final report

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Lamb middle cutting system, Ex-Post Review

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Executive Summary

Scott Technology in conjunction with MLA and a New Zealand lamb processing company have developed an automated lamb middle cutting system guided with the use of camera visioning and integration with an existing x-ray primal cutting system. This report is an ex-post review of the commercial viability of installing the system in a large Australian lamb abattoir and identifies where and how the system delivered benefits. The middle machine could be installed with or without the fed manually from a primal breaking bandsaw but would not realise the full benefits reported in this integrated installation.

The main benefit of this middle machine installation has improved cutting accuracy over manual operations and is associated with yield improvements averaging $2.22/head (between $2.05 to $2.39/head). The middle system automatically conducts the cuts in Table 1 without an operator. Benefit for each of the automated cuts is displayed the ex-post performance in Australia against the manual baseline.

Manual processes will always show a range in variation as will automated process (hopefully less than manual). This variation produces a range in value or cost and is reported as the lower (left column) and upper (right column) confidence intervals for the data collected. This range in accuracy is of interest with narrow variation increasing the ability to control and refine the process.

Table 1: Range in value of yield benefit per head for the Australia middle machine when compared to manual operations

ACCURACY BENEFIT		
	Aus Ex-Post	
Benefit summary	$/hd From	$/hd To
Rack loss to shortloin pair	$0.64	$1.17
Rack flap removal	$0.35	$0.13
Shortloin pair - flap	$0.27	$0.31
Chine removal	$0.79	$0.79
$ Benefit	**$2.05**	**$2.39**

Chine removal – (Manual and ex-post values in a separate MLA Lamb chining review use average values rather than range of variation)

The current installation is expected to pay the capital cost back in between 0.54 and 0.60 years based on Table 1 benefits. The actual performance and resultant payback is summarised in Table 2 and demonstrates compares the ex-post values and the expected projections with an increased throughput against the manual baseline. The calculations have all be been completed using 7.6 hours per shift over 2 shift.

Table 2: Summary of ex-post benefits relative to manual cutting performance over one shift, with and without an increase in throughput

SUMMARY PERFORMANCE MEASURES		
	Aus Ex-Post	
Hd / annum	1,271,255	
Production increase with equipment	9.90%	
	From	To
Capital or Lease cost	$2,100,000	
Gross return Per head	$3.01	$3.35
Total costs Per head	$0.30	
Net Benefit Per head	$2.72	$3.05
Annual Net Benefit *(Incl. capital cost)*	$3,452,962	$3,881,450
Annual Net Benefit *(Excl. capital cost)*	$3,496,700	$3,925,188
Pay back (years)	0.60	0.54
Net Present Value of investment	$23,627,109	$26,636,636

The middle machine system can be supplied without chine removal. The chining module is also available as a manual-fed stand-alone module but would lose labour savings when integrated in fully automated middle machine. Chine removal contributes 33% of total middle machine's cut accuracy value so it is not recommended to install the middle machine without chine removal.

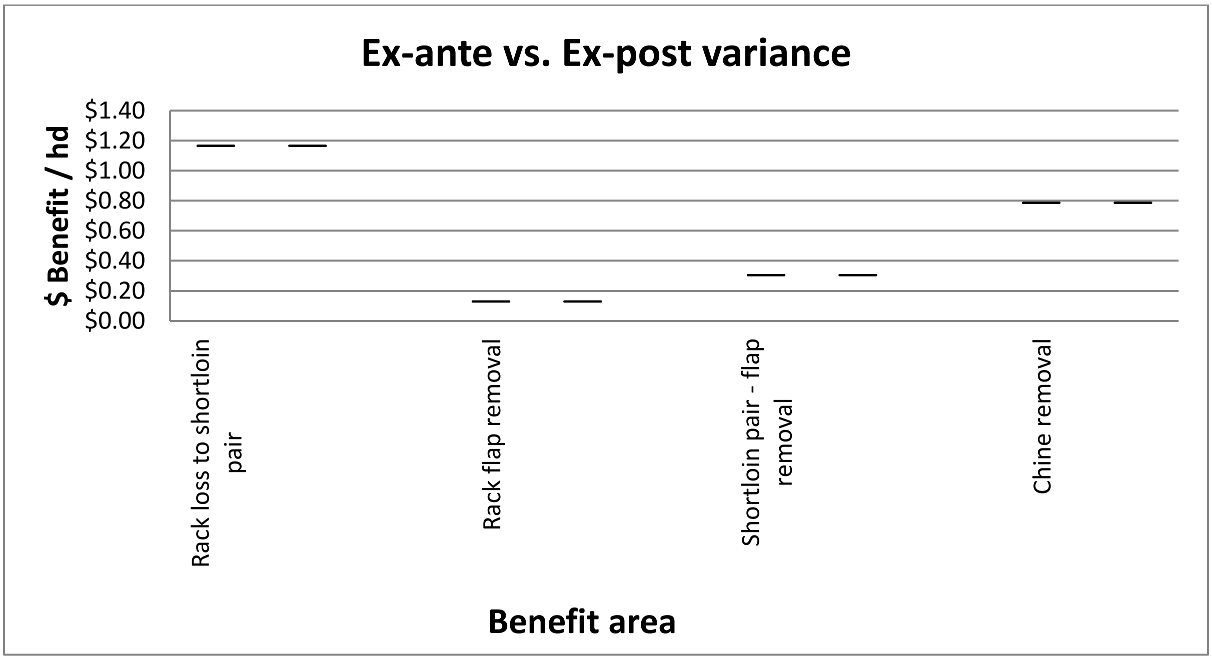
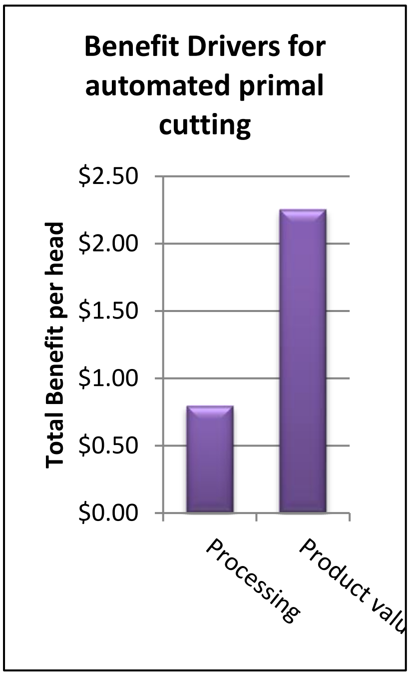


Figure 1: Variance between estimated performance benefits and actual benefits observed

Installation of this system included improvements in both production efficiency and increased saleable product value as shown in the left of Figure 2. All product value benefits are from increased saleable meat yield due to increased cutting accuracy. Processing benefits reflect increased production per person.

The breakdown of benefits is summarised in the right of the figure and primarily focused on increased saleable yield (cutting accuracy), improving production efficiencies, as well as reducing the number of bandsaws and decreasing likelihood of OH&S incidents.



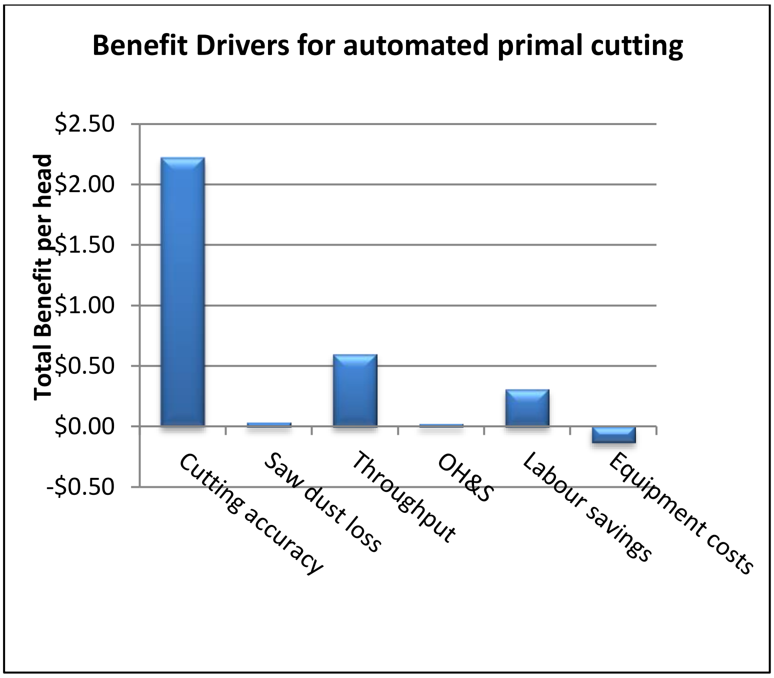


Figure 2: Broad grouping and detailed breakdown of benefits delivered by Middle system on 1 shifts including chine removal.

Glossary

Term	Description
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)
FTE	A Full-Time Equivalent labour unit (may include multiple specified pay rates)
Caudal	Caudally: toward the posterior end of the body
Cranial	Refers to the direction toward the head of carcass
Dorsal	Belonging to or on or near the back or upper surface of an animal
Ventral	Pertaining to the front or anterior of any structure. The ventral surfaces of the carcass include the brisket /abdomen cavity
Lairage	Livestock lairage refers to the physical pens required to hold livestock after delivery to plant and prior to abattoir processing.
MLA	Meat and Livestock Australia
OH & S	Occupation Health & Safety
RTL	Robotic Technologies
SLP	Short Loin Pair
Statistical hypothesis test	A method of making decisions using data, whether from a controlled experiment or an observational study (not controlled). In statistics, a result is called statistically significant if it is unlikely to have occurred by chance alone, according to a pre-determined threshold probability, the significance level. The phrase "test of significance" was coined by Ronald Fisher: "Critical tests of this kind may be called tests of significance, and when such tests are available we may discover whether a second sample is or is not significantly different from the first."[1]

Contents

1 Introduction

Robotic Technologies Limited (RTL), a joint venture between Scott Technology Ltd and Silver Fern Farms, developed a vision in 2001 to fully automate the lamb boning process. This vision proposes to remove human interaction with bandsaws and in addition, provide significant yield improvement and other beneficial processing outcomes.

The components of this vision include (1) Primal cutting which has been successfully commercialised, along with (2) Forequarter processing, (3) Middle processing and (4) Hindquarter processing which are in various stages of development.

The middle processing system have been developed in conjunction with MLA to a point where operational performance can be assessed on an ex-post basis. The financial and performance results from this commercial trial have been summarised in a production and financial model and underpin this report which provides an overall summary of the effectiveness and paybacks for the middle machine.

2 Objectives

The objective of this project was to review performance of the middle machine and determine the likely benefits the system could provide under commercial Australian conditions.

This is to be used for:

1. Yield and performance benchmarks to measure the ex-post opportunity of the system for each area of benefit that exists when compared against manual cutting systems.
2. Summarise the value benefit and main drivers for adoption of the equipment for Australia lamb processing plants.

The key activities in achieving the project objectives include:

- Measurement of accuracy in achieving cutting lines.
- Data was collected including distance measurements from target cutting lines and frequency of varying degrees of accuracy for each cut.
- Development of standards to quantify the cost of different 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 Technology Description

3.1 Saddle Integration

The Figure 3 below shows the x-ray primal cutting system in the background and the integration system which transfer the cut primals (saddle and shoulder) to the associated middle machine.

Figure 3: Primal System (background), Saddle and Forequarter integration (foreground)

The saddle integration has been included in the middle machine capital costs and return on investment calculations included in this report. It is possible to install a middle machine system as a stand-alone unit, independent of a primal curring system. However, the middle machine has only been installed to date in conjunction with a middle machine primal cutting and x-ray visioning system. A number of advantages arise from a full integration of the primal cutting system and the middle machine stand-alone installations should be assessed carefully with consideration given to the following trade-offs:

- Advantages of stand-alone middle machine installation
    - Lower capital installation and smaller foot print
- Disadvantages of stand-alone middle machine installation:
    - Reduced labour saving due to manual loading of middles
    - Reduced throughput advantages due to variable manual loading speed
    - Reduced cut accuracy benefits between the rack and shortloin without x-ray visioning of ribs

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3.2 Saddle/Middle Processing System

The saddle/middle processing machine automatically takes the saddle from the primal system with the use of the integration robot (refer Figure 3) and further processes the saddle/middle section into the required bone-in cuts.

The current cut lines include:

- Rack/loin separation
- Flap removal
- Spinal cord removal
- Splitting of rack and/or loin
- Chine bone removal

Additional developments yet to be developed include:

- Frenching

The middle machine can be supplied without the Chine Removal module which is also available as a stand-alone unit. Labour savings would not be achieved in a manual-fed stand-alone chining unit.

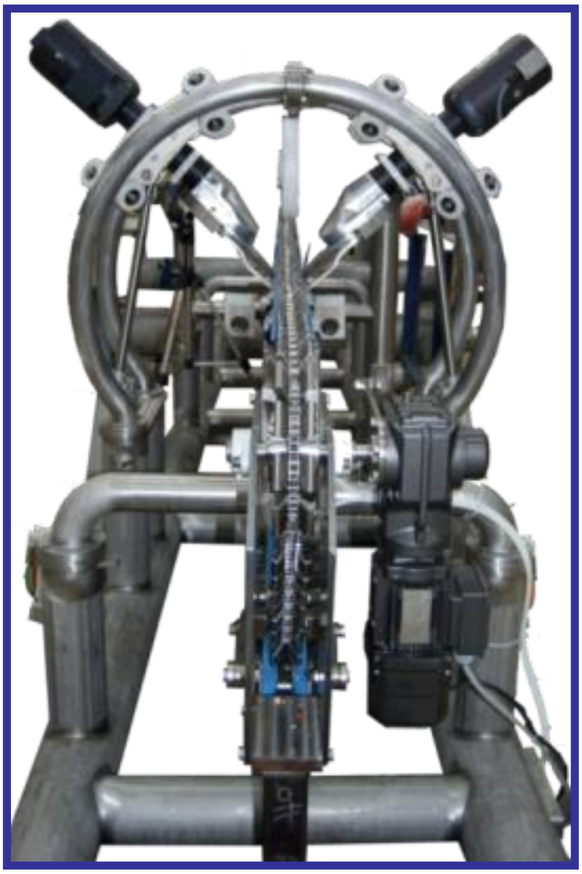

Figure 4: Middle/Saddle processing system

4 Methodology

4.1 Data Quality Control

There is always a range in accuracy and performance within manufacturing environments and particularly where a biological product like a carcase is involved. Manual processes will always show a range in variation as will automated processes (but hopefully to a lesser degree). This variation produces a range in value or cost and is reported in the cost/benefit and financial tables as the lower (left column) and upper (right column) confidence intervals for the data collected. The range in accuracy is also of interest with narrower variation increasing the ability to control and refine the process.

Manual baseline data and ex-post analysis of performance was conducted over 7 site for a total of 15 days of commercial production. Samples measured under manual conditions were collected out of sight from operators to reflect normal unobserved performance. Collection periods were spread evenly across the days production summarised in Table 3.

Over the 2 days of manual operation 4,600 carcases were processed in total with 1,002 samples being taken (22% of production). The range of carcases processed represents the full range in carcase weights expected across the Australian population. Figure 5 indicates the samples measured were representative of the total population.

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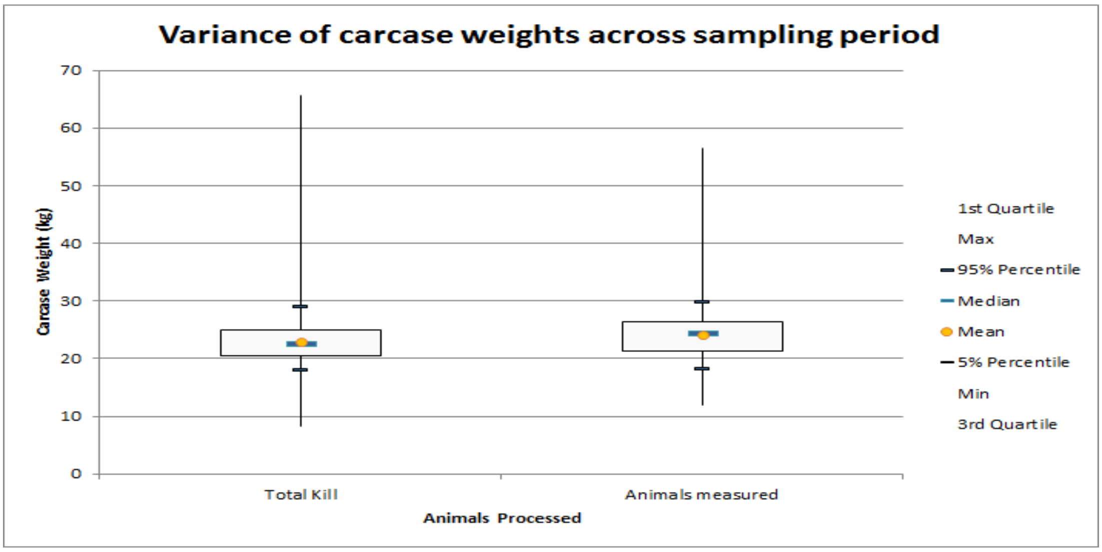

Figure 5: Carcase weights sampled are representative of the total population of lambs measured during the trials in Australia

The summary of data collected during the ex-post trials is included in Table 3. There is a significant difference in rack weight but this is due to finished racks being compared to unfinished racks between the manual and ex-post trials. The calculations used to quantify differences in cutting accuracy are not affected by measurement of finished or unfinished racks so Middle machine accuracy measurements can be taken in either form. In additional to these values, significant differeces in the length of the racks could also be attributed to an increase in accuracy attributing to the value presented in this report.

Table 3: Summary statistics on data collected across manual and ex-post trials

Data collection		
Meaurement	Manual	Australia Automation
Plant	7 sites	Australia
Start Date of collection	2013	3/03/2015
Finish Date of collection	2015	4/03/2015
Number of collection periods	28	2
Rack Weight		
Number of samples	778	512
1st Quartile (mm)	450	1006
Median (mm)	529	1168
3rd Quartile (mm)	676	1333
P-value		0.00
Rack length		
Number of samples	190	216
1st Quartile (number of ribs)	185	210
Median (number of ribs)	195	220
3rd Quartile (number of ribs)	205	230

4.2 Cutting Yields

The market requirements determine the location of cutting lines for fabrication of lamb carcasses into primals. All other processing that occurs on the lamb carcases is based around these cutting lines. If the initial primal cutting lines are not accurate then this will have an impact on the ability to process the product according to market specifications. Ultimately costs will be incurred through discounts if inaccuracies in the cutting lines don't allow product to meet the market specifications. The accuracy of the cutting lines was an important part of the data collection phase. The section gives consideration to the measurement of accuracy levels observed with the manual cutting system, and the costs incurred because of inaccuracies.

The middle machine receives the primal from the primal cutting robot and conducts the following processes on the middle:

1. Removal of spinal chord
2. Separation of rack from short loin (optional) shown in Figure 6
3. Removal of flaps
4. Chine bone removal
5. Splitting of rack OR full loin (optional)

Figure 6 shows the predominant cutting lines observed during the trials. Variations to this figure included:

1. Different length of tail on rack and shortloin pair
2. Scallop cut between the rack and short loin (Figure 8)

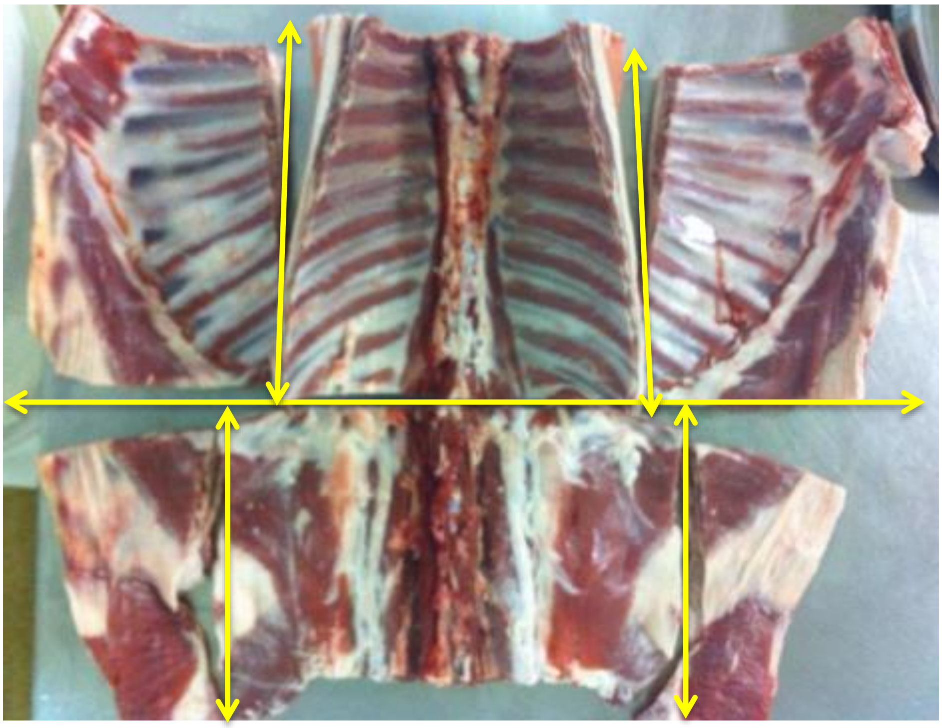

Figure 6: Separation of flaps from rack and shortloin adjustable to customer specification, the yellow lines identifies the cutting lines to be conducted by the middle machine.

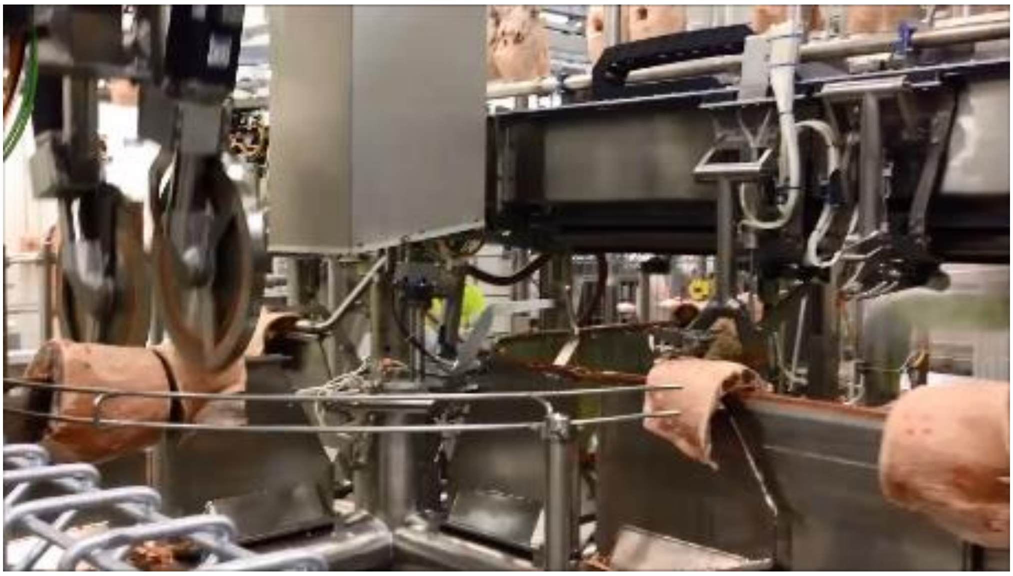

Figure 7: Separation of rack and loin in left of image prior to transfer to further processing of flap and chine removal in right hand side of image.

Figure 8: Alternative middle machine system cutting specifications (full loins & scallop cut racks)

4.2.1 Separation of Rack From Loin

The separation of the rack from the loin has 4 measurements recorded to estimate the accuracy of the cut. The four measurements are as follows:

- Millimetres that the cut between the rack and loin is from the ideal location;
- Number of ribs on the rack;
- Length of last partial rib from the vertebrae; and
- Angle of the cut between the rack and loin (either a straight cut or a scallop cut);

Separation of the rack from the loin as shown in Figure 9 was measured to show the accuracy and value changes effected by the middle machine. The figure shows the angle of cut and the distance measures taken.

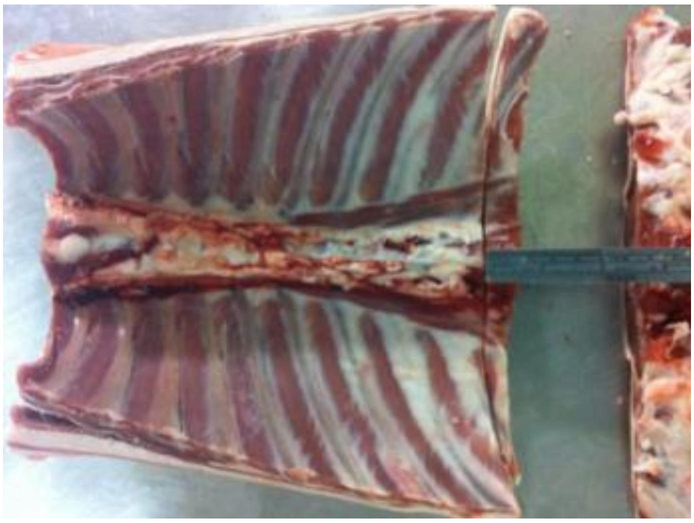

Figure 9: Angle of cut and millimetres from target separation were measured

Measurement of manual cutting accuracy consisted of selecting random racks from the belt, counting the number of ribs relative to the cutting specification, and making sure the tail of caudal ribs was long enough to meet the required cutting specification. The angles of the cut on both cranial and caudal edges of the rack were also observed. Because ribs tend to angle back caudally, the cutting line between the rack and SLP needed to move cranially or caudally depending on the tail specification. For example when a 25mm tail was required as opposed to a 100mm tail the rib length on the partial last rib had to be much shorter to meet specifications.

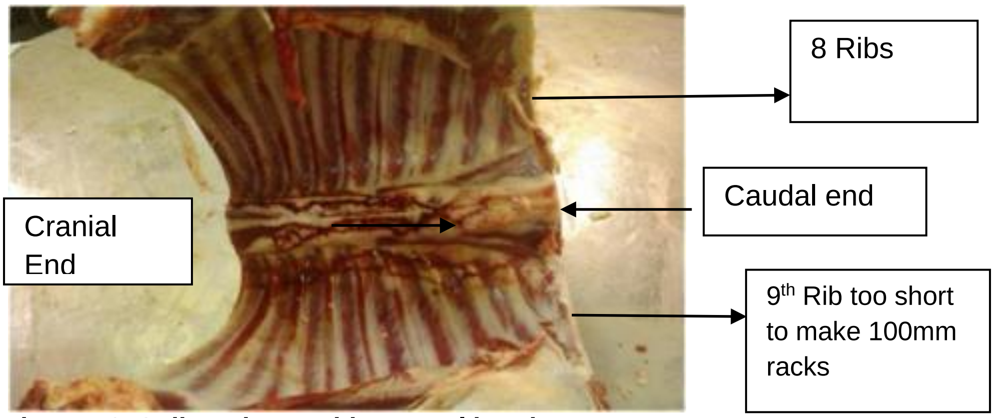

Figure 10: 8 rib rack cut with manual bandsaw.

Short loin pairs (SLP) were also observed prior to splitting to determine the number of bones left in. In most cases when the specification was a bone in SLP only two ribs were allowed to remain. Any more ribs than this (either as a result of the cutting inaccuracy on the first cut, or the number of ribs in the carcass) were removed and placed in rendering with the boned product costed as trim and fat as per Figure 14.

Figure 11 and Figure 12 show the impact on finished product of this cutting line. Eight rib racks are the target specification in Figure 11. Figure 12 has 9 ribs attached at the backbone which is acceptable if it does not protrude above the frenching line. Both figures are within specification but racks tend to be worth more than shortloin pairs. In that case optimising all rack cuts to that in Figure 12 will significantly increase carcase value. Figure 13 has one less rib and will be downgraded. Figure 14 is the result of too many ribs where one has to be removed and downgraded to trim.

Figure 11: Perfect 8 full ribs. 9th rib not present.

Figure 12: 8 rib rack in specification. Portion of 9th rib does not go above the frenching line

Figure 13: 7 rib rack, cut too short between rack and shortloin

Figure 14: Impact of cutting one rib long showing amount of loin lost that would have otherwise been sold on shortloin pair

Figure 15: Establishing value of miliimeters of accuracy and value differences in cutting line between rack and shortloin

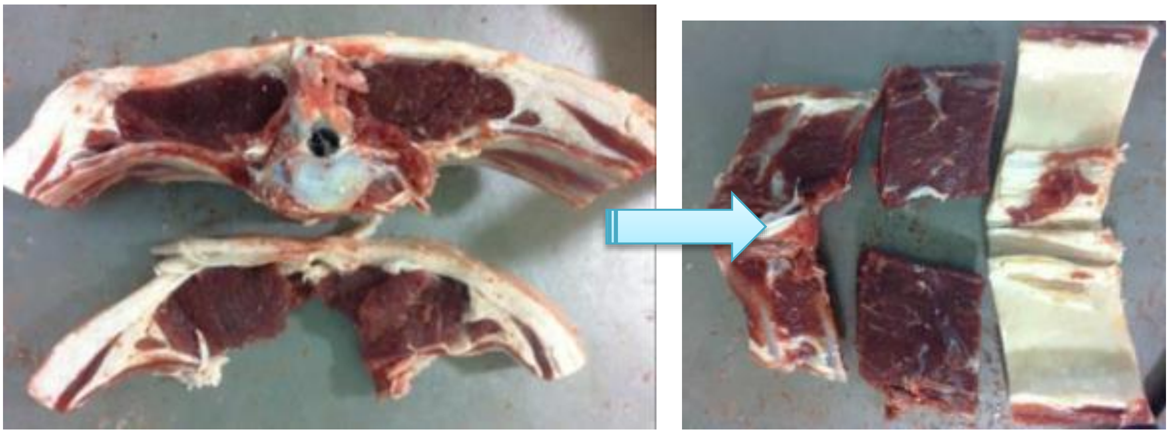

Figure 16: 2 rib portion of Figure 15 boned and valued as part of standard setting activity to establish cost of cutting inaccuracy

Optimising the angle and location of the cut between the rack and loin is a large value opportunity. This cut can only be conducted in a relatively straight pass through the ribs using a bandsaw. As a result of the design of the automated system it can conduct the cut perpendicular to the vertebrae or on an angle. Depending on the cutting specification, tail length and the frenching length the location of the cut should change to optimise rack weight within specification. These two types of cuts can be seen in Figure 17. The lines in the below image represent the following variation in yield.

- The yellow line represents yield improvement with the middle machine where a manual cut was not perpendicular and rack is lost to short loin trim/flap.
- The blue line demonstrates the yield transferred from the rack to shortloin as a result of performing the scallop cut.
- The red line represents the yield gained through conducting the scallop cut compared with an inaccurate manual straight cut

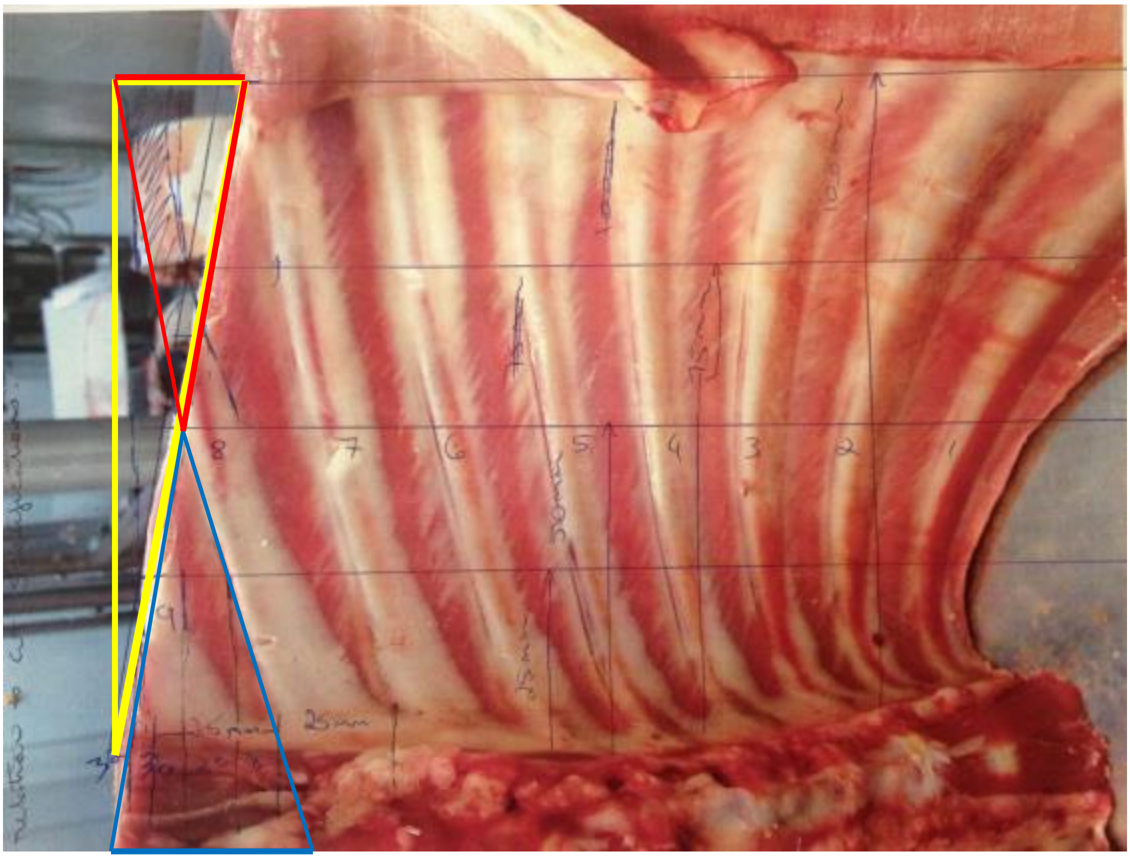

Figure 17: Yield lost and gain through the installation of the automated solution, the yellow triangle will be weight gained when conducting a straight cut. The blue triangle will be weight lost and the red triangle will be weight gained when conducting a scallop cut.

The process involved with the development of the standards for the straight cut and scallop cut were conducted separately. The development of the standards for the straight cut shown in Figure 18 measured the millimetres of angulation from perpendicular in conjunction with the measurement of length of cut from the centre line in Figure 19 to calculate the surface area of the lost meat and bone.

Figure 18: Development of the standards for the straight cut as shown by the yellow line in Figure 17

Figure 19: Length of the ribs measurement.

The process involved with the development of the standard for the scallop cut can be seen in Figure 20. The area of the triangle shown by the blue and red lines in Figure 17 were then calculated to estimate the value of loss and gain for both segments.

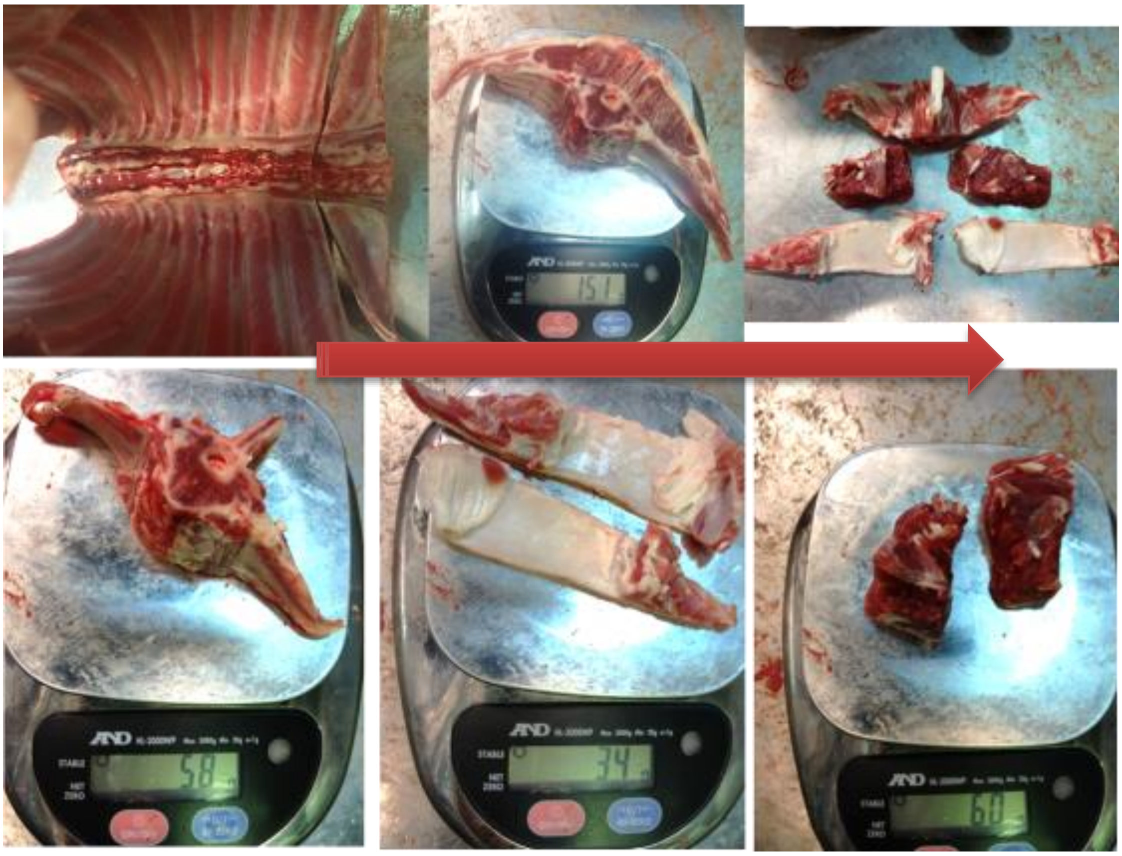

Figure 20: Development of the standard for the scallop cut

4.2.2 Flap cutting

Separation of flaps from rack

A range of customer specified tail lengths (length of flap remaining on loin) determine where the cutting line between the flaps and rack/loin must occur. The largest difference in primal price on a lamb carcase is between the flaps and loins. Figure 21 shows a frenched rack with much of the flap meat already removed on the left and an unfrenched rack on the right. Preparing a cap off, frenched rack removes a lot of the flap meat into trim and minimises the value of accuracy for this cut because the trim removed from the rack is of similar value to flap meat. However frenching length is still set by the length of the ribs so the weight of bone and muscle for rack length by rack cutting spec has been included in the costings.

Figure 21: Trimming racks back to frenched cap off specification reduces much of the gain resulting from more accurate flap removal

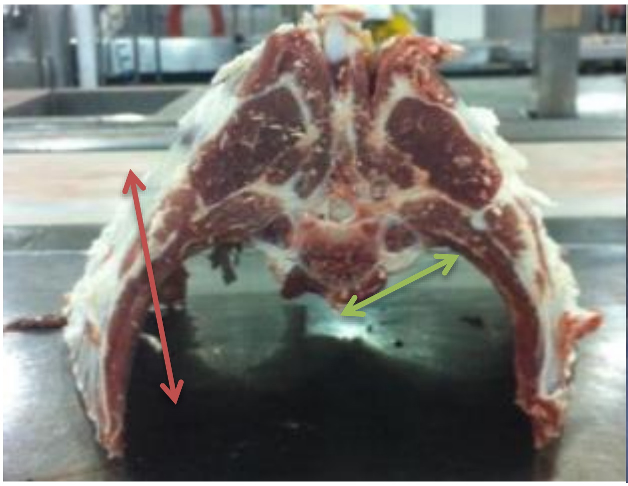

Figure 22: Difference in angle of bandsaw separation of flap (red) as compared to machine removal (green) perpendicular to ribs

Figure 23: Squarer, less pointy ribs will minimise blown vacuum seals and re-packing labour

Removal of the flap by manual bandsaw is at a much sharper angle than the middle machine. This does create more weight on the rack but only the bone portion of the end of the frenched ribs will contribute to the finished rack weight and is not signficiant. The main advantage for the middle machine cut over manual bandsaw is squarer, blunter ribs. Figure 23 shows packing of racks without bone guard. The potential to pack racks without using bone guard is possible with some of the newer shrink packaging films being used and less pointy ribs reduces number of broken bags.

Figure 24: Standards set for weight of flap and value for a range of cutting accuracies

Separation of flaps from short loin

The separation of the flap from the shortloin pair involves a bandsaw cut to ensure separation of the last rib at the correct location, followed by a knife cut to trim back the fat portion to various customer specifications.

The majority of product was processed to a denuded specification during the trials. The cut separating the flap from the loin cut into the backstrap at times resulted in loss of backstrap to flap value as seen in Figure 25.and Figure 26. A standard was developed to measure the inaccuracy in this cutting line.

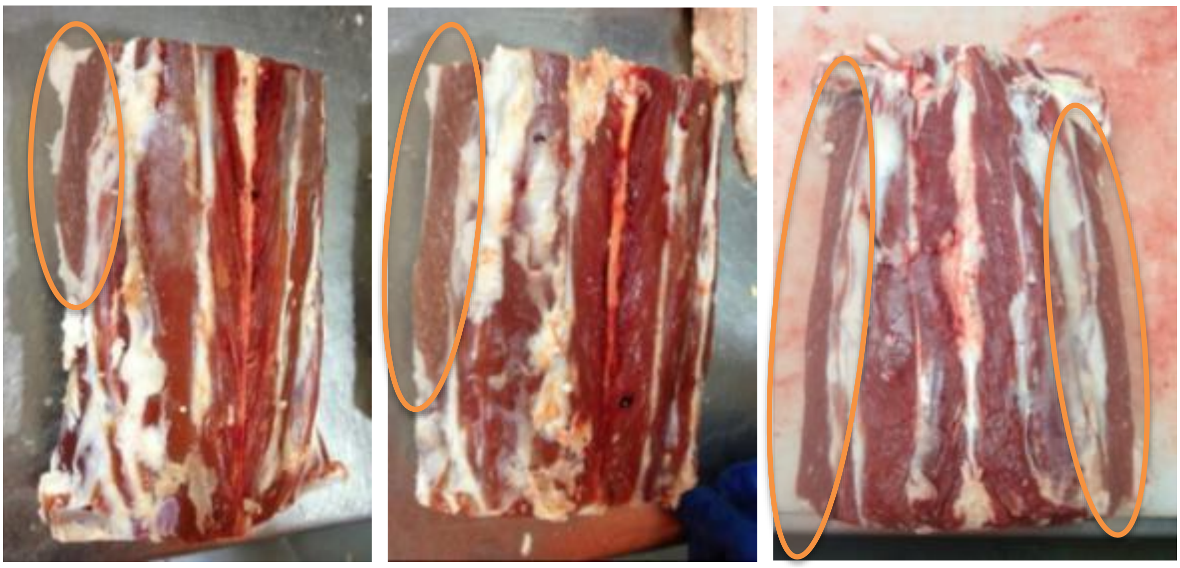

Figure 25: Standard for assessing degree of damage to shortloin pair with increasing severity from left to right of cut into the backstrap

Figure 26: Calculation of yield loss of backstrap from shortloin pair

Figure 27: Loss of loin to flap value as a result of cutting too short a tail

4.2.3 Chining

The Scott's chining machine has been designed as a stand-alone unit in Figure 28 and for integration with the middle deboning system as shown in Figure 29 and Figure 30.

Comparison between the Scott's and manual bandsaw chining

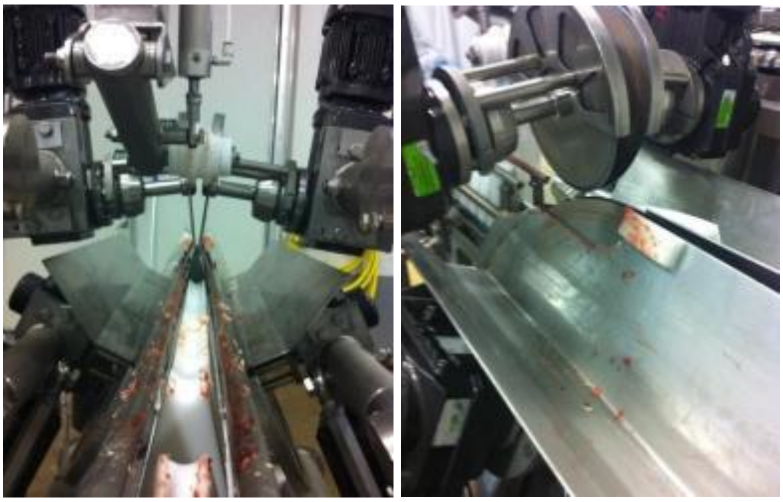

Figure 28: Scott's stand-alone chine removal system showing top and bottom sets of blades

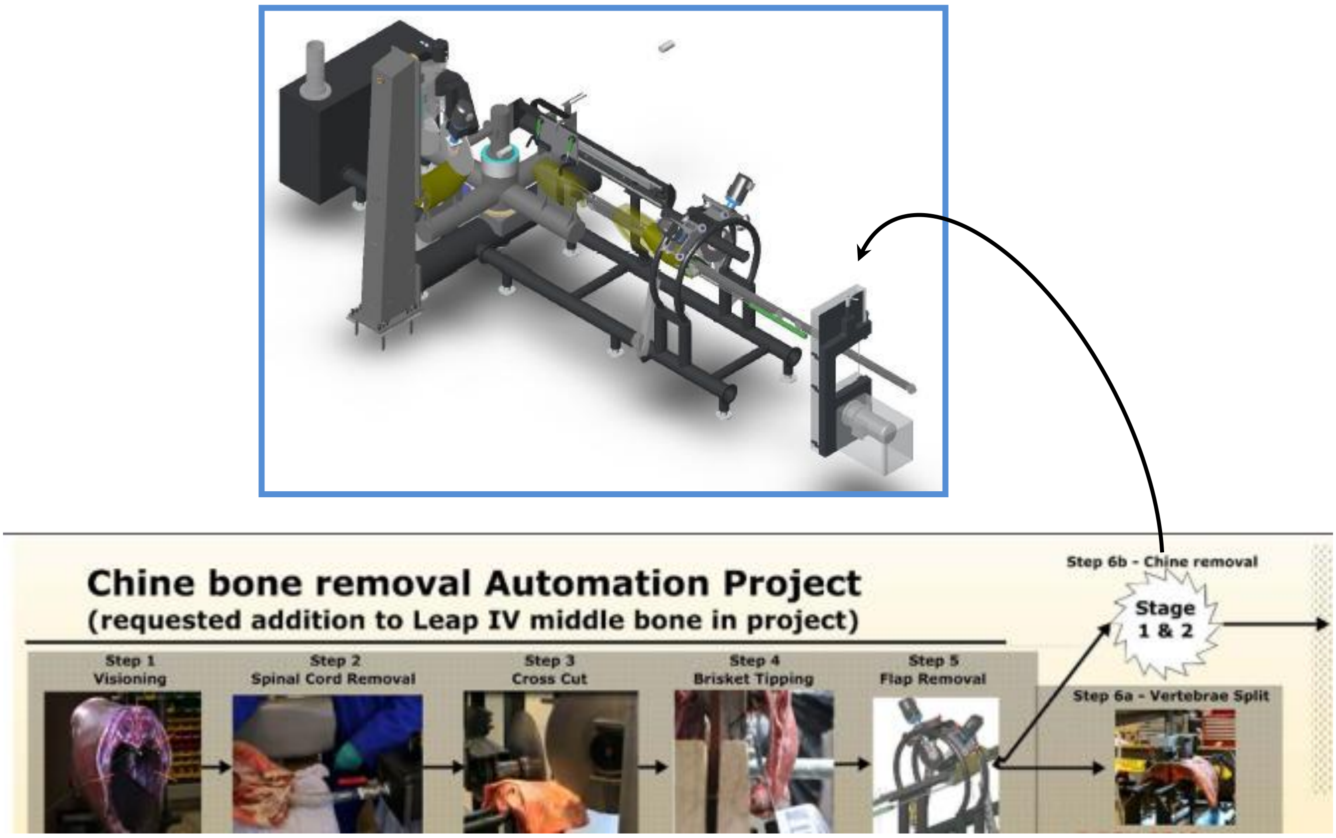

Figure 29: Integration of chine bone removal as part of the middle boning project

Figure 30: Fully automated chining unit installed as part of commercial middle system

The chining module was installed as part of the middle machine and was tested under commercial conditions during the ex-post review in the Australian processing plant. The figures included here compare these results against a manual chining baseline developed as part of the study.

Removing Ribs from the Chine Bone

Four cuts are made with the machine as shown in Figure 31. The chining machine removes the ribs closer to the chine bone and with a neater cut than the manual bandsaw. This plays a large part in delivering higher yields of bone-in racks.

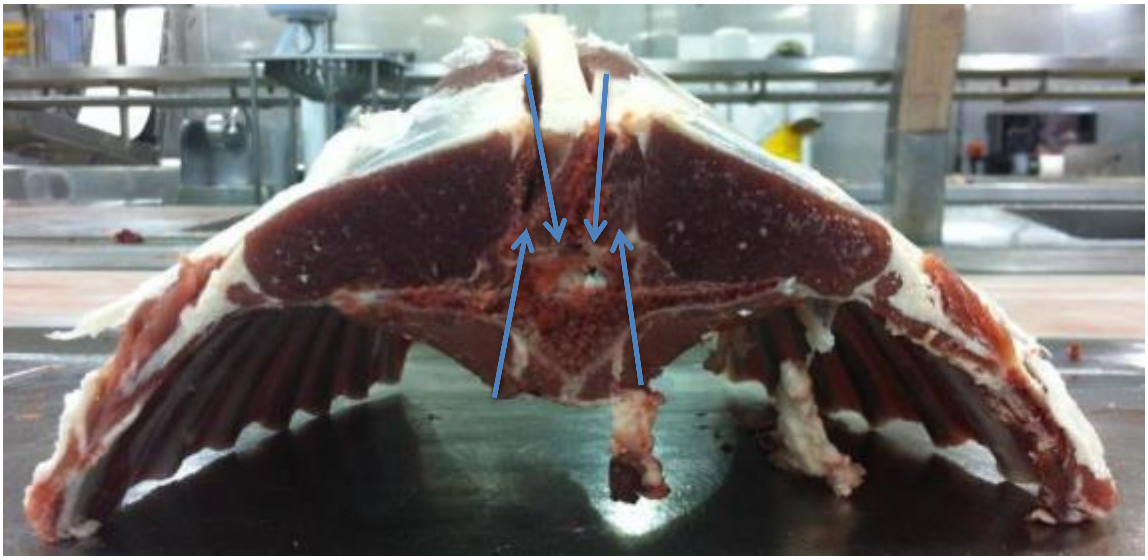

Figure 31: Four cuts removing chine bone from rack

Figure 32: Scott's chining machine

Figure 33: Manual chining

Removing Loin Close to Spinous Process

The top set of blades separate the loin from the spinous process dividing the right and left longissimus muscles. How well the blades follow the centre line has a big impact on how much loin meat is left on the chine bone.

The methodology used to measure this difference involved use of a sharp boning knife to remove all remaining meat from the loin side of the chine bone. Left and right sides were weighed individually and showed the consistency of each machine in cutting down the centre line without skewing to the left or right.

Figure 34: Scraping remaining loin from chine and weighing for each side of the chine bone enabled comparison between both systems

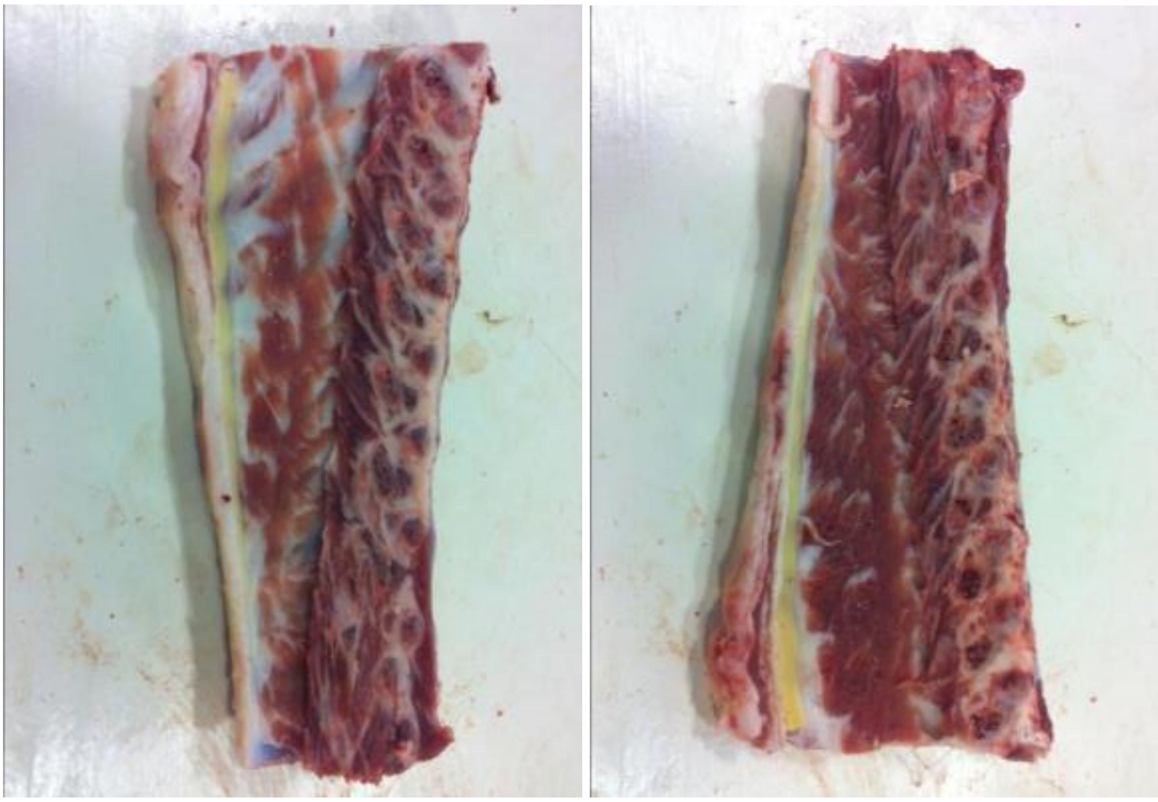

Figure 35: Chine bones from Scott's system directly after chining, prior to scraping bones

Figure 36: Chine bones from manual bandsaw process directly after chining, prior to scraping bones (left) and after scraping (right)

Figure 37: Racks from Scott's chining system – note the amount of meat remaining between the loin and the chine bone

Figure 38: Racks from Scott's chining system – note the amount of meat remaining between the loin and the chine bone

Figure 39: Manual bandsaw chining cuts into the loin muscle sometimes reducing yield

4.3 Operating and OH & S Costs

The operational and OH & S data collected was as follows:

- Staffing levels per shift;
- Cost per hour for staff and AQIS officials;
- OH & S claim costs over the last 10 years;
- Power costs associated with bandsaws;
- Maintenance costs of bandsaws;

These costs have been used to calculate an average operating cost reduction for each area through the installation of the automated cutting system.

4.4 Fixed Model Drivers

To establish the dollar value per head for each cost and benefit, the following production numbers were used in Table 4. The table summarises the manual performance as a base line and compares the automated system improvement over the the manual process and the ex-post actual performance of the system. Details for each of these scenarios are in sections 4.4.1 and 4.4.2.

Table 4: Calculation used for determining production volume base line

Processing room operation speeds		
	Manual	**Aus Ex-Post**
Carcases / min	5.28	5.81
Carcases / Statn./hr	317	348
Carcases / day	4820	5297
Annual days	240	240
Annual # of hd	**1,156,754**	**1,271,255**

4.4.1 Manual Process

The current manual process of the room has the following specifications:

- 1 shift per day
- 5.28 carcases per minute for a 7.6 hour shift

4.4.2 Ex-post Automation – Increased throughput

The variations between this process and the manual processes are as follows:

- Automated chining, rack and flap removal and spinal cord removal by the middle machine with improved cutting accuracy
- The following staff changers have been included:
  - 2 bandsaw opperators removed
  - 1 chine removal operator
- 10% increase in throughput speed

5 Results and Discussion

The main value propositions for the installation of the lamb middle cutting system are attributed to savings in the following areas:

- Increase yield
- Increase in labour productivity
- Reduction in operational costs;
- Reduction in work cover premiums;

The cost savings will be discussed in detail in the following section.

5.1 Yield Benefits

Improvement in accuracy of cutting lines over manual was observed for all cuts. Different customer specifications required different distances of cutting lines from anatomical locations in most cases. These variations between customer specifications were taken into account when calculating value benefits. The dollar benefit reflects distribution across product specifications and has been analysed to account for differences tail lengths, yield of each sub primal and associated cut sale price per kg.

5.1.1 Spinal Cord Removal

The removal of the spinal cord is conducted by the automated system. Trials conducted on the middle cutting system confirmed that there was no difference observed in the effectiveness of the spinal cord removal between the manual and automated system. Therefore the only benefit of the automated system on the removal of the spinal cord is the reduction in labour requirements for the boning room. One labourer was saved across this task and bone dust scraping.

5.1.2 Shortloin Pair - Flap removal

The variation observed in the removal of the flap from the shortloin pair is shown in Figure 40. This variation has a substantial effect on the value of the shortloin pair. When the cut is conducted in a negative direction (shorter tail) product is lost from the shortloin pair as trim. Value of loss shown in this graph represents an improvement of between $0.29 and $0.33/hd. Cutting variation is less in the manual results than observed during trials which makes it easier to adjust and optimise cutting lines for accuracy and increased value than was possible with manual processes.

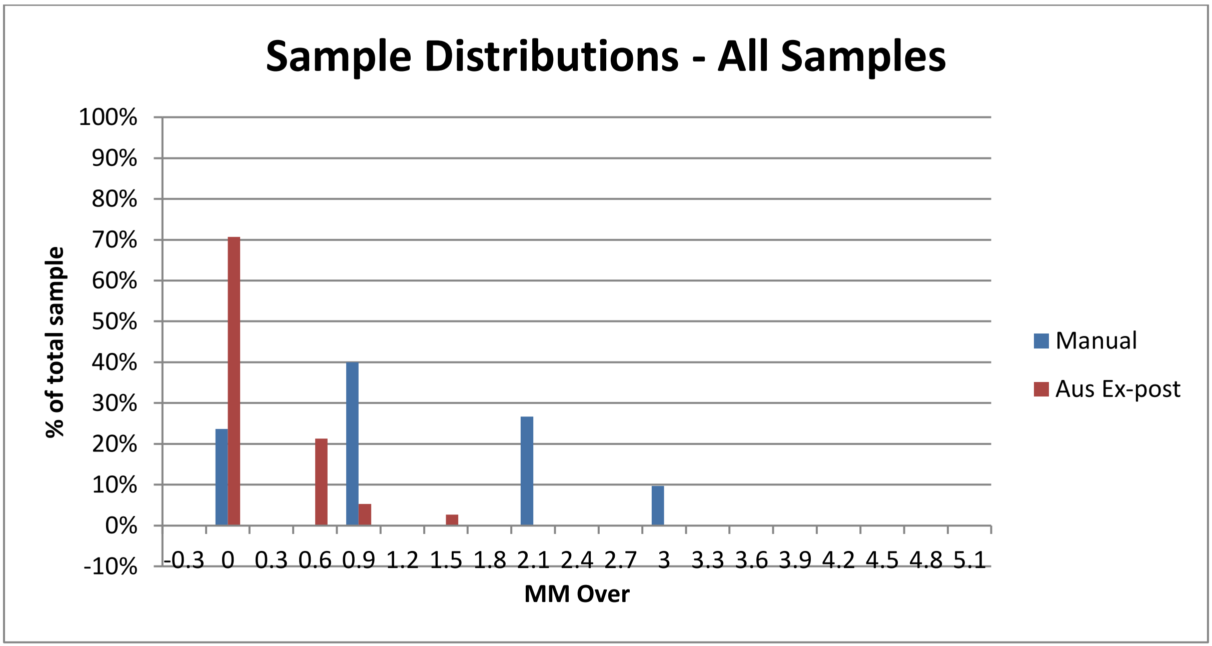

Figure 40: Cutting inaccuracy in the length of the flap removed off the Shortloin pair

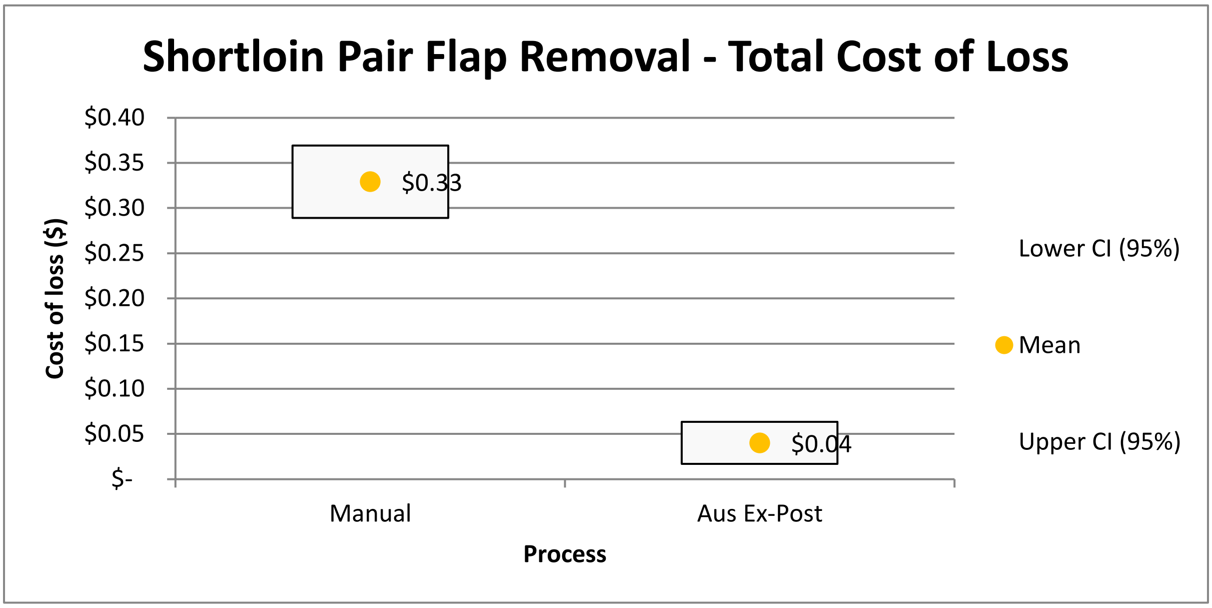

Figure 41: Value of loss per carcases for removal of the flap from the shortloin pair.

5.1.3 Rack - Flap Removal

The variation in the removal of the flap from the Rack can have a considerable affect in the value of the product sold. The variation observed in the removal of the flap off a Cap-off frenched 100mm rack is shown in Figure 42.

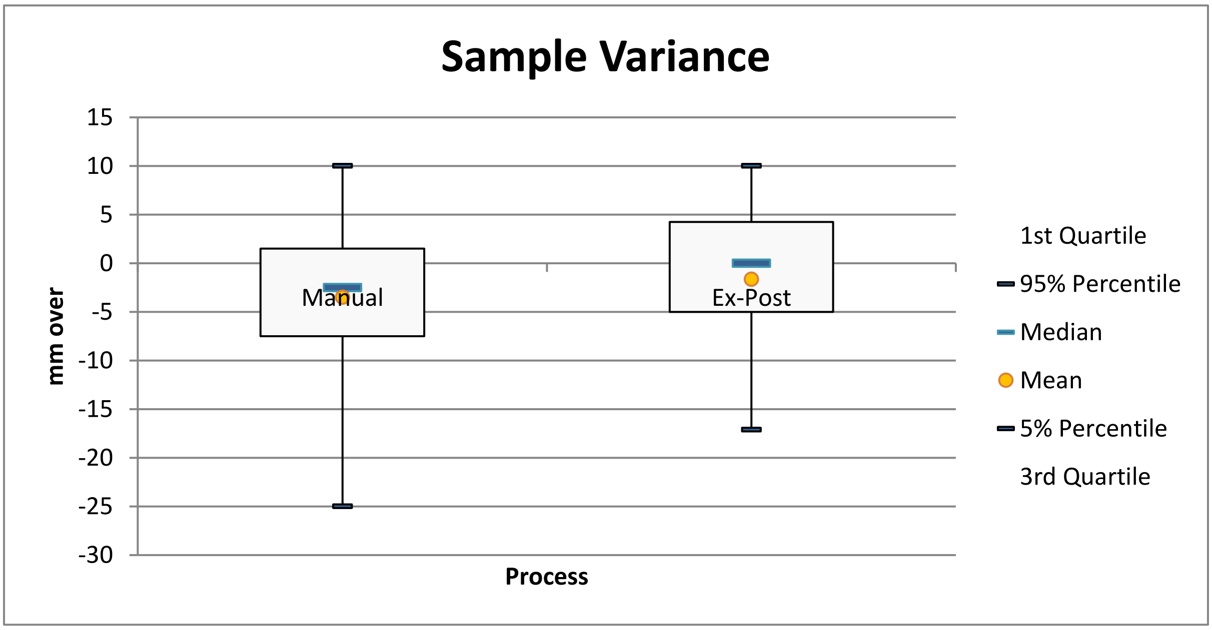

Figure 42: Tail length variation from the ideal cut length when removing the flap from the rack

The value of loss attributed to un-frenched products was calculated to incorporate the total value of loss for the cap, intercostal and bone.

The methodology for costing frenched product has changed slightly when compared to previous studies on the primal cutting system. The costing method of frenched product in this study did not included a change in the value of intercostal as frenched rib length changed. This is due to the plant manually freching racks and thus the frenching line is dependent on the frencher not the automation system.

The combination of the 8 different cutting specifications was used to calculate the value of loss attributing to the savings shown in Figure 43. The breakdown of these cutting specifications can be seen in Figure 43 below. The yield benefit across these specifications has caused substantial reduction in the cost of loss between manual and the ex-post performance in Figure 43. The reduction in variation in the cutting locations allows processors to maximise the tail length whilst remaining within the customer's specifications.

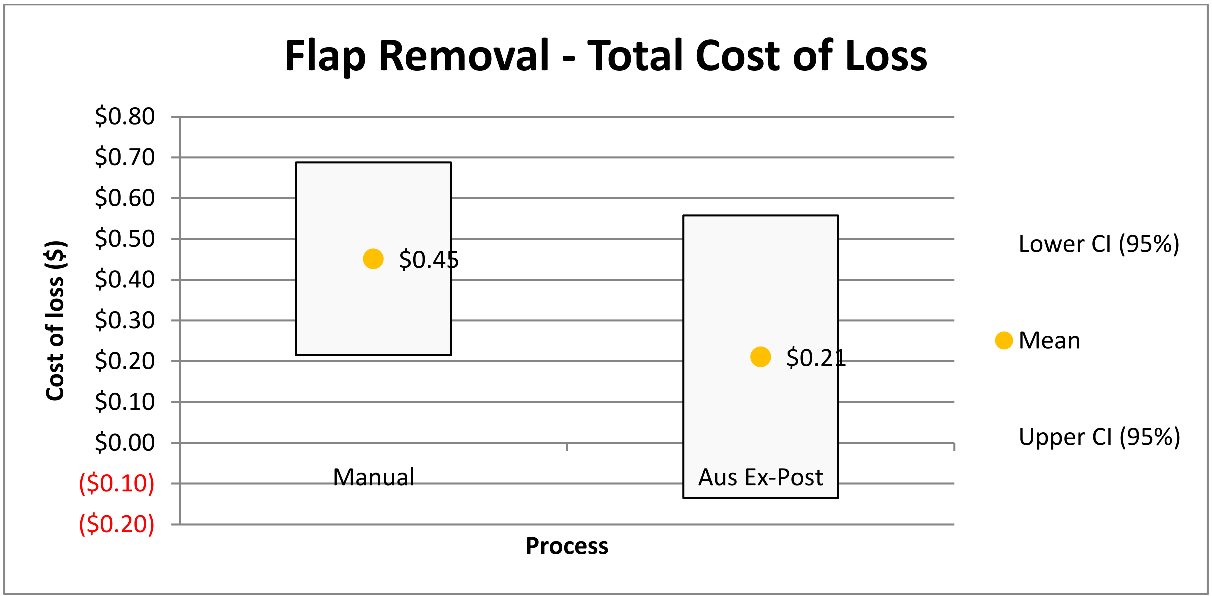

Figure 43: Total cost of loss for the removal of flaps from racks

5.1.4 Rack lost to Shortloin Pair

The variation in the cut between the shortloin pair and rack required 4 measurements to be completed to estimate variation occurring from the manual operator. The collection methods of the following three measurements can be observed in section 4.2.1.

- Angulation of the cut;
- Number of ribs;
- Millimetres over the ideal location of the cut;
- Number of ribs removed

Angulation

The angulation of the cut mainly affects the amount of bone and intercostal sold as rack or render and trim. The value increase for this cut was minimal as operators accurately line up the angle when cutting the ribs. The variation can be seen in Figure 44 which shows the grams from the rack to render and shortloin pair.

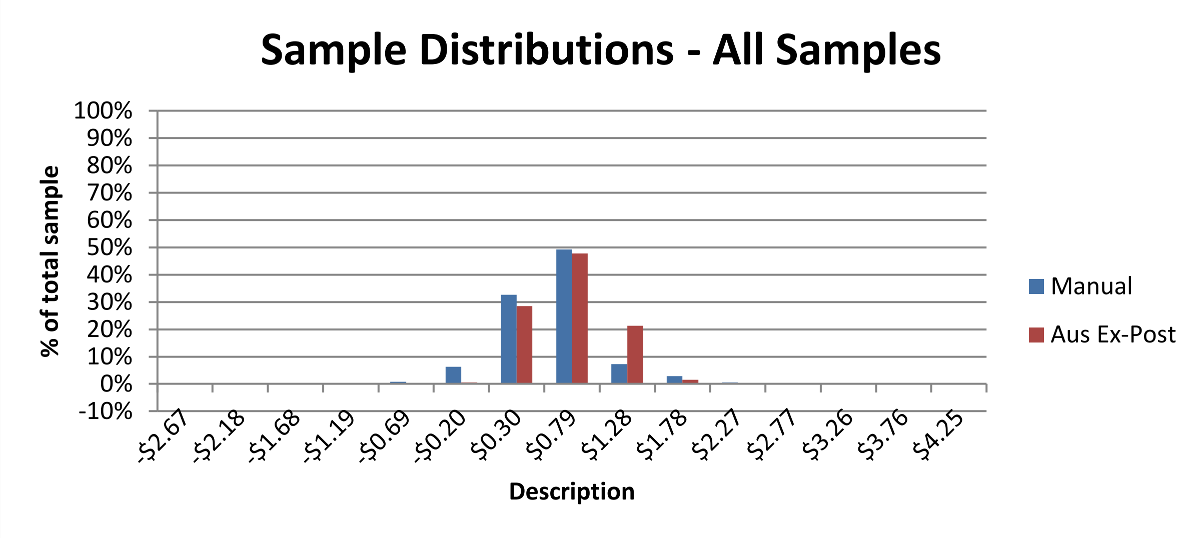

Figure 44: Square centimeters of meat lost from the rack to the shortloin pair as a result of the angle and location of the cut

The total value of loss per head demonstrated by this cut is -$0.09/hd.

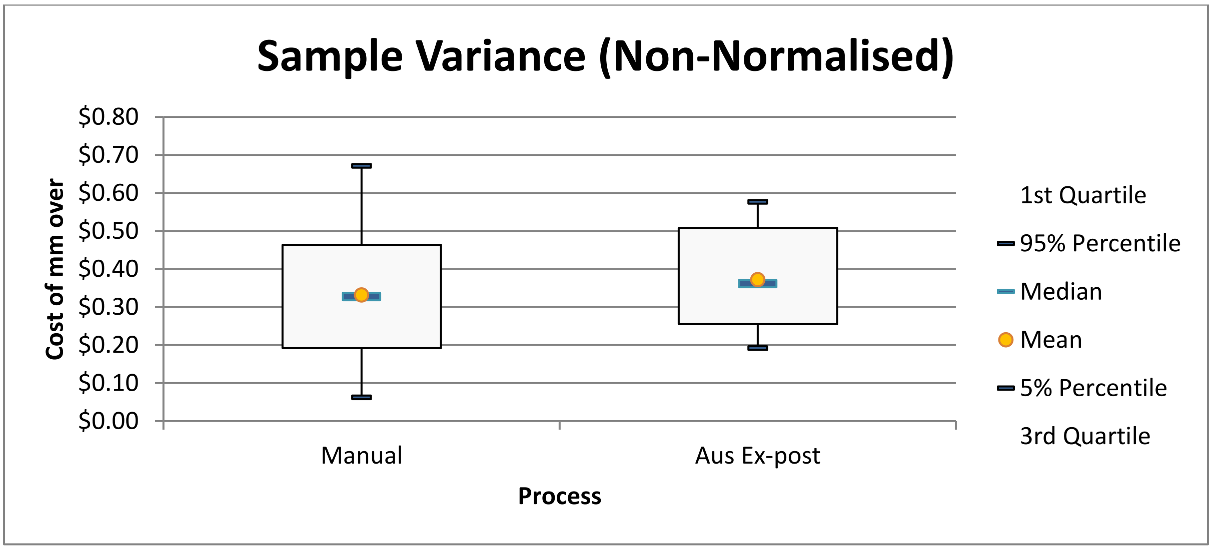

Figure 45: Total value of loss due to the variation in the angle of the shortloin pair to rack cut

Number of ribs

There was very minimal value attributed to the number of ribs on primals, as the manual operator was constantly cutting the right number of ribs.

The total value across all the cutting specifications was $0.00/hd. The variations in costs shown below are only for a 8 rib rack which demonstrated the greatest variation of all the cutting specifications.

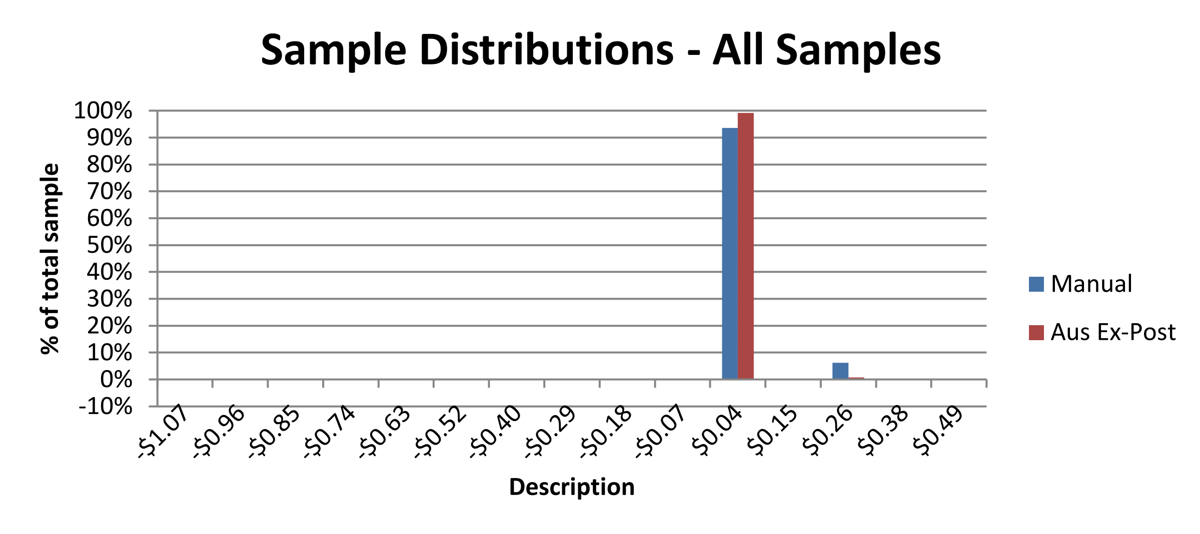

Figure 46: Value of loss associated with cutting the incorrect number of ribs, the peak at $0.04 is the ideal number of ribs, the 0.26 peak is one rib short.

The two peaks in Figure 46 are representative of 0 and 1 ribs missing from left to right respectively. The middle peak is this graph would have been cut as shown in Figure 47, which represents a 9 rib rack which has been cut as an 8 rib product.

Figure 47: Variation observed in the number of ribs a product contains

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Maximising weight and length of rack

The cut between the rack and shortloin pair tends to be cut too far into the rack. This 5 to 10mm over the cutting line accounts for most of the value of loss between the rack and shortloin pair and is a significant value opportunity seen in Figure 48. The ideal location for this cut is at the left hand black line; this is where the 9th rib is slightly below the frenching line.

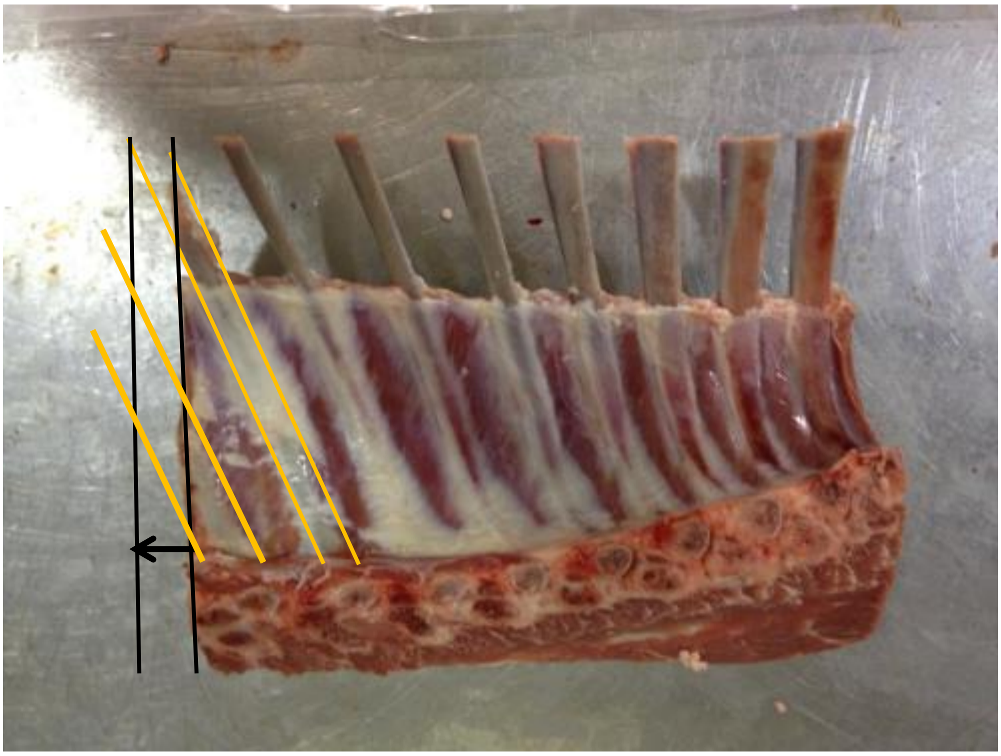

Figure 48: The Left hand black line represents the length of product added to a frenched rack (move to number of ribs)

Optimising accuracy of this cutting line represents the largest value opportunity of the automated system. The variation on this cut can be observed in Figure 49, the ideal location of this cut varies between cutting specifications for 9 rib racks the maximum width from the 8th rib is 45mm whereas with a frenched 8 rib rack the maximum width is only 22mm. The value of loss was estimated by maximising the weight of the rack without causing a half rib to protrude into the frenching line.

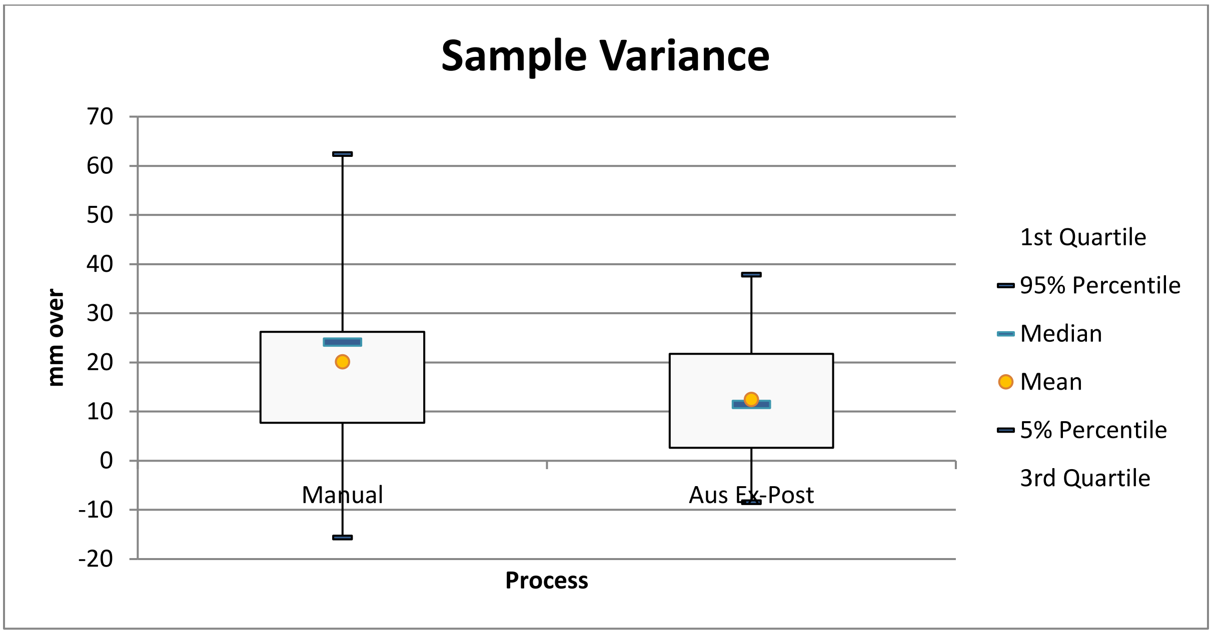

Figure 49: Variation observed when splitting the rack and shortloin pair on a 8rib rack.

The weight gained on un-frenched (Figure 47) products will be greater than that of frenched (Figure 50) product. The main factors enhancing the extent to which the system can add value is as follows:

- Angulation of the 8th of 9th rib depending on the specification
- Whether products are frenched or un-frenched as there will be additional weight added to the frenched product as per the black lines in Figure 47 and Figure 50.

The automation system demonstrated it was able to identify the ideal location of the cut on un-frenched products. The variation in value attributed to this cut for the 100mm frenched rack is shown in Figure 50. The variation in the total value of rack over the 8 cutting specifications was $0.87/hd

The client has not requested differentiation of cutting length based on frenching line but if this were to be provided further improvement in value is expected. This increase in value is suggested as possible based on minimal variation in cutting accuracy during the trials indicating further precision is possible and within the systems accuracy performance. A future research and development project in this area would allow the following to occur:

- Understand how the processor differentiates and assigns rack tail length and frenching specifications
- Test the visioning capability to optimise distribution of racks to different cutting specifications
- Trial enhanced visioning accuracy from DEXA to determine if increased cutting accuracy supports plant processes

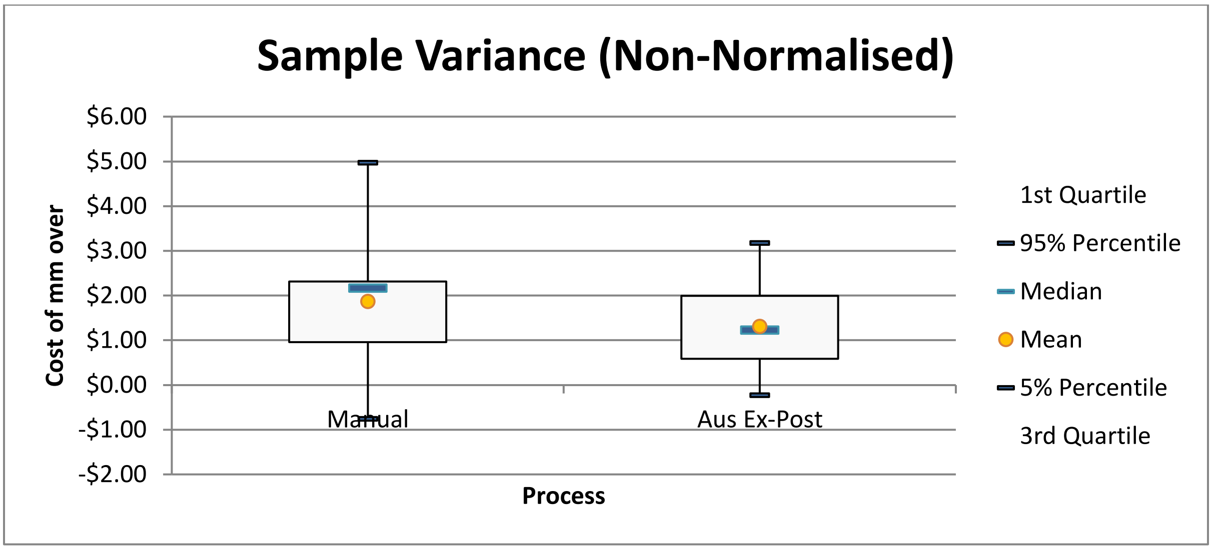

Figure 50: Value of loss attributed to maximising the weight of the rack from the shortloin.

Total Cut Value

The total value attributed to the cut between the Shortloin pair and the racks for all 8 cutting specifications can be seen in Figure 51 with the automated system between $0.64 and $1.17/hd better than manual.

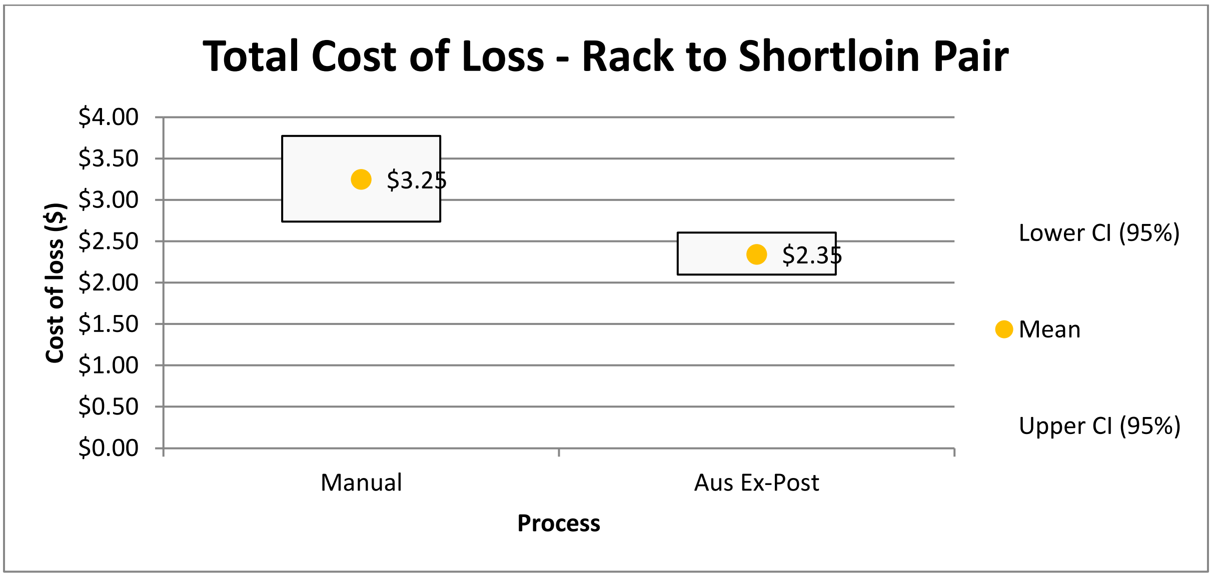

Figure 51: Total value of loss attributed to separating the Shortloin pair and Rack.

5.1.5 Chine Removal

The performance of the chining module for the middle machine was compared to manual bandsaw operations. The improvement in yield of the automated process over the manual bandsaw chinning process was $0.79/hd in yield and savings of one labour unit.

5.2 Reduced Bandsaw Dust

The use of bandsaws for cutting lamb results in bandsaw dust. This has two negative impacts; a) yield loss from the carcass and b) negative visual impact from the residual saw dust left on the surface of the product. The average amount of bandsaw dust collected from the main bandsaw where lamb carcases were being broken into primals was 19.9 grams per carcass across two different manual processing plants (Table 5). An assumption was made that there would be a 90% reduction in sawdust with the automated cutting system. This returned a value of 36.83 kg/ day (based on daily production of 5002 hd), which was costed at an approximate retail carcase value of $7.50/ kg. This resulted in an achievable saving of $0.03/hd.

Table 5: Value of band sawdust lost during manual cutting

Number of head for collection		5002
Weight (kg)	Tub weight	Dust weight
11.70	1.92	9.78
4.17	1.92	2.25
15.83	1.92	13.91
6.40	1.75	4.65
	Total dust weight	30.59
Dust from cut splitting chime bone		30.00%
Total dust that could be saved using equipment (kg)		21.41
Saw dust per cut (from 1500 hd)		7.14
Band saw dust / cut / hd (kg)		0.0014
Value of saw dust (retail value of whole lamb		$7.50
Cost / hd / Cut		$0.01

5.3 Increased Shelf Life

Increases in shelf life are expected with the use of the automated cutting equipment. This is largely due to:

a) Eliminating oxidized bone dust causing browning of meat surface. (Natural process of oxymyoglobin converting to metmyoglobin and causing browning will still occur).
b) Reduced biological loading
    a. Removal of bone dust from meat surface;
    b. Eliminating the use of water on bandsaw tables currently used during the cutting process;
    c. Reduced human handling of meat;

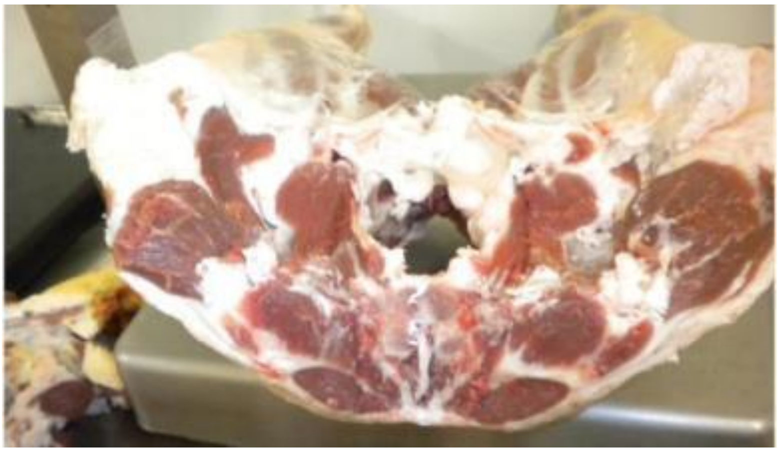

Figure 52: Lamb hindquarter cut with the x-ray primal cutting system, note cut meat surface and lack of bone dust. The same quality of cut is assumed with the middle machine

Based on the assumptions the following reductions in discounts are estimated (Table 6) due to improved visual appearance of the product and increased shelf life. Increased shelf life is a benefit to the retail customer. Export chilled and domestic retail contracts place importance on shelf life, but given a number of other factors influence customer buying decisions, no value benefit of increased shelf life has been captured in this report for the processor.

Table 6: Calculation used to value the increase in shelf life of lamb product via reduced retail discounts.

Increased Shelf Life (reduced level of discounting)			
	Shoulder (Boneless square cut shoulder)	Loin (Rack Standard)	Leg (Boneless leg chump on)
Average primal weight (kg)	2.57	2.80	5.20
Number of items in 1 year	2,311,373		
Current level of discounting	4.00%		
Number of items discounted	92,455	92,455	92,455
Weight of discounted (kg)	237,609	258,874	480,766
True Value	$2,043,438	$4,918,601	$4,322,082
Discount Value	$1,634,751	$3,934,881	$3,457,666
Current cost of discounting	$408,688	$983,720	$864,416
Reduction in level of discounting	4.00%		
New level of discounting	3.84%		
New number of items discounted	88,757	88,757	88,757
New quantity (kg)	228,105	248,519	461,535
New True value	$1,961,701	$4,721,857	$4,149,199
New Discount Value	$1,569,361	$3,777,486	$3,319,359
New cost	$392,340	$944,371	$829,840
SAVING	$16,348	$39,349	$34,577
Saving per head (leg reduced discounting)	$0.014	$0.034	$0.030
Number of cuts	2	$0.04	
	3	$0.08	
	4	$0.11	
Total Saving /hd	Total	$0.11	

**Average primal weights are based on results from industry bone out trials of 121 lamb carcases (average carcasses weight 24.58 kg)*

5.4 Labour Savings (Reduced Staff)

Labour savings provide benefits in two areas:

- Reduction in staff numbers as a direct result of automation
- Reduction in cost of labour per kilogram processed (include increased number of staff BUT an increase in throughput greater than the increase in labour cost)

5.4.1 Reduction in Staff Numbers

Table 7 shows the number of staff required in each position of the boning and packing rooms per day for the manual process. The second column shows no change in throughput and five staff members saved.

The estimated labour saving of $0.31/head depending on the throughput of the system is expected by the plant with the refinement of the middle machine when considering throughput productivity gains. The number of staff saved at this plant will depend largely on the number of boners maintained.

Table 7: Labour savings achieved with the lamb middle cutting per shift.

Labour Savings per day		
	Number labour units required per day	
Task	Manual	Aus Ex-Post
Supervisor	4	4
QA	1	1
Boners	16	16
Bandsaw operators	6	3
Ticketing	4	4
Knife hand	16	16
Trimmers	5	5
Packers	36	36
General Labour	6	9
Total FTE's required	94	94
Total FTE's saved	-	3
Saving per head	$0.00	$0.31

5.5 Labour Savings (Increased Productivity)

The main driver behind increases in efficiencies for existing labour is a more consistent throughput of product through the cutting room. The manual processes rely on the bandsaw operator to set the speed at which the carcasses enter the boning belt. This rate varies depending on the bandsaw operator and carcase size. This leads to labourers either operating at less than optimum speeds or a build-up of product where operators are not able to keep up.

One of the main advantages of lamb middle cutting is the increases in the consistency of throughput which can improve flow. The information detailed in Table 8 demonstrates the increase in efficiency that may be achieved through the room in addition to the bandsaw and general labourer savings. This table quantifies the value of increased throughput created by a consistent product flow.

Table 8: Manning of processing room

Increased throughput through the room			Manual	Aus Ex-Post
Average daily hd			4820	5297
Hd/annum			1,156,754	1,271,255
Average kg			21.88	21.88
Total Kg boned per day			105,457	115,896
Boning room cost / hour			$3,051	$3,145
Boning room cost / day			$46,377	$47,799
Labour cost \ per kg to bone			$0.44	$0.41
Labour cost \ per hd to bone			$9.62	$9.02
Labour productivity savings/ head			**$0.00**	**$0.60**
Task	**Rate / hour**	**WW Loading** 35.00%	**Number labour units per shift - Manual Process (Note - this is gross of labour savings - based on No. of Head above)**	
Supervisor	$35.00	$47.25	4	4
QA	$31.00	$41.85	1	1
Boners	$24.00	$32.40	16	16
Bandsaw operators	$26.23	$35.41	6	6
Ticketing	$23.10	$31.19	4	4
Knife hand	$23.10	$31.19	16	16
Trimmers	$23.10	$31.19	5	5
Packers	$23.10	$31.19	36	36
General Labour	$23.10	$31.19	6	9
		$0.00		
Total FTE's required			94	97

The improvement in labour productivity delivers a benefit of $0.60/head when operating at the 9.9% increase in processing rate of the the room. The ex-post speed of 5.81 carcases per minute which could be achieved once commissioning stoppages have been overcome. Manning levels may increase to accommodate the 9.9% increase in throughput per man hour and have been factored in the calculations.

5.6 OH&S Issues

Two main areas are identified where the automated primal cutting system will provide OH&S benefits. These are reduced sprain and strain injuries through eliminating the need for bandsaw operators to be lifting primals, and eliminating the need for any operator interaction with a saw blade for the cutting of lamb primals.

Based on these assumptions the following frame work is presented to show OH&S Benefits (Table 9).

Table 9: OH&S Benefits of automated middle cutting

OH&S				
	Band Saw cutting	Sprain and Strain		
Job Role Affected	Bandsaw operators	3		
Claims in last 10 years	4.0	40.0	Manual	Aus Ex-Post
Risk / FTE / Year	6.7%	66.7%		
Annual Premium	$19,200	$10,000		
Job Annual Hours			21,888	10,944
Limb Losses per year			0.40	0.20
Sprains and Strains per year			4.00	2.00
Annual Cost			$47,680	$23,840
Annual Cost / Head			$0.04	$0.02
Annual saving per head			$0.00	$0.02

5.7 Operational Costs

Table 10 shows the total cost of the equipment Including both capital and operational costs. Real costs will be site specific to every application particularly installation costs.

Table 10: Estimated capital and operating costs of automated x-ray primal cutting equipment

Capital Cost	Manual		Aus Ex-Post	
	Cost	Life span	Cost	Life span
Capital Cost of the equipment			$1,710,000	10
Installation Costs			$200,000	10
Other Capital install			$190,000	10
Total			**$2,100,000**	
Service maintenance	Manual		Aus Ex-Post	
	Units	Cost	Units	Cost
Estimated - COSTS				
Electricity	6.00 KW	$0.14 /KWH	6.00 KW	$0.22 /KWH
Maintenance labour (Daily)		0 /Yr		0 /Yr
Maintenance labour (Preventative)		$0,000 /Yr		$50,000 /Yr
Maintenance labour (Breakdown)		$13,056 /Yr		$80,000 /Yr
Maintenance labour (Training)		0 /Yr		0 /Yr
Operational		**$2,999**		**$54,815**
Maintenance		**$13,056**		**$80,000**
Annual Sub Total (excluding major overhaul costs)		**$16,055**		**$134,815**
Combined Total: (cap ex + operating)				
Total Annual Estimated Expenses	Hours	Cost	Hours	Cost
Expected downtime hours per year		0.00 /Yr	10	$31,447 /Yr

5.7.1 Capital Costs

Equipment purchase price is based on prices supplied by the manufacturer. Installation costs will be site specific, and will depend largely on the foot print available within the existing plant. Infrastructure upgrades may be required at some plants and allowance has been provided in the model for site specific numbers to be included. The capital cost per head processed will reduce as the total annual number of head processed increases.

5.7.2 Maintenance and Service Costs

Maintenance and service costs are also supplied by the equipment manufacturer. Maintenance costs are additional running costs that the plant will incur with the installation of the equipment and include components such as parts and labour. The service contract covers ongoing service and maintenance of the system. The assumption is made that these costs will be a “per head cost” and for this reason no reduction in these costs is seen with increasing production.

5.7.3 Risk of Down Time

To estimate the cost of down time for an average installation 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 (Table 7) is used to calculate the cost of down time. The amount of weekly down time is an adjustable figure found on the “Costs” sheet of the model.

5.8 Cost Benefit Analysis

The source of benefits all came from operational efficiencies, increased yield and labour savings. The summary results in Table 11 demonstrate the performance of the Ex-post machine at the current throughput and at an increase of 9.9% in room efficiency.

The ex-post net benefit between $3.01/hd to $3.35/hd with an increased in throughput of 9.9%. This delivers an estimated return on investment of between 0.54 and 0.60 years.

Table 11: Summary of benefits for the Ex-post increase using no throughput benefit and a 9.9% increase in labour efficiency.

SUMMARY PERFORMANCE MEASURES		
	Aus Ex-Post	
Hd / annum	1,271,255	
Production increase with equipment	9.90%	
	From	To
Capital or Lease cost	$2,100,000	
Gross return Per head	$3.01	$3.35
Total costs Per head	$0.30	
Net Benefit Per head	$2.72	$3.05
Annual Net Benefit *(Incl. capital cost)*	$3,452,962	$3,881,450
Annual Net Benefit *(Excl. capital cost)*	$3,496,700	$3,925,188
Pay back (years)	0.60	0.54
Net Present Value of investment	$23,627,109	$26,636,636

The benefits identified can be broadly summarised as either product value or processing efficiency benefits with the larger portion of benefits being related to product value in Figure 53.

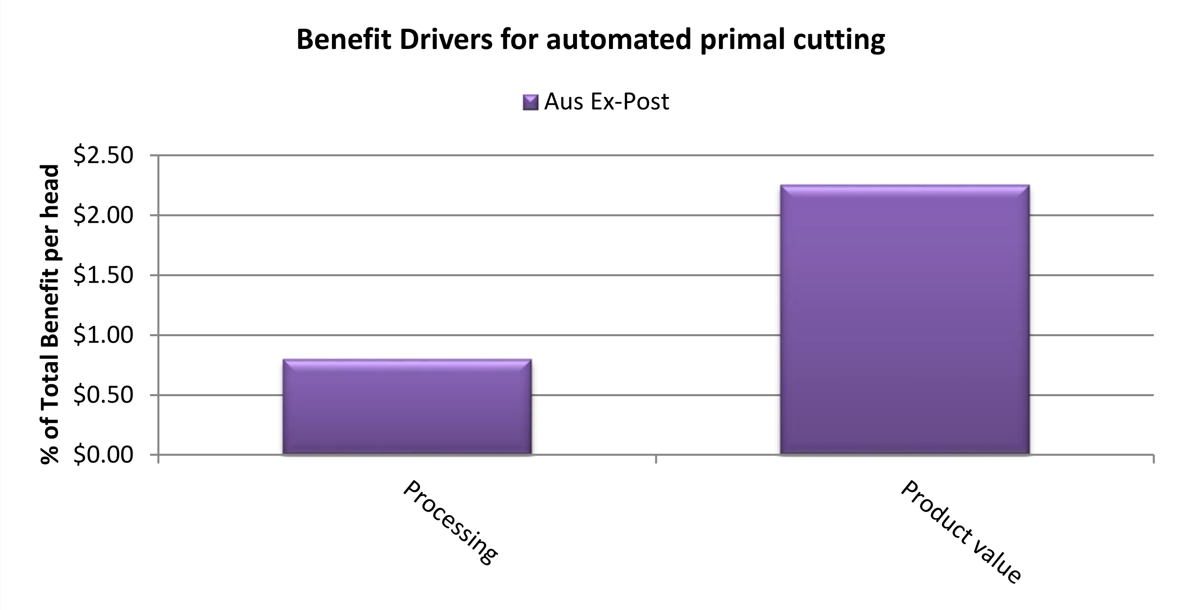

Figure 53: Broad grouping of benefits delivered by lamb middle cutting for the Ex-post benefit.

The main benefits of the automated cutting technology are increased yield, increased labour productivity as a result of more consistent product flows, and a reduction in labour units required. Occupational health and safety costs will reduce by removing bandsaws and reducing primal weights managed through the remaining bandsaws. There may be small yield gains through reduced bandsaw dust but this was not counted in the modelling. The contribution of each individual benefit is summarised in Figure 54 and Table 12.

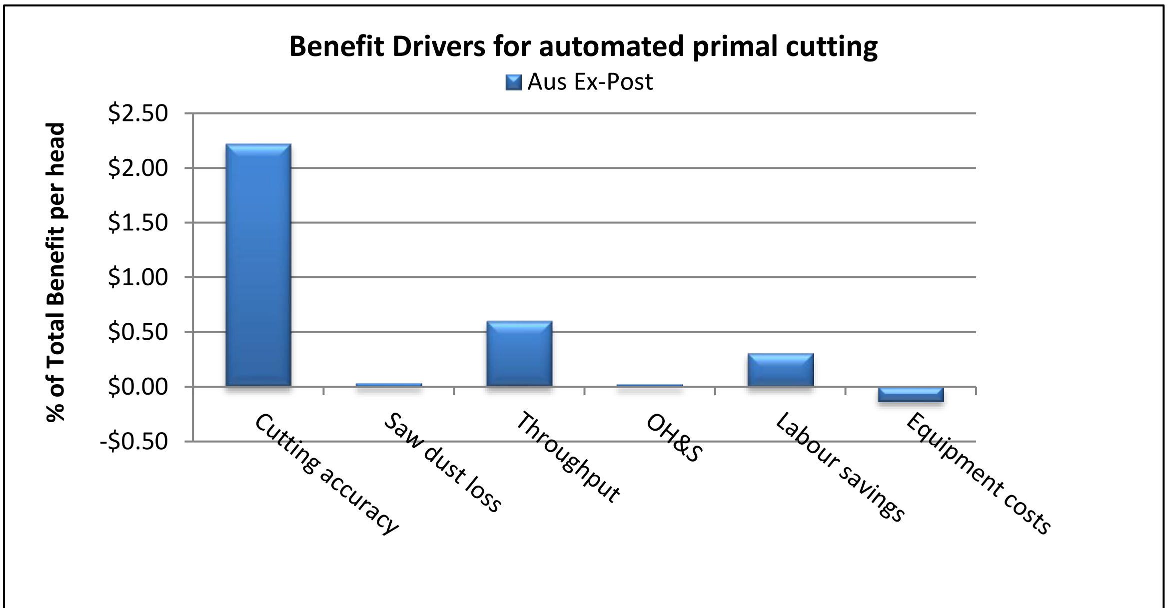

Figure 54: Summary of benefits expected to be delivered from the installation of the lamb middle cutting.

Table 12: Breakdown of benefits and costs by area expected as a result of the installation of the system

Benefit Drivers for Equipment		
	Aus Ex-Post	
	$/ hd	$/ annum
Processing	$0.80	$1,012,228
Product value	$2.32	$2,955,115
	$3.12	**$3,967,342**
Cutting accuracy	$2.29	$2,914,299
Saw dust loss	$0.03	$40,816
Throughput	$0.60	$760,456
OH&S	$0.02	$28,560
Labour savings	$0.31	$389,474
Equipment costs	-$0.13	-$166,262
	$3.12	**$3,967,342**

Increases in labour productivity have been observed with similar types of machines in other processing plants. The expected increase in labour productivity is summarised in Table 13. The first scenario assumes no room modifications and reflects the increase in throughput by having a consistent flow through the room. The likely increase will be around 9.90% in the second scenario which includes labour savings.

Table 13: Summary of benefits for the installation of the lamb middle machine

SUMMARY PERFORMANCE MEASURES	
	Aus Ex-Post
Hd / annum	1,271,255
Production increase with equipment	9.90%

A summary of the range in costs and benefits for each scenario are included in Table 14 below.

Table 14: Ex-post costs and benefits breakdown for the current throughtput and increased throughput.

COST - BENEFIT ANALYSIS OF ROBOTIC PRIMAL CUTTING EQUIPMENT		
	Aus Ex-Post	
Benefit summary	$/hd	
	From	To
$ Accuracy Benefit per head	$2.05	$2.39
$ Technique Benefit per head	$0.03	$0.03
$ Labour Benefit per head	$0.93	$0.93
$ Automation Costs	($0.13)	($0.13)
$ Overall Benefit per head	**$2.88**	**$3.22**
** Cost is reported as the inaccuracy from target specification OR as the difference between Manual vs. Auto costs*		
COST ASSOCIATED WITH THE EQUIPMENT		
	$/hd	
Capital cost	$0.17	
Maintenance	$0.06	
Operation	$0.04	
Risk of mechanical failure	$0.02	
Total cost per head *(Incl. capital cost)*	$0.30	
Total cost per head *(Excl. capital cost)*	$0.13	

Table 15 shows the range in value associated with each cost of processing. The cost is calculated as any loss from the maximum benefit possible. Presenting the figures this way in the detailed section of the model demonstrates the total costs involved and highlights areas that future savings could be generated.

Table 15: Summary results of individual savings associated with lamb middle cutting for Smallstock

TOTAL BENEFIT			
		Aus Ex-Post	
Loss summary		$/hd From	$/hd To
1.1 Accuracy	Rack loss to shortloin pair	$0.64	$1.17
	Rack flap removal	$0.35	$0.13
	Shortloin pair - flap	$0.27	$0.31
	** Chine removal	$0.79	$0.79
1.2 Cutting Technique	Saw dust loss	$0.03	$0.03
2. Throughput benefit		$0.60	$0.60
3. OH&S benefit		$0.02	$0.02
4. Labour benefit		$0.31	$0.31
Equipment costs	**Maintenance**	-$0.06	-$0.06
	Operation	-$0.04	-$0.04
	Risk of	-$0.02	-$0.02
	$ Benefit per head	**$2.88**	**$3.22**
$ Annual Benefit overall plant		**$1,664,983**	**$1,859,750**

The Figure 55 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.

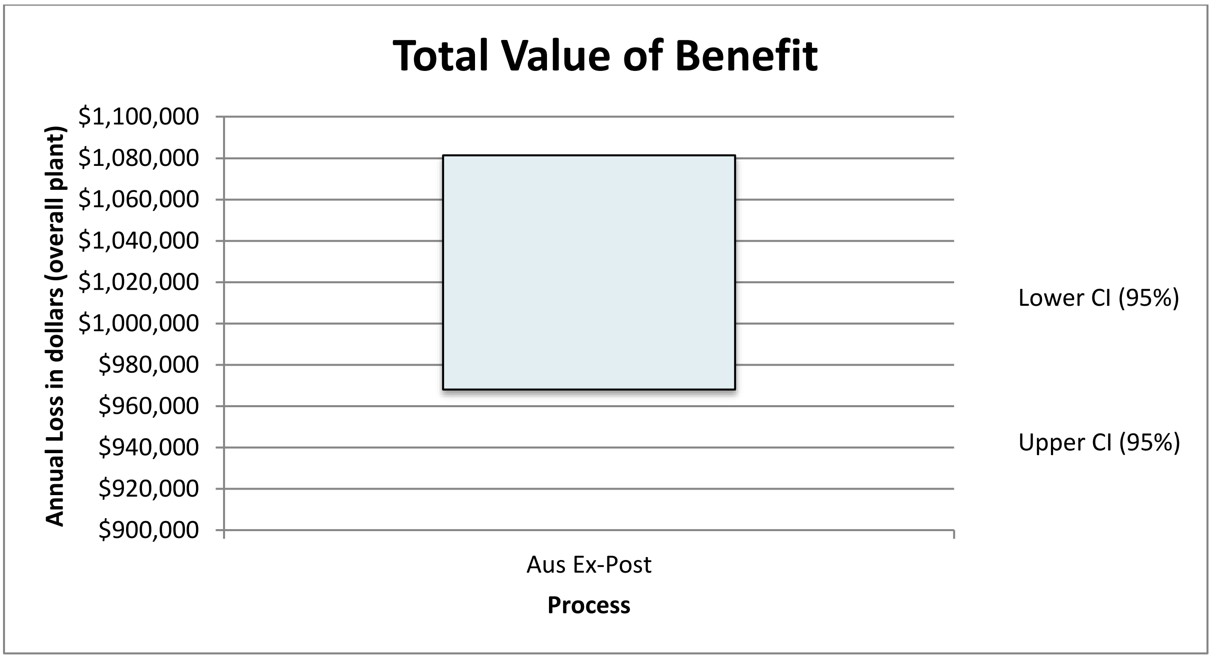

Figure 55: Graphical representation of losses captured in Table 15 showing value of the benefit expected through using the automated systems

6 Appendices

6.1.1 List of Tables

6.1.2 List of Figures