final report

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LEAP IV lamb middle cutting, 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 (LEAP IV) and integration with an existing LEAP III 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 LEAP IV middle machine could be installed without the LEAP III and fed manually from a primal breaking bandsaw but would not realise the full benefits reported in this integrated installation.

The main benefit of this LEAP IV installation is improved cutting accuracy over manual operations and is associated with yield improvement of $2.93head. The middle system automatically conducts the cuts in Table 1 without an operator. Benefit for each of the automated cuts is displayed and compares both ex-ante forecasts and actual ex-post performance against manual baseline performance collected across a year at the site.

Manual processes will always show a range in variation as will automated process (hopefully less than manual).

Table 1: Range in value of yield benefit per head for the LEAP IV system when compared to manual operations

ACCURACY BENEFIT		
	Ex-ante	Ex-post
Benefit summary	$/hd Avg.	$/hd Avg.
Rack loss to Shortloin Pair	-$0.83	$0.34
Rack - Flap Removal	-$0.01	$0.02
Shortloin Pair - Flap removal	$0.03	$0.27
Chine Removal	$2.15	$2.29
$ Benefit	**$1.33**	**$2.93**

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

The system is expected to deliver a return on investment in less than 1 year based on Table 1 benefits. The actual performance and resultant payback is summarised in Table 2 and compares ex-ante projections and ex-post actual performance against the manual baseline. When the manual baseline was set the plant was operating on one 11 hour shift per day. Since then the plant has increased production and operates on two 7.6 hour shifts per day. To ensure a true comparison between manual and automation the manual hours of operation have been adjusted to match the ex-ante and ex-post 2 shift operations.

Table 2: Summary of ex-ante and ex-post benefits relative to manual cutting performance over two shifts

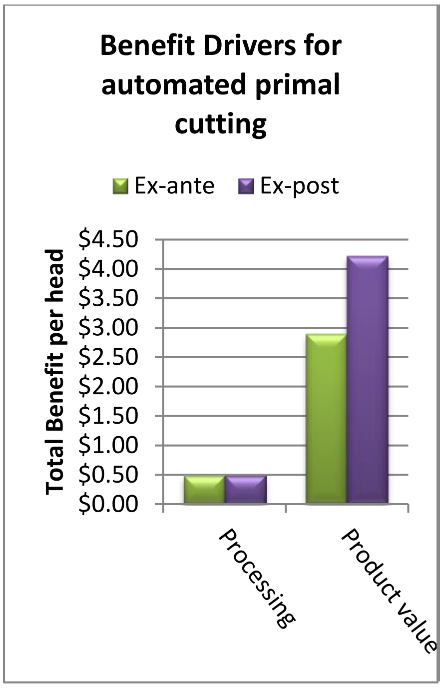
SUMMARY PERFORMANCE MEASURES		
	Ex-ante	Ex-post
Hd / annum	2,120,400	2,120,400
Production increase with equipment	4.21%	4.21%
	From	From
Capital cost (pmt option, upfront)	$2,100,000	$2,100,000
Gross return Per head	$1.53	$3.13
Total costs Per head	$0.18	$0.18
Net Benefit Per head	$1.35	$2.95
Annual Net Benefit *(Incl. capital cost)*	$2,868,523	$6,257,918
Annual Net Benefit *(Excl. capital cost)*	$3,078,523	$6,467,918
Pay back (years)	0.68	0.32
Net Present Value of investment	$20,693,487	$44,499,182

The actual performance in the ex-post review was greater than that forecast in the ex-ante study as all the cutting lines generated a greater value than expected, the following is an explanation of the variation (as seen in Table 1 and Figure 1):

1. Actual separation of shortloin from rack had slightly tighter cut accuracy. The largest improvement over ex-ante estimations was placement of the cut to optimise rack weight without cutting any racks short of the rib specification.
2. Ex-post removal of flap from the rack was less accurate but improved cutting line placement to maximise rib length within specification tolerance.
3. Ex-post separation of flap from shortloin was more accurate than expected. Ex-ante estimates allowed for a small piece of loin to be lost in 50% of cases compared to the manual bandsaw operation had loin missing in 77% of cases. Actual results removed a small piece of loin in 33% of cases.
4. Ex-post chine removal yield percentage improved over prototype trials.

The LEAP IV 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 LEAP IV system. Chine removal contributes 54% of total LEAP IV cut accuracy value so it is not recommended to install LEAP IV without chine removal. Although capital cost would reduce without a chine module the return on total LEAP IV investment would take 3 months longer without including chine removal. A stand-alone manual chine module can be integrated into a fully automated LEAP IV system at a later date.

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.



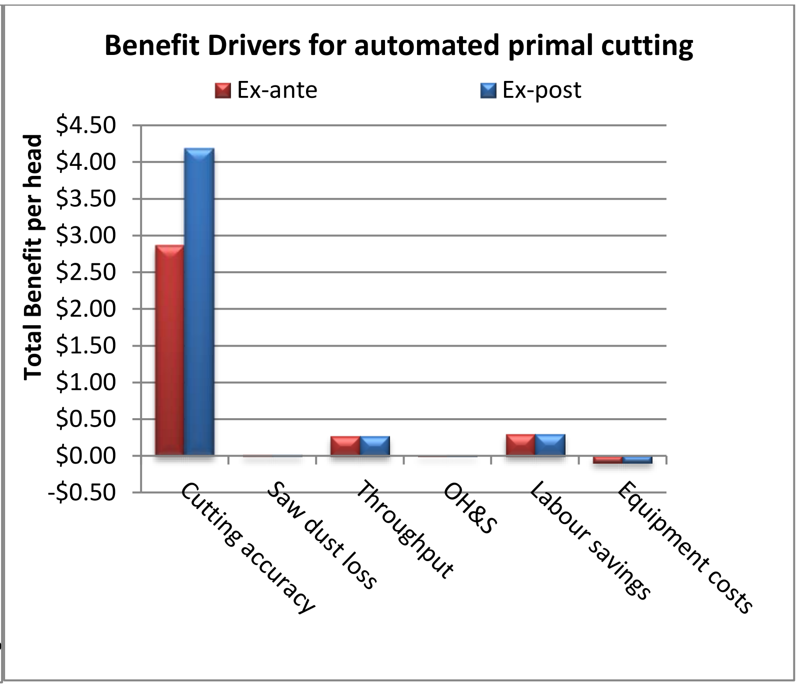


Figure 1: Broad grouping and detailed breakdown of benefits delivered by LEAP IV Middle system on 2 shifts including chine removal.

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
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 LEAP IV system.

2 Objectives

The objective of this project was to review performance of the LEAP IV Middle cutting system 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 in an Australian processor.
2. Summarise the value benefit and main drivers for adoption of the equipment for Australian 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 Integration Robots

The Figure 2 below shows the LEAP III x-ray primal cutting system in the background and the integration systems which transfer the cut primals (saddle and shoulder) to the associated LEAP IV Middle.

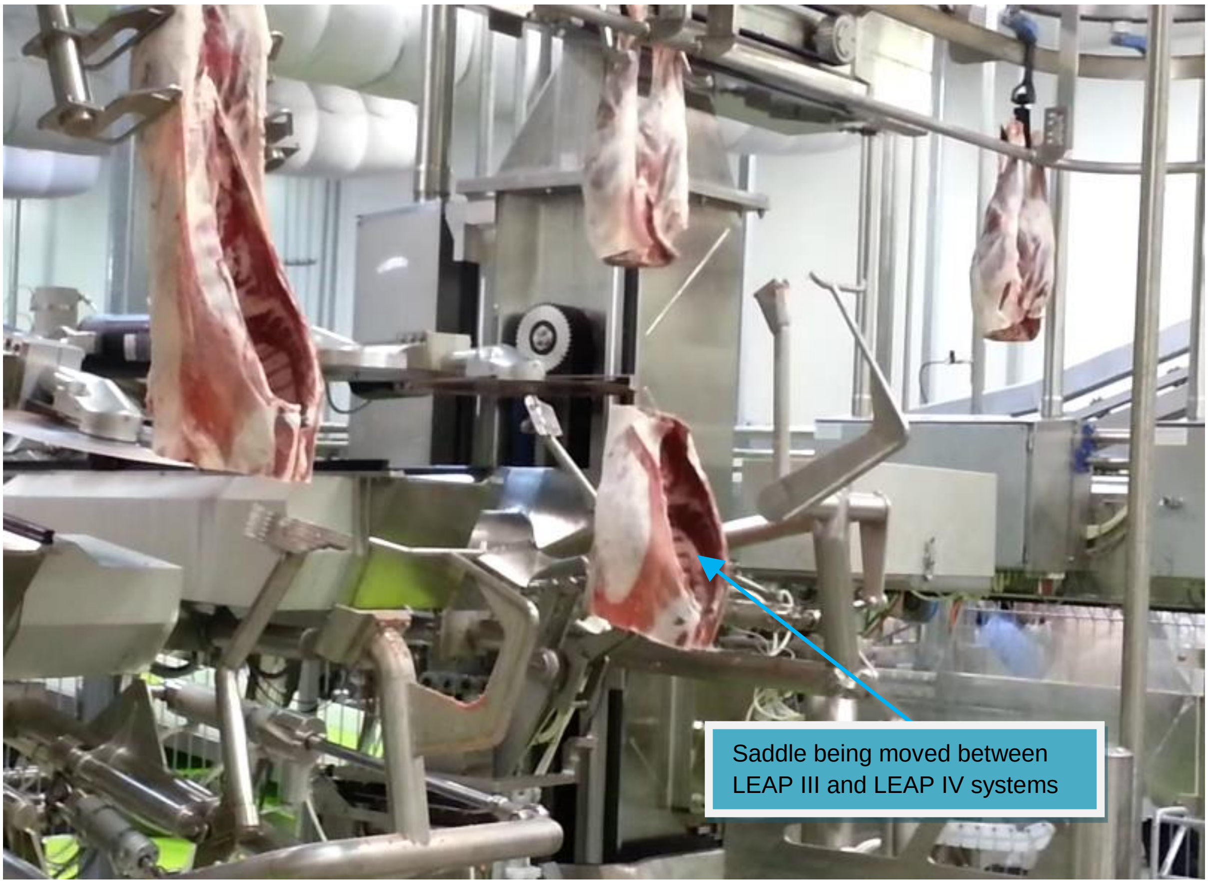


Figure 2: Primal System (background), Saddle and Forequarter integration system (foreground)

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

- Advantages of stand-alone LEAP IV installation
    - Lower capital installation and smaller foot print
- Disadvantages of stand-alone LEAP IV 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

3.2 LEAP IV 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 2) 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 LEAP IV system 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.

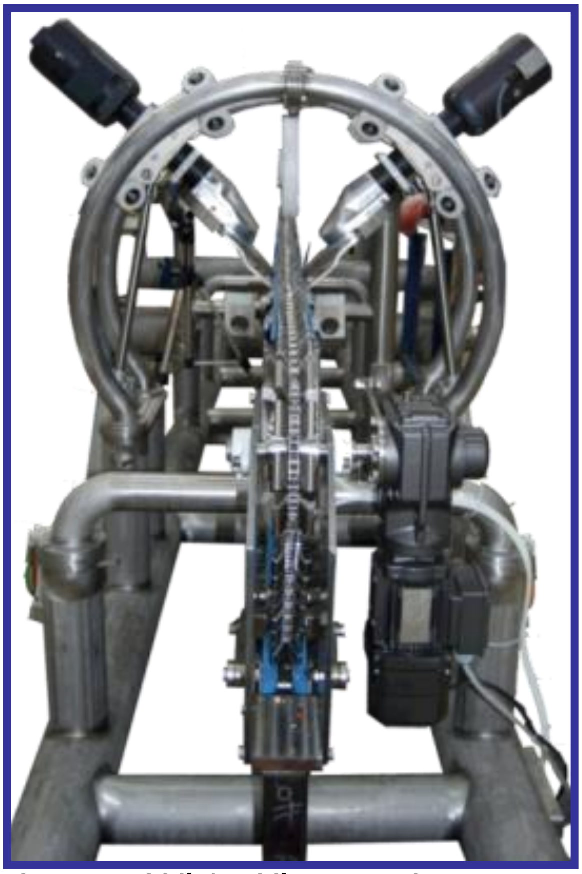


Figure 3: Middle/Saddle processing system

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 3 consecutive days of commercial production totally 6 days of data. 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 3 days of automated operation 14,030 carcases were processed in total with 2,748 samples being taken (19.6% of production). The range of carcases processed represents the full range in carcase weights expected across the Australian population. Figure 4 indicates the samples measured were representative of the total population.

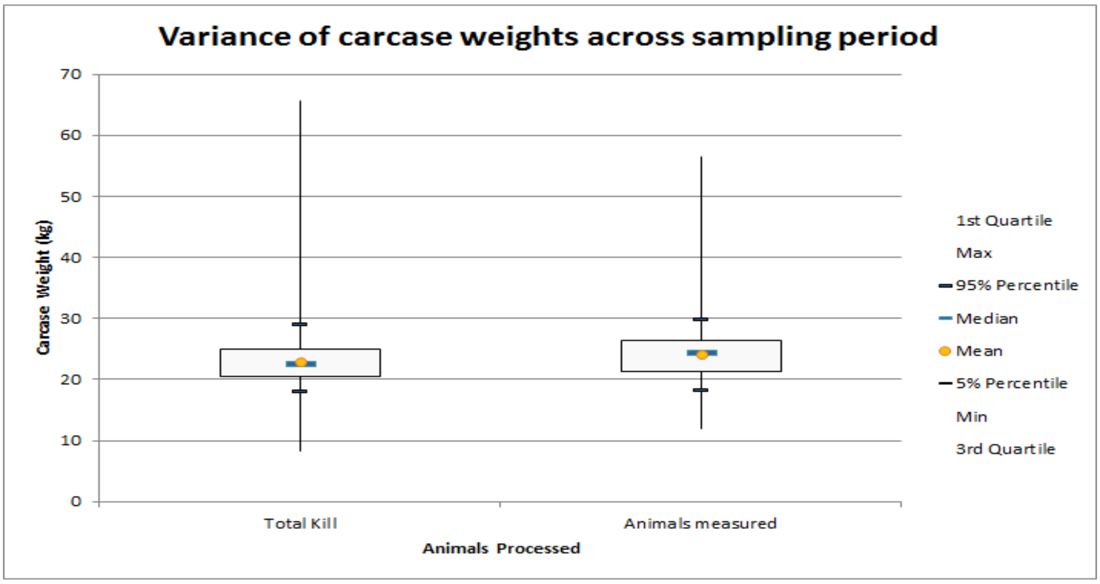


Figure 4: Carcase weights sampled are representative of the total population processed

The summary of data collected during the ex-ante and 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 ex-ante 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. The size (length) of racks is important and there is a non-significant difference in rack length between the trials.

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

Data collection		
Meaurement	Manual	Ex-post
Start Date of collection	25/06/2013	26/05/2014
Finish Date of collection	27/06/2013	28/05/2014
Number of collection periods	12	24
Rack Weight		
Number of samples	120	218
1st Quartile (mm)	622	1012
Median (mm)	703	1192
3rd Quartile (mm)	841	1360
P-value		0.00
Rack length		
Number of samples	120	217
1st Quartile (number of ribs)	210	210
Median (number of ribs)	215	220
3rd Quartile (number of ribs)	225	235
P-value		0.08
Rack Tail length		
Number of samples	263	219
1st Quartile (mm from tip of cartilage)	73	78
Median (mm from tip of cartilage)	88	98
3rd Quartile (mm from tip of cartilage)	100	103
P-value		0.00
Width of ribs		
Number of samples	120	140
1st Quartile (mm from tip of cartilage)	145	140
Median (mm from tip of cartilage)	155	155
3rd Quartile (mm from tip of cartilage)	160	160
P-value		0.04
Number of ribs		
Number of samples	263	219
1st Quartile (mm from tip of cartilage)	8	8
Median (mm from tip of cartilage)	8	8
3rd Quartile (mm from tip of cartilage)	8	8
P-value		0.00

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 5
3. Removal of flaps
4. Chine bone removal
5. Splitting of rack OR full loin (optional)

Figure 5 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 7)

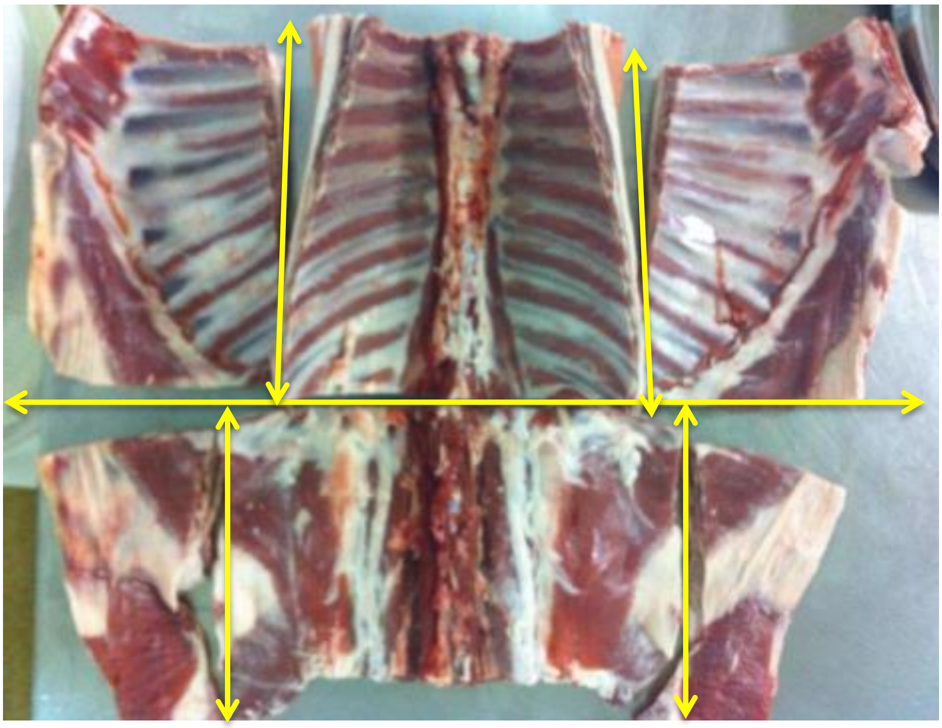


Figure 5: Separation of flaps from rack and shortloin adjustable to customer specification, the yellow lines identifies the cutting lines to be conducted by the LEAP IV system.

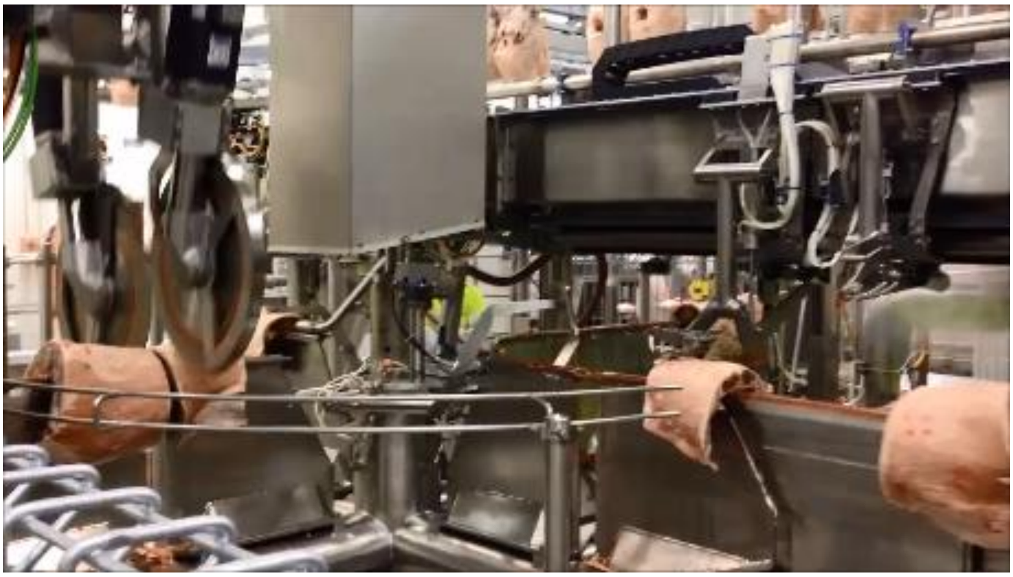


Figure 6: Separation of rack and loin in left of image prior to transfer to further processing of flap and chine removal in right hand side of image.

Figure 7: Alternative LEAP IV 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 8 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.

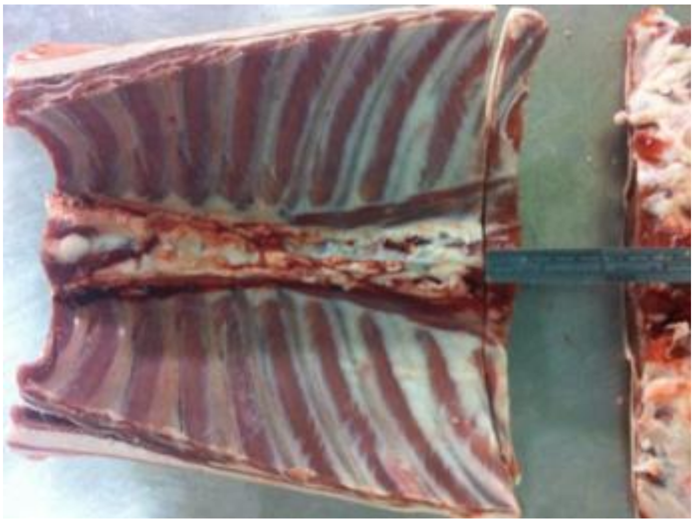


Figure 8: Angle of cut and millimetres from target separation were measured

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.

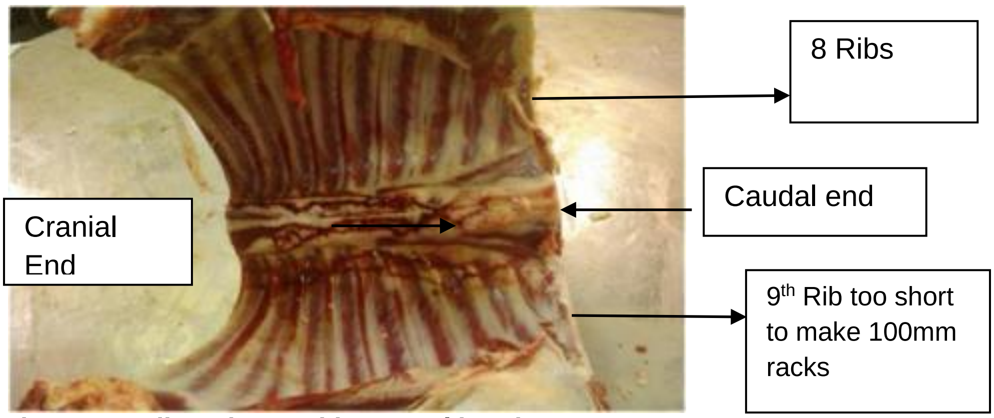


Figure 9: 8 rib rack cut with manual bandsaw.

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 13.

Figure 10 and Figure 11 show the impact on finished product of this cutting line. Eight rib racks are the target specification in Figure 10. Figure 11 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 11 will significantly increase carcase value. Figure 12 has one less rib and will be downgraded. Figure 13 is the result of too many ribs where one has to be removed and downgraded to trim.

Figure 10: Perfect 8 full ribs. 9th rib not present.

Figure 11: 8-rib rack in specification. Portion of 9th rib does not go above the frenching line

Figure 12: 7 rib rack, cut too short between rack and shortloin

Figure 13: Impact of cutting one rib long showing amount of loin lost that would have otherwise been sold on shortloin pair

Figure 14: Establishing value of millimetres of accuracy and value differences in cutting line between rack and shortloin

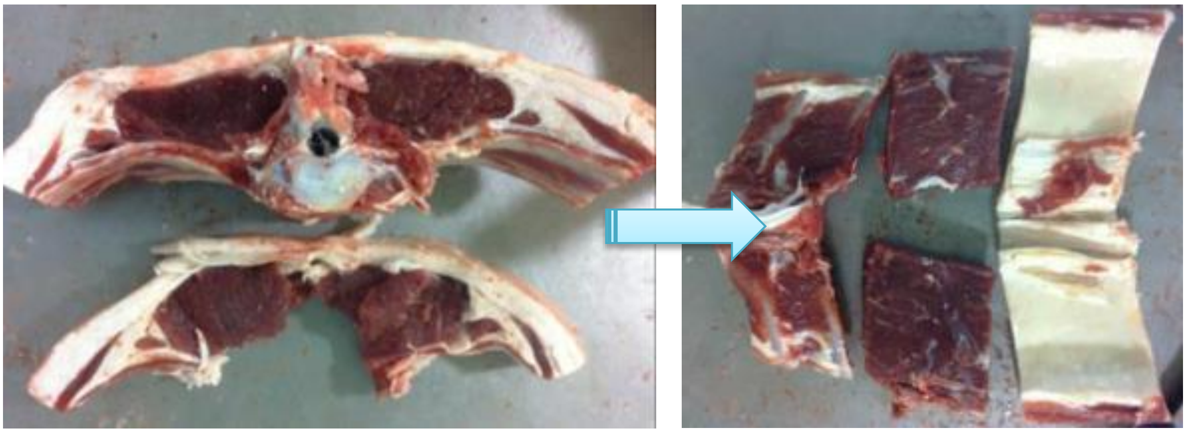


Figure 15: 2 rib portion of Figure 14 boned and valued as part of standard setting activity to establish cost of cutting inaccuracy

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 16. The lines in the below image represent the following variation in yield.

- The yellow line represents yield improvement with the LEAP IV system 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

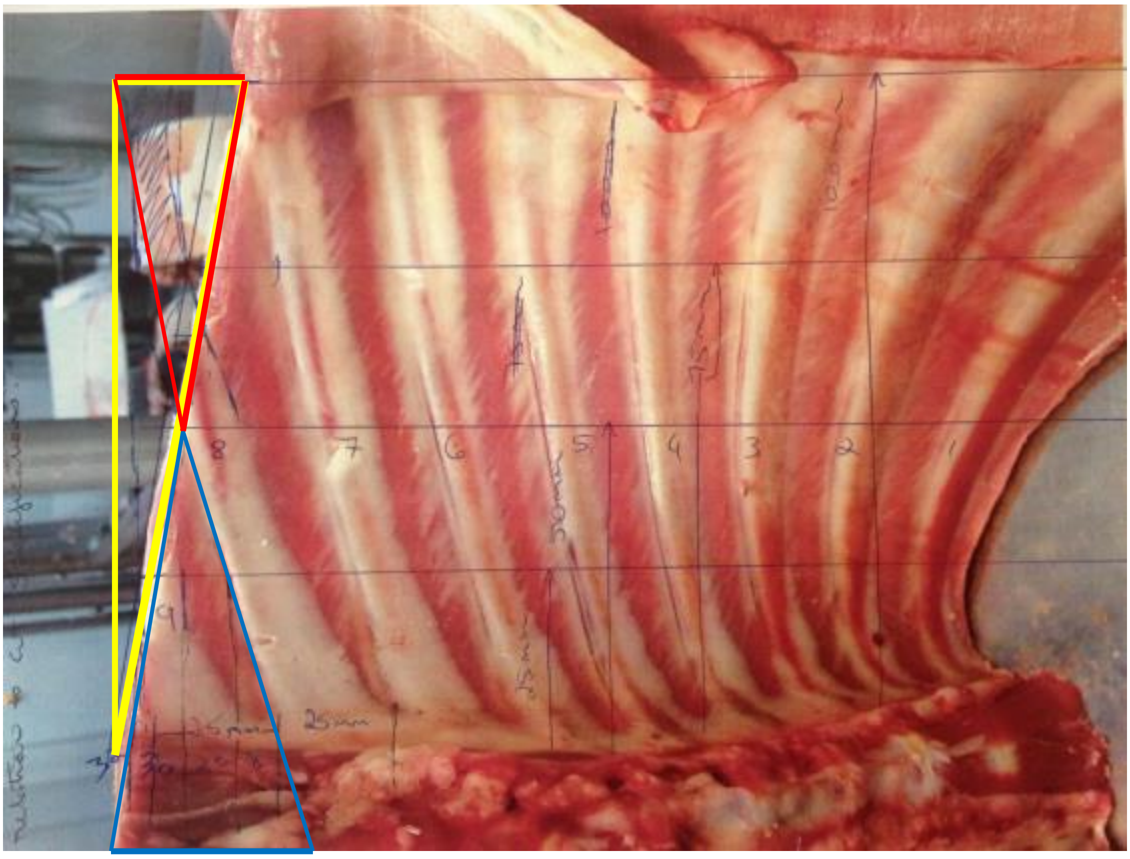


Figure 16: Yield lost and gain through the installation of the automated solution, the yellow triangle will be weight gained when conducting a straight cut. The blue triangle will be weight lost and the red triangle will be weight gained when conducting a scallop cut.

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 17 measured the millimetres of angulation from perpendicular in conjunction with the measurement of length of cut from the centre line in Figure 18 to calculate the surface area of the lost meat and bone.

Figure 17: Development of the standards for the straight cut as shown by the yellow line in Figure 16

Figure 18: Length of the ribs measurement.

The process involved with the development of the standard for the scallop cut can be seen in Figure 19. The area of the triangle shown by the blue and red lines in Figure 16 were then calculated to estimate the value of loss and gain for both segments.

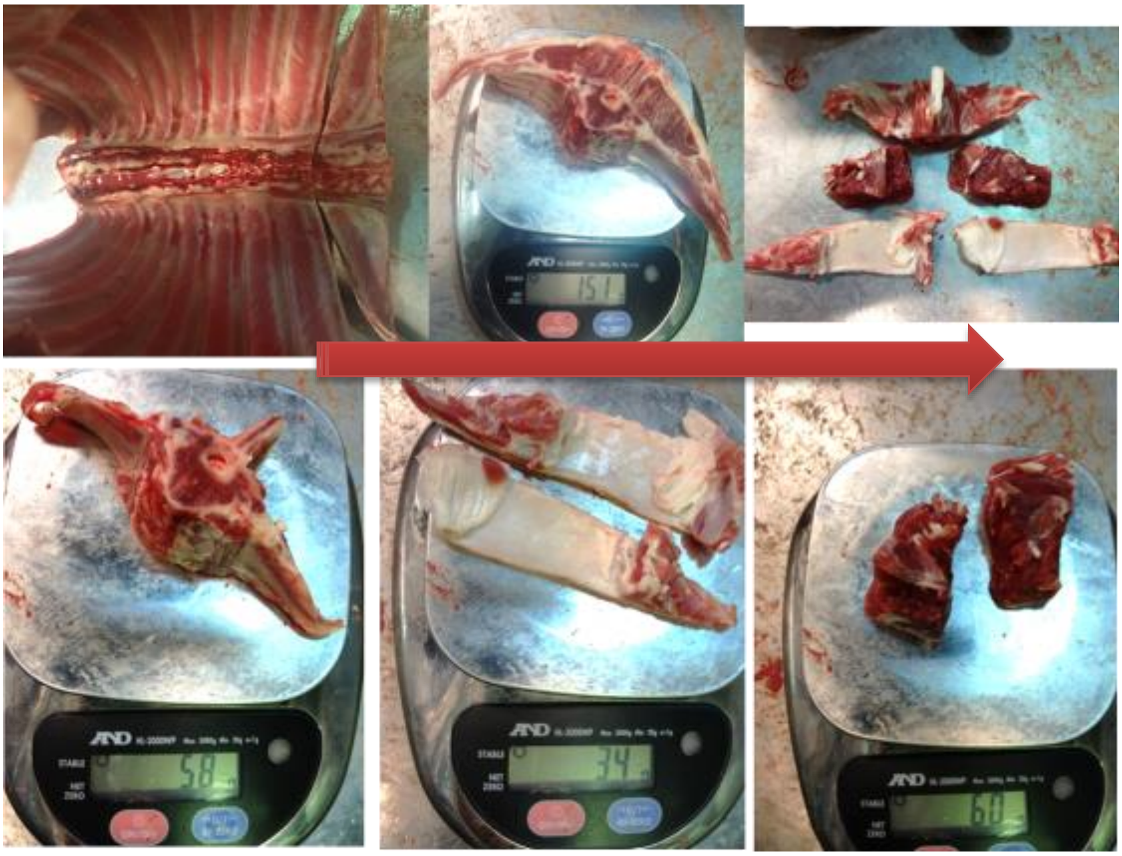


Figure 19: Development of the standard for the scallop cut

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 20 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 20: Trimming racks back to frenched cap off specification reduces much of the gain resulting from more accurate flap removal

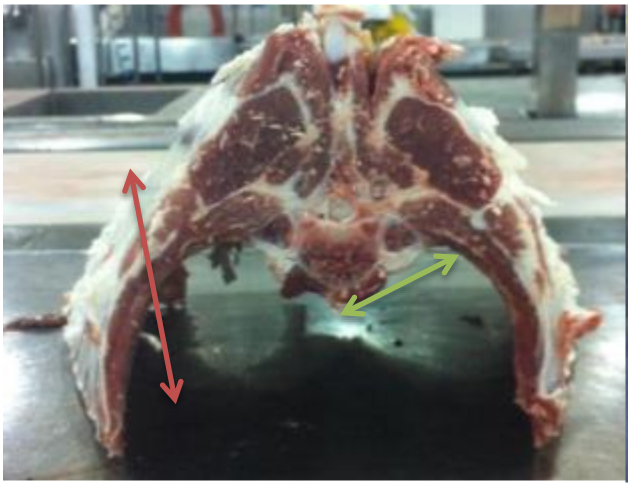


Figure 21: Difference in angle of bandsaw separation of flap (red) as compared to machine removal (green) perpendicular to ribs

Figure 22: 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 significant. The main advantage for the LEAP IV cut over manual bandsaw is squarer, blunter ribs. Figure 22 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 23: 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 24.and Figure 25. A standard was developed to measure the inaccuracy in this cutting line.

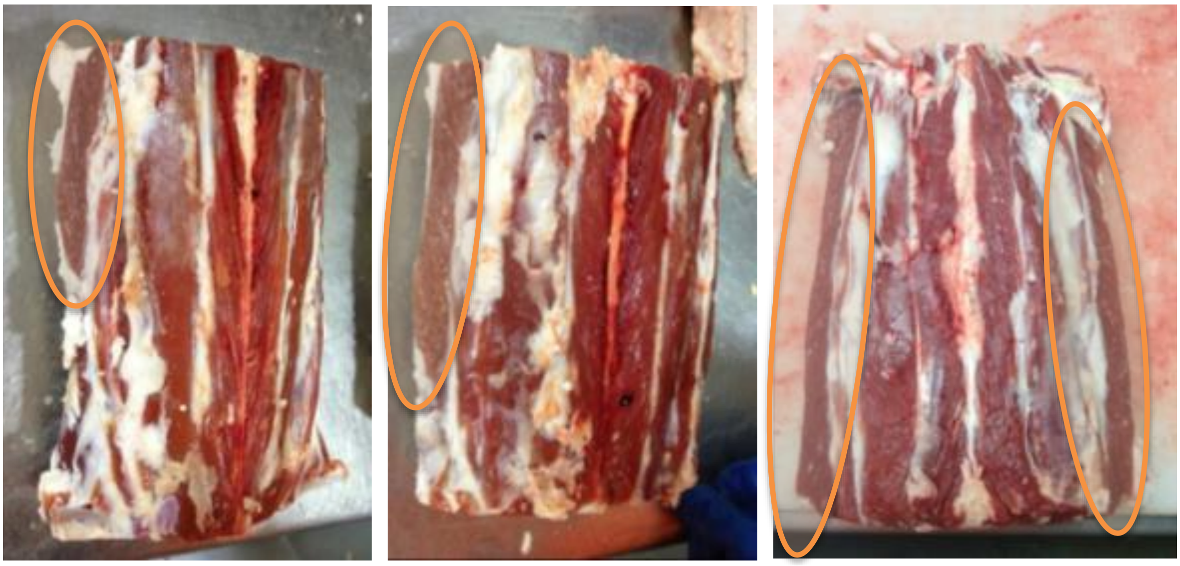


Figure 24: Standard for assessing degree of damage to shortloin pair with increasing severity from left to right of cut into the backstrap

Figure 25: Calculation of yield loss of backstrap from shortloin pair

Figure 26: 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 27 and for integration with the middle deboning system as shown in Figure 28 and Figure 29.

Comparison between the Scott's and manual bandsaw chining

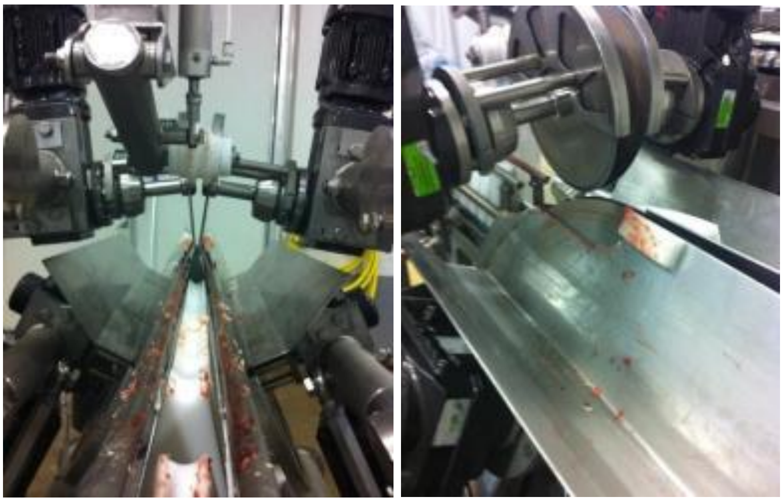


Figure 27: Scott's stand-alone chine removal system showing top and bottom sets of blades

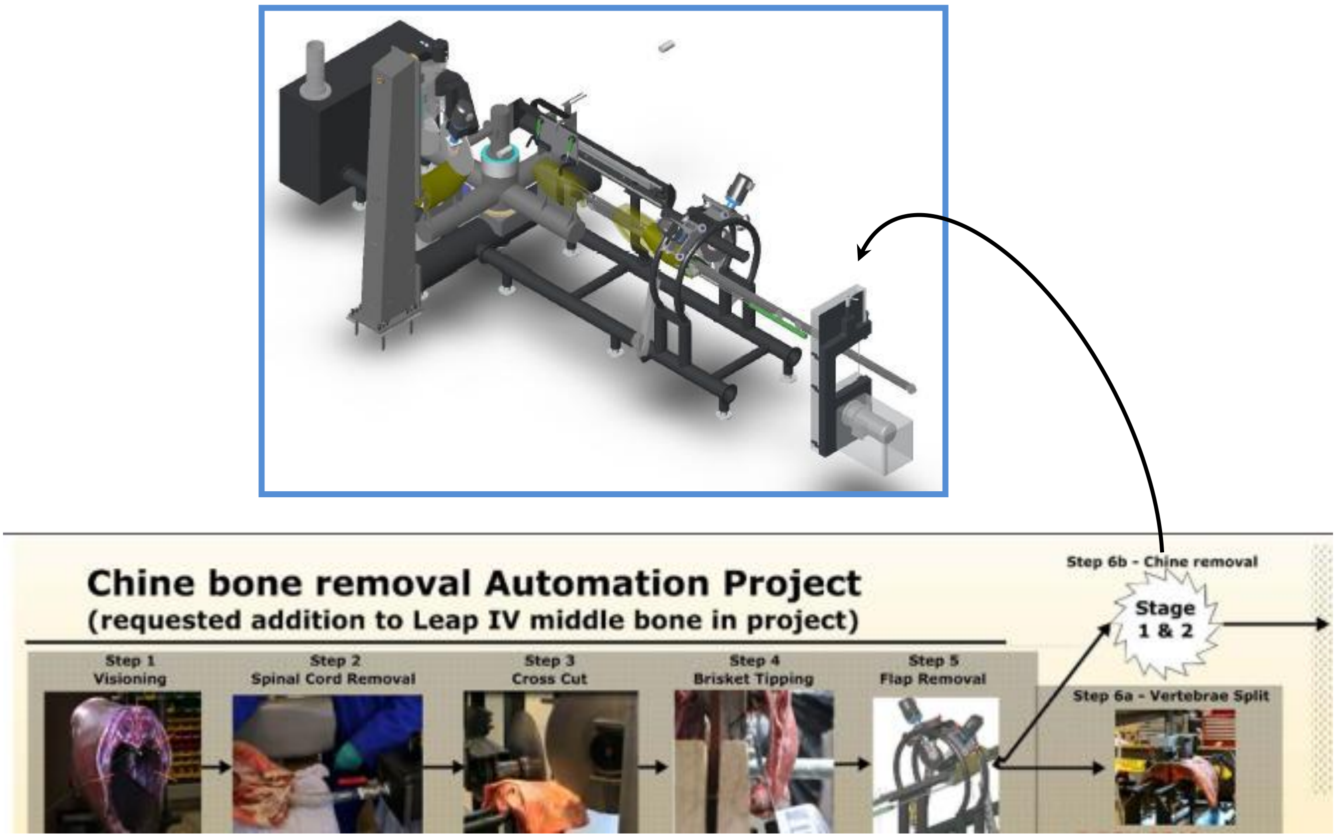


Figure 28: Integration of chine bone removal as part of the Leap IV middle boning project

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Figure 29: Fully automated chining unit installed as part of commercial LEAP IV middle system

The chining module was installed as part of the LEAP IV middle system 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 30. 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.

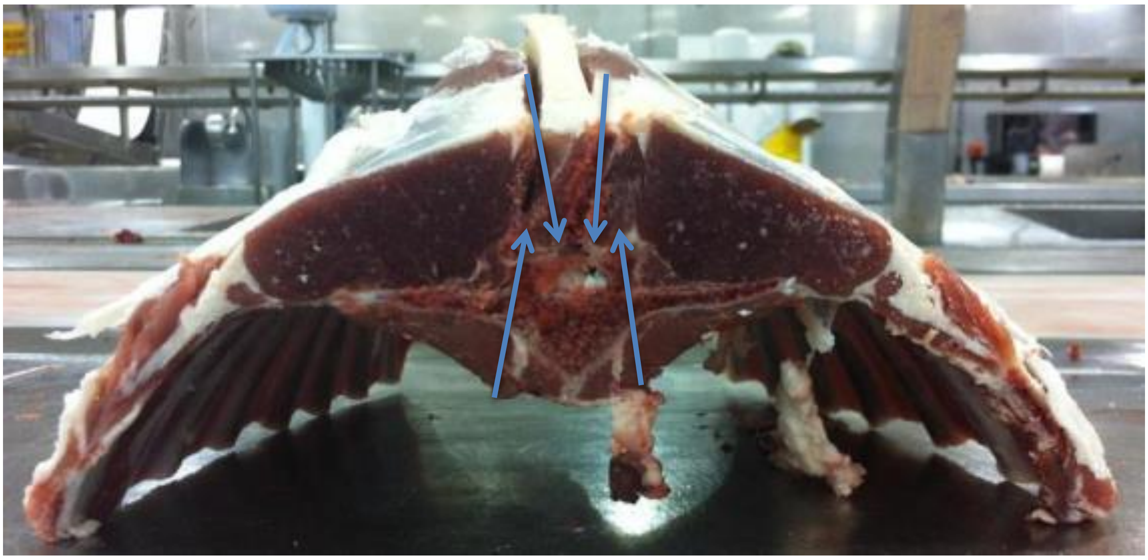

Figure 30: Four cuts removing chine bone from rack

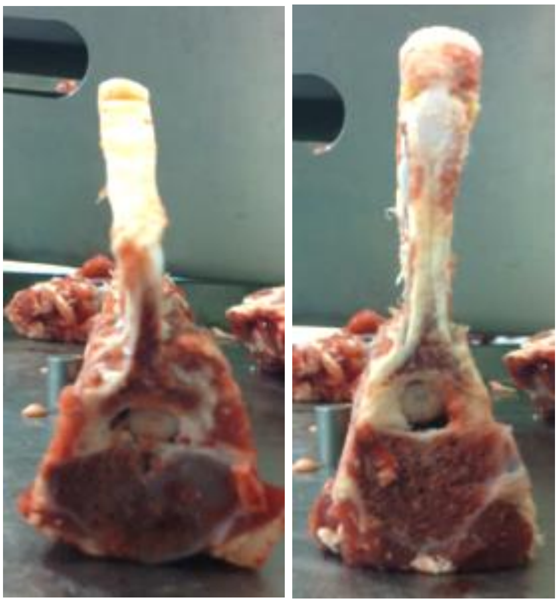

Figure 31: Scott's chining machine

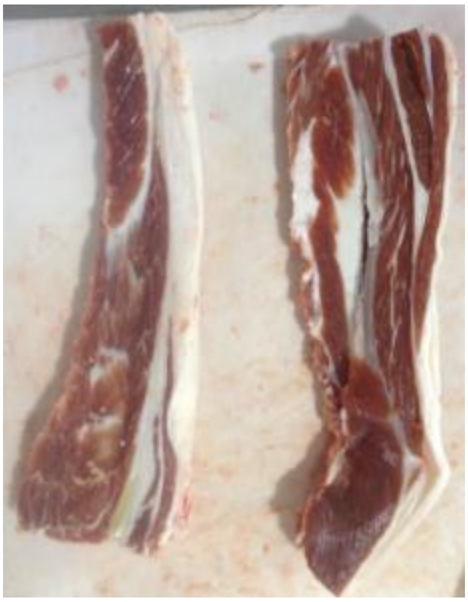

Figure 32: Manual chining

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

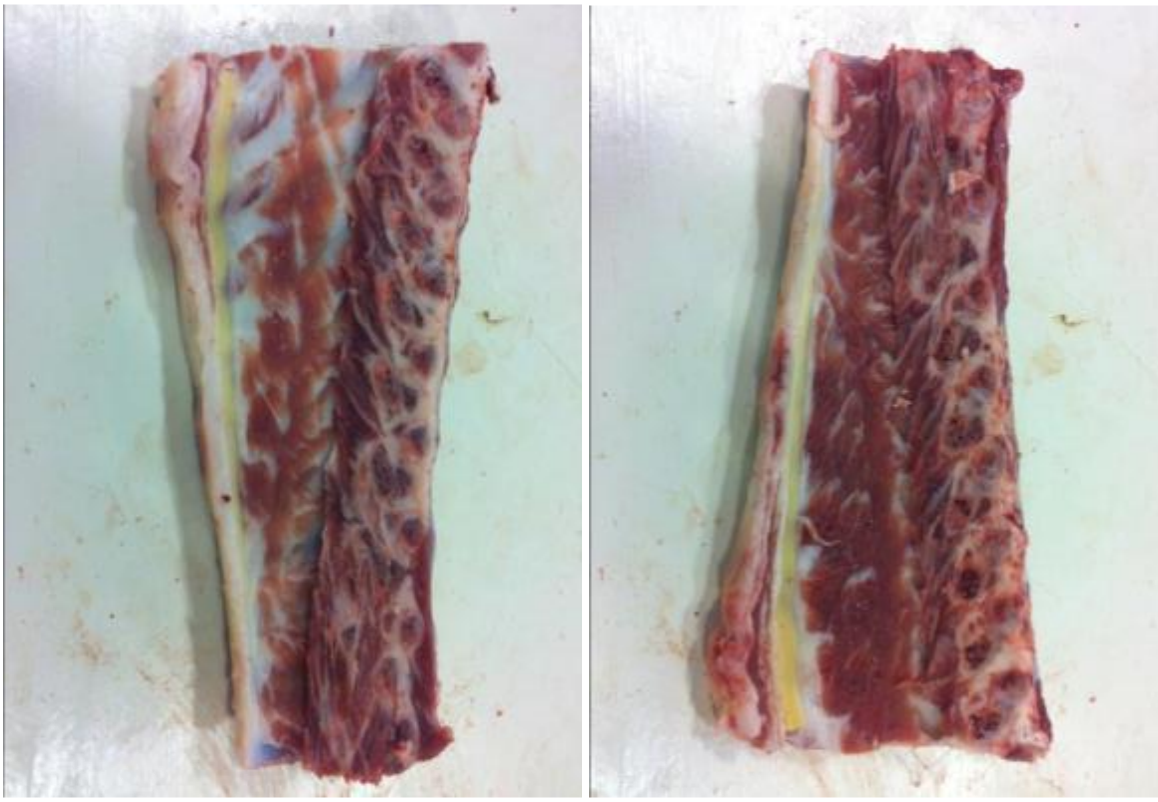

Figure 34: Chine bones from Scott's system directly after chining, prior to scraping bones

Figure 35: Chine bones from manual bandsaw process directly after chining, prior to scraping bones (left) and after scraping (right)

Figure 36: Racks from Scott's chining system – note the amount of meat remaining between the loin and the chine bone

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

Figure 38: 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 manual process in both the ex-ante estimate and the ex-post actual performance of the system. Details for each of these scenarios are in sections 4.4.1, 4.4.2, and 4.4.3.

Table 4: Calculation used for determining production volume base line

Processing room operation speeds			
	Manual	Ex-ante	Ex-post
Carcases / min	7.58	7.88	7.88
Carcases / Statn./hr	455	473	473
Carcases / day	6913	7187	7187
Annual days	250	250	250
Annual # of hd	1,728,240	1,796,640	1,796,640

4.4.1 Manual process

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

- 1 shift per day
- 7.58 carcases per minute for an 11 hour shift

4.4.2 Ex-ante LEAP IV automation - increased throughput

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

- An increase in efficiency of 8.3% due to more consistent cutting rates was expected based on other automation installations
- A reduced number of hours worked per day for the same team
- The removal of 2 bandsaws per shift
- Automated chining, rack and flap removal and spinal cord removal by the LEAP IV system with improved cutting accuracy

4.4.3 Ex-post LEAP IV automation – increased throughput

- The increase in throughput was as expected at in the ex-ante at 8.3%
- The removal of 2 bandsaws per shift
- Automated chining, rack and flap removal and spinal cord removal by the LEAP IV system with improved cutting accuracy

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5 Results and Discussion

The main value propositions for the installation of the LEAP IV 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 LEAP IV 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 installation of the LEAP IV system has increased the yield of shortloin pair through increasing the length of the tail has provided an estimated increased yield by $0.27 per head. Cutting variation is less in the ex-post results than observed during manual trials which makes it easier to adjust and optimise cutting lines for accuracy and increased value than was possible with manual processes.

5.1.3 Rack - Flap Removal

The methodology for costing frenched product has changed slightly when compared to previous studies on the LEAP IV system. The costing method of frenched product in this ex-post study included a change in the value of intercostal as frenched rib length changed. The previous study assumed the frenching line and rib length were set independently meaning a change in rib length on frenched product only impacted on rib bone weight which had almost no impact on value.

The modification for the methodology was a result of observing the automatic water frenching system. The system frenched at a set distance from the end of the rib so the frenching line moves in correlation to the length of the tail. So a change in accuracy of the rack tail length due to accuracy of flap removal will have an impact on the yield of intercostal and flap meat left on a range of specifications of frenched racks. This can be seen in Figure 39, when the blue line at the end of the tail moved towards the yellow line, the same process occurred on the frenching line. This has increased the value of more accurate flap removal on the LEAP IV system compared with manual operations.

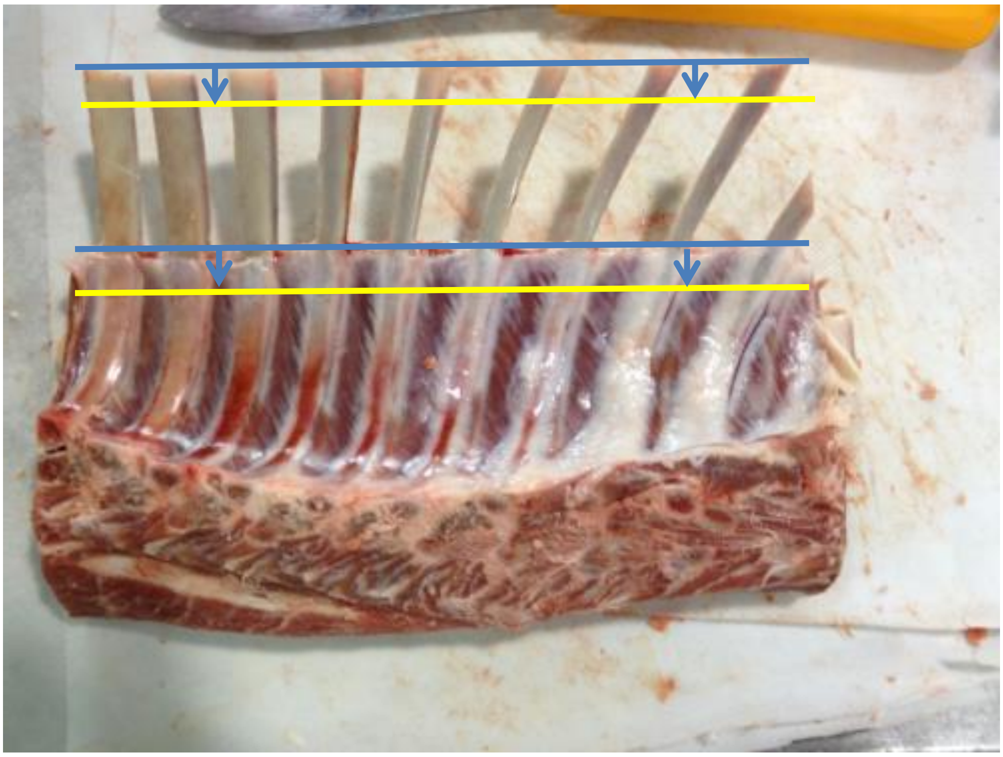

Figure 39: Tail length accuracy on frenched racks is just as important as on unfrenched. Intercostal yield loss as the blue line moves towards the yellow line decreases rack weight and value.

The combination of the 7 different cutting specifications was used to calculate the value of loss attributing to the savings of $0.34 per head. The breakdown of these cutting specifications can be seen in Table 5 below.

Table 5: Percentage of racks Frenched or un-Frenched

Product	Frenching length (mm)	Tail length (mm)	Percentage
A	35	70	9%
B	25	100	45%
C	50	100	1%
		Total Frenched	**55%**
D		100	4%
E		70	7%
F		75	9%
G		100	25%
		Total un-Frenched	**45%**

5.1.4 Rack lost to Shortloin Pair

The variation in the cut between the shortloin pair and rack required 3 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;

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 total value of loss per head demonstrated by this cut was estimated at -$0.38 as the plant was conducting a slight scallop cut on all product.

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 $0.01/hd. The variations in costs shown below Figure 40 are only for a 9 rib rack which demonstrated the greatest variation of all the cutting specifications.

Figure 40: Variation observed in the number of ribs a product contains

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 41. 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.

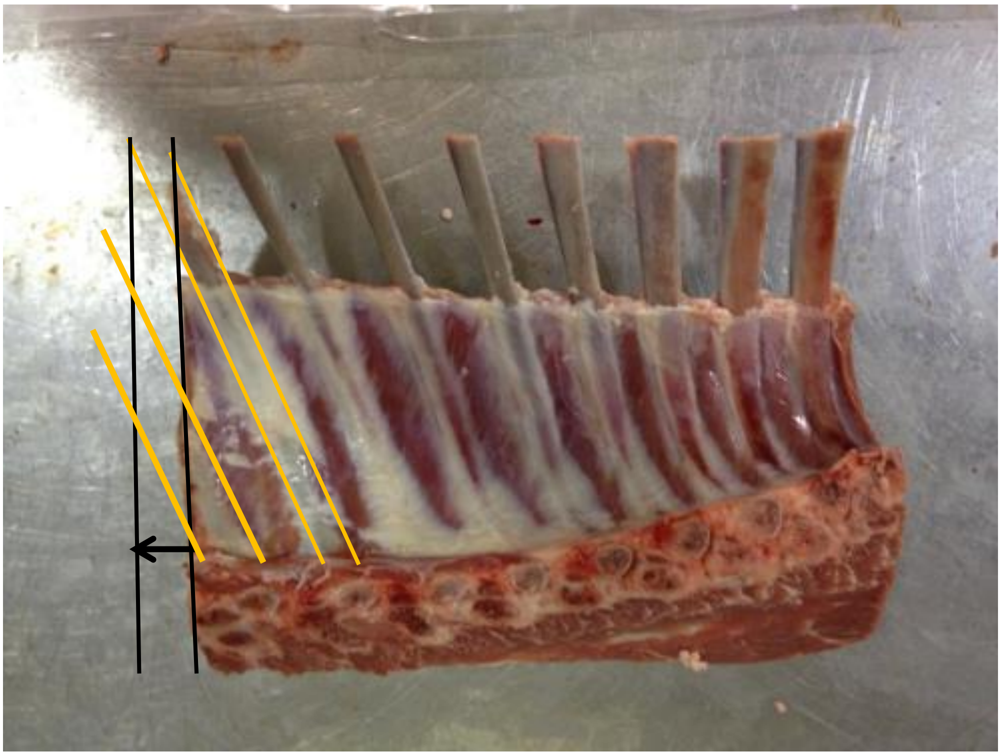

Figure 41: The Left hand black line represents the length of product added to a frenched rack (move to number of ribs)

The weight gained on un-frenched (Figure 40) products will be greater than that of un-frenched 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 41

The automation system demonstrated it was able to identify the ideal location of the cut on un-frenched products. The variation in the total value of rack over the seven cutting specifications was $1.06/hd.

Total Cut Value
The total value attributed to the cut between the Shortloin pair and the racks for all 8 cutting specifications with the automated system is estimated at $0.34/hd better than manual.

5.1.5 Chine removal

The performance of the chining module for the LEAP IV machine was compared to manual bandsaw operations. The improvement in yield of the automated process over the manual bandsaw chinning process was $2.29/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 $0.06/hd.

Table 6: Value of band sawdust lost during manual cutting

Number of head for collection		7187
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)		10.71
Band saw dust / cut / hd (kg)		0.0015
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;

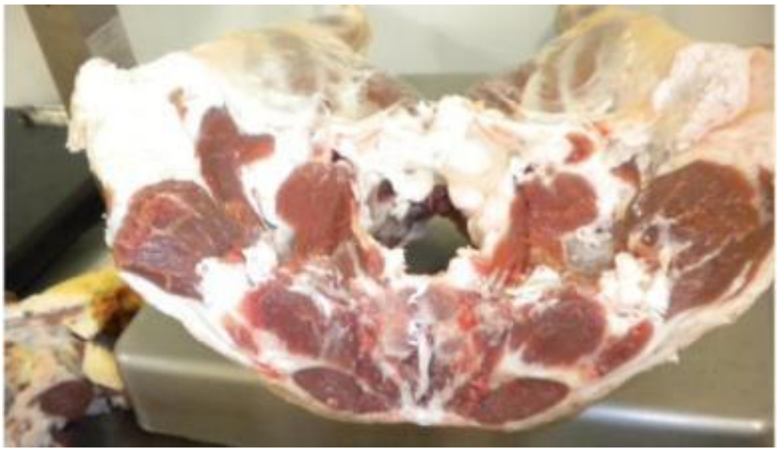

Figure 42: Lamb hindquarter cut with the LEAP III x-ray primal cutting system, note cut meat surface and lack of bone dust. The same quality of cut is assumed with the LEAP IV system

Based on the assumptions the following reductions in discounts are estimated (Table 7) 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 7: 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	3,593,280		
Current level of discounting	4.00%		
Number of items discounted	143,731	143,731	143,731
Weight of discounted (kg)	369,389	402,447	747,402
True Value	$3,176,747	$7,646,500	$6,719,146
Discount Value	$2,541,398	$6,117,200	$5,375,317
Current cost of discounting	$635,349	$1,529,300	$1,343,829
Reduction in level of discounting	4.00%		
New level of discounting	3.84%		
New number of items discounted	137,982	137,982	137,982
New quantity (kg)	354,614	386,349	717,506
New True value	$3,049,677	$7,340,640	$6,450,380
New Discount Value	$2,439,742	$5,872,512	$5,160,304
New cost	$609,935	$1,468,128	$1,290,076
SAVING	$25,414	$61,172	$53,753
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 (Bandsaw operators)

Table 8 shows the number of staff required in each position of the boning and packing rooms per day for the manual process. The second ex-ante column estimates no changes to number of shifts but reflects the saving of three bandsaw operators and one labourer in the second last row. The third column shows the actual ex-post savings and confirms the ex-ante estimate of 3 bandsaw operators and 1 general labourer. This was not due to the machine being installed but was related to running the room much faster, giving an increased productivity which is covered in the next section.

The estimated labour saving of between $0.29/head can be expected by a plant with the installation of the LEAP IV middle machine without considering throughput productivity gains. The number of staff saved at other plants will depend on the layout of the abattoir's cutting room and chilling and slaughter capacities.

Table 8: Labour savings achieved with the LEAP IV lamb middle cutting per shift.

Labour Savings per day			
	Number labour units required per day		
Task	Manual	Ex-ante Bordertown	Ex-post Bordertown
Supervisor	1	1	1
Band Saw operator	6	3	3
Knife hand	0	0	4
Trimmers	24	24	24
Packer	41	41	45
General Labor	3	2	2
Boners	12	12	12
Slicers	12	12	12
Total FTE's required	99	95	103
Total FTE's saved	-	4	4
Saving per head	$0.00	$0.29	$0.25

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 LEAP IV lamb middle cutting is the increases in the consistency of throughput which can improve flow. The information detailed in Table 9 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 9: Manning of processing room

	Manual	Ex-ante	Ex-post
Average daily hd	6913	7187	7187
Hd/annum	1,728,240	1,796,640	1,796,640
Average kg	21.88	21.88	21.88
Total Kg boned per day	151,256	157,242	157,242
Boning room cost / hour	$3,174	$3,174	$3,174
Boning room cost / day	$48,246	$48,246	$48,246
Labour cost \ per kg to bone	$0.32	$0.31	$0.31
Labour cost \ per hd to bone	$6.98	$6.71	$6.71
Labour savings/ head	$0.00	$0.27	$0.27

The improvement in labour productivity delivers a benefit of $0.27/head when operating at the 4% increase in processing rate of the room. These savings will vary from plant to plant as a result of the layout of rooms.

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 10).

Table 10: OH&S Benefits of automated middle cutting

OH&S			
Job Role Affected			
Claims in last 10 years	Manual	Ex-ante	Ex-post
Risk / FTE / Year			
Annual Premium			
Job Annual Hours	22,800	11,400	11,400
Limb Losses per year	0.40	0.20	0.20
Sprains and Strains per year	4.00	2.00	2.00
Annual Cost	$47,680	$23,840	$23,840
Annual Cost / Head	$0.03	$0.01	$0.01
Annual saving per head	$0.00	$0.01	$0.01

5.7 Operational Costs

Table 11 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 11: Estimated capital and operating costs of automated x-ray primal cutting equipment

Capital Cost	Manual		Ex-ante		Ex-post	
	Cost	Life span	Cost	Life span	Cost	Life span
Capital Cost of the equipment			$1,710,000	10	$1,710,000	10
Installation Costs			$200,000	10	$200,000	10
Chinning system			$190,000	10	$190,000	10
Total			**$2,100,000**		**$2,100,000**	
Service maintenance	Manual		Ex-ante		Ex-post	
	Units	Cost	Units	Cost	Units	Cost
Estimated - COSTS						
Electricity	6.00 KW	$0.14 /KWH	6.00 KW	$0.22 /KWH	6.00 KW	$0.22 /KWH
Maintenance labour (Daily)		0 /Yr		0 /Yr		0 /Yr
Maintenance labour (Preventative)		$13,600 /Yr		$130,000 /Yr		$130,000 /Yr
Maintenance labour (Breakdown)		0 /Yr		0 /Yr		0 /Yr
Maintenance labour (Training)		0 /Yr		0 /Yr		0 /Yr
Operational		**$16,724**		**$135,016**		**$135,016**
Maintenance		**$0**		**$0**		**$0**
Annual Sub Total (excluding major overhaul costs)		**$16,724**		**$135,016**		**$135,016**
Major maintenance	Manual		Ex-ante		Ex-post	
	Total	Life span	Total	Life span	Total	Life span
Robot attachment replacement						
Upgrade electronics						
Robot overhaul						
Other						
Sub Total: Operating Expense						
Combined Total: (cap ex + operating)						
Total Annual Estimated Expenses	Hours	Cost	Hours	Cost	Hours	Cost
Expected downtime hours per year		0.00 /Yr	10	$31,741 /Yr	10	$31,741 /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 8) 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 12 demonstrate the performance of the Ex-Post machine on a 4% increase in room efficiency, and the maximum capacity of the system processing carcases for two 7.6 hour shifts per day.

The ex-post net benefit was of $3.13/hd. This delivers an estimated return on investment of between 0.32 years depending on the rate at which carcases can be processed.

Table 12: Summary of benefits for the Ex-Post and Ex-ante reviews both with a 4% increase in throughput efficiency.

SUMMARY PERFORMANCE MEASURES		
	Ex-ante	Ex-post
Hd / annum	2,120,400	2,120,400
Production increase with equipment	4.21%	4.21%
	From	From
Capital cost (pmt option, upfront)	$2,100,000	$2,100,000
Gross return Per head	$1.53	$3.13
Total costs Per head	$0.18	$0.18
Net Benefit Per head	$1.35	$2.95
Annual Net Benefit *(Incl. capital cost)*	$2,868,523	$6,257,918
Annual Net Benefit *(Excl. capital cost)*	$3,078,523	$6,467,918
Pay back (years)	0.68	0.32
Net Present Value of investment	$20,693,487	$44,499,182

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 43.

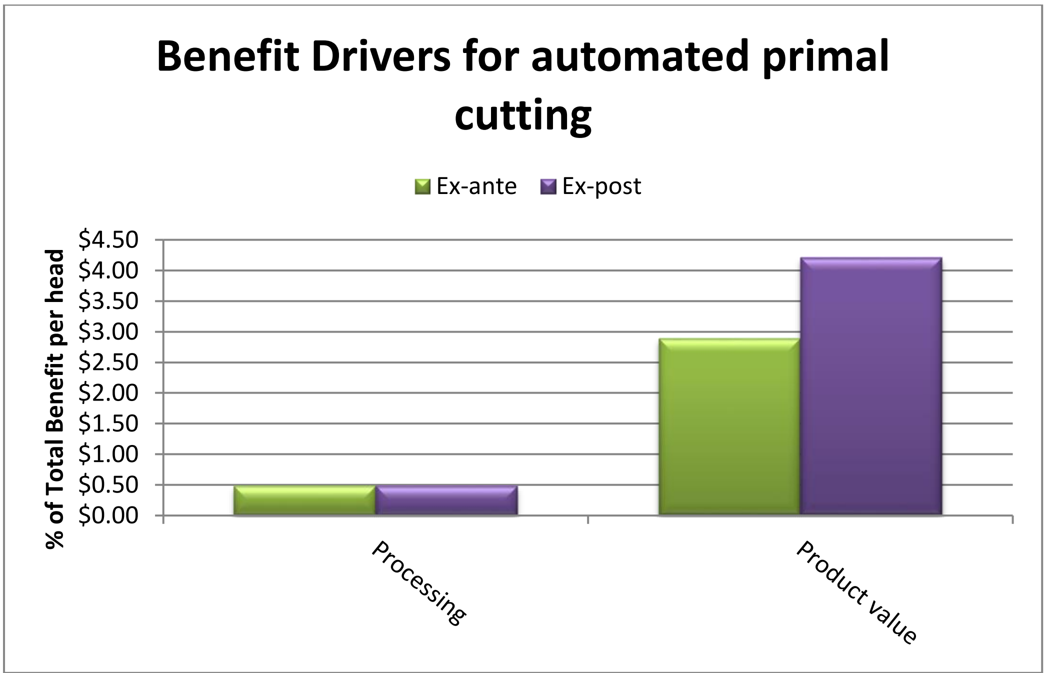

Figure 43: Broad grouping of benefits delivered by LEAP IV lamb middle cutting

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 44 and Table 13.

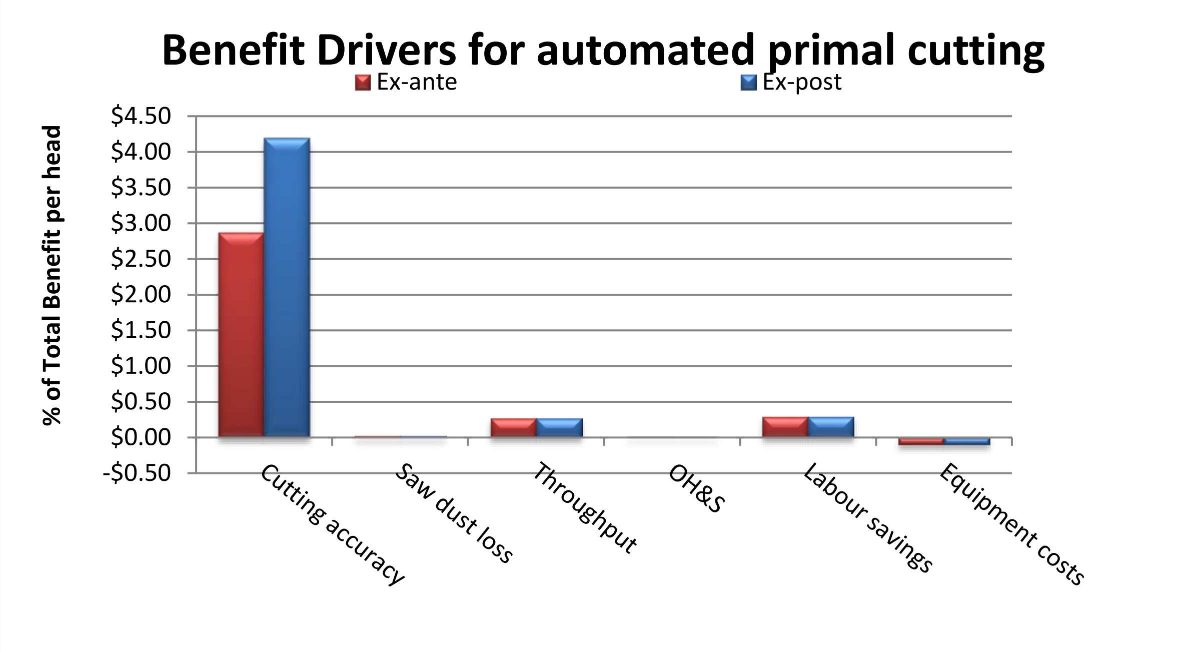

Figure 44: Summary of benefits expected to be delivered from the installation of the LEAP IV lamb middle cutting.

Table 13: Breakdown of benefits and costs by area expected as a result of the installation of the ex-post system

Benefit Drivers for Equipment				
	Ex-ante		Ex-post	
	$/ hd	$/ annum	$/ hd	$/ annum
Processing	$0.48	$861,087	$0.48	$861,087
Product value	$2.89	$5,188,411	$4.21	$7,564,847
	$3.37	**$6,049,498**	**$4.69**	**$8,425,934**
Cutting accuracy	$2.86	$5,146,673	$4.19	$7,523,109
Saw dust loss	$0.02	$41,738	$0.02	$41,738
Throughput	$0.27	$477,370	$0.27	$477,370
OH&S	$0.01	$25,727	$0.01	$25,727
Labour savings	$0.29	$524,746	$0.29	$524,746
Equipment costs	-$0.09	-$166,757	-$0.09	-$166,757
	$3.37	**$6,049,498**	**$4.69**	**$8,425,934**

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 14. 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 8.3% in the second scenario which includes labour savings.

Table 14: Summary of benefits for the installation of the LEAP IV lamb middle machine

SUMMARY PERFORMANCE MEASURES		
	Ex-ante	Ex-post
Hd / annum	1,796,640	1,796,640
Production increase with equipment	8.33%	8.33%

A summary of the range in costs and benefits for each scenario are included in Table 15 below.

Table 15: Costs and benefits breakdown for the ex-post and ex-ante reviews.

COST - BENEFIT ANALYSIS OF ROBOTIC PRIMAL CUTTING EQUIPMENT		
	Ex-ante	Ex-post
Benefit summary	$/hd	$/hd
	Avg.	Avg.
$ Accuracy Benefit per head	$1.33	$2.93
$ Technique Benefit per head	$0.02	$0.02
$ Labour Benefit per head	$0.57	$0.57
$ Automation Costs	($0.09)	($0.09)
$ Overall Benefit per head	**$1.83**	**$3.43**
** Cost is reported as the inaccuracy from target specification OR as the difference between Manual vs. Auto costs*		
COST ASSOCIATED WITH THE EQUIPMENT		
	$/hd	$/hd
Capital cost	$1.17	$1.17
Maintenance	$0.00	$0.00
Operation	$0.08	$0.04
Risk of mechanical failure	$0.02	$0.01
Total cost per head *(Incl. capital cost)*	$1.26	$1.22
Total cost per head *(Excl. capital cost)*	$0.09	$0.05

Table 16 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 16: Summary results of individual savings associated with LEAP IV lamb middle cutting for Smallstock

COSTS DUE TO INACCURACIES AND MANUAL INTERVENTION		Manual	Ex-ante	Ex-post
Loss summary		$/hd Avg.	$/hd Avg.	$/hd Avg.
1.1 Accuracy	Rack loss to Shortloin Pair	$2.36	$3.20	$2.02
	Rack - Flap Removal	-$0.19	-$0.18	-$0.21
	Shortloin Pair - Flap removal	$0.29	$0.26	$0.02
	** Chine Removal	$2.42	$0.27	$0.13
1.2 Cutting Technique	Saw dust loss	$0.02	$0.00	$0.00
2. Throughput cost		$6.98	$6.71	$6.71
3. OH&S costs		$0.03	$0.01	$0.01
4. Labour costs		$0.00	-$0.29	-$0.29
Equipment costs	**Maintenance**	$0.00	$0.00	$0.00
	Operation	$0.00	$0.08	$0.08
	Risk of failure	$0.00	$0.02	$0.02
$ Costs per head		**$11.92**	**$10.08**	**$8.48**
$ Benefit per head		**$0.00**	**$1.83**	**$3.43**
$ Benefit overall plant		**$0**	**$3,295,041**	**$6,166,916**
$ Annual Costs overall plant		**$4,003,662**	**$3,387,735**	**$2,666,392**

The Figure 45 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.

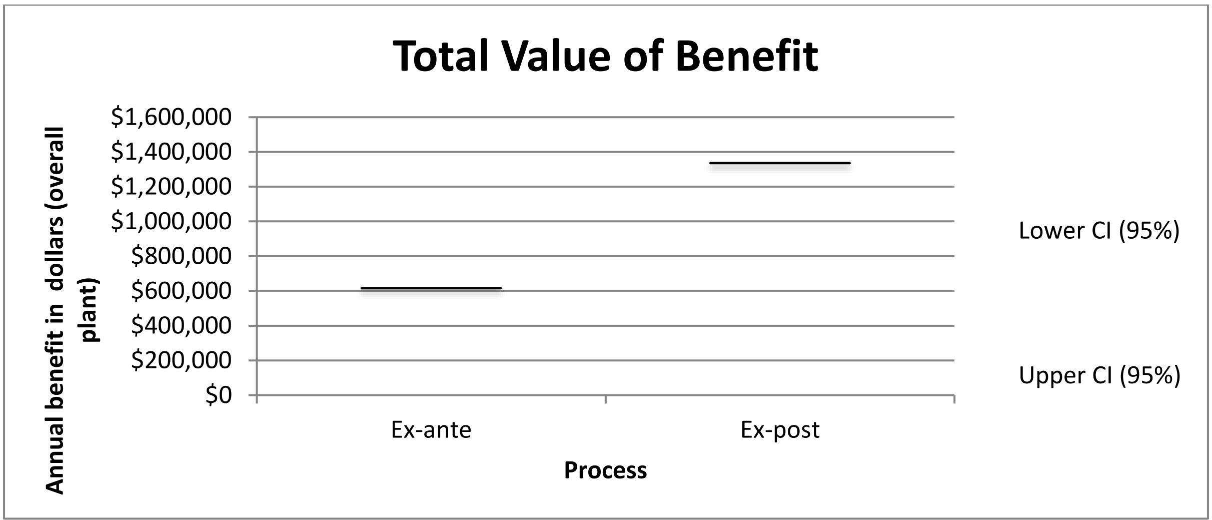

Figure 45: Graphical representation of losses captured in Figure 15 showing value of the benefit expected through using the automated systems

6 Appendices

6.1.1 List of Tables

6.1.2 List of Figures