Final report

LEAP V Forequarter integration arm mechanical upgrade to improve accuracy, reliability, and uptime

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Abstract

Scott Automation and Robotics (within its joint venture company Robotic Technologies Ltd) and Meat and Livestock Australia have been developing their vision of a fully automated bone-in lamb boning system that removes operators from bandsaw interaction, provides uniform boning room production speed and significantly increases yield. The vision is depicted in Figure 1.

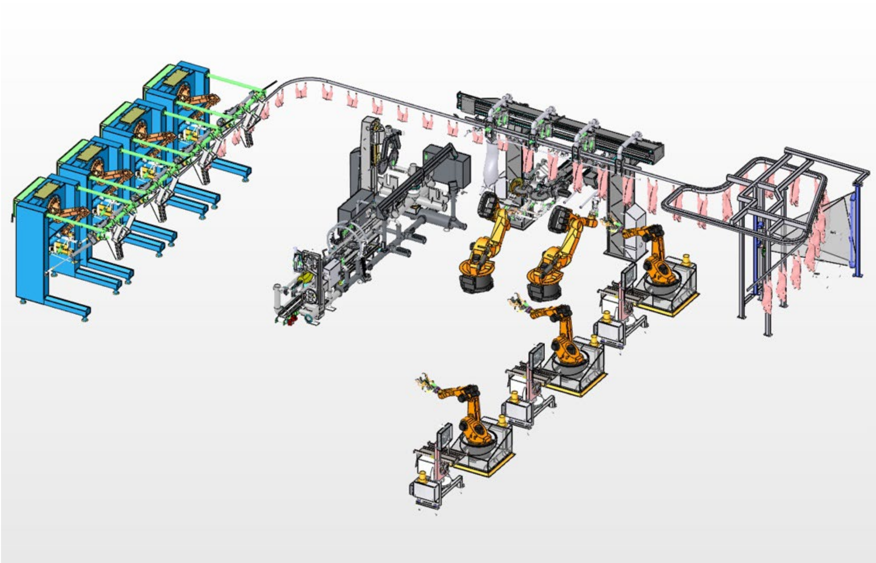

Figure 1: Boning Room Vision (fully automated room)

There has been significant expansion and adoption since inception with the recent system demonstrating a vertically integrated value chain operation with feedback to producers. There is evidence that significant opportunity exists to build and improve on the LEAP technology.

The fully integrated x-ray, Primal and Middle system technology has been successfully operating in Australia since 2012 and is now relied on as an integral, mission critical, component of efficient processing. Continued development by Scott Automation and MLA has seen further benefit achieved off the back of the LEAP success.

It has been identified through ongoing analysis and support of the systems operating across Australia and New Zealand that there are substantial additional benefits to be attained by upgrading the Forequarter system to achieve the next level in accuracy and reliability.

Executive summary

Scott Automation and Robotics (Scott) and Meat and Livestock Australia (MLA) through strategic partnership have successfully developed and are rolling out to industry the LEAP III, LEAP IV and LEAP V automated primal, middle and forequarter bone in processing systems for lamb.

This project builds on crucial learnings and developments that have been acquired through observing LEAP V systems operating across a wide range of plants and products. The upgrades from this project target improvements in design that increase the benefit from accuracy, achieve a reliable 10/min throughput as well as improve mechanical reliability. The upgrades include:

1. LEAP V Forequarter integration arm mechanical upgrade to improve reliability and uptime.

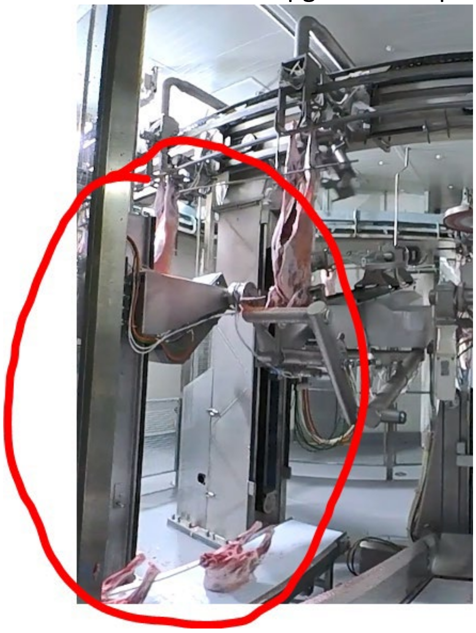

Figure 2: The LEAP V Forequarter integration arm was redesigned, built, and commissioned on an Australian processor site as part of this project. The upgraded integration arm has been strengthened significantly to address fatigue failures and allow the system to achieve a sustained 10 parts per minute.

2. LEAP V Forequarter lifter upgrade to improve clamping reliability and accuracy. .

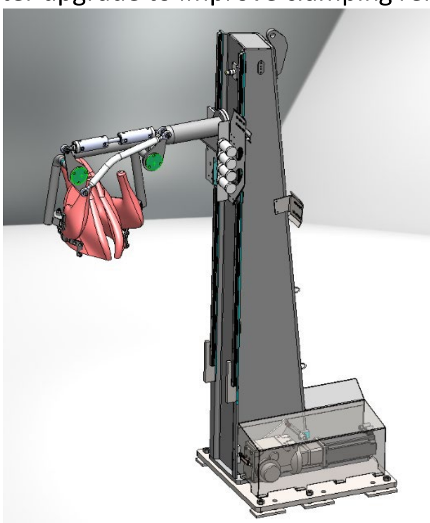

Figure 3: The LEAP V Forequarter lifter was redesigned, built, and commissioned on an Australian processor site. By minimising movement during pickup, accuracy is improved, and the reject rate for the system is reduced.

As a part of this project, Greenleaf Enterprises Pty Ltd produced an independent cost benefit analysis of the LEAP V Forequarter system, comparing the existing LEAP V Forequarter system (Mk 1) to the upgraded system (Mk 2). This cost benefit analysis took into account the upgrade package and other system improvements that have been implemented since the original 2019 cost benefit analysis was completed. The key results are shown in the tables below.

Table 1: Per head benefit achieved from the original and upgraded forequarter systems.

TOTAL BENEFIT					
		MK. 1 Install		MK. 2 Install	
Benefit summary		$/hd From	$/hd To	$/hd From	$/hd To
1.1 Accuracy	Knuckle Tipping	$0.06	$0.08	$0.09	$0.09
	Brisket Removal	$0.03	$0.03	$0.03	$0.03
	Neck Removal	$0.12	$0.14	$0.21	$0.20
2. Throughput benefit		$0.01	$0.01	$0.01	$0.01
3. OH&S benefit		$0.01	$0.01	$0.01	$0.01
4. Labour benefit		$0.12	$0.12	$0.12	$0.12
Equipment costs	**Maintenance**	$0.00	$0.00	$0.00	$0.00
	Operation	-$0.01	-$0.01	-$0.01	-$0.01
	Risk of failure	-$0.01	-$0.01	-$0.01	-$0.01
	$ Benefit per head	**$0.33**	**$0.36**	**$0.45**	**$0.43**
$ Annual Benefit overall plant		**$698,637**	**$766,227**	**$948,936**	**$922,584**

Table 2: Cost benefit analysis summary

SUMMARY PERFORMANCE MEASURES				
	MK. 1 Install		MK. 2 Install	
Hd / annum	2,122,038		2,122,038	
Production increase with equipment	**2.06%**		**2.06%**	
	From	To	From	To
Capital cost (pmt option, upfront)	**$2,875,000**		**$2,875,000**	
Gross return Per head	**$0.33**	**$0.36**	**$0.45**	**$0.43**
Total costs Per head	**$0.16**		**$0.16**	
Net Benefit Per head	**$0.17**	**$0.20**	**$0.29**	**$0.28**
Annual Net Benefit for the plant	**$ 363,750**	**$ 431,340**	**$ 614,049**	**$ 587,698**
Annual Net Benefit for the ex cap	**$ 651,250**	**$ 718,840**	**$ 901,549**	**$ 875,198**
Pay back (years)	**4.41**	**4.00**	**3.19**	**3.28**
Net Present Value of investment	**$1,708,998**	**$2,152,479**	**$3,351,298**	**$3,178,397**

With the conclusion of this project Scott and MLA now have a set of upgrades that can be rolled out as retrofittable packages to existing machines, as well as incorporated as standard into new machines. The presents an opportunity to increase Return on Investment (ROI) for these machines and for the industry as a whole.

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1. Background

Scott Automation and Robotics (Scott) and MLA through strategic partnership have successfully developed and are rolling out to industry the LEAP III, LEAP IV and LEAP V automated primal, middle and forequarter bone in processing system for lamb. Scott and MLA were supporters of the initial adoption of the technology with the first systems going into production in 2012. These systems are still performing strongly and a further 13 systems are now in operation.

Since inception, Scott and MLA have continued with targeted development and through the continued operation of these systems in the field to gain further value and realise new opportunities due to advances in technologies. Notable successful developments that are a direct continuation of LEAP include x-ray sensing for accurate skeletal measurement, standalone lower throughput modules for small to medium size processors, carcase yield measurement using dual energy x-ray, system upgrades to improve yield and reliability, loin deboning and short rib processing.

Given the strategic importance and success of the LEAP systems to Scott, MLA, and the Australian lamb industry this project looks to further develop the system to gain additional value for lamb processing through yield and reliability improvements.

The benefits of the LEAP system are well understood and documented. Yield recovery is known to be the major source of benefit to processors and producers, with $7.70/head attributable to yield alone.

This project builds on crucial learnings and developments that have been acquired through observing systems operating across multiple plants and product specifications with target high value areas of benefit such as primal breaking and sub primal preparation cuts as a focus. The upgrades target improvements in design that increase the benefit from accuracy, reliable 10/min throughput as well as improving mechanical reliability (uptime efficiency).

Forequarter primal separation from the lamb carcase requires a precision cut between the 4th and 5th ribs. Carcase sizes, shapes and weights vary significantly between locations, across seasons as well as over time as advances in genetics and animal husbandry result in phenotypic evolution. As such, the LEAP III system materials handling assemblies need to be robust and have the flexibility to position product critical accurately and reliably for achieving accuracy, mechanical uptime as well processing efficiency.

The integration arm is integral to both the reliable removal of the forequarter primal in the LEAP III primal machine as well as the transfer of forequarters to the LEAP V forequarter bone in processing cells. It is imperative that this mechanism always works accurately and reliably, as a failure to do so will result in a loss utilisation of the LEAP III Primal machine as well as all integrated forequarter processing cells, and in extreme cases the operation of the entire LEAP system.

The arm is designed to clamp and hold the fore of the carcase while the Primal machine separates the Forequarter from the carcase, and then inverts and places the Forequarter onto the system integration belt that transfers Forequarters in a controlled and tracked manner to each of the LEAP V downstream cells.

2. Objectives

2.1 Project objectives

The key objectives of the project were to:

1. Design and build retrofittable packages for the critical Forequarter upgrades identified for existing and future LEAP systems.
2. Demonstrate the upgrades through installation on an existing LEAP system.

A final report detailing the upgraded packages was prepared.

3. Methodology

3.1 LEAP V Integration arm upgrades

The first Scott/MLA LEAP V Forequarter system was installed as a production system in 2019. Currently there are 7 robotic Forequarter cells in operation having processed more than 2 million carcases with a further 3 cells being manufactured for installation in the next 6 months. 6 of the existing systems are automatically integrated with a LEAP III Primal machine. With the existing systems in operation there has been a great deal of data acquired through system operation and scheduled maintenance relating to uptime reliability, effectiveness, and efficiency. The data (in the form of database records and maintenance logs) provide an opportunity to identify and target system improvements which are well understood to be important in the first few years of operation as the systems are tested with quantity of processed product as well as experiencing the full range of seasonal variation.

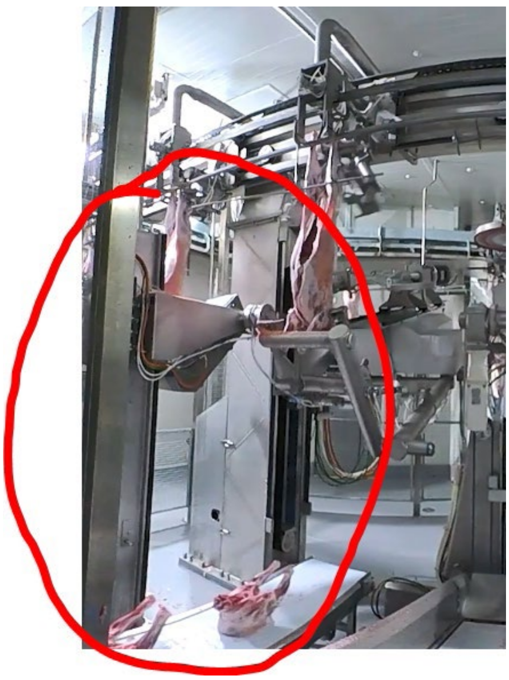

Figure 4: Existing integration arm and processed more than 2 million products over 2 seasons.

Shown (and circled) in Figure 4 is the existing arm design that has been in operation for two years within an Australian processor facility with over 2 million carcases processed to date.

The upgrades identified to be addressed in this project include a LEAP V Forequarter integration lifter arm mechanical upgrade to improve reliability and uptime as well as a LEAP III Forequarter integration arm upgrade to improve reliability and uptime.

As a result of this project Scott and MLA will have a set of upgrades that can be rolled out as retrofittable packages to any existing machines, as well as incorporated as standard into new machines. This will present an opportunity for greater ROI for these machines and for the industry more broadly.

Records show that initial integration arm component sizing has been undersized for the range of Forequarter variation seen over a season. The records highlighted the following key areas of concern:

- The main vertical carriage linear track and mount frame has suffered from distortion and fatigue.
- The main pivot axis that inverts the separated forequarter has reduced performance and fatigue failure due to the inertia sustained at 10 parts per minute with heavy lamb forequarters.
- The structural arm that extends underneath the lamb carcase suffers fatigue with the inertia of large forequarters accelerating to clear the Primal cutting assembly within the required cycle time at full extension.

Figure 5: Main pivot has been identified as undersize for full range of Australian product.

Within these areas of concern there are several significant failure modes on the first Primal Forequarter Integration tower which have led to some fixes being made during operation, which are within this project either addressed by way of a new design or incorporated into the upgrade package as permanent fix using the changes made during production incorporated into the latest production design. The key failures experienced early in the integration arm life included:

1. Carriage weld failures.
2. Tower bending and Linear bearing overloading due to the cutting load.
3. Clamp offset and placement onto the FQP load indexing belt.
4. Cycle time – vertical carriage.

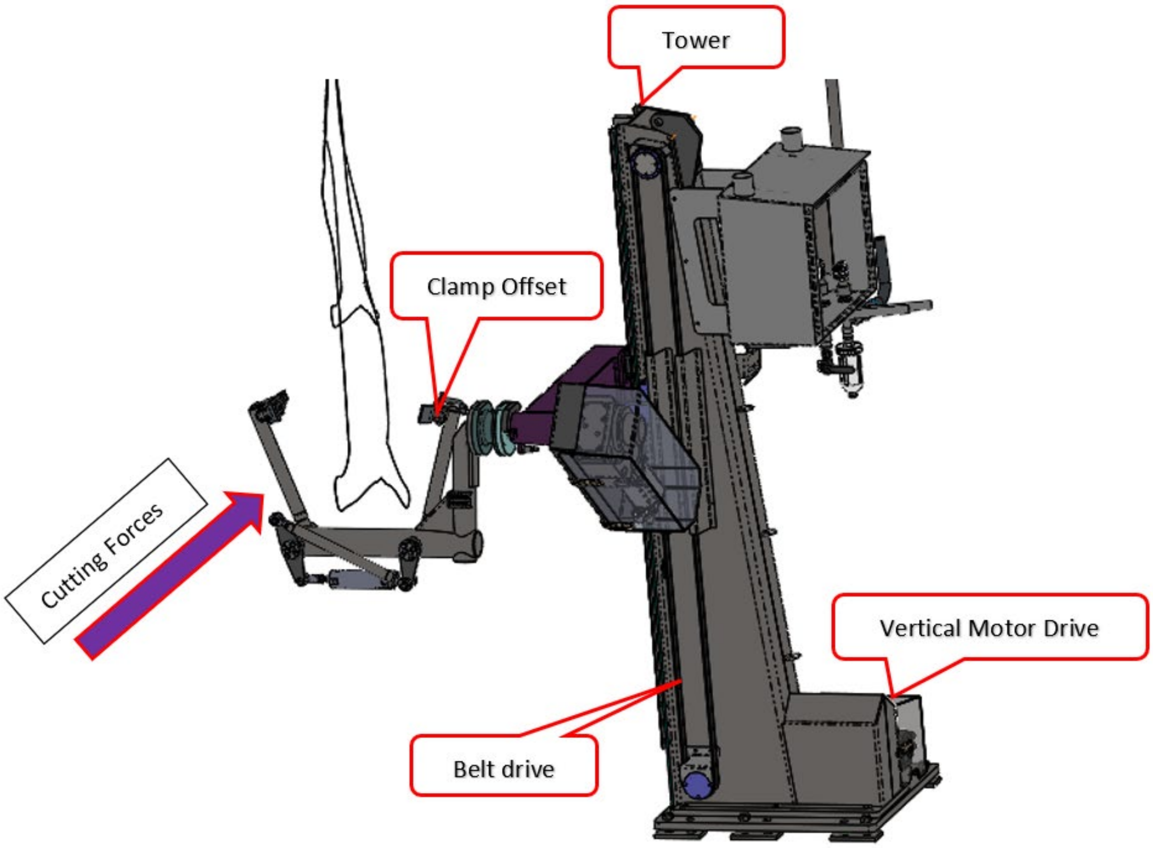

Figure 6: Original FQ Integration Tower as first installed into a production environment.

Carriage weld failure

Due to the large cutting forces encountered during production we found a weld fatigue crack in the clamp carriage after just over a year of operation. At the time the clamp carriage was re-welded and re-enforced using available section and in a manner that kept the system in service. The solution for this was identified to design and remake a stronger carriage which is reshaped to avoid having stress raiser in the areas shown on the following page.

Furthermore, the structural arm that extends underneath the lamb carcase suffers fatigue with the inertia of large forequarter product accelerating to clear the Primal cutting assembly within the required cycle time at full extension. Additional Figures related to the weld fatigue areas are available in Appendix 8.1.

As a result, a series of mechanical strengthening's and component sizing has been re-conceptualised and designed to make the carriage bigger and utilise a larger motor with increased pulley and transmission belt drive. These address the historical operational and failure records that, when addressed, will significantly lift machine performance, reliability, accuracy, and cycle speed. The build and demonstration of these upgrades are discussed further in the results section of this report.

Tower Deflection and Linear Bearing Failure

With higher-than-expected inertial load introduced by accelerations required to meet cycle time and heavier than anticipated product it was found that the original sizing of linear bearings was unable to meet a satisfactory lifespan. The initial solution was to retrofit a Linear Bearing with higher capacity. These have 2.5 times the moment load capacity compared to the original bearings and are much better at taking load from cutting forces. It was found that the solution required involved a redesign of the carriage transfer mount plate to bring forward the increased performance to new builds.

Figure 7: Example of Vertical carriage tracks are found to have suffered distortion and excessive wear.

Additionally with the higher than anticipated loads it was identified that a revised structural strength of the Vertical tower was required to facilitate the cutting forces when cutting small lambs which induced significant loads on the tower itself and the linear bearings. This involves implementing internal bracing plates within the tower on future models.

Clamp offset and placement onto the Forequarter integration transfer indexing belt.

Resulting from analysis of the initial installation, the clamp arms have been modified in situ to position the forequarters on the belt without a product offset when cutting at the full range of angles. The initial installation experienced issues retaining small forequarters with a large fat cover, particularly if the fat cover was not set hard through the chill process as well as large forequarters being rotated about an offset axis. It was discovered that applying strategically placed spike pins to the clamp pads to avoid the product slipping or becoming misaligned was highly effective at managing the full range of specifications and inputs. Movement of the forequarter in the clamp pads translates directly to mis-aligned placement on the integration system and results in an incorrect presentation to the forequarter processing cells. It is therefore critical for Forequarter Robot processing stations as this has a direct effect on cut accuracy and must line within the robot pickup limits.

Cycle time – vertical carriage.

With the greater than expected loads and resulting in situ changes made and re-commissioning to achieve 10 forequarters per minute across 3 forequarter bone in processing cells made described above the rating of the servo motor and gearbox on the vertical tower had to be increased to achieve the required index time. This also required an increase in the transmission system including wider drive belts and pulleys.

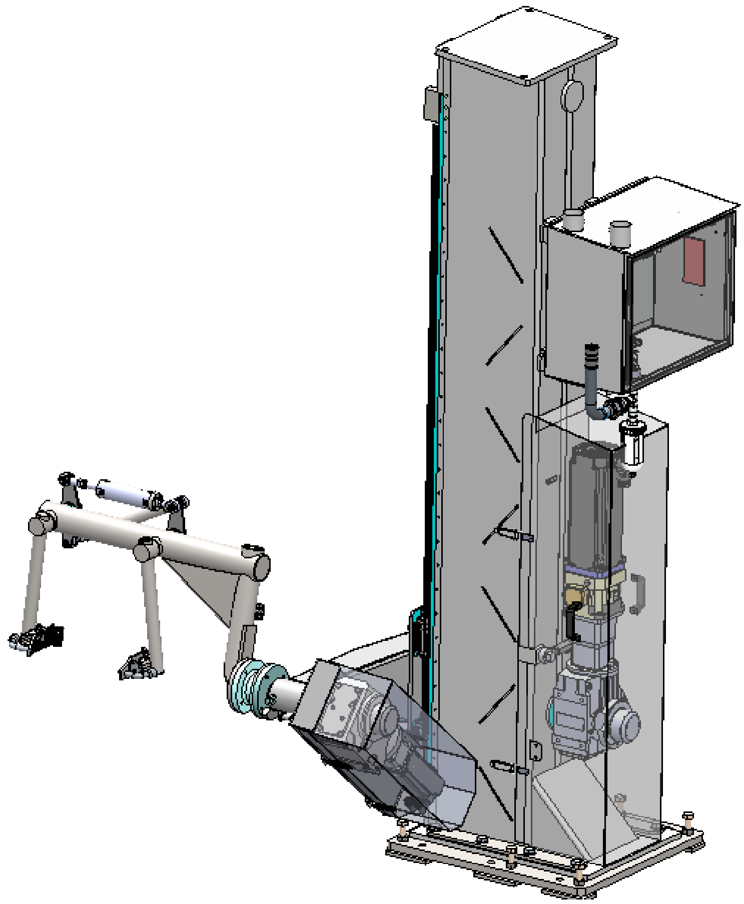

Figure 8: Improved Tower with fixes designed into upgrade kit.

3.2 LEAP V Lifter arm upgrades

Forequarter bone-in (square cut) processing involves removal of knuckle tips, the neck (as one piece or as slices), the breast pieces, the shanks, cut through the round bone and splitting the square shoulder down the centre of the spine to expose the spinal cavity. Forequarter sizes, shapes, weights, and symmetry vary significantly from product to product, between locations, across seasons as well as over time as advances in genetics and animal husbandry result in phenotypic evolution. The LEAP V system materials handling has a requirement to accommodate the variation in product, as well as to ensure that product feature location measurements and information is retained from upstream sensing.

As such the LEAP V system materials handling assemblies need to be robust and have the flexibility to position product and ensure accuracy as well as mechanical uptime and processing efficiency can be achieved accurately and reliably.

The Forequarter lifter arm, shown in Figure 9, is integral to both measurement of the forequarter as well as positioning the forequarter within the robot end effector to enable all cuts to be performed accurately and reliably without yield loss or downtime. The lifter arm acts to retrieve the forequarter from the Primal machine integration device (belt) and present it in a controlled manner to the robotic end effector.

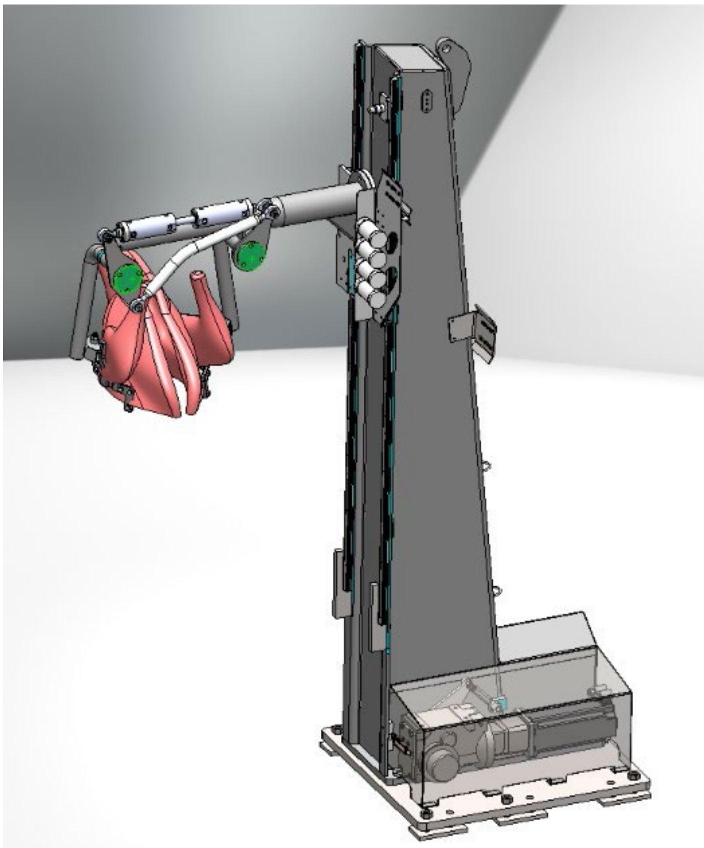

Figure 9: 3D model of the existing LEAP V lifter arm.

The first Scott/MLA LEAP V Forequarter system was installed as a production system in 2019. Currently there are 9 robotic Forequarter cells in operation having processed more than 3 million carcases with a further 3 cells being manufactured for installation in the next 12 months as of November 2023. 8 of the existing LEAP V Forequarter systems are automatically integrated with a LEAP III Primal machine. A significant amount of data has been acquired through system operation and scheduled maintenance relating to uptime reliability, effectiveness, and efficiency. The data (in the form of database records and maintenance logs) provide an opportunity to identify and target system improvements.

In the lead up to, as well as in the initial stages of this project, Scott undertook an analysis of the various data sources including:

1. System fault log data: The LEAP system both records and stores a log of critical faults with information pertaining to the time, date, device that has caused an error and the amount of time that the system is affected.
2. Maintenance logs: Scott are closely partnered with processing plants where LEAP systems are installed and perform both planned and un-planned maintenance. A log of corrective actions is recorded to guide machine lifecycle management.
3. System failures records: It is sometimes the case when a development first goes into production that un-foreseen failures can occur if a processing variable has not been sufficiently understood at the design phase. A log of any failures is held by the product development team and provide insight into critical improvements for systems that have progressed from development to early stages of production.
4. Yield test results.

This analysis has highlighted the following key improvements that are being targeted in this project:

The LEAP V lifter arm is integral to transfer of forequarters within the LEAP V forequarter bone in processing cells. Any movement of the product as the lifter arm is manoeuvred will result in a loss in accuracy and possible failure within the forequarter cutting cell. The existing arm has been in operation for two years now and an important upgrade has been identified to improve the clamping performance and product stability.

Typical symptoms that occur when the LEAP V lifter arm is not operating successfully include:

- Forequarters moving in the robotic end effector leading to mis-aligned cuts and loss of yield,
- Forequarter cell not meeting cycle time requirements, and,
- Worst case forequarters dislodging from the system and not being processed.

Records show that initial lifter arm design has been undersized for the range of Forequarter variation seen over a season. The records highlight the following key areas of concern:

- The main vertical carriage linear track and mount frame has suffered from distortion and fatigue.
- The structural arm that extends over the belt to pick-up the forequarter suffers fatigue with the inertia of large forequarter product accelerating to achieve the required cycle time.
- The gripper design allows product movement particularly with soft and laminated product.

Figure 10: Example where grippe design is being assessed for effective product handling.

As a result of this project Scott and MLA will have a set of upgrades that can be rolled out as retrofittable packages to any existing machines as well as incorporated as standard into new machines. This will present an opportunity for greater Return on Investment (ROI) for these machines and for the industry as a whole.

Lifter Vision Pickup Zone

It has been found through extensive commissioning and system monitoring that the Forequarter Robot cells were not able to pick up the product if it was outside the pickup zone and the product will be rejected by the vision camera. With the initial design and installation of the forequarter processing cells it was found that these rejects were reaching 5.2% (analysing a 120,000-forequarter dataset) which introduces significant costs for manually processing forequarters that were not presented correctly.

There has been significant development work done to reshape the clamp pads to allow for better clamping of product and to ensure the handover process between the lifter and the Robot end effector does not move the product. Additionally, clamp design was improved to increase the probability that the lifter mechanism clamps the product symmetrically to reduce handling errors. A focus of this improvement was to increase the clamp jaws opening distance as some product could get jammed on the load index belt. It was assessed from analysis of data collected from the original forequarter lifter and integration design that approximately 7% of forequarters were being rejected based on parameters that align with forequarter placement, which directly impacts location in the pickup zone, as well as movement in the clamp of the lifter station.

The upgrades performed have been incorporated into the designs for this upgrade kit and are implemented as discussed in the results section herein.

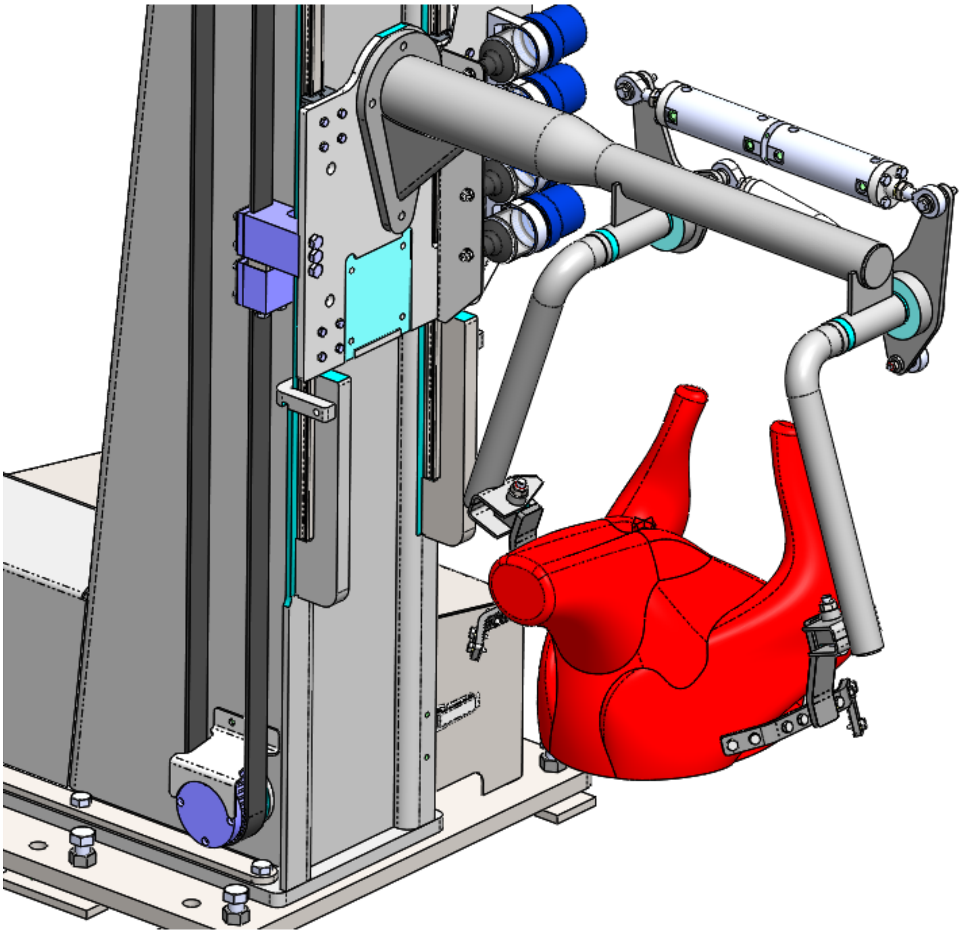

Figure 11: New design Forequarter lifter containing upgrade kit.

3.3Cost Benefit Methodology

The key activities in achieving the project objectives include:

- Measurement of accuracy in achieving cutting lines.
    - Data was collected i.e., distance measurements from target cutting lines, frequency of varying degrees of accuracy for each cut,
- Development and application of standards to quantify the cost of varied degrees of cutting accuracy.
    - This included the weighing of meat, fat, and bone for different widths of cuts for different primal weights.
- Review of all cutting specifications and their percentage of total product mix were assessed and integrated with labour savings by product line and product specific yield and value differences.

3.3.1 Standards and data collection

The data collected for each site was taken with respect to Handbook of Australian Meat (HAM) cutting line specifications, which makes each measurement a distance from zero, either positive or negative.

- For example, in case of a brisket (breastbone) removal from the square-cut shoulder, the HAM specification will be the divide line between white bone and red meat. **This point may be different to the site's target specification.**
- If the site's target specification deliberately cuts 10 mm long to put more weight on the shoulder, the machine seems inaccurate by 10 mm on average. The measurement from HAM specifications is demonstrated in Figure 31. The data is then normalised to the site target specification, so each cutting method's accuracy variation can be compared directly.

To support further analysis and show the value of each cutting method, accuracy distributions at the target specification are used to illustrate focus points of inaccuracy which do not come through in a box-and-whisker plot, clearly exampled in Figure 39. These focus points may point to an underlying issue with the machine and how it recognises cutting lines or how a change in manual bandsaw operator affects accuracy.

These three graphs:

1. Measurement variance from HAM cutting lines,
2. Cost of inaccuracy with target specification adjusted to HAM cutting line, and
3. Accuracy distributions at target specification,

depict how well the machine performs, and how well the site uses it.

Greenleaf Enterprises established method and model for determining cutting accuracy, yield, and value for the various cuts (knuckle tipping, brisket bone removal, shank removal, neck removal, splitting shoulders) and products (knuckle as bone, shoulder, neck, shank, breast) was applied. These standards are used to convert accuracy measures into weights of meat, which can be converted into a dollar value. Standard yields were determined by correlating yield weights with measurements for each of the products (shoulder, shank, breast, neck, knuckle tip). Figure 12 and Figure 13 show examples of the data collection methods used for the removal of the shank and neck respectively.

Figure 12: Weighing different thickness of shank to establish costing standards for cutting line accuracy to remove shank.

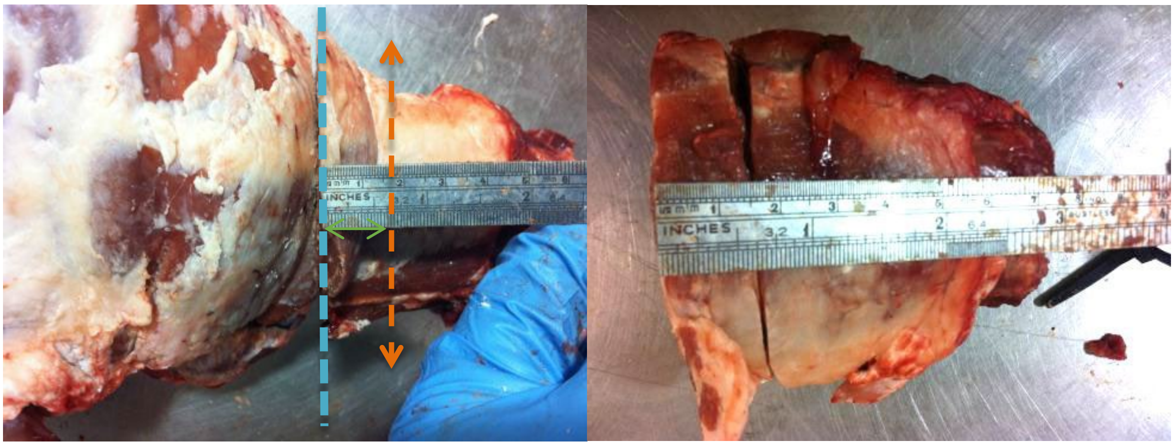

Figure 13: Neck cut accuracy.

4. Results

4.1 Upgrade kit build

The Scott/MLA LEAP V integration and lift arm upgrade kit was conceptualised and designed in Milestone 1 and then manufactured in the SCOTT Dunedin factory in Milestone 2.

An opportunity was leveraged to install the upgrade kit as part of a new system that built and installed in the first half of calendar year (CY) 2022. Leveraging this opportunity has allowed the upgrade kit to be assessed in a production environment as well as uncover any challenges with integrating with the inter-connecting stations.

Fitting the upgrades to a new system also has the added benefit that it is representative of the latest design version LEAP system, which ensures that new systems can accommodate the upgrade kit as well as being certain that pre-existing LEAP installations are compatible with the upgrade kit.

Figure 14: Recent system assembly is being used to incorporate of the build of the upgrade kit components.

The LEAP system used here as a testbed for the upgrade kit was configured with a DEXA x-ray, Primal cutting system, Middle processing system and 2 forequarter cells for a total bone in processing capacity of 10 lamb carcases per minute into the full range of bone in cut specifications and within this the ability to process 6.5 forequarters per minute into the select range of bone in cut specifications.

The system configuration was aligned to the standard LEAP configurations except for a newly designed Forequarter integration transfer which incorporated a flexible curvilinear belt able to facilitate the placement of the forequarter bone in processing cells parallel to the alignment of, and separated by distance from, the Primal cutting system.

4.1.1 LEAP V Forequarter integration arm build

Integration arm build was completed without any significant issues, albeit, several of the proprietary components used within the design had extended lead times due to COVID restrictions and global events effecting logistics and supply chains. These delays resulting in a longer than anticipated build time, although fortunately, some efficiencies were able to be identified which made completion of Milestone 2 possible within the originally scheduled timeframe. It was also noted that the delays on the proprietary components related to temporary supply conditions and that there was no indication that long term supply issues or availability would be experienced.

The build and integration with the interconnecting station assemblies occurred seamlessly without any need for re-work or design modification into a location within the Scott Dunedin factory where components could be assembled in a manner that correlates directly to how the system was to be configured in the production environment.

Clamp transfers assembled within expected tolerances and movement of axis were smooth and without restriction. The wider transmission belts and pulleys installed true and aligned, and the product clamp mechanism aligned well with the Primal cutting station and forequarter integration transfer.

Importantly there were no interference or collision points identified between the new upsized and strengthened components within the assembly or with interconnecting assemblies. This was tested for the full range of motion profiles.

With the build performing as anticipated meant that there was a high chance the station would install and commissioning within the production environment without issue.

Figure 15: Upgraded forequarter integration station build implemented onto a recent system assembly.

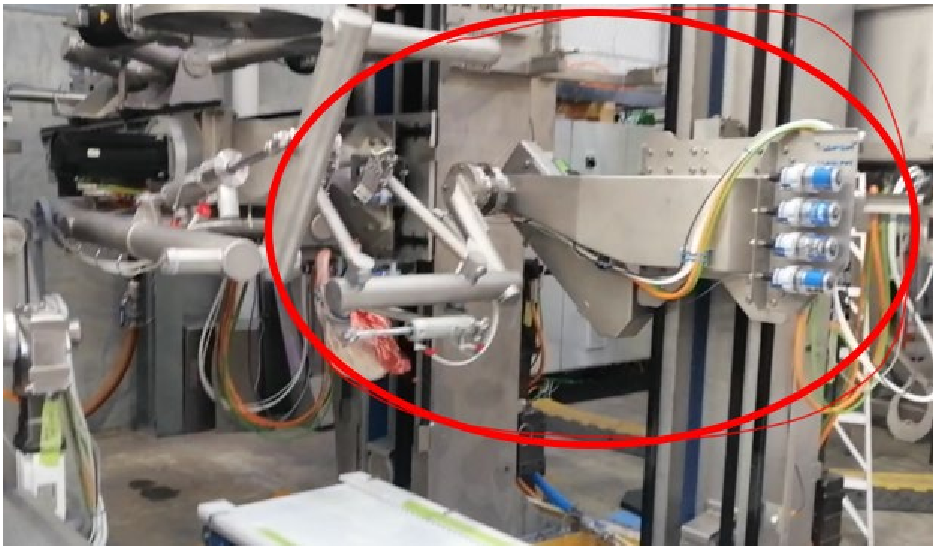

Figure 16: Upgraded forequarter integration arm has been strengthened and has enhanced load bearing capability.

It is well understood from analysis of the original forequarter system performance data that movement of the forequarter in the clamp pads will translate directly to mis-aligned placement on the integration system and result in an incorrect presentation to the forequarter processing cells. The build and demonstration of the upgrade kits has shown that this product movement is significantly improved.

Figure 17: Upgraded forequarter integration arm shows improved forequarter placement.

It has been determined from analysis of the original forequarter robot cells that product outside the pickup zone was not able to be picked up and processed successfully and therefore the system rejects the forequarters for manual processing. With the original design it was found that these rejects were reaching over 5.2%.

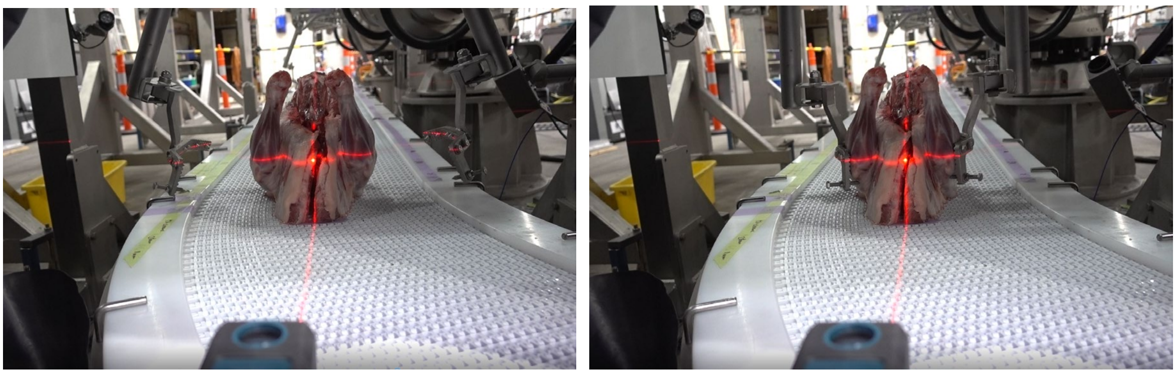

Figure 18: Reliable forequarter placement translates to a reliable location in the pickup zone for the forequarter lifter stations.

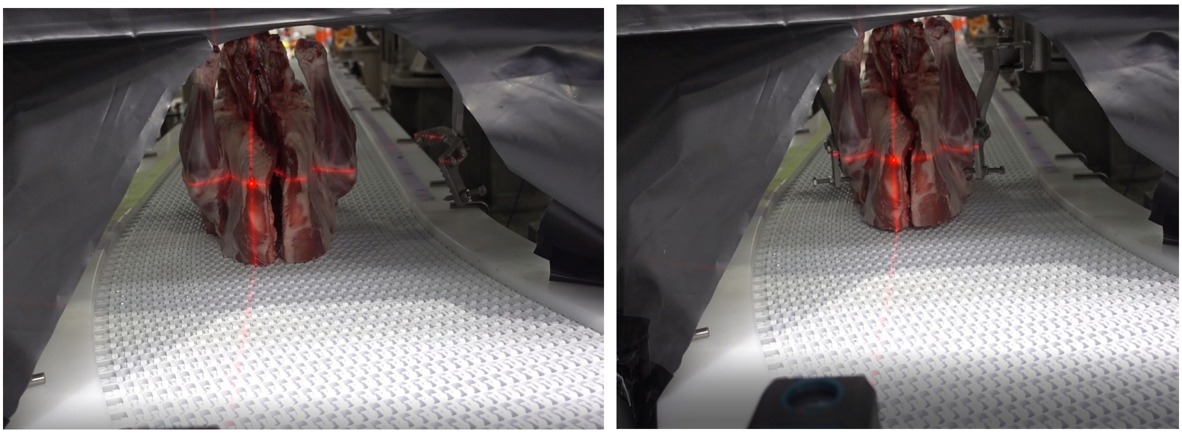

Figure 19: Poor placement by the forequarter integration will result in poor location in the pickup zone.

It has been demonstrated through preliminary analysis of the upgrade kit that the alignment of the forequarters is significantly enhanced and where over 7% of forequarters were being rejected onto the infeed (load) conveyor due to a combination of off-centre placement as well as movement in the clamps in the original design, the upgraded design has improved this to a level where it is barely measurable from a limited trial sample achievable in this Milestone. After the upgrade rejection of forequarters due to the forequarters being placed out of alignment was no longer detected.

4.1.2 LEAP V Lift Arm upgrade build

The lift arm build was also completed without any significant issues, yet, similar to the integration arm build, suffered from various of the proprietary components experiencing extended lead times resulting in a longer than anticipated build time, again fortunately, some efficiencies were able to be identified which has made completion of Milestone 2 possible within the originally scheduled timeframe. It was also noted that the delays on the proprietary components related to temporary supply conditions and that there was no indication that long term supply issues or availability would be experienced.

Figure 20: Lifter arms during the build phase – Fabrication and assembly completed successfully without notable issue.

As the system to be used for demonstrating the upgrade kit has two forequarter robot cells, the build also included two upgraded lifter arms. The pair of lifter arms are programmed to synchronise based on an algorithm that delivers cut forequarters in a single stream with an even distribution between the two cells. It is imperative therefore that the lifter arms can achieve the required cycle time at the risk of reducing the efficiency of both forequarter cells with any over-run-in cycle which translates to more than double time penalty for the entire LEAP system. At the completion of the build process, the two lift arm stations were cycled to prove that they operate comfortably within the design cycle time.

Figure 21: Lifter arms were cycled to test for cycle time at the completion of the build phase.

4.2 Installation & Demonstration at a processing site

The SCOTT/MLA LEAP V integration and lift arm upgrade kit was part of the SCOTT Leap system installed and commissioned at a host lamb processing site which came into operation in the first half of 2022. The system upgrades were installed and operated without issue and have shown to be effective in achieving the desired outcomes.

To satisfy the requirements of Milestone 2 and prepare for the analysis of the benefit achieved in Milestone 3, an opportunity was leveraged to demonstrate the upgrade kit as part of a new system commissioned in early 2022. The system contained all the key elements of the upgrade kit and has been running in a production environment at full specification limits.

Leveraging this opportunity provided the ability to fine tune the upgraded components for cycle time, product size variations, product consistency variations, product quality variations and cut specification range significantly reducing the time and complexity trying to achieve this during production on a pre-existing installation.

Figure 22: System installation being used for demonstration of the upgrade kit components in production environment.

Figure 23: Forequarter integration station upgrade kit commissioning and demonstration on a production system.

Work completed on upgrading the lifter camps to prevent the lifter arms going out of alignment, being one of the key contributors to rejects at older sites, has been successful in demonstration. Analysis over 5 months of production on the upgraded site installation have not found the lifter arms moving out of alignment or causing the issues originally identified as leading to rejects. During this time, a full range of typical product variations have been run and roughly half a season of seasonal variation has been experienced.

Importantly the typical symptoms experienced on the original design were not occurring including:

- Forequarters sitting skewed in the robot end effector which can lead to an inability to successfully split central to the spinal cavity (meaning the cavity cannot be cleaned sufficiently without further processing),
- Forequarters moving in the robotic end effector leading to mis-aligned cuts and loss of yield,
- Forequarter cell not meeting cycle time requirements, and,
- Worst case forequarters dislodging from the system and not being processed.

The upgrades have resulted in better placement, so better location under primal tower, reduced reject rates to near zero and reliable location of the forequarters in pickup window.

Figure 24: Forequarter lifer arm assemblies installed into production environment ready for demonstration.

A preliminary assessment has been completed as an indication of success and from a finite dataset and observation, rejects related to out of alignment product presented to the robot gripper, which includes product movement in the clamp and lifter station, have reduced from over 7% identified on the original design to no detectable issues causing rejection.

4.3 Cost benefit analysis results

4.3.1 Cutting line accuracy

The benefit by cut for the plant, over manual cutting, is (cut prices obtained in June 2023):

	MK. 1	MK. 2	EXPLANATION
KNUCKLE TIP	0.06 to 0.08 $/hd	0.08 to 0.09 $/hd	-
SHANK REMOVAL	-	-	No benefit; shank = shoulder price
BRISKET REMOVAL	0.03 to 0.03 $/hd	0.03 to 0.04 $/hd	-
NECK REMOVAL	0.12 to 0.13 $/hd	0.21 to 0.20 $/hd	-
SHOULDER SPLIT	-	-	No benefit; left = right price

The yield benefits associated with the automation of the shoulder cuts is mainly contributed to the removal of the brisket and neck. This is due to the variation in the value of cuts between each side of the cutting lines.

4.3.2 Shoulder Split

The final cut splitting the left and right sides of the forequarter passes through the spinal column and should separate the vertebrae leaving equal amounts of bone on each primal as in Figure 25.

There is no value added to this cut as both the shoulders are sold at the same value, as long as the LEAP V robot performs the cut within ± 5mm from the centre line of the vertebra. This has been validated under MK. 1 installs at various sites. The variation observed may be caused by movement when transferring the product between two robotic cells.

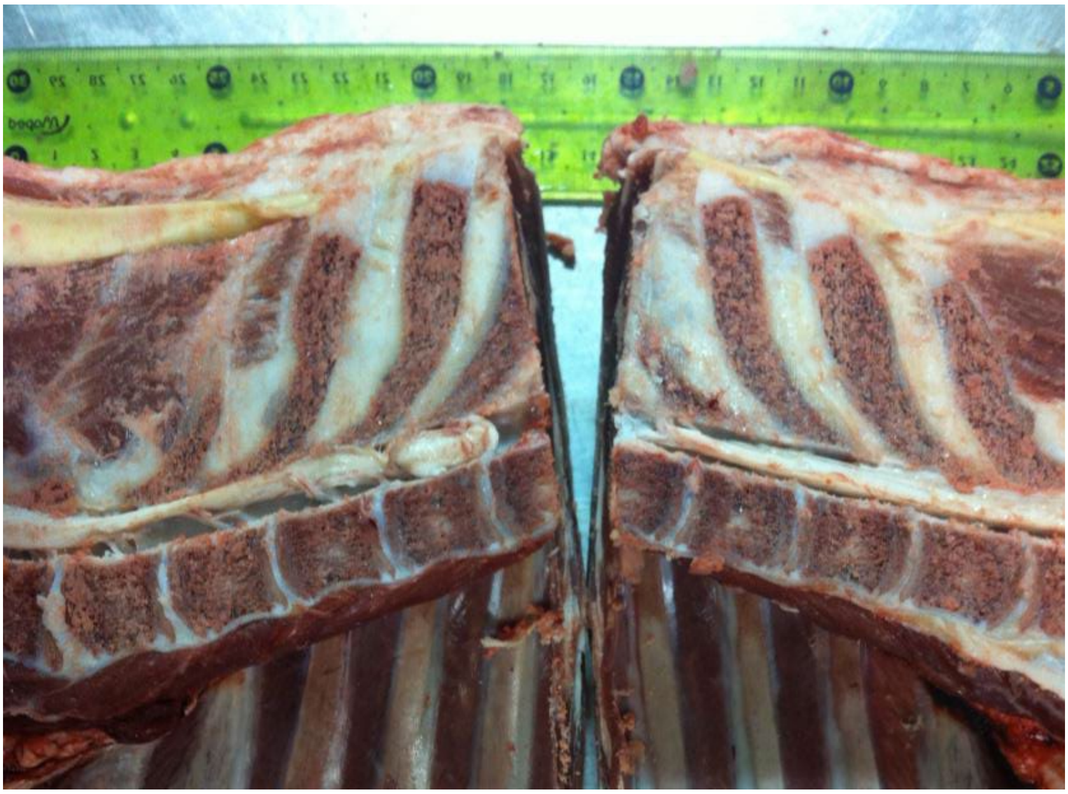

Figure 25: Perfect cutting line leaves equal amounts of spinous process on each primal and spinal column split in half.

4.3.3 Neck removal

Separation of the neck from the forequarter should be parallel to the backbone for unstrung carcases and perpendicular to the neck vertebrae for strung carcases in Figure 26. Only Unstrung carcases were observed during the data collection for all three systems.

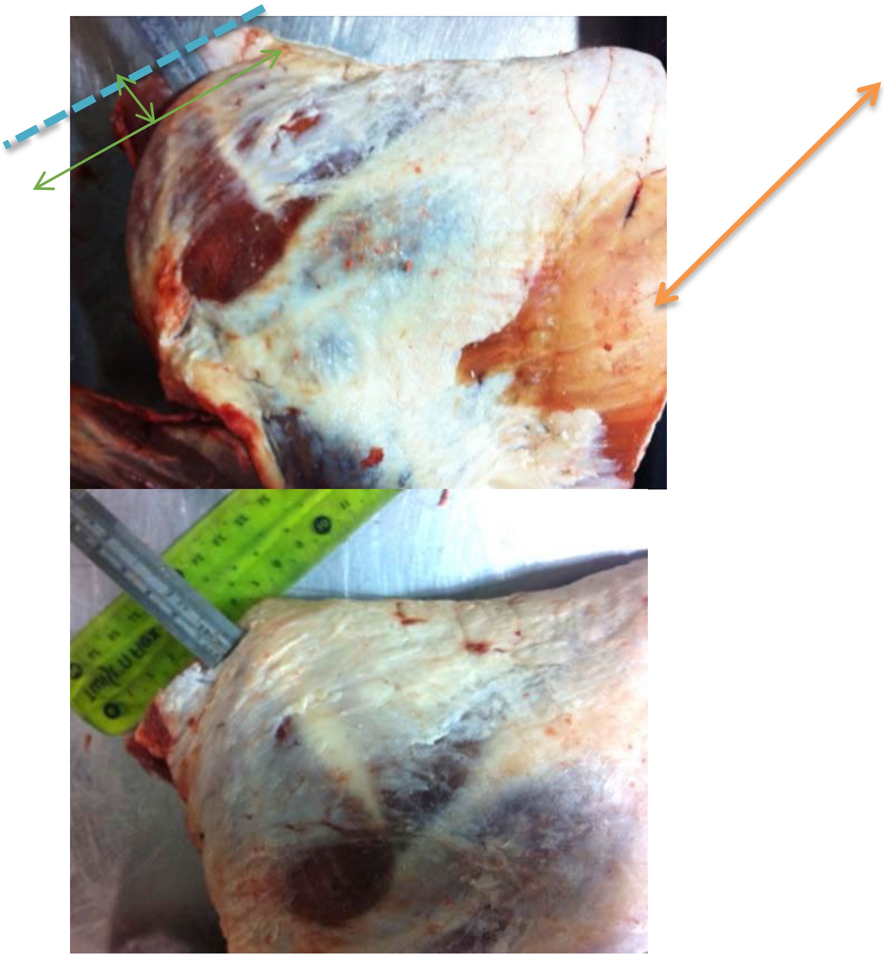

Figure 26: Removal of neck from forequarter perpendicular to neck for unstrung carcases

The accuracy for each system (Manual, MK. 1, and MK. 2) can be seen in Figure 27. Both systems have reduced the variation in accuracy when compared to the manual operator. The accuracy of the MK 2 system is similar for the 25 to 75 percentile band but the overall variation in accuracy has increased slightly over MK. 1. This may have been caused by the MK 2 system being in the final stages of commissioning when compared to the MK 1 system.

Plant staff operating the MK 2 system can push the length of the neck slightly longer, this increases the value generated by the system, see Figure 28. **On average the plant is gaining $0.20 to $0.21/head** when compared to the manual operators. This is an **increase in value of $0.08/ head from the MK 1 system,** but this is due to plant pushing the cutting line specifications not an increase in accuracy from the upgrades.

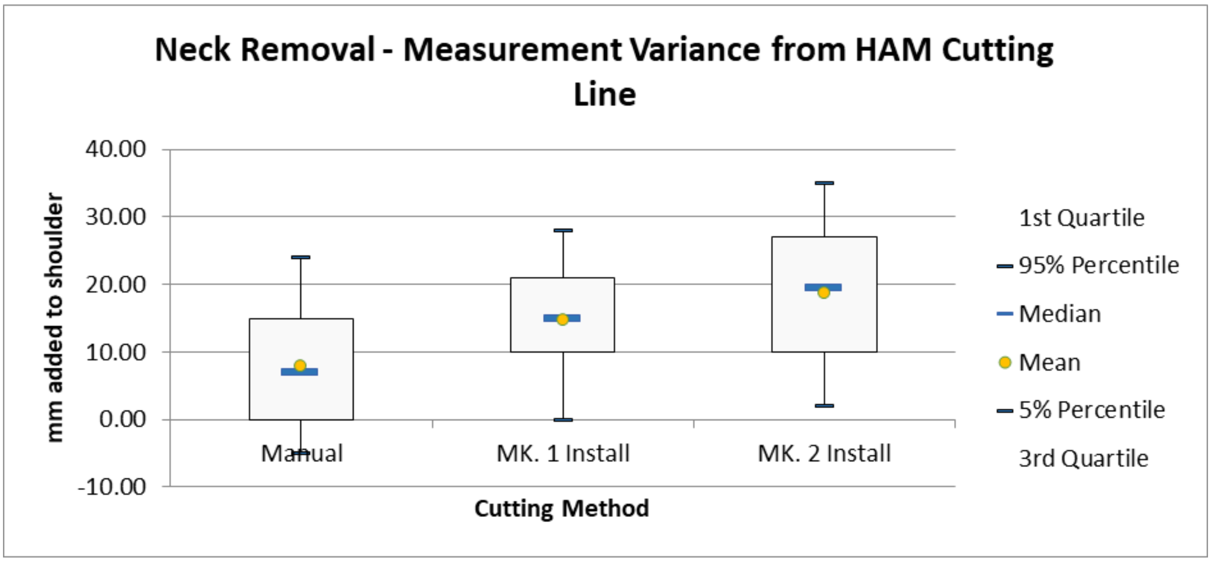

Figure 27: Neck-Shoulder separation accuracy

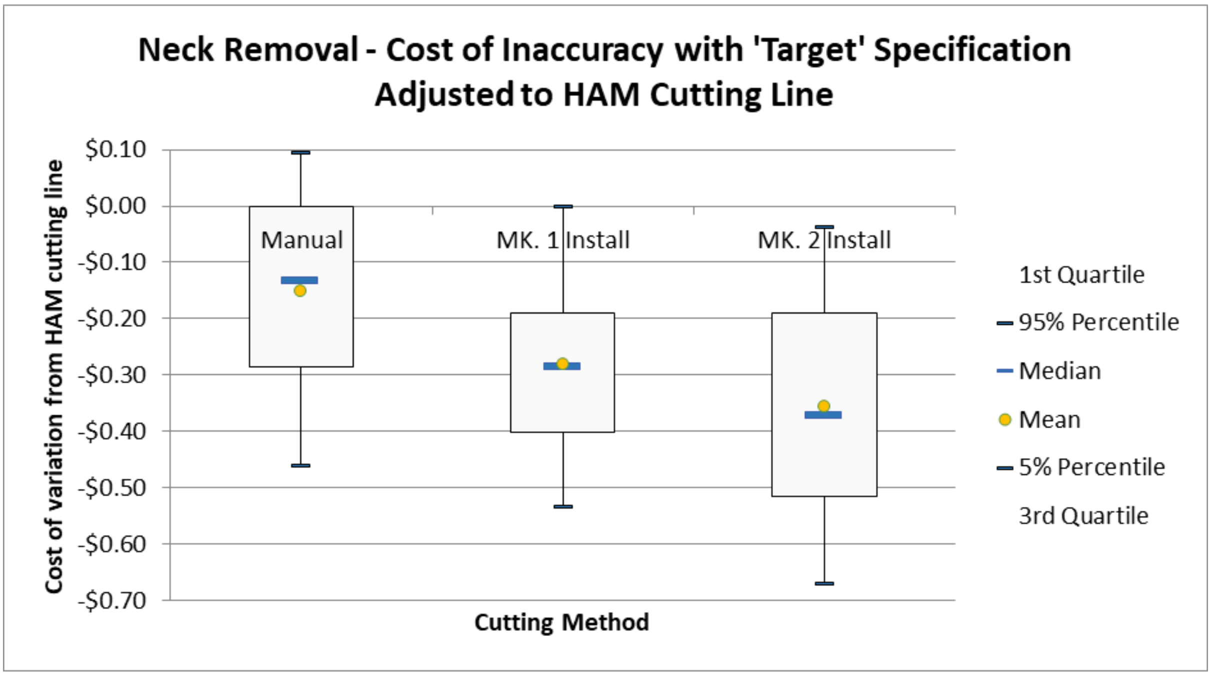

Figure 28: Cost of loss value for the neck removal. The results are all negative as the operators are increasing the weight of the shoulder and decreasing the weight of the neck.

4.3.4 Brisket Removal

Removal of brisket from the forequarter is completed by the forequarter robot making a straight cut across the full forequarter perpendicular to the midline of the vertebrae. The saw cut through the brisket must leave the elbow joint intact and, on some carcases, drops down very low on the brisket. The cut removing the brisket is usually parallel to the back. Where the elbow joint is too low the robot angles the cut to remove enough brisket to meet customer specifications as in Figure 29. A maximum of 45mm of brisket is removed, measured from the brisket tip as shown in Figure 30.

Figure 29: Removing brisket without tipping elbow joint sometimes requires angled cut to ensure enough brisket removal.

Figure 30: Removal of brisket no more than 45mm from the brisket tip.

The accuracy for each system (Manual, MK. 1, and MK. 2) can be seen in Figure 31. Both systems have reduced the variation in accuracy when compared to the manual operator. The accuracy of the MK 2 system has become worse between the 25 to 75 percentile band. This may have been caused by the MK 2 system being in the final stages of commissioning when compared to the MK 1 system. However, the plant management operating the MK 2 system can push the length of the neck slightly longer, this increases the value generated by the system, see Figure 32. **On average, the plant gains $ 0.03/head** compared to manual operators. This is an **increase in value of $0.01/ head from the MK 1 system,** but this is due to plant pushing the cutting line specifications, not an increase in accuracy from the upgrades.

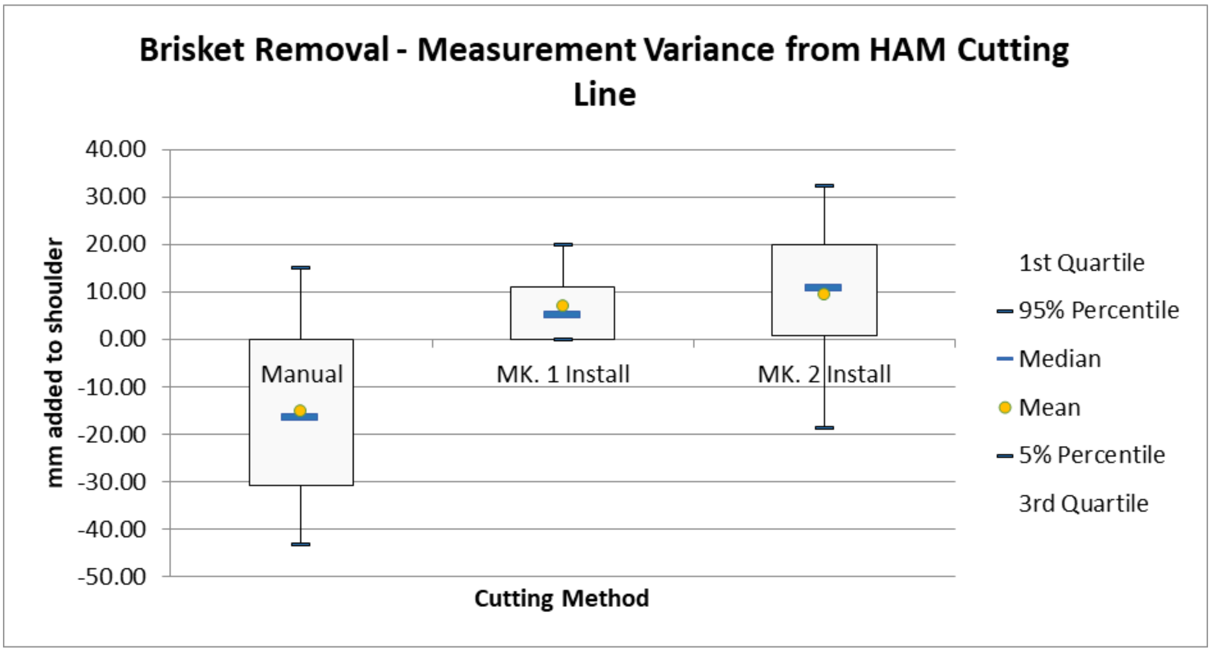

Figure 31: Breast - shoulder separation accuracy

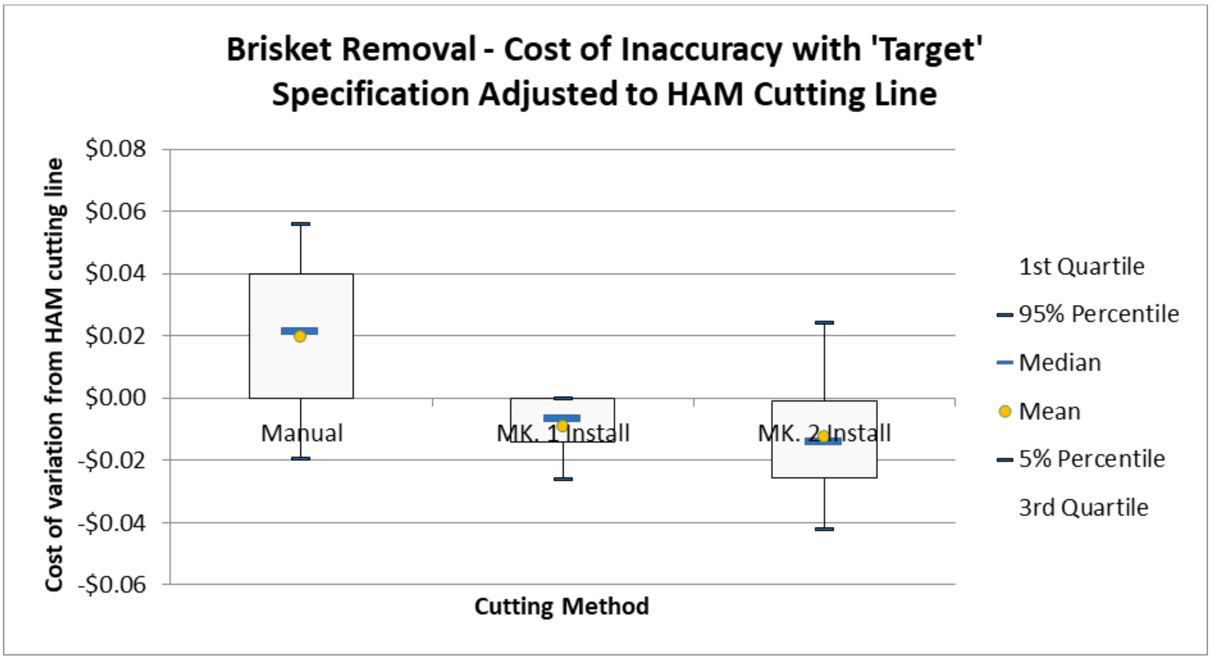

Figure 32: Cost of loss value for the brisket removal. Negative costs (benefits) mean increasing the weight of the shoulder and decreasing the weight of the breastbone.

The value of this cut will vary plant to plant depending on the value of brisket tips and shoulders. The benefit of automating this cut would be to modify the cutting line depending on the value of each cut. The automated solution will allow the specifications to be modified to increase the value of the cut.

4.1.3 Shank Removal

Removal of shank is parallel to the back and just through the junction between the shank and the brisket as in Figure 33 below. Shank and brisket should be removed in the same cut with both parts being barely joined as in Figure 34. A range of cutting lines and the resultant weight of each were captured during the trials.

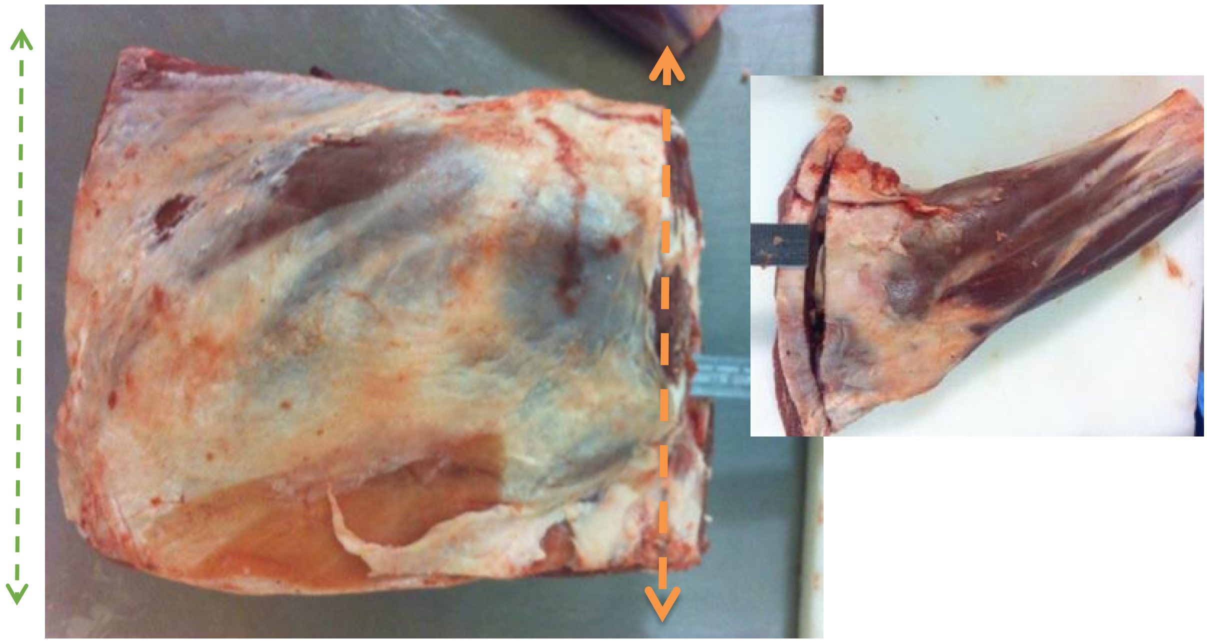

Figure 33: Removal of shank from forequarter parallel to the back

Figure 34: Brisket and shank removed at the point where both attach to the forequarter.

The accuracy for each system (Manual, MK. 1, and MK. 2) can be seen in Figure 35. Both systems have reduced the variation in accuracy when compared to the manual operator. The accuracy of the MK 2 system has become worse for the 25 to 75 percentile band. This may have been caused by the MK 2 system being in the final stages of commissioning when compared to the MK 1 system. However, the plant management operating the MK 2 system can push the length of the neck slightly longer. This increases the value generated by the system.

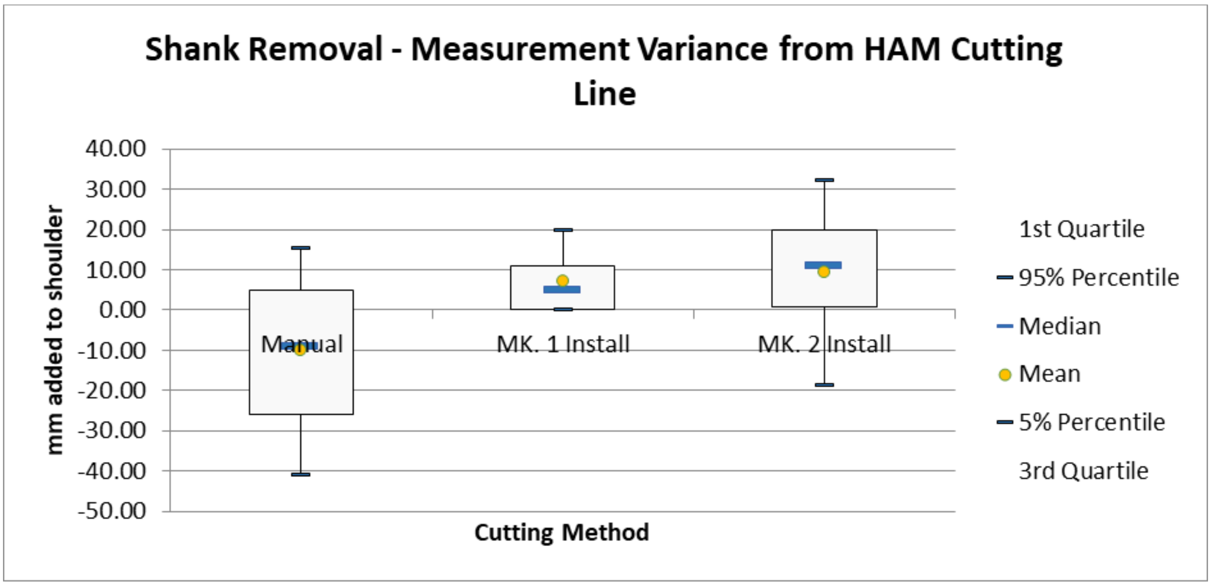

Figure 35: Shank - shoulder separation accuracy

The value of this cut will vary between plant to plant depending on the value of shanks and shoulders. With currently equal prices between shanks and shoulders, there is no cost benefit. The benefit of automating this cut would be to modify the cutting line as the value of each cut changes. The automated solution will allow the specifications to be modified to increase the value of the cut.

4.1.4 Knuckle tip

Knuckle tipping is a single cut removing the leg bone from the shank above the knuckle joint as shown in Figure 36 and Figure 37. The accuracy of this cut is relatively high with only minimal variation within 10mm of the ideal location of the cut. The value which can be added to the cut could be maximised if the location of the blue line in Figure 36 could be increased within the customer specifications.

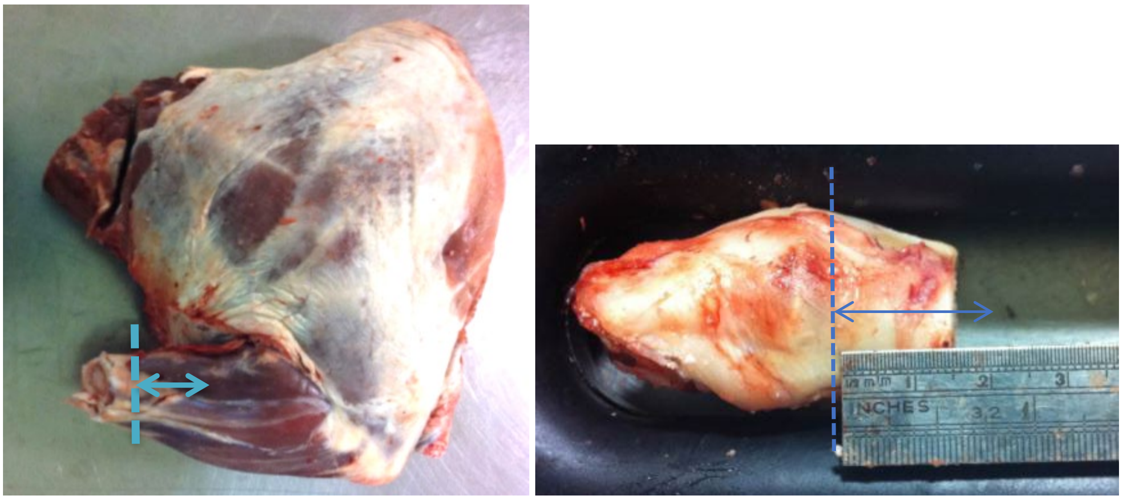

Figure 36: Removal of knuckle from fore shank

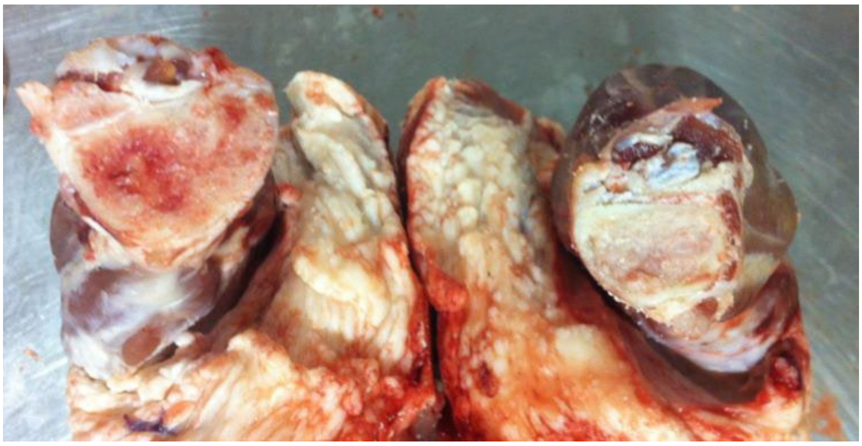

Figure 37: Left knuckle removed at the joint. Right knuckle cut higher up into shank.

The accuracy for each system (Manual MK. 1 and MK. 2) can be seen in Figure 38. Both systems have reduced the variation in accuracy when compared to the manual operator. The accuracy of the MK 2 system is similar for the 25 to 75 percentile band but the overall variation in accuracy has improved between the two systems. Additionally, plant management operating the MK 2 system can push the length of the neck slightly longer. This increases the value generated by the system, see Figure 39. **On average, the plant gains $ 0.09/head** compared to manual operators. This is an **increase in value of $ 0.02/head from the MK 1 system.**

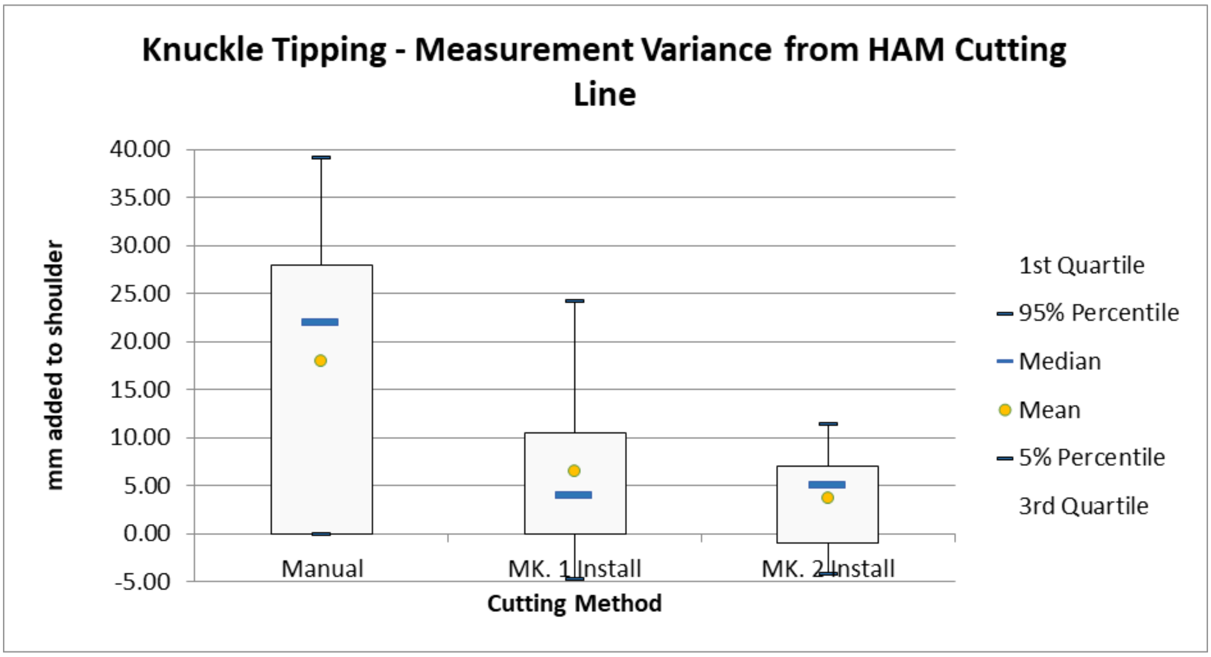

Figure 38: Knuckle - shank separation accuracy

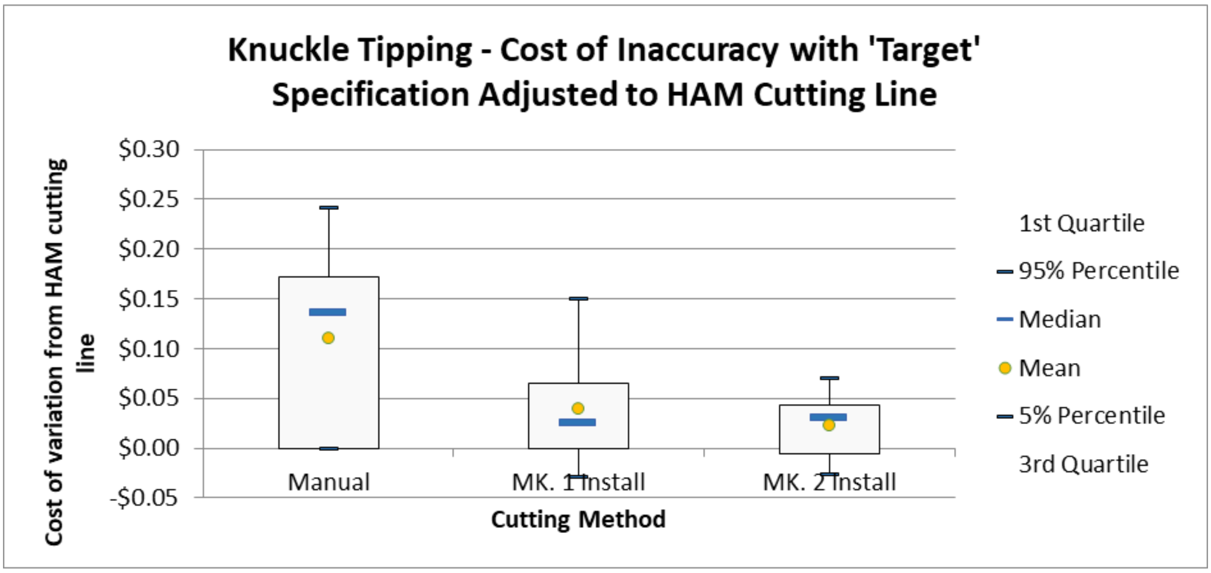

Figure 39: Cost of loss value for the knuckle tipping. Negative costs (benefits) mean increasing the weight of the shank and decreasing the weight of the knuckle.

The value of this cut will vary plant to plant depending on the value of knuckle tips and shanks. The price differential of knuckle tips as bones and shanks is assumed to be worth $6.50/kg. The benefit of automating this cut would be to modify the cutting line depending on the value of each cut, eliminate operator bias, and guarantee pushing the boundaries of customer spec. The automated solution will allow the specifications to be modified to increase the value of the cut.

4.2 Operational benefit

4.2.1 Cost Benefit Results

The summary results in Table 3 demonstrate the benefit of the LEAP V system over manual performance and compares the MK. 1 and MK. 2 installs. The value came from yield benefits, occupational health and safety savings and labour savings. There has been no improvement in the efficiency of the boning room factored into the cost benefit analysis as additional factors affect the ability of the LEAP V system to increase the throughput.

The net benefit expected for the system was up to $ 0.20/hd (net benefit) under the MK. 1 system install. The MK. 2 system, as installed, increases that value to a $ 0.29/hd net benefit.

Table 3: Summary of benefits

SUMMARY PERFORMANCE MEASURES				
	MK. 1 Install		MK. 2 Install	
Hd / annum	2,122,038		2,122,038	
Production increase with equipment	2.06%		2.06%	
	From	To	From	To
Capital cost (pmt option, upfront)	$2,875,000		$2,875,000	
Gross return Per head	$0.33	$0.36	$0.45	$0.43
Total costs Per head	$0.16		$0.16	
Net Benefit Per head	$0.17	$0.20	$0.29	$0.28
Annual Net Benefit for the plant	$ 363,750	$ 431,340	$ 614,049	$ 587,698
Annual Net Benefit for the ex cap	$ 651,250	$ 718,840	$ 901,549	$ 875,198
Pay back (years)	4.41	4.00	3.19	3.28
Net Present Value of investment	$1,708,998	$2,152,479	$3,351,298	$3,178,397

The production increase shown in Table 3 is a result of the decrease in labour requirements of the boning room over manual operation.

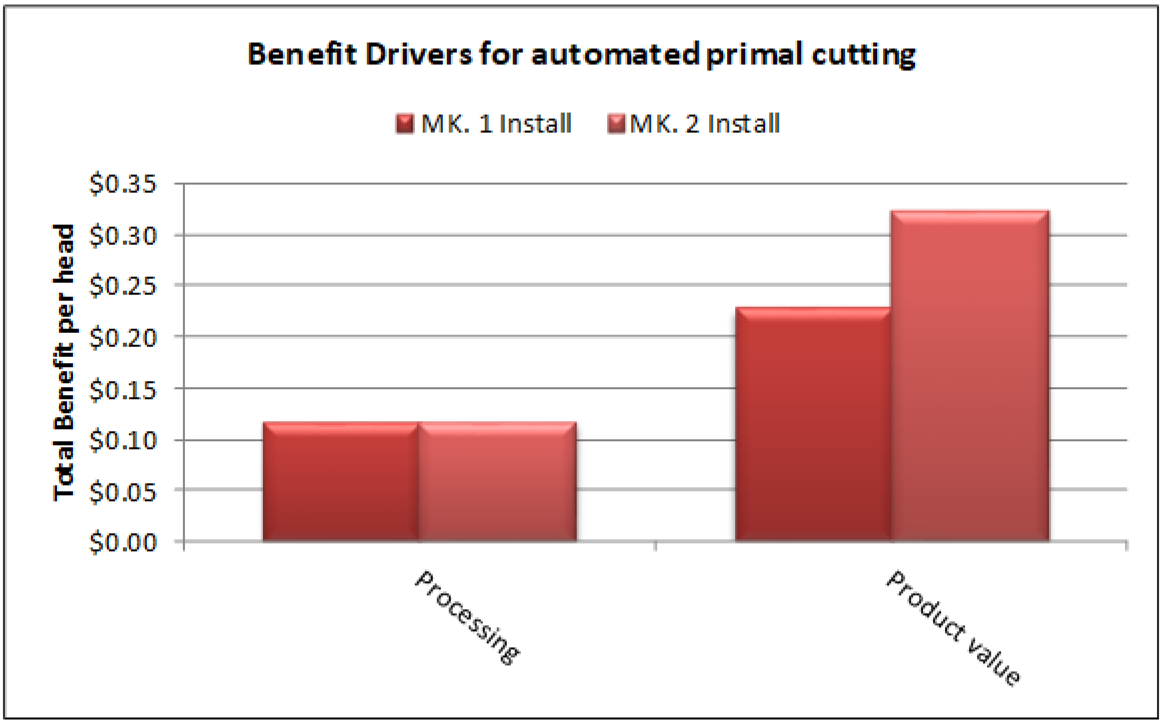

Figure 40: Broad grouping of benefits delivered by the LEAP V solution.

The main benefits of the automated cutting technology are the increase in yield and a reduction in labour units required. Occupational health and safety (OH&S) costs will reduce by removing bandsaws. There may be small yield gains through reduced bandsaw dust and shelf life. The contribution of each individual benefit is summarised in Figure 41 and Table 5.

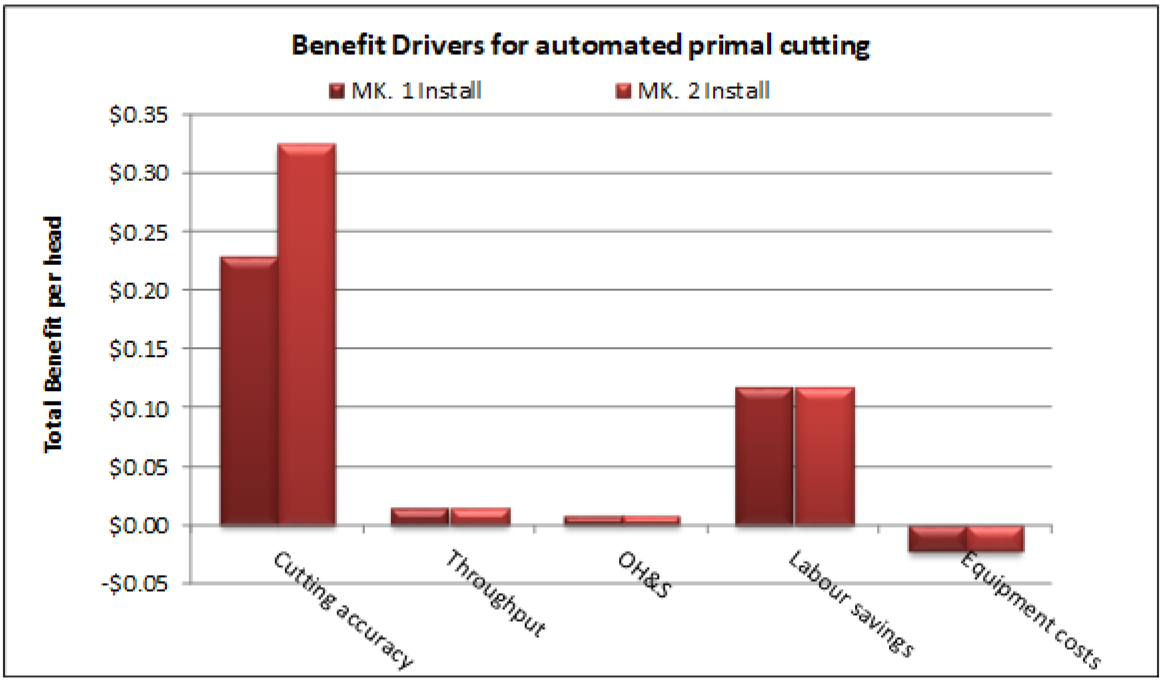

Figure 41: Summary of benefits expected to be delivered from the LEAP V solution.

Table 4: Breakdown of benefits and costs by area.

Benefit Drivers for automated primal cutting				
	MK. 1 Install		MK. 2 Install	
	$/ hd	$/ annum	$/ hd	$/ annum
Processing	$0.12	$248,977	$0.12	$248,977
Product value	$0.23	$483,455	$0.32	$686,783
	$0.35	**$732,432**	**$0.44**	**$935,760**
Cutting accuracy	$0.23	$483,455	$0.32	$686,783
Throughput	$0.01	$29,889	$0.01	$29,889
OH&S	$0.01	$16,000	$0.01	$16,000
Labour savings	$0.12	$250,475	$0.12	$250,475
Equipment costs	-$0.02	-$47,387	-$0.02	-$47,387
	$0.35	**$732,432**	**$0.44**	**$935,760**

A summary of the range in costs and benefits for each scenario are included in Table 6 below.

Table 5: Ex-post costs and benefits breakdown for the current ex-post review.

COST - BENEFIT ANALYSIS OF ROBOTIC PRIMAL CUTTING EQUIPMENT				
	MK. 1 Install		MK. 2 Install	
Benefit summary	$/hd		$/hd	
	From	To	From	To
$ Accuracy Benefit per head	$0.21	$0.24	$0.33	$0.32
$ Technique Benefit per head	$0.00	$0.00	$0.00	$0.00
$ Labour Benefit per head	$0.14	$0.14	$0.14	$0.14
$ Automation Costs	($0.02)	($0.02)	($0.02)	($0.02)
$ Overall Benefit per head	**$0.33**	**$0.36**	**$0.45**	**$0.43**
** Cost is reported as the inaccuracy from target specification OR as the difference between Manu*				
COST ASSOCIATED WITH THE EQUIPMENT				
	$/hd		$/hd	
Capital cost	$0.14		$0.14	
Maintenance	$0.00		$0.00	
Operation	$0.01		$0.01	
Risk of mechanical failure	$0.01		$0.01	
Total cost per head	$0.16		$0.16	
Total cost per head (EX CAP)	$0.02		$0.02	

Table 6 shows the range in value associated with each cost of processing including breakdown of value opportunity for each cutting line. The cost is calculated as any loss from the maximum benefit possible. Throughput cost is the cost of labour for the boning process. Presenting the figures this way in the detailed section of the model demonstrates the total costs involved and highlights areas where future savings could be generated. Note the cost of knuckle tipping cutting accuracy for manual operations in the first column is between $0.09-0.13 per head from optimal. But Neck Removal is a negative cost of -$0.19 to -$0.12/hd. This <u>negative</u> cost means manual operations are better than optimal and creating positive value.

Mk. 2 is providing a net negative cost of -$0.38 to $0.50/head against optimal manual. The $ Benefit per head in second last green row compares Mk. 1 and Mk.2 against the actual manual performance (not optimal manual). The $ cost per head of -$0.07 to +$0.04/head for manual is removed from MK. 2 costs. This leaves the $ Benefit per head in second last green row as $0.42 – 0.43/head.

Table 6: Summary results of individual costs associated with the LEAP V boning solution.

TOTAL COST							
		Manual		MK. 1 Install		MK. 2 Install	
Cost summary		$/hd From	$/hd To	$/hd From	$/hd To	$/hd From	$/hd To
1.1 Accuracy	Knuckle Tipping	$0.09	$0.13	$0.03	$0.05	$0.01	$0.04
	Brisket Removal	$0.02	$0.02	-$0.01	-$0.01	-$0.02	-$0.01
	Neck Removal	-$0.19	-$0.12	-$0.31	-$0.25	-$0.40	-$0.32
2. Throughput cost		$3.97	$3.97	$3.95	$3.95	$3.95	$3.95
3. OH&S cost		$0.01	$0.01	$0.00	$0.00	$0.00	$0.00
4. Labour cost		$0.00	$0.00	-$0.12	-$0.12	-$0.12	-$0.12
Equipment costs	**Maintenance**	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Operation	$0.00	$0.00	$0.01	$0.01	$0.01	$0.01
	Risk of failure	$0.00	$0.00	$0.01	$0.01	$0.01	$0.01
$ Costs per head		**-$0.07**	**$0.04**	**-$0.38**	**-$0.30**	**-$0.50**	**-$0.38**
$ Benefit per head		**$0.00**	**$0.00**	**$0.32**	**$0.35**	**$0.43**	**$0.42**
$ Benefit overall plant		**$0**	**$0**	**$668,748**	**$736,338**	**$919,047**	**$892,696**
$ Annual Costs overall plant		**-$139,647**	**$94,566**	**-$808,395**	**-$641,772**	**-$1,058,694**	**-$798,130**

** Cost is reported as the inaccuracy from target specification OR as the difference between Manual vs. Auto costs*

Figure 42 shows the difference in cost between the systems. Thickness of the box in the graph represents the upper and lower variation in value based on performance variation captured in the data. MK. 1 creates approximately $720,000 of benefit per annum for this plant and volumes, while MK. 2 creates a benefit over $900,000 per annum.

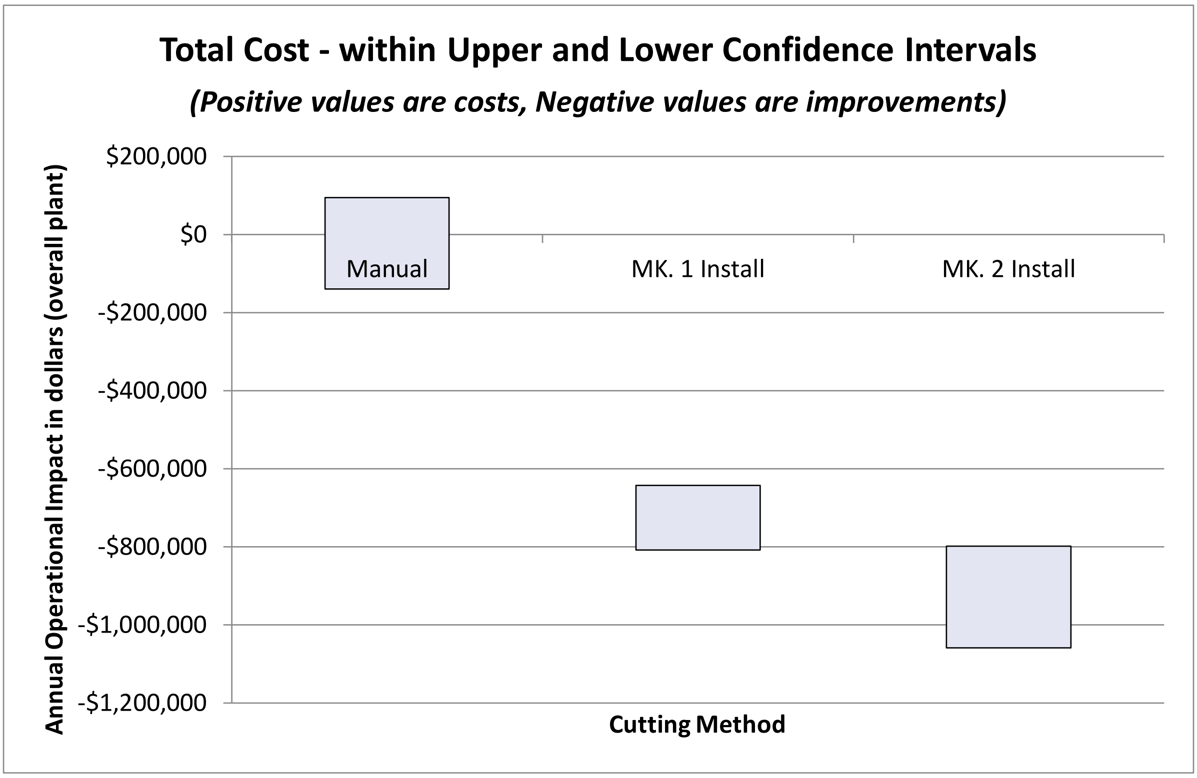

Figure 42: Graphical representation of losses captured in Table 7.

4.2.2 OH&S costs

Based on the assumptions above, the following framework in Table 7 shows OH&S Benefits. The estimated OH&S savings that can be achieved through the installation of the automated system is up to $0.01 per head. These costing do not include the trauma which can be caused through amputations as this is difficult to cost.

Table 7: OH&S Benefits of the LEAP V solution.

OH&S						
	Band Saw cutting	Sprain and Strain from lifting				
Job Role Affected	Band Saw operator	3				
				Manual	MK. 1 Install	MK. 2 Install
Claims in last 10 years	4.0	40.0				
Risk / FTE / Year	6.7%	66.7%				
Annual Premium	$30,000	$3,000				
Job Annual Hours				21,220	7,073	7,073
Limb Losses per year				0.40	0.13	0.13
Sprains and Strains per year				4.00	1.33	1.33
Annual Cost				$24,000	$8,000	$8,000
Annual Cost / Head				$0.01	$0.00	$0.00
Annual saving per head				$0.00	$0.01	$0.01

The current boning room chain employs 6 bandsaw operators and one scribing knife throughout the chain with 4 bandsaws being used on the forequarter. Through the removal of these saws, it will decrease the risk level of the room.

4.2.3 System operational costs

Table 8 shows the total cost of the equipment including both capital and operational costs.

Table 8: Estimated capital and operating costs of automated LEAP V primal cutting equipment

Capital Cost	Manual		MK. 1 Install		MK. 2 Install	
	Cost	Life span	Cost	Life span	Cost	Life span
Capital Cost of the equipment			$2,875,000	10	$2,875,000	10
Essential and insurance spares				10		10
Other Capital install				10		10
Total			$2,875,000		$2,875,000	
Service maintenance	Manual		MK. 1 Install		MK. 2 Install	
	Units	Cost	Units	Cost	Units	Cost
Estimated - COSTS						
Electricity	6.00 KW	$0.22 /KWH	6.00 KW	$0.22 /KWH	6.00 KW	$0.22 /KWH
Maintenance labour (Daily)		$0,000 /Yr		0.00 /Yr		0.00 /Yr
Maintenance labour (Preventative)		0 /Yr		19000.00 /Yr		19000.00 /Yr
Maintenance labour (Breakdown)		$0,000 /Yr		0.00 /Yr		0.00 /Yr
Maintenance labour (Training)		$0,000 /Yr		0.00 /Yr		0.00 /Yr
Operational		**$4,668**		**$23,668**		**$23,668**
Maintenance		**$0**		**$0**		**$0**
Annual Sub Total (excluding major overhaul costs)		**$4,668**		**$23,668**		**$23,668**
Major maintenance	Manual		MK. 1 Install		MK. 2 Install	
	Total	Life span	Total	Life span	Total	Life span
Sub Total: Operating Expense						
Combined Total: (cap ex + operating)						
Total Annual Estimated Expenses	Hours	Cost	Hours	Cost	Hours	Cost
Expected downtime hours per year	0	$0,000 /Yr	10	23718.42 /Yr	10	23718.42 /Yr

The risk of down time shown in Table 9 is the estimated cost of down time for an average installation across the wider industry and has been calculated as follows. The allowance is made for 1 occurrence per week where the stoppages associated with the equipment would cause the entire room to be at a standstill for 15 minutes. The same labour cost used for calculating increases in labour efficiency.

5. Conclusion

This project was created to design and build retrofittable packages for critical upgrades to the LEAP V Forequarter integration arm and to the LEAP V Forequarter lifter. The retrofittable packages were designed, built, and installed on processing sites in New Zealand and Australia.

Once the upgrade kits had been installed and commissioned on an Australian processor site Greenleaf Enterprises Pty Ltd updated the LEAP Cost Benefit Analysis (CBA) model for the LEAP V Forequarter system. The updated CBA includes the benefit from the upgrade modules, analysis improvements, and external factors such as changes in product prices.

5.1 Key findings

Two upgrade kits were developed as part of this project which address separate aspects of the forequarter handling and processing. The key findings for each upgrade are given below:

LEAP V Forequarter Integration Arm Upgrade

- A key issue to address with the original LEAP V Forequarter Integration Arm is the reliability of the placement of the forequarter on the conveyor. Misalignment of the forequarter with the original integration was responsible for a reject rate of up to 5.2%. Following the upgrade, Scott was unable to detect any rejects due to misalignment of the forequarter.
- To improve the reliability and uptime of the system the LEAP V Forequarter Integration Arm was mechanically strengthened to address areas of fatigue and warping that were identified in the original design.
- To address greater than expected loads and ensure that the system was able to achieve a reliable 10 carcases per minute the servo motor and gearbox was upgraded to a higher rated motor and gearbox. Additionally, the transmission system was also upgraded to utilise wider drive belts and pulleys.

LEAP V Lifter Arm Upgrade

- Post-clamping product movement in the LEAP V Lifter Arm was shown to be responsible for a reject rate of more than 1.8% in the original system. Following the upgrade, Scott was unable to detect any rejects due to post-clamping product movement. Including the benefits of the LEAP V Forequarter Integration Arm Upgrade the system now rejects 7% fewer forequarters.
- To improve the uptime of the system the main vertical carriage and structural arm were mechanically strengthened to address fatigue induced by accelerating large forequarters at the rate required to meet cycle time.

Updated LEAP Cost Benefit Analysis for LEAP V Forequarter systems

- The net return per head processed in the LEAP V Forequarter system has increased from $0.17-$0.20 to $0.28-$0.29 or a 45% - 65% increase in net return.
- Since the pre-upgrade ex-post review in 2019, the accuracy of each cut has improved, resulting in the changed returns observed.

- The value differential between primary and secondary cuts produced from the shoulder has reduced, decreasing the benefits from the system from the previous report. Currently the value of shanks, breast pieces and necks only have low variations in value from shoulder, up to $ 6.50/kg. The payback period will change as the market value of secondary cuts changes.

5.2 Benefits to industry

The retrofittable upgrades developed in this project represent opportunities for new installations as well as existing sites to improve reliability and uptime. The reduction in rejects of more than 7% of product represents a significant benefit both in terms of value added by the system and in terms of labour savings required for processing rejected product.

The mechanical strengthening and servo motor/gearbox upgrades reduce the likelihood of fatigue-related downtime for the machines. Not only does this reduction in breakdowns improve machine uptime but frees up maintenance staff to address other issues and perform more preventative maintenance instead of addressing unexpected breakdowns. Additionally, with the upgrades in place the system can achieve a reliable 10 carcases per minute and so is able to keep pace with the LEAP III Primal and LEAP IV Middle systems developed by Scott and MLA.

Greenleaf Enterprises Pty Ltd independently audited the LEAP V Forequarter system and found an improvement in gross return per head from $0.17-$0.20 to $0.28-$0.29. For an annual production of 2,122,038 forequarters, this represents a change in net return from $1,708,998 - $2,152,479 to a new net return of $3,178,397 - $3,351,298.

6. Future research and recommendations

The upgrades developed in this project represent a significant step forward for the LEAP V Forequarter system. To further improve the benefit to industry of the system further improvements could be developed and implemented in new installations or retrofitted as upgrades. Additional improvements are given below:

- The addition of a load cell in the LEAP V Lifter Arm. If a load cell is also added to the outfeed of the hindquarters from the LEAP III Primal and the carcase weight is known then the system would be able to send forequarter, middle, and hindquarter weights to the processor. These weights, in conjunction with DEXA Lean Meat Yield data, could be used to reward farmers who are able to breed more high-value animals.
- The integration of artificial intelligence (AI) into the LEAP V Forequarter analysis. Recent collaborations between Scott and MLA have shown great promise in integrating AI-based analysis into other LEAP systems. Currently the LEAP V Forequarter system utilises more traditional computer vision-based analysis and the accuracy of the system could be improved from an AI-based analysis.
- The development of additional cuts that the system could perform. Some processors have indicated that they would benefit from the LEAP V Forequarter system being able to perform additional cuts. As part of this development, the shoulder split cut in the LEAP V Forequarter system could be further improved to perform blade adjustments from the neck while still positioning the bandsaw blade between the forequarter clamp arms.