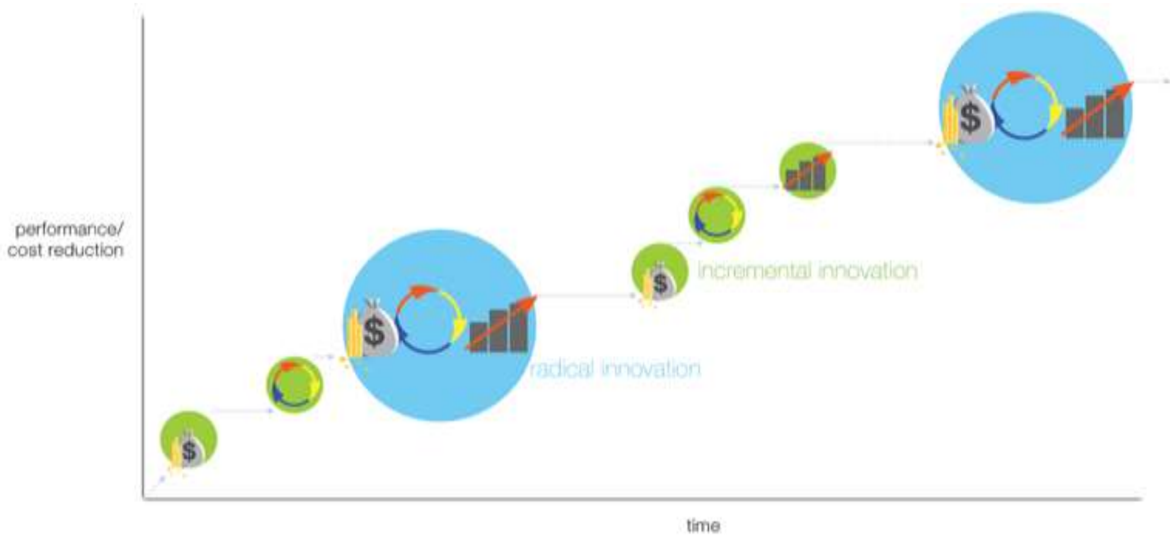

Figure 23: Radical innovation is usually pre-ceded by a number of enabling incremental innovations

These kinds of innovations are often seen as 'breakthrough' innovations, some of which can change the entire way an organisation operates and, on occasion, can result in a new product or service that impacts an entire market sector. Hook Assist if commercialised only represents incremental improvement in this next 12 month testing phase. However, it would enable a range of other incremental innovations and could lead to quite different ways of tackling difficult jobs requiring high sensory involvement.

Some longer term radical innovations could be:

- Battery power packs with light weight arms that move with the human arms but amplify force exerted (Amplify human sensory capability)
- Robots that mimic human movements but light weight, lower cost and not in a fixed position (Replace human sensory capability AND replace existing industrial robot formats)
- Changing the beef boning process with support of these tools to greatly increase kilograms packed per FTE.

Industry Engagement

Industry needs to be aware of the strategic considerations around this project that is:

- Firstly development of an enabling technology platform and
- Moves into development of a tool for a job as a secondary and later focus.

If the original objectives can be achieved they will meet a clear gap in industry capability. Whether industry stakeholders have appetite for this ongoing process is another question and one that needs to be discussed with appropriate stakeholders.

12 Key Findings

The development of the Hook Assist prototype provided a window into cobotic technology and its potential benefits, but it has also revealed the challenges of bringing this new technology to full commercial viability.A number of areas of investigation have been integrated to identify the challenges and opportunities in this section and underpin the recommendations on how to proceed with the technology. The key findings as are as follows:

Project outputs

Two significant capability assets have been developed – The key output developed from the hook assist project are summarised in the top two rows of Table 3. These capabilities combined to work seamlessly (when the prototype worked) resulting unprecedented amplification of human skill in row three of the table delivered. Potential alternative boning processes were intended in the last row of the table before the prototype failed in the harsh commercial environment.

Project capabilities developed greatly amplify human capacity - Hook Assist delivers a significantly better integration with human capability than any other human assist devices (based on when the system worked). This seamless integration between machine and human is critical for future cobotics success. This is particularly critical where technology has to integrate with a wide range of human sensing and visioning capabilities.

- Operators felt there was a significant improvement (60% more integration with the operator) in the system and were clearly more engaged than with RTL or Proman hook assist devices.
- This increase in engagement is a potential opportunity expanded further below.

No future without further industry R&D - The Hook Assist technology is not commercial ready and requires investment in re-design. This is the minimum investment needed to enable trials prior to undertaking the planned commercialisation activities. Two options to get the prototype to commercial operation are:

- Low cost rewire - Approximately $250,000 will fix waterproofing and maintenance issues but will not address some fundamental shortcomings like too short a swing arm.
- Higher cost redesign – Approximately $550,000 involves a complete rebuild. Although it will address the known issues, twelve months of commercial trials will generate new learnings, most likley requiring a further refinement of the base technology platform.

R&D / Commercialisation path not a failure - Some re-design issues had been identified with the prototype prior to the commercialisation tender. It was decided not to further invest in R&D to re-engineer at the time. Pre-existing issues were not the reason for system failure. A number of new issues only arose during the commercial trials after Scott Technology won the commercialisation tender. If industry money had been spent earlier, these new (yet to be identified) issues would still not have been addressed. The technology would still have been inoperable but with a higher industry investment cost.

- The main disadvantage of this path has been loss of time while the commercialiser and industry decide whether to proceed or not.
- The main positive is a clearer understanding of what is required from commercialiser and industry to develop a successful cobotics technology platform.
- The development path required is not dissimilar to the multi-stage building and refining of the LEAP technology for lamb where a number of trial and error developments were required to find a successful solution.

Commercial viability of project outputs

Traditional approach ("tool for a job") delivers mixed benefits – Hook Assist benefits include yield, OH & S, throughput and labour saving but these vary across the range of jobs (refer to figure 1). Return on investment varies from 6 months to 4 years between jobs as a result. Taking the approach of "a tool for a job" will limit adoption to two to four tasks in the boning room with the most immediate tangible benefits.

Industry cost / opportunity – OH&S and labour related costs are expected to increase by 30% over the next 15 years and will make investment in cobotics more viable. Effective cobotics could address an opportunity cost estimated at $21 million per annum (see Potential Industry Benefit section on page 53).

Simplistic short-term approach limits future opportunity - If hook assist is viewed as a single tool for an existing job without considering potential innovation opportunities redevelopment will be hard to justify.

- Hook assist does not deliver much better financial benefit than other cobotics in a task for task comparison when only considering yield.
- Capital cost needs to reduce from the projected $150,000 to $200,000 per unit to be commercially viable for single task applications.

Cobotics discussions require a fresh approach to innovate

Innovative engagement and adoption strategies - Existing competing cobotics technologies have had limited adoption. The difference between plants that have successfully installed cobotics and those that haven't has been the approach to engaging existing staff. A potential new development and adoption process that focuses on the people should be considered and would be required for Hook Assist if it is further developed. Careful engagement of industry is required to encourage adoption.

New systems approach increases benefits - Hook Assist technology has the potential to seamlessly amplify human capability. A systems approach where 5 to 6 Hook Assists were installed on a line to support all difficult boning jobs could deliver benefits around throughput, not possible when only installing two to three systems for jobs with yield payback. This systems approach would further address absenteeism and staff engagement. Because two to three of the installs don't deliver high payback in isolation from the other installs a different approach to installing equipment is required. This would require significant testing and demonstration to prove the approach.

Options to address OH&S challenges

Full automation cannot replace cobotics - Fully automated solutions could replace straight cutting tasks like scribing. However manual boning tasks have no visible automation development pathway at this point in time. If Hook Assist is not progressed, alternative cobotics will be required to overcome current labour and OH & S challenges around these jobs (approximately 80% of beef boning tasks).

Cobotics and automation deliver similar ROI - More automated solutions come at a greater capital investment and require higher processing volumes to provide an attractive payback. Although fully automated systems can deliver greater value the capital cost is also much greater. Interestingly, ROI for the automated and cobotics systems compared in the study were not that different.

Small and large processor needs – Plant foot print, volume processed and flexibility of operations influence a plants appetite for full automation. If cobotics modules can be developed they will be more suitable to smaller processors than full automation. Even if fully automated solutions are developed, smaller cobotics solutions (if developed) would better suit many processing plants.

Industry still requires a cobotic solution - If manual assist technology is not advanced, some other technology approach will be required to address the original labour and OH&S challenges that instigated the project investment to date. Full automation is not an alternative pathway to cobotics in the short to medium term.

3. No other solutions so look harder or develop more strategically with more specific target outcomes but longer term development pathway.
4. Cost of small multiple unit installations versus large single complete overhaul installations – different target audiences.

Industry R&D would "kick start" commercial investment – Further R&D beyond testing of the base technology will be required to build end effectors and adapt the base technology into a range of manual assist applications. The commercialiser had already committed to this ongoing investment in collaboration with interested processors as future funded PIP projects. However, they intended 12 months testing in the production environment which the prototype failed to deliver (less than 6 weeks in fact). If industry want to realise the assets developed to date, investing in a commercially robust prototype would get the technology to a point where the commercialiser would take over R&D.

13 Recommendations

The following recommendations require input from industry to step through the best future direction for the Hook Assist technology.

1. **Confirm industry commitment to reduce boning OH&S risks** – Confirm with industry that cobotics is still an important strategic initiative for reducing physical strain and difficulty from the hardest boning tasks as the first step in considering the way forward with Hook Assist. This is important when considering industry adoption.
2. **Double-check alternative cobotic development pathways** - Confirm that no alternative cobotic technologies exist that present a shorter commercialisation path than Hook Assist. This is unlikely given previous industry research. Adapting alternative technology to the meat industry would probably be more expensive than further development of Hook Assist.
3. **Value engineering is absolutely critical to success** - If industry agree to proceed with this technology a value-engineering strategy will be required to reduce the capital cost as current $150-200,000 Hook Assist capital cost will limit adoption. Target capital costs should be agreed with industry as part of this strategy.

If these recommendations can be agreed on between industry and the commercialiser, it is recommended to proceed with redevelopment of Hook Assist in order to:

1. Test whether the significant project learnings can deliver an acceptable cobotic tool – *Success seems likely*.
2. Identify how a second stage adaptation could innovate around OH&S and worker engagement. – *Success depends on findings from 1. but could lead to radical innovation*.

If redevelopment proceeds it should be on the following basis:

- **Redesign the prototype** - in order to conduct 12 months of commercial trials as originally planned.
- **Re-design using the more expensive option** - Preference is towards the more involved redesign as a number of physical constraints on the existing prototype (such as redesign of new hook and longer arm to keep up with chain speed) would limit effectiveness of the 12 months of trials. NOTE: discussions with engineers and commercialiser are required to decide on the best redevelopment option.
- **Agree on a target capital cost window with industry** for a range of applications of Hook Assist prior to conducting the redesign. This will guide design requirements and may help uncover a more innovative approach.
- **Improved engagement could occur** - Agree to further investigate the employee engagement component of this equipment. Significant potential could come out of improved engagement.
- **Manage expectations with industry** - This 12 month trial will not produce a commercial product. Further refinement of the redesigned system will be required either to adapt learnings, or to develop end effectors for specific manual tasks like Scribe Assist. Previously, false expectations arose that the prototype was commercial ready. When it failed some considered the whole

project to have been a failure. The capabilities built to date have potential to transform complex manual boning tasks but will require a lot of testing.

14 Literature

Figure 24 lists the documents that have been referenced as part of the technology assessment.

Figure 24: List of documents reviewed as part of the technology assessment

Data	Information/Data Type	Reference
Previous investment	Kinea design's findings	Santos-Munné (2008)
	Scott Technology investment	Scott's Technology Limited (2012)
	AMPC Conference	Santos-Munné (2011a)
System capabilities	System upgrades required	Santos-Munné (2011b)
	Current capabilities	Scott's Technology Limited (2012) (NCMC, 2014) (JBS Swift, 2014)
	Additional system applications	Starling (2014) Teys Brothers, (2014) (NCMC, 2014) (JBS Swift, 2014)
Company background	Kinea Design's capabilities	Malone (2010)
Adoption of innovation	Red meat industry experiences	Australia Meat Processor Corporation (Unknown) Burrow (2010)
Processing capacity in Australia	Demographic of plants in Australia	Hassall & Associates Pty Ltd (2006) Scott's Technology Limited (2012)
Cost Benefit Analysis	OH & S injuries in QLD	Department of Justice and Attorney-General (Unknown)
	Capital and R&D costs to upgrade Hook Assist	Scott Technology Limited (Unknown)
	Competing technologies	Greenleaf Enterprises (2009a) Greenleaf Enterprises (2009b) Greenleaf Enterprises (2011) Green, Bryan, & Fischer (2013) Green & Bryan (2014) Li & Hinsch (Unknown) Shaw (Shaw, Unknown)

15 Reference List

Australia Meat Processor Corporation. (Unknown). Case Study 23: Identifications of Barriers to the adoption of Technology in the meat Processing Industry.

Burrow, H. (2010). Achieving adoption and innovation in Australia's beef industry. Animal Production Science (50), 418-423.

Corporate Leadership Council 2004 Employee Engagement Survey.

Department of Justice and Attorney-General, Q. G. (Unknown). Workplace Health and Safety Queensland, Meat processing.

Green, P., & Bryan, K. (2014). Final Report: LEAP III lamb middle cutting, Ex-Post Review, P.PIP.0327. In Greenleaf Enterprises (Ed.).

Green, P., Bryan, K., & Fischer, S. (2013). Feasibility Review – Automated X-ray Beef Boning Solution. In G. Enterprises (Ed.).

Greenleaf Enterprises. (2009a). Cost Benefit analysis of customised manual assist equipment installed in two plants for aitch bone removal and knuckle pulling: Industry Report. In M. L. Australia (Ed.).

Greenleaf Enterprises. (2009b). Review of Scott's Technology Manual Assist Boning System: A Benefit Analysis prepared for Meat and Livestock Australia in M. L. Australia (Ed.), Final Report.

Greenleaf Enterprises. (2011). Value proposition for automated beef scribing. In M. L. Australia (Ed.).

Hassall & Associates Pty Ltd. (2006). The Structure and Dynamics of Australia's Sheep Population. In O. o. t. C. V. Officer (Ed.).

JBS Swift (2014). [Personal Communications, 2nd September, 2014].

Li, Z., & Hinsch, A. (Unknown). A New Approach to Detect the Cutting Positions for a Robotic Beef Carcass Scribing System. In C. Food Science Australia (Ed.).

Malone, L. D. (2010). Testing Rx for Medical Mechatronics. Test & Measurement World.

NCMC. (2014). Personal Communication, 3rd September, 2014.

Santos-Munné, J. J. (2008). Hook Assist 0.1 workshop summary report and proposed design changes for phase 3, A.OHS.0046. In M. L. Australia & AMPC (Eds.), Final Report.

Santos-Munné, J. J. (2011a). Advancements in Cobotics: Where might we take this technology, Presentation at the AMPC Conference 2011. In K. Design (Ed.), Advancing the Future for Meat Processing through Engineering, Research, Efficiency and Sustainability.

Santos-Munné, J. J. (2011b). Hook Assist development, A.OHS.0050 In M. L. Australia & AMPC (Eds.), Final Report.

Scott Technology Limited. (Unknown). Hook Assist–Update and Next Steps (including Scribe Assist) Hook Assist 2.0.

Scott's Technology Limited. (2012). Response to Terms of Reference: Commercialisation of Intelligent Assisted Device for beef boning Hook Assist Technology Tender Response.

Shaw, S. (Unknown). Robotic Beef Scribing: New MAR Technology Development for Beef processing In M. A. R. (MAR) (Ed.).

Starling, S. (2014). Final Report: Manual Assist (Hook Assist) Commercialisation. In M. D. Company (Ed.). Meat & Livestock Australia Limited.

Teys Brothers (2014). [Personal Communications, 11th September, 2014].

COMPENDIUM OF WORKERS' COMPENSATION STATISTICS AUSTRALIA 2007–08 and _2008-09

ABS Data Sets:

- 5673055003_1a - Average wage in Australia,
- Superannuation increase of 2.5% by 2025
- 5206014_household_income

16 Appendix

Time Line of Events

A summary of activities undertaken from initial development to current commercial testing is included in the time line in Figure 25 and relates to the investment already made. It also indicates the level of industry engagement that has existed for the technology. Since the failure of the system, credibility with some industry representatives has been lost. It will be important to consider the types of expectations created in any future approach.

Figure 25: Development timeline

2005 Study Commissioned

- Study commissioned by MLA and AMPC to find best global provider of manual assist technology.

2006 Kinea Design (USA) appointed

- R & D begins, obtain industry relevant background to identify opportunity areas and orientation to tasks
- A one axis power assist device is identified as the best target application.
- Kinea develop and build two prototype systems, one using a pull down cable and the other using a full arm.
- AMPC and MLA identify arm as more promising direction, provide feedback to make design improvements.

2008 Kinea workshop the prototype in Australia

- Demonstration and workshop at NMIT and Harvey Beef WA
- Comment and feedback captured from industry operators
- Kinea identify and document a list of requirements and proposed modifications
- Kinea outline phase 3 commencing with industry trials in a controlled environment.
- These learnings will then combine with those previously obtained to refine the set of requirements for the design of Hook Assist 0.2

2010 Scott Technology awarded commercialization rights

- Commercialization is expected in the second half of 2012.
- Technology transfer from Kinea to Scott commences.
- Various design notes were made during a week of familiarisation in the US but agreed that most could be covered in future iterations and not critical to short term operation for the proposed industry evaluation.

2011 May - Prototype is prepared for shipment to Australia

2011 - June AMPC Conference Presentation trialled by participants though not with meat

2011 First Industry Trial - Controlled Environment

- JBS Brooklyn: Intial trial goes well but when the system is relocated to the main boning room, electronics and mechanicals in the arm fail. The inability to rectify these issues, quickly, reliably and satisfactorily, cause momentum and support to be lost and it was agreed that a new trial venue be sought.

2011 Second Industry Trial - Controlled Environment

- NCMC: This trial experienced a similar pathway with inital use of the system going well in the 'off line' location, but then failing when it was moved to the main boning room. Water ingress was the main cause of electrical component issues and it was concluded that the system was not commercially ready.
- The system was , shipped back to Scott Technology where it remains.

Value of Staff Engagement

Emotional commitment (gaining a sense of meaning and joy) has four times the power to impact on performance relative to rational commitment (the extent to which employees believe managers, teams and organisations are in their self-interest (financial, developmental or career). Studies on talent retention (Phillips & Edwards) indicate that only 11% of the workforce is committed at this level and 76% with only strong commitment to one aspect of the job such as income (Figure 26, Figure 27, Figure 28, Figure 29). Findings in the meat industry support the evidence that the lesser the degree of commitment the more likely a person will leave the organization. Other studies identify focal points of commitment and strategies for improvement. They cite examples of increased retention and reduced safety costs in companies that have improved employee engagement.

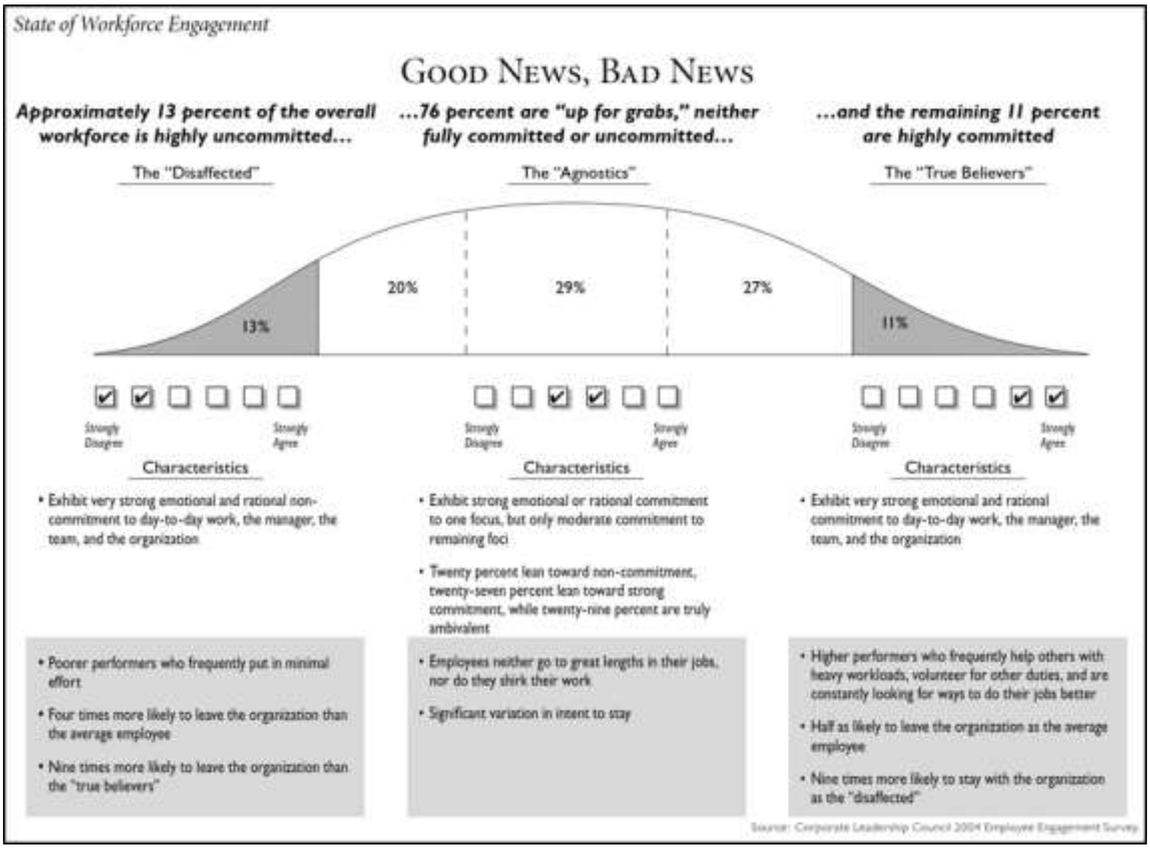

Figure 26: Employee commitment levels and characteristics

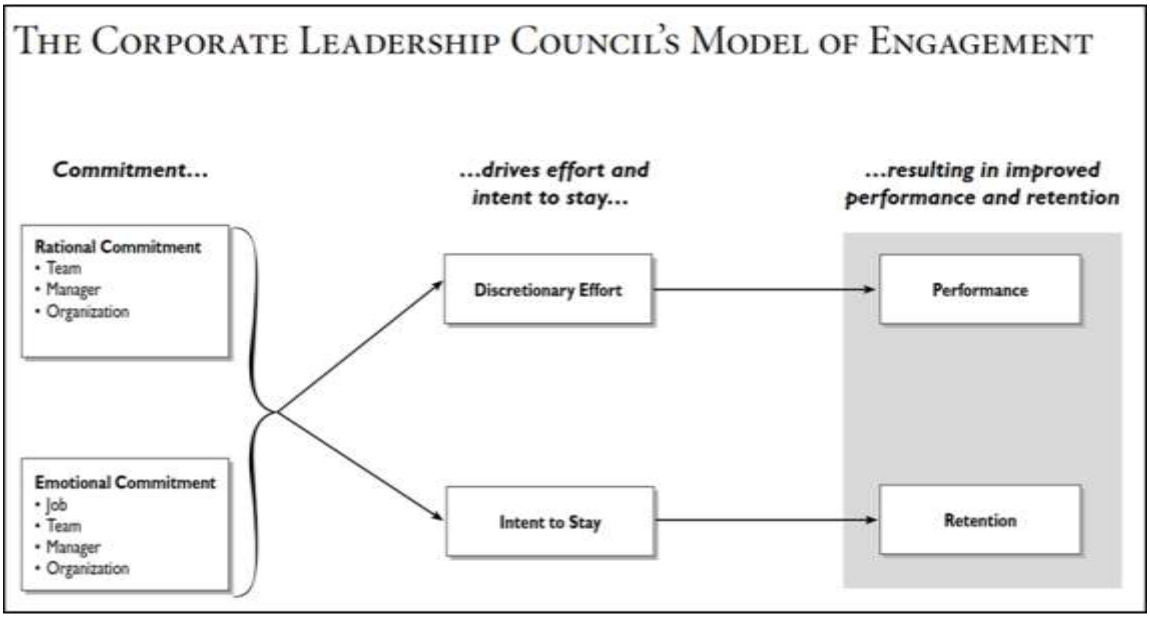

Figure 27: Model of engagement

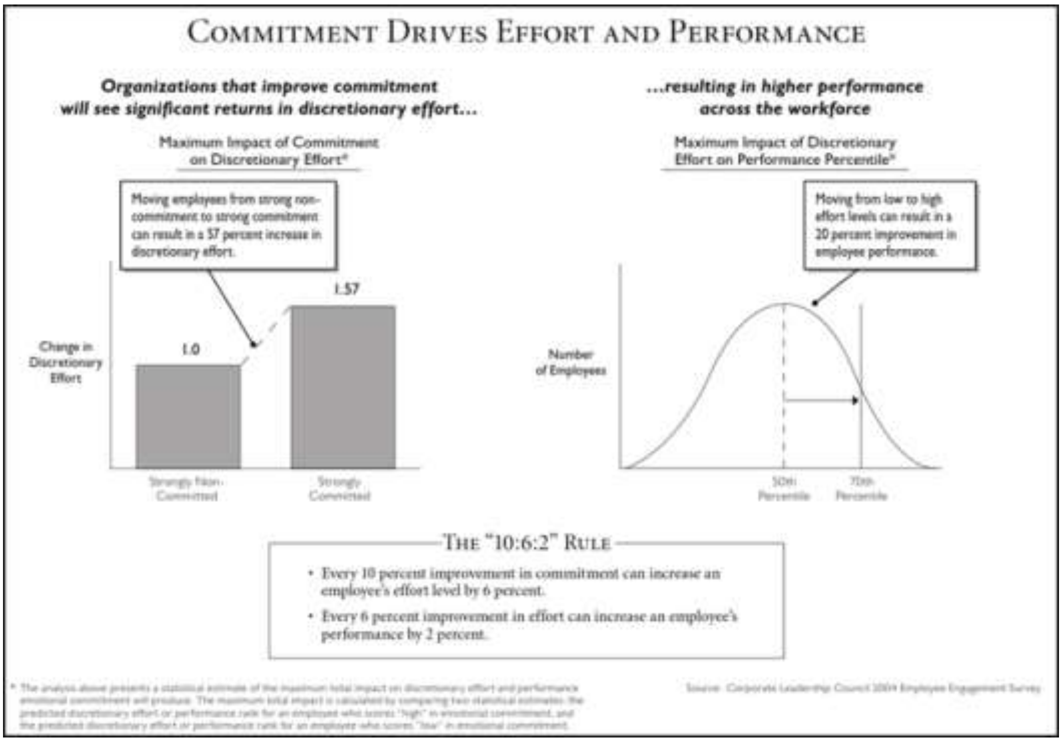

Figure 28: Commitment drives effort and performance

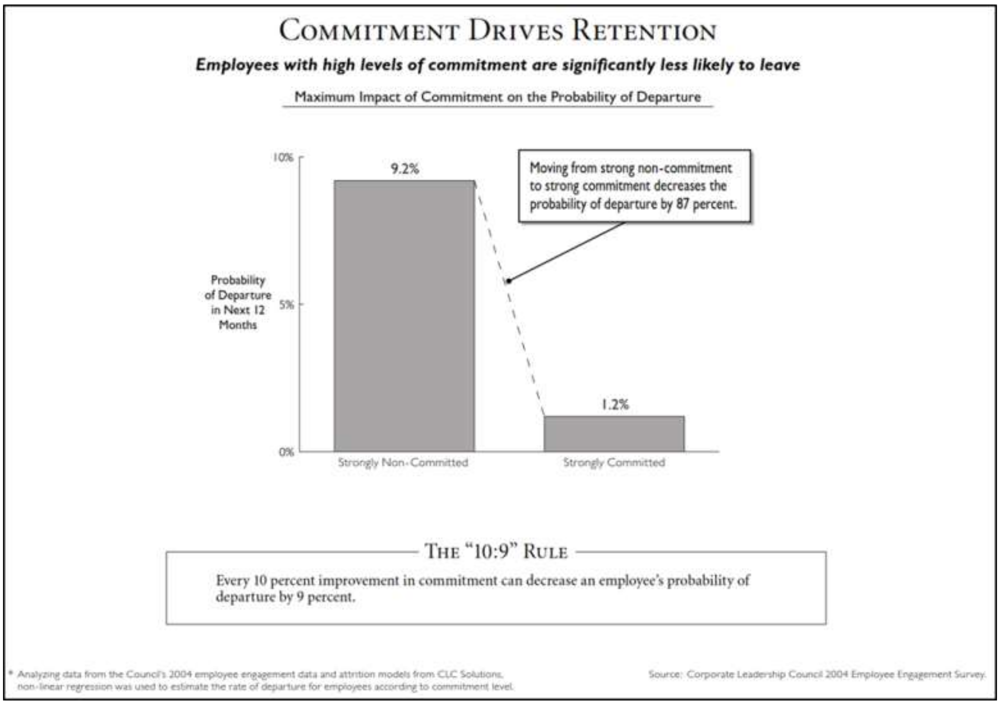

Figure 29: Commitment drives retention

Hook Assist Limitations and Constraints

Scott Technology provided a statement of issues that were identified during the commercial trials which require re-design before the system would be considered ready for further trailing pre-commercialisation. The key areas are summarised in Table 20.

Table 20: Hook Assist issues preventing commercial operation

Mechanical Issues
The horizontal reach of the system limited the boners ability to finalise the process
The electronics of the system were not rigorous enough for the environment
The aluminium casing corroded rapidly
Design of the elbow joints caused meat to get stuck resulting in cleaning issues
Fixing issues was very inefficient due to the design and lack of diagnostics system
The mode of failure was often erratic arm behaviour
Improvements could be made to the hook profile
There was mechanical shear in the hook assembly due to force, material selection and corrosion
The counterweight system at the Gimbal needs to be improved as it applies strain to operators hand and fails mechanically
The sensing in the handle was "hit and miss". It was not suitable for use with glove and appeared to be affected by environmental factors
The machine would often loose calibration

The size and arrangement of components in the design meant that maintenance was difficult, time-consuming, required a number of specialty tools and meant that there were a number of very small parts that could be dropped/lost/misplaced into the boning room process.
The electronics and control systems used meant diagnostics was difficult and specialty programming tools and knowledge are required to make any modifications from a development perspective.