final report

Project Code: P.PIP.0313

Prepared by: P. Green
Greenleaf Enterprises

Date published: September, 2013

PUBLISHED BY
Meat and Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

ROC 450 Ovine Primal Cutting System Ex-Post Review

This is an MLA Donor Company funded project.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government and contributions from the Australian Meat Processor Corporation to support the research and development detailed in this publication.

Executive Summary

Machinery Automation and Robotics (MAR) in conjunction with Meat & Livestock Australia (MLA) have been developing automated lamb processing equipment. This report is an ex-post review of the commercial operation of MAR's ROC 450 lamb primal cutting system which automates the primal carcase breakdown previously done manually with bandsaw operators.

This ex-post investigation found improvements in plant productivity to be larger than first expected and the most significant area of value. Other benefits including reductions in full time labour and training costs, and improvements in safety, and production rates all contribute to the return on equipment investment.

It was expected that yield gains through improved cutting accuracy would be a large benefit and increase in carcase value. This was not the case due to inaccuracies in cutting lines on larger carcases and in the forequarter cut in particular. Costs associated with the equipment included the capital costs, maintenance, operational, and costs associated with the risk of mechanical failure.

A plant would achieve a positive return on a one-shift basis using capital costs supplied by the manufacturer and a using the net present value calculation 10 years and a discount rate of 7%. At a processing rate of 3.8hd/minute for three cuts (8hr/day 250 day/ annum) an annual net return of approximately $500,000 is estimated, or a net present value of $4.5M (AUD) over the estimated 10 year life expectancy of the equipment.

Table 1 shows the results of cutting performance on small carcases in the first site trials on the left hand side. The second site trials in the centre column included a mix of carcases over 22 kilograms with lower cutting accuracy. The right hand column estimates return on investment at maximum operating speed of 6 carcases per minute with 3 cuts and based on cutting performance observed in the first trials.

Table 1: Summary of benefits for ex-ante, ex-post and maximum machine speed relative to manual cutting performance[1]

1.1 [1] Note the modelling and calculations used in this ex-post analysis of the base data than used in the original ex-ante modelling. This has insights arising from these studies. To allow easy comparison this against the ex-ante data set. Detail of the analysis is explained in section 4.1 "Data Quality Control

A range of statistical hypothesis tests were used in the analysis to determine robustness of correlations between data collected in ex-ante and ex-post studies. We have reanalysed previous data as well to ensure consistency across the analysis.

Statistical Analysis of Data Sets".

SUMMARY PERFORMANCE MEASURES						
	ROC450-GM Scott (3-12)		ROC450-GM Scott (6-13)		EQUIP. MAX	
	Hd/ annum	456,000	Hd/ annum	456,000	Hd/ annum	720,000
Production increase with equipment	18.75%		18.75%		87.50%	
	From	To	From	To	From	To
Capital cost (pmtt option, upfront)	$1,050,000		$1,050,000		$1,050,000	
Gross return Per head	$1.19	$1.25	$1.03	$0.89	$1.57	$1.27
Total costs Per head	$0.33		$0.33		$0.22	
Net Benefit Per head	$0.87	$0.93	$0.70	$0.56	$1.36	$1.05
Annual Net Benefit for the plant	$394,997	$422,149	$321,266	$256,111	$976,403	$757,110
Annual Net Benefit for the ex cap	$500,993	$528,145	$427,262	$362,108	$997,644	$778,352
Pay back (years)	2.10	1.99	2.46	2.90	1.05	1.35
Net Present Value of investment	$2,537,458	$2,728,164	$2,019,603	$1,561,987	$6,025,725	$4,485,508

The benefits identified can be broadly summarised as either product value or process efficiency benefits with the larger portion of benefits being related to processing efficiencies rather than product value or cut yields as in Figure 1 and Figure 2.

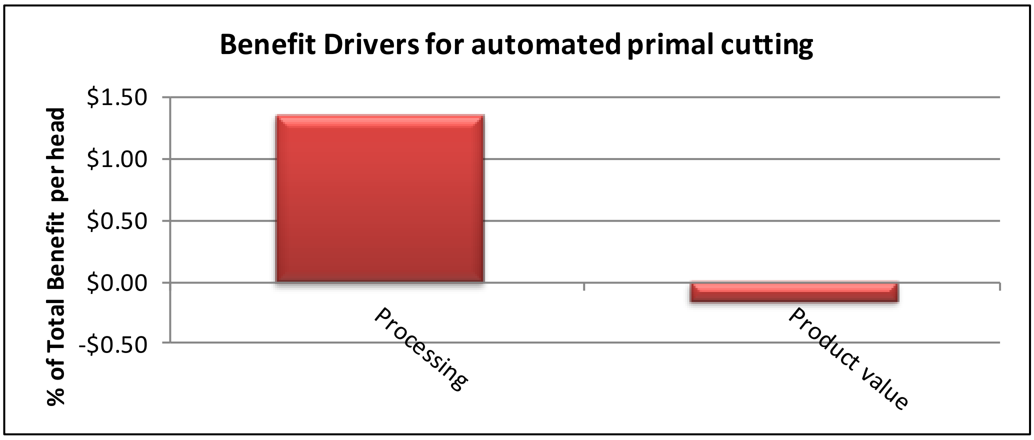

Figure 1: Broad grouping of benefits delivered by automated primal cutting solution

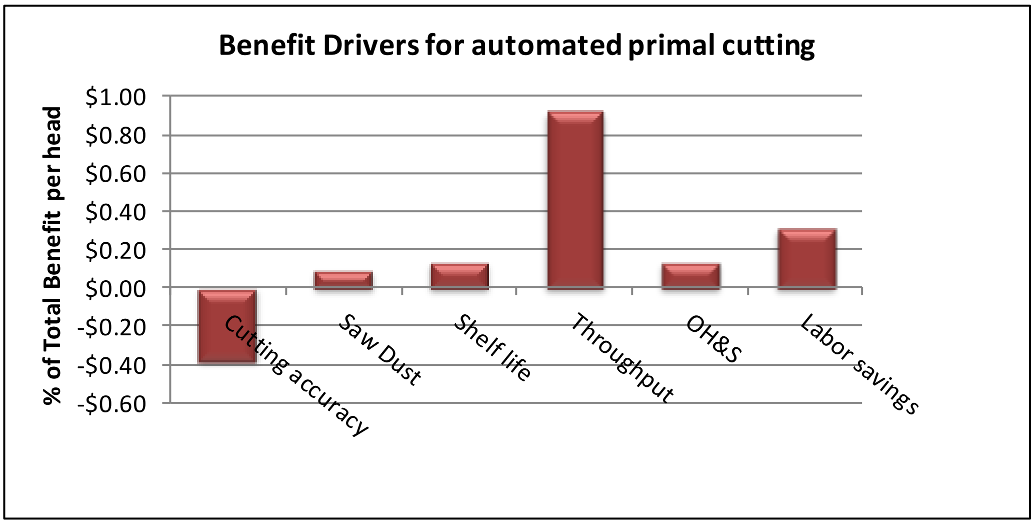

Figure 2: Summary of benefits delivered from automated primal cutting solution

Glossary

Term	Description
Caudal	Caudally: toward the posterior end of the body
CBA	Cost Benefit Analysis
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
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)
MAR	Machinery Automation and Robotics
MLA	Meat and Livestock Australia
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]
Ventral	Pertaining to the front or anterior of any structure. The ventral surfaces of the carcass include the brisket /abdomen cavity

Contents

1 Introduction

Machinery Automation and Robotics (MAR) in conjunction with MLA have been developing automated lamb processing equipment. This report investigates the commercial operation of MAR's ROC 450 lamb primal cutting system.

The ex-ante studies indicated the primary financial benefit of MAR's Primal Cutting Robot would be an improvement in yield when compared with manual operation. However, this ex-post study found improvements in plant productivity to be larger than first expected and the most significant area of value. Other benefits including reductions in full time labour, training costs, improvements in safety, and production rates all contribute to the return on equipment investment.

The following ex-post report measures the actual benefit delivered by this system after 12 months of commercial operation. The report is designed to build on the methods used for data collection and analysis in the ex-ante study to enable comparison of both ex-post and ex-ante results back to manual processes where appropriate.

2 Objectives

The objectives of this study were to:

1. Using the benchmarks and measurement methods developed in the ex-ante study, measure the real value opportunity demonstrated by the equipment when compared against manual cutting systems for each area of benefit that exist.
2. Summarise the value benefit and main drivers for adoption of the equipment for Australian lamb processing plants.

Both outcomes were achieved effectively and included two separate site visits to collect data over four days of production.

3 Technology Description

The solution consists of a scanning area shown in Figure 3 where a two dimensional photograph of the carcase is captured. Image analysis software runs algorithms across the image to determine the cutting lines as shown in the middle image. Two robotic cutting systems shown in the right image of Figure 3 and Figure 4 grasp alternate carcases and cut between 2 and 4 primal cuts depending on product specification. The system is able to operate at speeds of 450 carcases per hour.

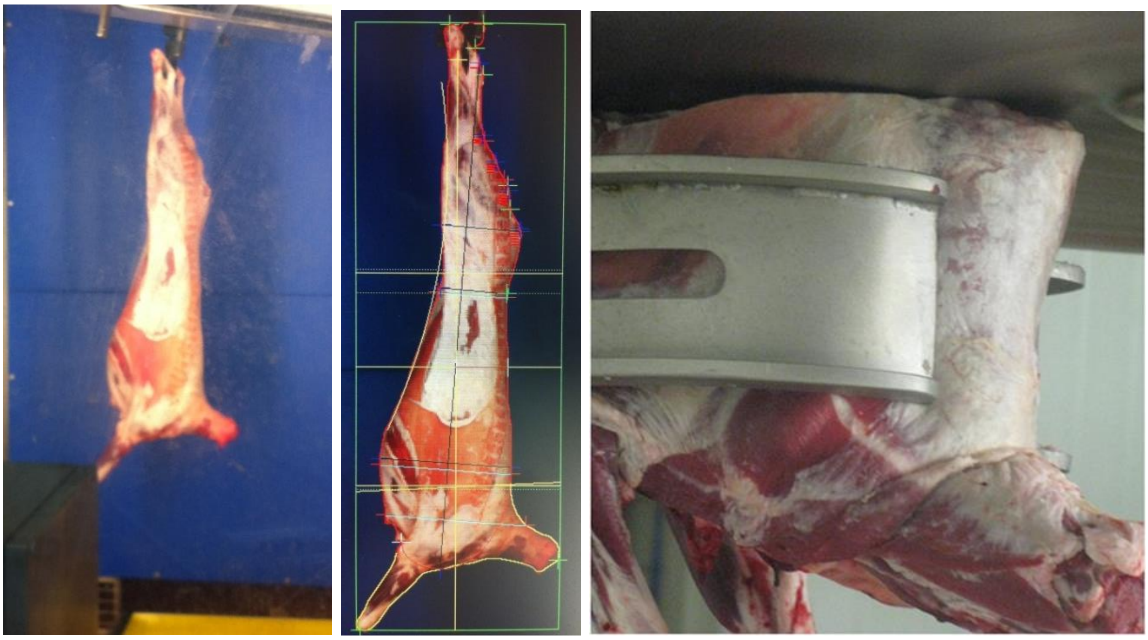

Figure 3: Illuminated Image capture rail, 2D image analysis and coordinates for robotic cutting, holding and cutting robots

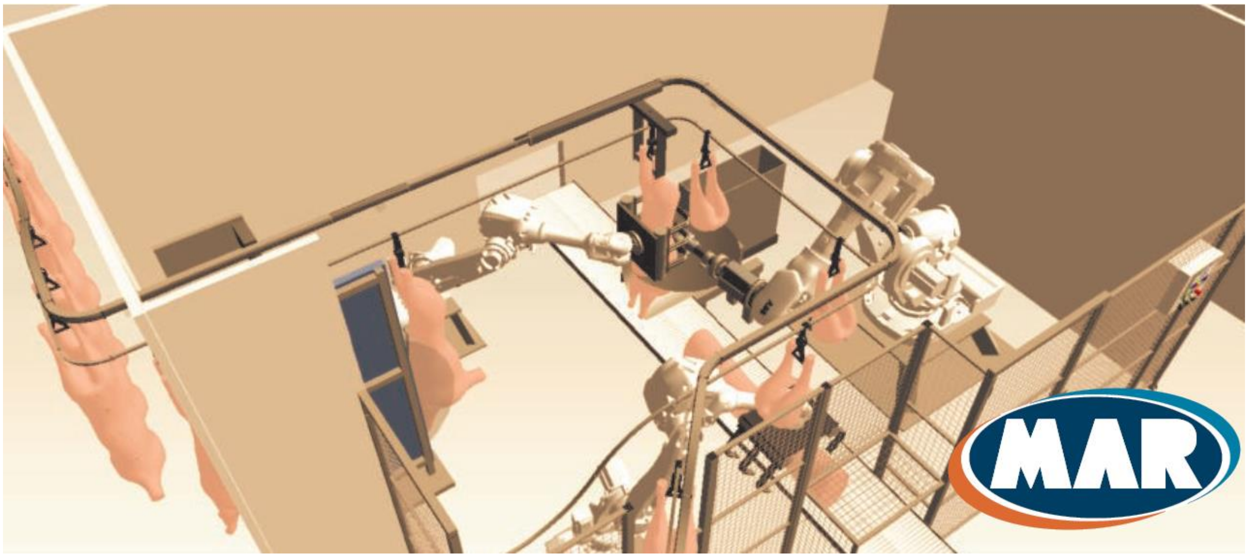

Figure 4: Robotic cutting system showing a carcase holding robot and 2 cutting robots

The following Figure 5 shows the various cutting options the system is able to perform.

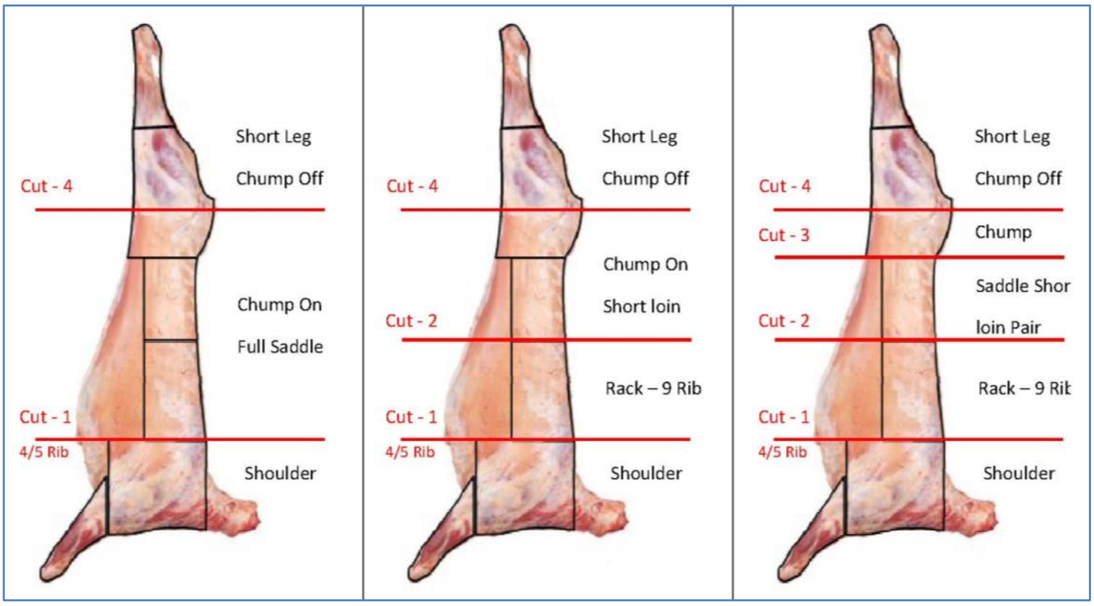

Figure 5: Cutting lines for ROC450 system **Source MAR Promotional literature 2010, provided by Stuart Shaw.

4 Data Collection and Calculation Methodology

The following costs and benefits shown in Table 2 were identified as being relevant financial drivers in the installation of an automated lamb primal cutting system.

Table 2: Costs & Benefits associated with use of automated primal cutting equipment

Benefits		Costs
Accuracy of cutting lines	1.1. First Cut (Forequarter : Loin)	1. Capital cost of the equipment
	1.2. Second Cut (Rack : SLP)	2. Ongoing maintenance of the equipment
	1.3. Third Cut (Loin : Hindquarter)	
Technical advantages of cutting technique.	1.5. Saw Dust yield Gains	3. Service agreement
	1.6. Increased Shelf life	4. Risk of plant down time caused by the primal cutting equipment
	2.1. Increased Labour efficiency	
Benefits to the operation of the processing plant	2.2. OH&S Savings	
	2.3. Labour Savings	

In order to validate the value opportunity for automated primal cutting, the same benchmarking methodology used in the ex-ante review was applied with the results compared back to the manual process. Further benchmarking measures were taken to ensure consistency between the ex-ante and ex-post data collection processes and to enable to ex-ante and ex-post comparisons.

The data collection phase of the review focused on trial work to establish the accuracy of current cutting systems, the costs associated with inaccuracy, and survey work to asses other production and logistic components such as current staffing levels and number of head being processed.

This section explains the various methods used for data collection, and calculations behind the value attributed to each of the benefits and costs highlighted in the table above.

4.1 Data Quality Control

A range of statistical hypothesis tests were used in the analysis to determine robustness of correlations between data collected in ex-ante and ex-post studies. We have reanalysed previous data as well to ensure consistency across the analysis.

4.2 Statistical Analysis of Data Sets

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 process but hopefully to a lesser degree. This variation impacts on the level of value created or lost. Four days of trial data was collected totalling more than 1000 measurements. However, carcase variation across the year, not observed during these trials could produce different results.

4.3 Model Drivers

The objective of the trial work was to establish the dollar per head value for each cost and benefit listed in Table 2. Calculations presented for these benefits are calculated using production numbers and sales prices discussed in the next section.

4.3.1 Fixed Model Drivers

To establish the dollar value of each of the listed costs and benefits as a per head number, the following production numbers were used for the calculation (Table 3). The table summarises manual performance (far left) as the base line with the ex-post machine on small <22kg carcases (left), the ex-post machine on >22kg carcases (middle) and theoretical maximum capacity of the machine (right) relative to manual operations are compared against.

These values are linked to adjustable drivers shown in the cost benefit summary section of the model.

Table 3: Calculation used for determining production volume base line

Processing room operation speeds				
	Manual Process	ROC450-GM Scott (3-12)	ROC450-GM Scott (6-13)	EQUIP. MAX
Carcases / min	3.20	3.80	3.80	6.00
Carcases / Statn./hr	192	228	228	360.00
Room speed	192	228	228	360
Shifts / day	1	1	1	1
Saw Hrs / Shift 1	8.00	8.00	8.00	8.00
Saw Hrs / Shift 2	0.00	0.00	0.00	0.00
Carcases / day	1536	1824	1824	2880
Annual days	250	250	250	250
Annual # of hd	384,000	456,000	456,000	720,000

Installation of the automated cutting system gave an increase in productivity, increasing room throughput without increasing the number of labour units. The key factor is the increased consistency at which product flows into the room. Previous manual methods resulted in sporadic product flow from the bandsaws where operators would go fast for a while, then slow down and rest, or go slow when boners further down the line went slow and product built up.

4.3.2 Sales Prices

Values shown in light green can be adjusted and the relevant prices will adjust all model results including summary financial drivers. Note average discount is a driver sourced from the summary page of the model and is used to account for discount in product value when shelf life is short.

Table 4: Retail Sales values used for driving economic analysis in the driver

Average discount level		20%
Cut	$/kg	Discount Value
Shoulder Rack	$8.60	$6.88
8 Rib Rack	$19.00	$15.20
7 Rib Rack (discount)	$17.00	$13.60
Back strap	$22.00	$17.60
Trim 65CL	$2.70	$2.16
Leg price	$8.99	$7.19
Loin Value/kg	$22.00	
Rump	$25.00	
Whole lamb retail price	$7.50	
Rendering	$0.16	

4.4 Benefits Achieved Through Cutting Accuracy

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 are based around these cutting lines. If the initial primal cutting lines are not accurate 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. As the accuracy of the cutting lines was an important part of the data collection phase the following section gives consideration to the measurement of accuracy levels observed with the manual cutting system, and the costs incurred because of these inaccuracies.

Figure 6 illustrates the 3 cutting lines that the automated primal cutting equipment will perform, and the various the cuts associated with the different primals. Furthermore

Table 5 communicates the expected losses with the various inaccuracies of the cutting lines.

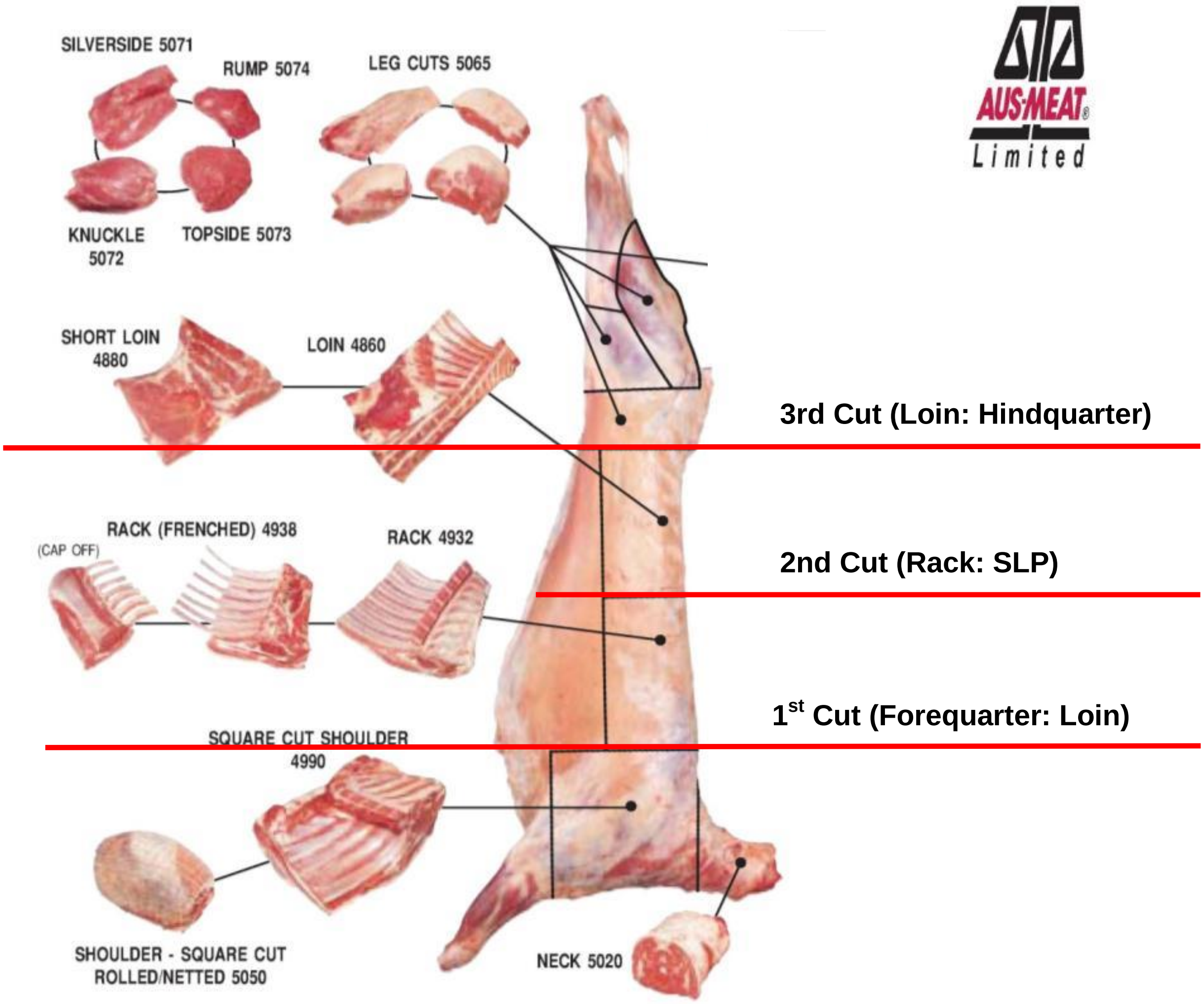

Figure 6: Cutting lines that the automated primal cutting system will perform on the lamb carcass (Source: Aus Meat 2003)

Figure 7 shows the carcase after primal cutting and the resultant four primals including Forequarter, Rack, short loin and Leg or hindquarter.

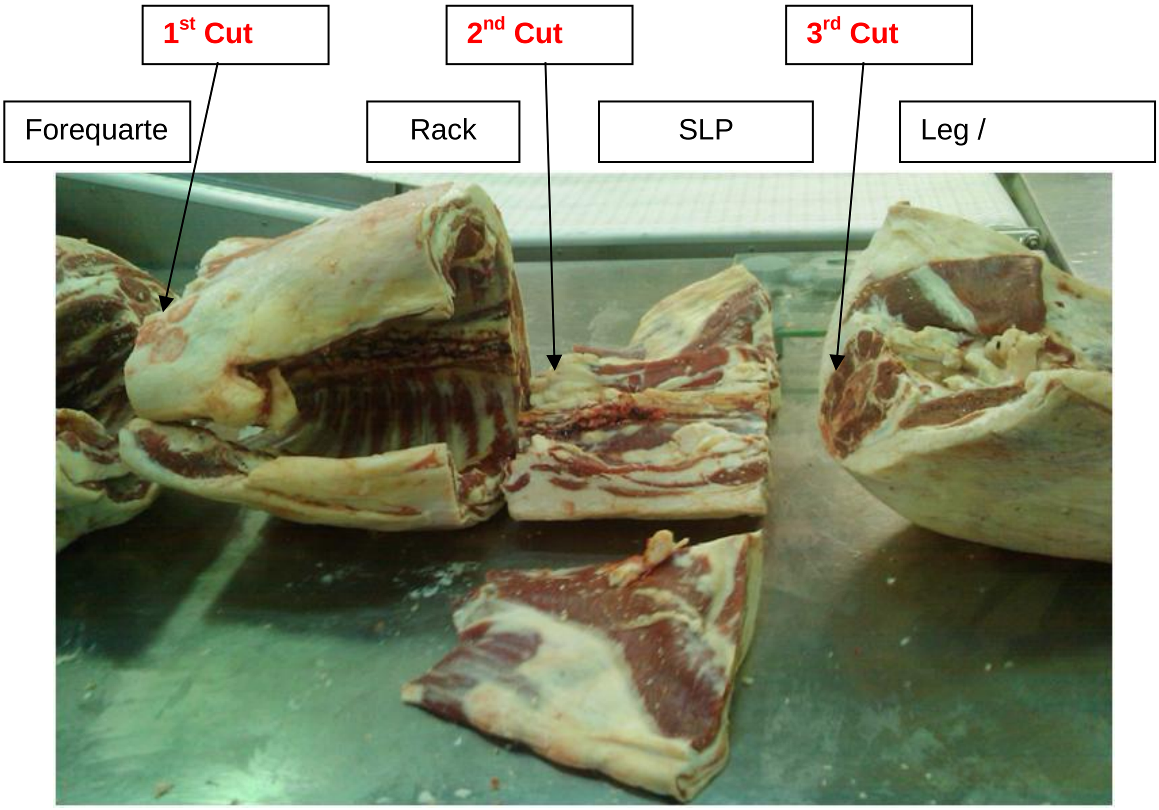

Figure 7: Three primal cuts, and the 4 respective primals

Table 5: Measurement Points for determining cost of inaccurate cutting between primals in lamb processing

Cuts (Cranial to Caudal)	Impact on Primals either side of each cut		Resulting Loss
Cut 1	Shoulder Short	Rack Long	Possible shoulder trimmed off 8 rib rack, discounted racks that don't meet market specs
	Shoulder Long	Rack Short	Rack loin achieves lower value as shoulder rack Discounted racks if not able to meet market specs
Cut 2	Rack Short	Loin Long	Ribs cut short, discount because didn't achieve 8 rib rack for export
	Rack Long	Loin Short	Extra back strap on rack, may need to be lost to trim. Back strap discounted because they are too short Loss of TDR
Cut 3	Loin Long	Leg Short	Leg muscles remaining loin lost to trim, Aitch bone needs to be trimmed from loin
	Loin Short	HQ long	Loss of back-strap and TDR to aitch bone and trimming or leg muscle depending cutting specification
Cut 3 (B) The operator of the primal cutting equipment can specify where cut 3 occurs.	Leg long	Chump Short	The primal cutting equipment can also perform the 3rd cut higher than the chump (toward distal end of leg) This cut was not considered in this analysis
	Leg Short	Chump Long	

5 Measurement Results

5.1 1st Cut, Forequarter & Loin

5.1.1 Measurement

The accuracy of the shoulder cut was largely determined by the number of ribs required in the cutting specification. Between the different site visits the cutting specifications remained consistent with a 4 rib shoulder, 8 rib rack and 1 rib short loin. Counts were conducted to assess the number of ribs relative to the cutting specification for both the left and right side of the carcass, zero = correct number of ribs (Figure 8), and inaccuracies were measured plus or minus the correct rib number. Observations were also taken to assess the angle of the cut in relation the rib. This was important because the cut may have been made at the correct rib number, but if the angle was wrong – this may result in a rib tail length that was too short to meet market specifications. Additional measurements were taken on the number of millimetres above the rib the cut was made. Width between ribs is around 20 millimetres. If a cut is made between the 4th and 5th ribs but 20 millimetres above the 4th rib, the weight of 20 millimetres of shoulder meat above the 4th rib could have been left on the rack at higher value if the cut had been made on the 4th rib (0mm above the rib).

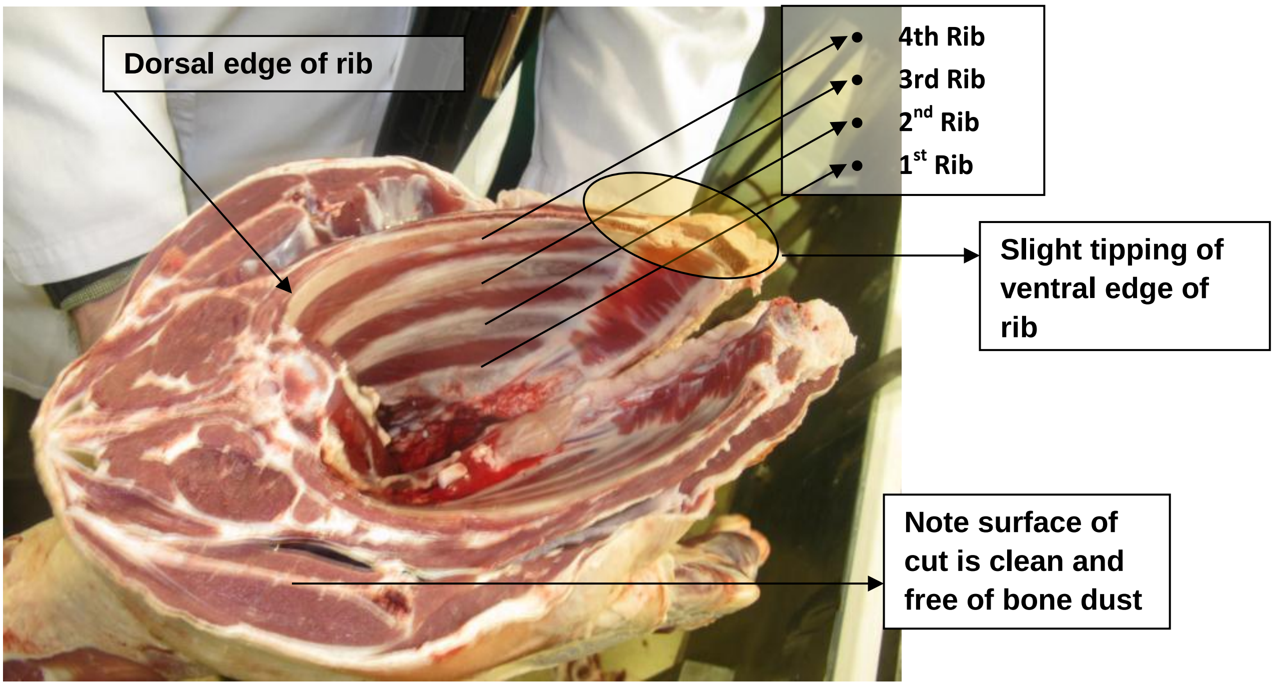

Figure 8: Measurement of cutting for forequarter rib

5.1.2 Costing

Cutting inaccuracies that resulted in longer shoulder (5 ribs) were costed as the loss of higher value M. Longissimus dorsi lost to lower value shoulder (Figure 9, Figure 10 & Figure 11).

Figure 9: Impact of cutting one rib long, figure showing amount of loin lost

Figure 10: Correct cutting line between forequarter and loin for a four rib shoulder rack

Figure 11: Cutting line long for a four rib shoulder rack. Highlighted items represent value lost (Loin lost to trim and part rib lost to render).

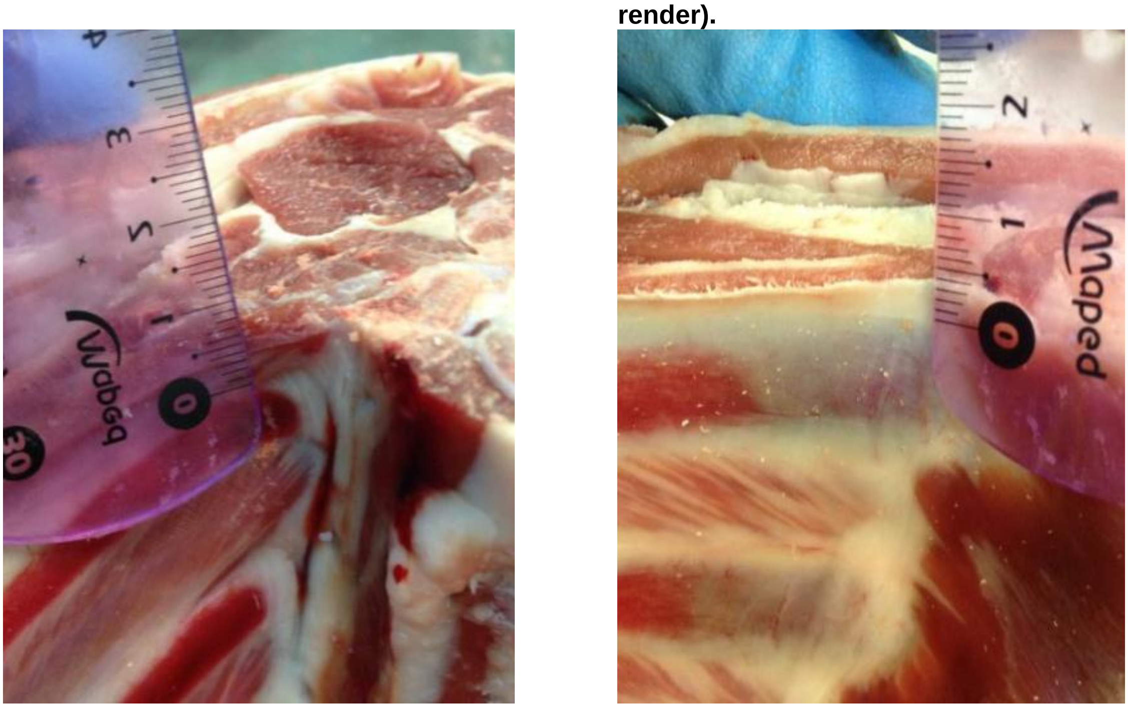

Figure 12: The number of millimetres above or below the 4th rib was measured at both the dorsal (left image) and ventral (right image) edges of the cutting line

5.1.3 Results – Impact of Rib Accuracy

Error! Reference source not found. shows that there was difference in cutting accuracy between manual and automated cutting systems. In terms of achieving the correct rib number the ex-post automated primal cutting system was less accurate than the manual cutting system. It should be noted that accuracy levels on the first review caused MAR and E+V to go back and review the measurement process. The reported accuracy helped identify areas for improvement in cutting accuracy. The numbers reported here since those changes indicate the performance of the system was not able to be improved for larger carcases and resulted in a greater number of three rib shoulders. It is important to note that measurements taken under manual operation were likely best case scenario, and would likely not be achieved consistently across an entire day, or week, while the systems accuracy levels will remain consistent.

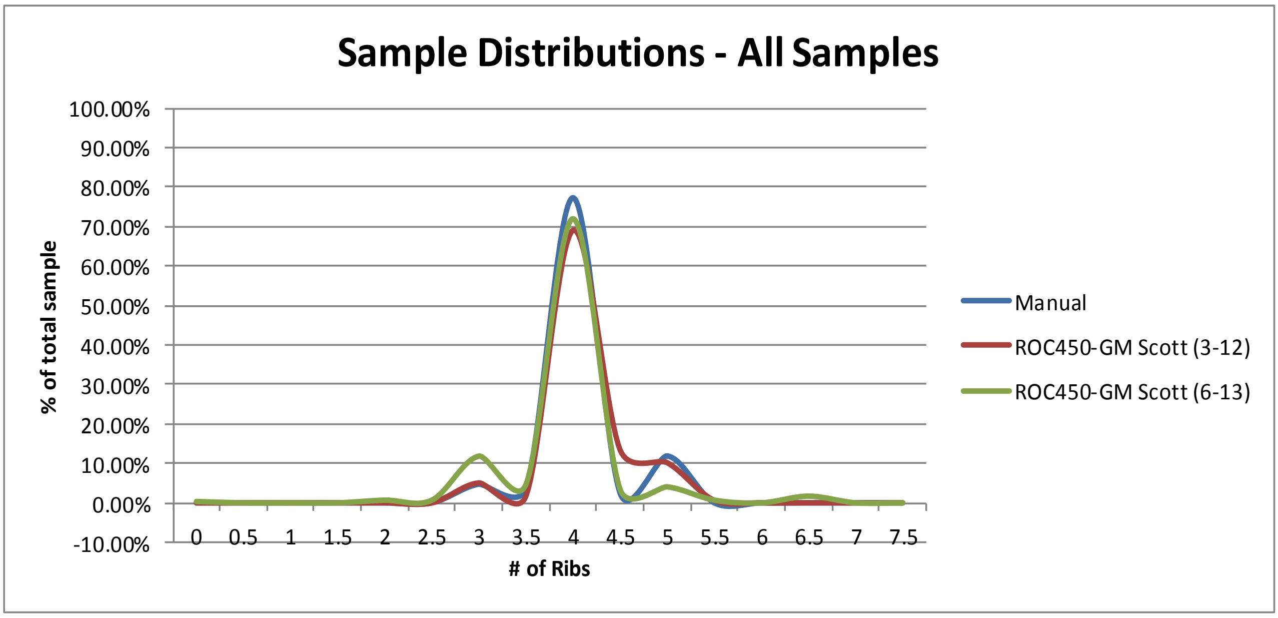

Figure 13: Shoulder cut accuracy observations for both manual and cutting systems

The method used to establish the cost of various cutting inaccuracies described below, indicates the cost of inaccurate shoulder cutting lines to be greater with the ex-post automated system than manual operation. This range of inaccuracy captures 95% of the sample population observed during the trials. Shoulder cutting cost is higher for the ex-post system and variation is increased. Note the accuracy of the system cutting large carcases is considerably less accurate than for smaller carcases. Although the system operating on smaller carcases was less accurate the variance was smaller than in manual systems and may be adjusted to obtain better accuracy. The original ex-ante study highlighted shoulder cutting inaccuracies in the automated system that exceeded MAR's targeted performance levels.

MAR worked with E+V on improving the accuracy of the image analysis and integration with the shoulder cutting robot after the initial study was completed. Review of that process improvement indicates the improvements were not successful for carcases over 22 kilograms.

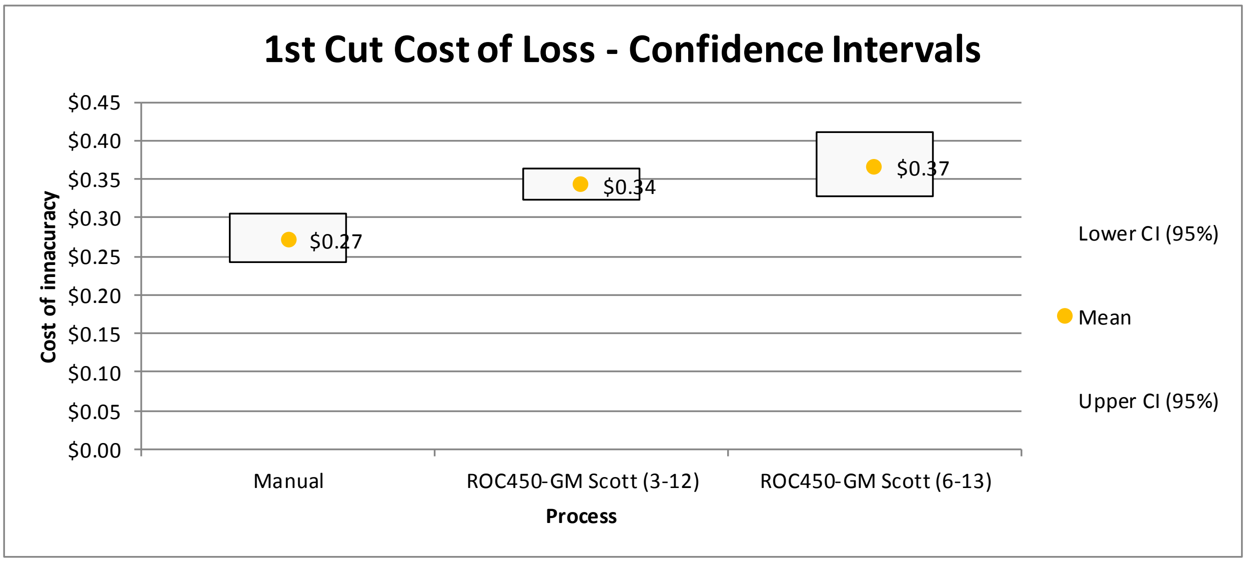

Figure 14: Cost of 1st cut inaccuracy due to incorrect number of ribs

In reality the true cost of these cutting inaccuracies will vary for every plant depending on existing markets, sales prices and many other drivers. Provision is made in the model for customized costings to be calculated and used in the cost benefit analysis.

5.1.4 Impact of Cut Angle

The distance in millimetres that the shoulder cut was made above or below the 4th rib is summarised in

for each cutting method observed. Negative values show where the cutting line has cut into the caudal edge of the 4th rib. Positive values show where the cutting line is located closer towards the cranial edge of the 5th rib, thus taking more loin from the rack and leaving it on the shoulder. The main point to note from this graph is the variation in distance away from the edge of rib under automated cutting conditions with a large proportion of cuts over 15mm or more. MAR is considering installing an offset to adjust the cut down which would reduce the cost of inaccuracy and improve ROI.

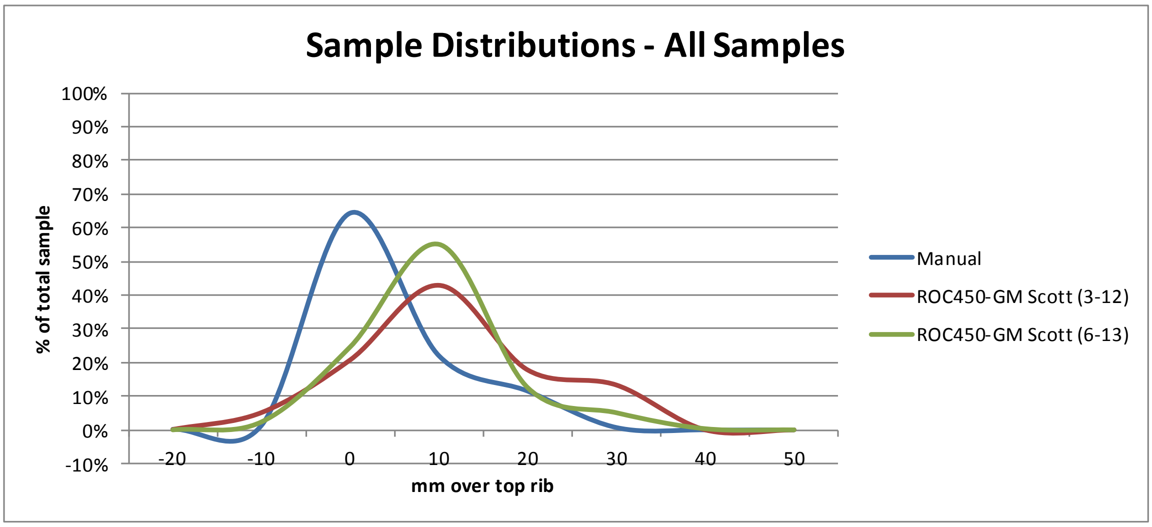

Figure 15: Distance of cutting lines from the edge of the 4th rib on a 4-rib shoulder cut.

When a shoulder is cut long (beyond the caudal edge of the 4th rib), loss occurs due to higher value rack loin muscle achieving only shoulder value. As shown in Figure 10 & Figure 11 lost loin was removed from the shoulder and weighed. Note the automated system left more meat above the shoulder cut than the manual method and impacted negatively on the costings in the model. Figure 16 illustrates the relationship between the levels of cut accuracy as the weight of loin lost relative to the primal weight. The main point to note is that there is a very strong relationship between millimetres of inaccuracy, and amount of loss that occurs relative to primal weights.

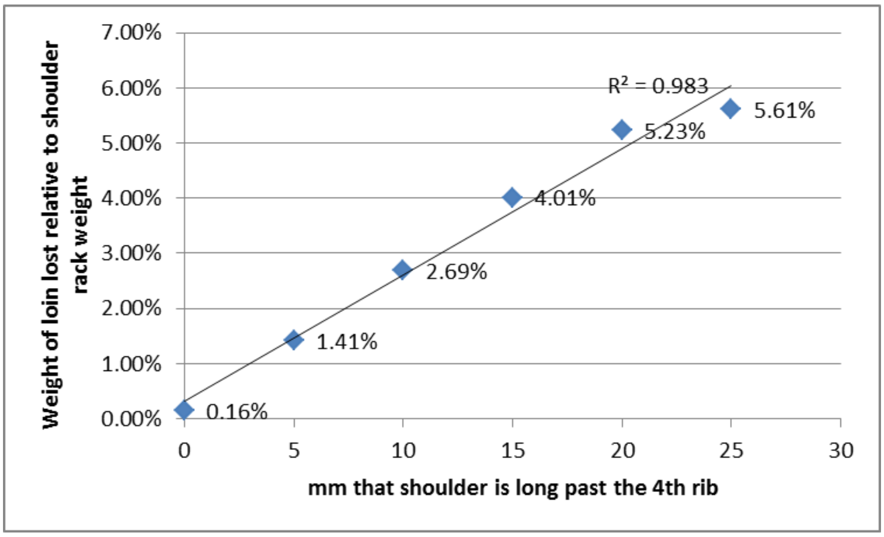

Figure 16: Scatter plot showing relationship between mm of inaccuracy and the loss of shoulder rack relative to its weight

Based on the level of accuracy observed in

, Figure 16 is used to calculate the cost of inaccuracy to the plant. The manual cutting system was resulting in a loss of $0.28/hd but this is better than observed automated accuracy. Cost of cutting shoulder long (loss of loin muscle from higher value rack product at $14/kg to lower value shoulder rack at $9/kg) has just as big an impact on value as the number of ribs.

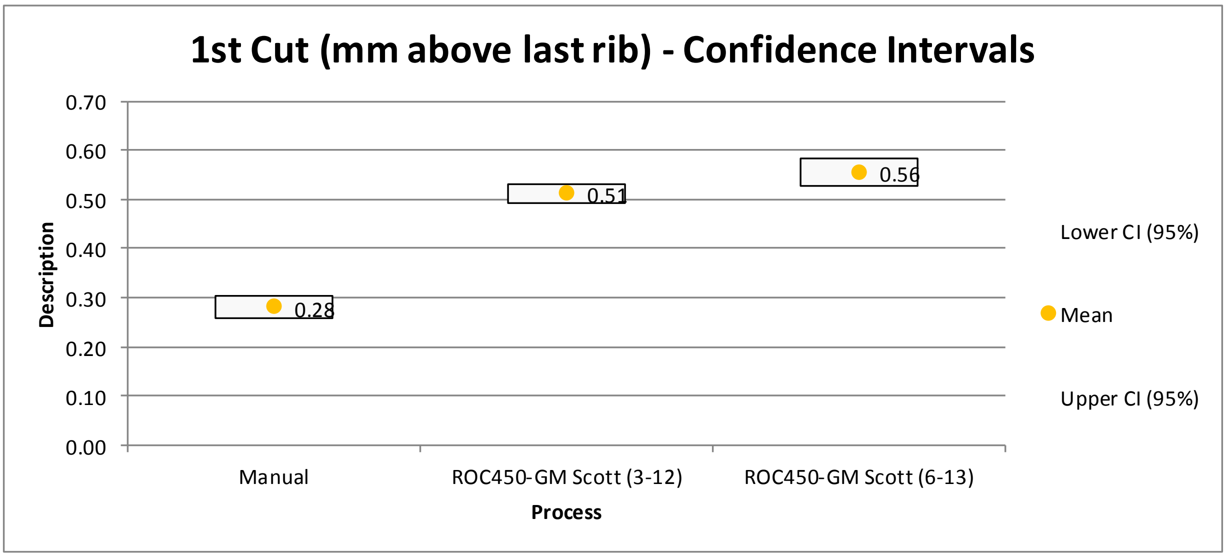

Figure 17: Range in cost of cutting accuracy above last shoulder rib for each cutting system

5.1.5 Total Shoulder Value

The combined cost of inaccuracy for number of shoulder ribs and for distance cut above the fourth rib is summarised in **Error! Reference source not found.**. The difference in cost between the manual cut method on the left and the automated system is due to poorer cut accuracy by the automated system for this cut. Manual cutting has a wider variation than the automated performance on smaller carcases. This reduced variation normally allows adjustment to systems for greater control of cutting lines between plants to meet different plant and customer requirements.

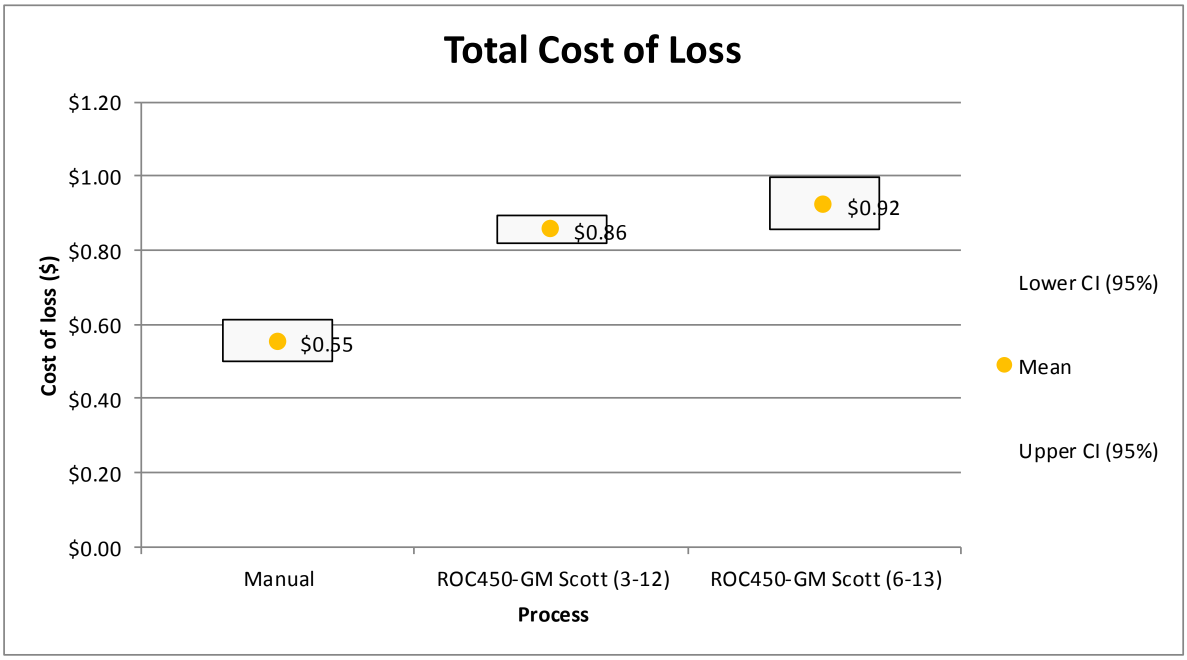

Figure 18: Combined value of loss on shoulder cut (rib # and mm's over last rib) for each cutting method

5.2 Second Cut (Rack & Short Loin Pair)

5.2.1 Measurement

Measurement of 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. For example when a 25mm tail was required as opposed to a 100mm tail the rib length did not need to be as long to meet specifications. The angle of the cut on both cranial and caudal edges of the rack was also observed.

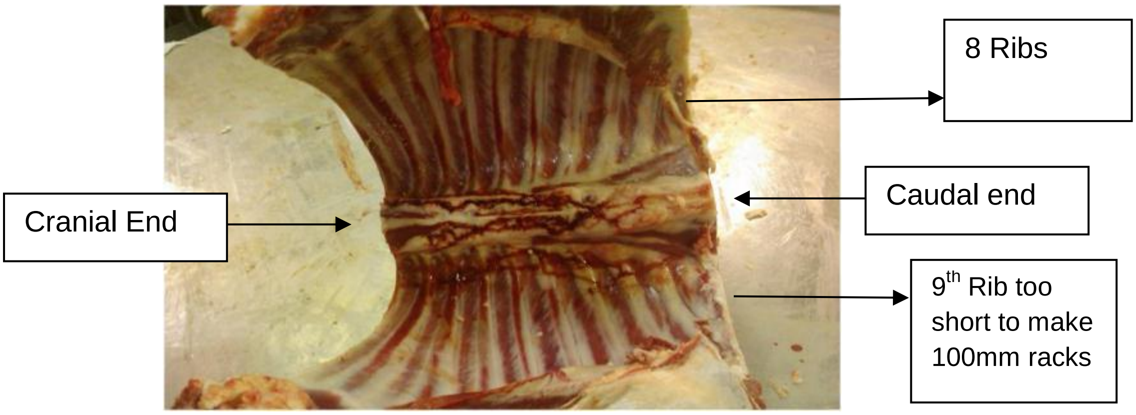

Figure 19: 8 rib rack cut with manual bandsaw.

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. Additional ribs (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 (Figure 20).

Figure 20: Bones removed from SLP as only two ribs may remain in bone in short loin.

5.2.2 Costing

Costing methodologies were developed in the ex-ante study (Greenleaf, 2010) and this same method was applied during ex-post data capture. Previous findings indicated different levels of benefit occurred for each product specification. Carcase specifications change from month to month depending on customer orders as will the associated benefits. The same average pricing and break down of specifications applied in the ex-ante study were used here. Provision is made in the model to customize costings on an individual plant basis.

5.2.3 Results

Error! Reference source not found. summarises the results and shows a reduction in accuracy of the automated process compared to the manual process.

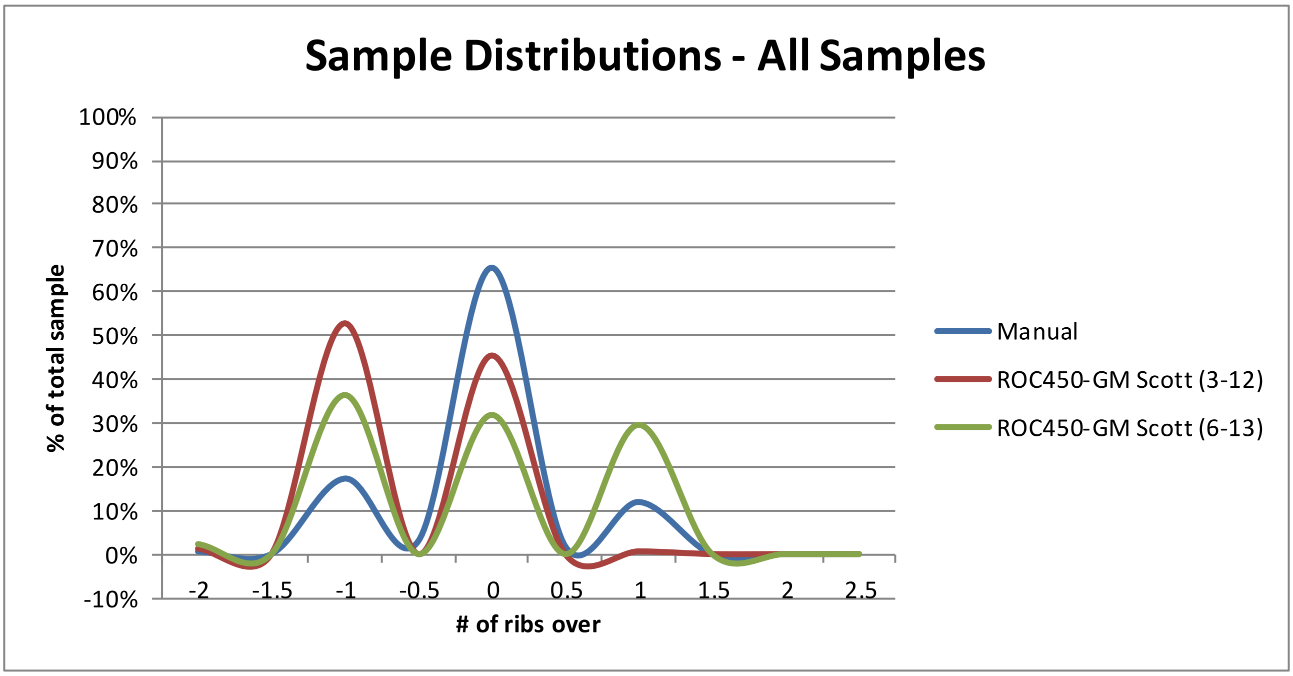

Figure 21: Observed cutting accuracies between rack and short loin pair

Error! Reference source not found. shows the variance that was observed for the length of the cut between the rack and the short loin pair.

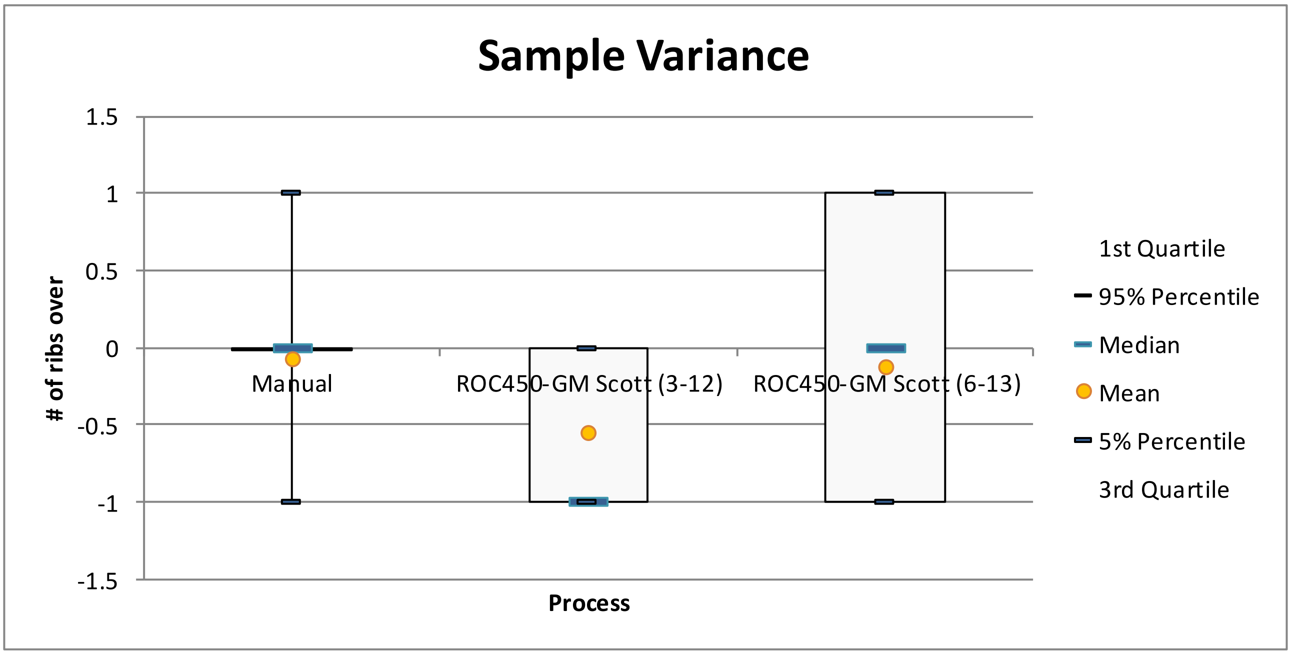

Figure 22: Current cost of cutting inaccuracies between rack and short loin pair

5.3 Third cut (Loin – Hindquarter cut)

5.3.1 Measurement

Accuracy of the leg cut was largely assessed by observing the proximity of the cut to the ilium section of the pelvic bone. An accuracy of level "0" or 100% was considered to be a cut at the lumbosacral junction of the vertebrae and cutting through the cartilage located on top of the ilium bone. The 'ideal' cut was considered to be through the top of the cartilage found on the ilium bone (Figure 23). Figure 24 shows where the tip of the ilium bone cartilage is just visible on the cut surface of the leg.

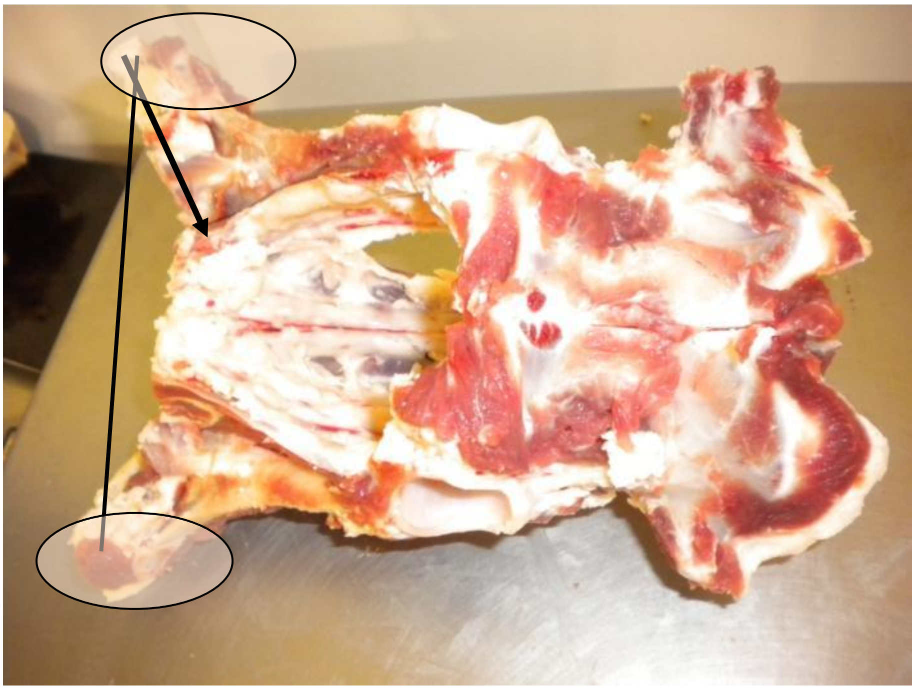

Figure 23: Correct cutting line between hindquarter and loin.

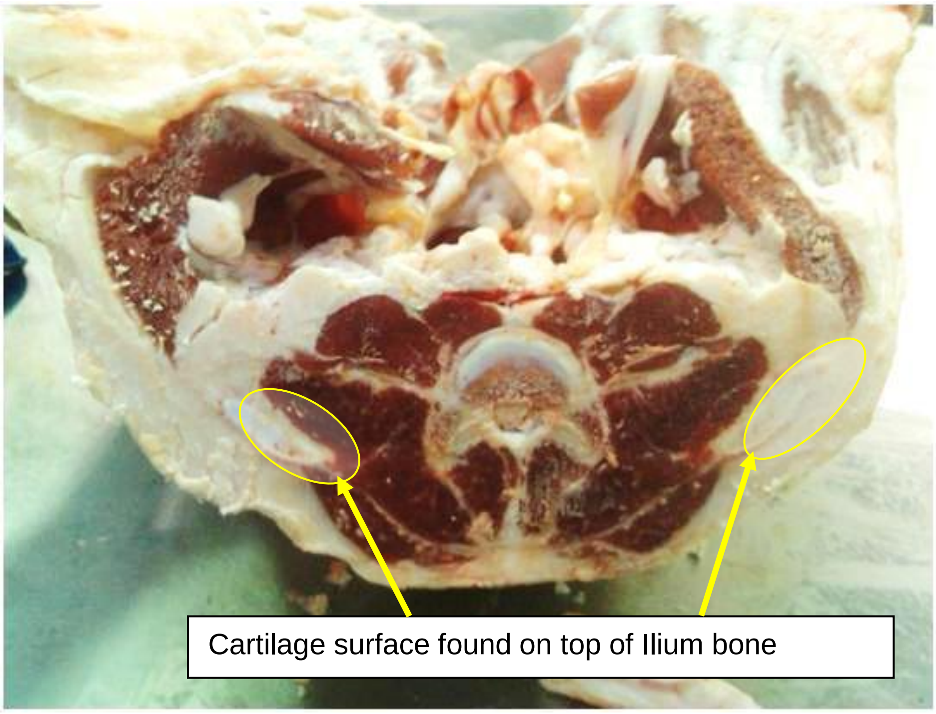

Figure 24: 100% accurate cutting line: Un-boned hindquarter with bone still remaining

Figure 25 illustrates a boneless back strap from the caudal edge. The section highlighted in the image shows here the some cartilage from the aitch bone remains on the boneless loin.

The higher the negative value recorded for the hindquarter cut the higher the cutting line was on the aitch bone, resulting in increased bone left on the loin.
While no cost has been applied to this as knife hands preparing the loin would remove this excess bone, however there would be an increased labour cost to trim the boneless loin.

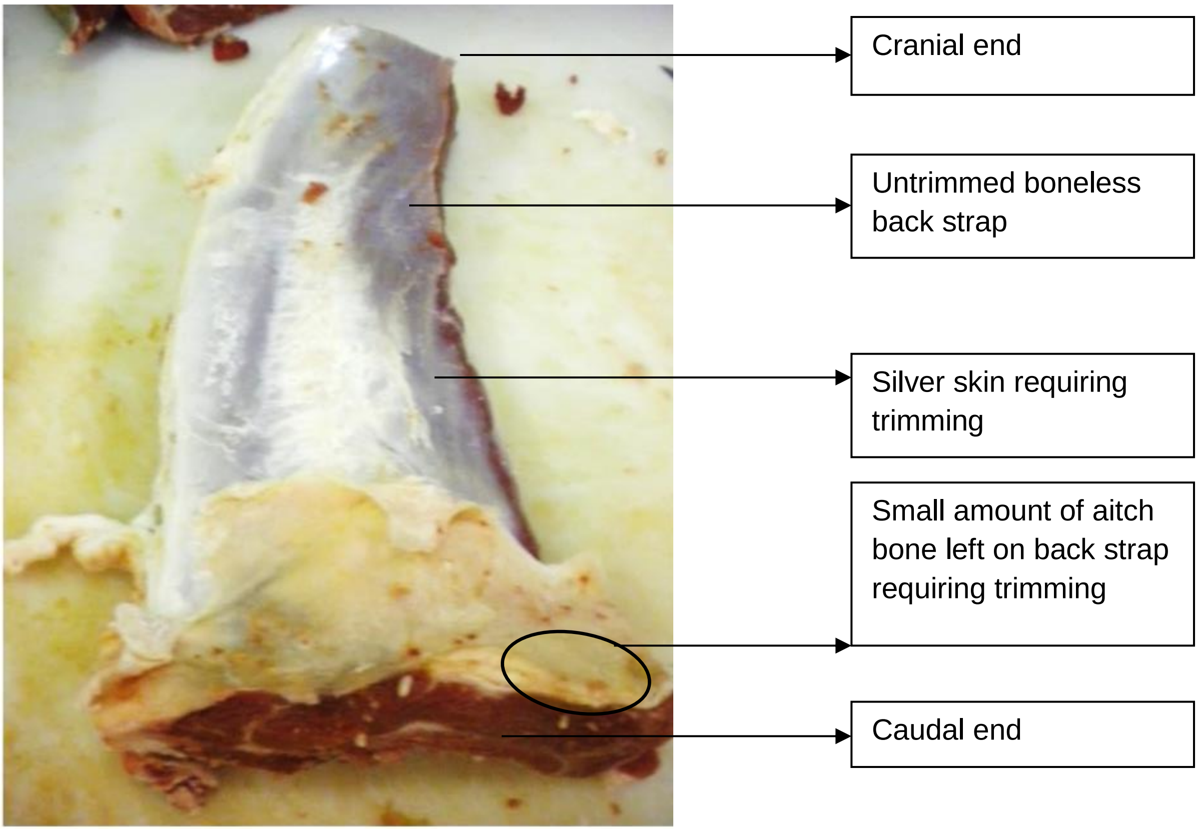

Figure 25: Boneless back strap showing small amount of aitch bone cartilage left on the surface of the muscle.

The following images (Figure 26, Figure 27 & Figure 28) illustrate the method used to calculate the cost of inaccuracies that occur on the leg cut. The images show an inaccurate leg cut where the cut occurs high on the leg, resulting in a long leg, and a shorter loin. Depending on the cutting specification loin is lost to rendering with aitch bone. Aitch bones were selected randomly from the belt, the accuracy observed, and amount of trim (grams) relative to the accuracy recorded.

Figure 26: Aitch bone showing cut where leg is long, and loin would be short, knife edge marks correct cutting line

Figure 27: Same aitch bone with trim removed

Figure 28: Loin muscle recovered from the aitch bone after fat was trimmed.

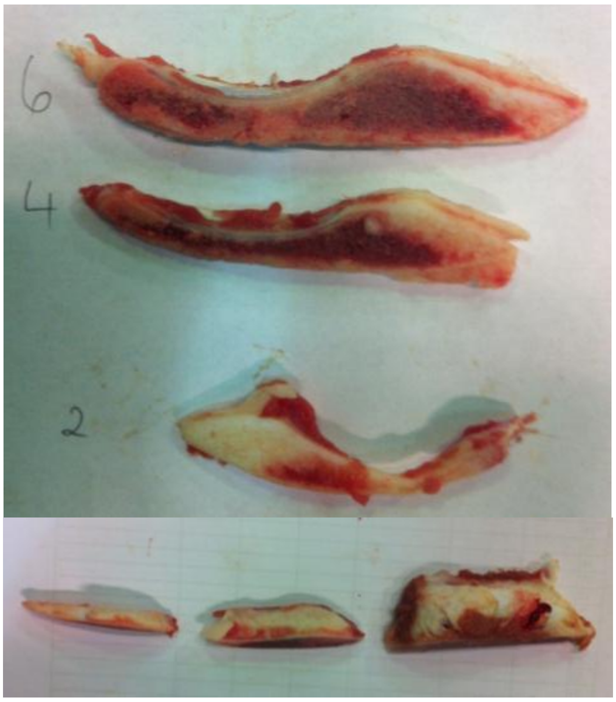

Figure 29: Calibration methods using ilium bone to establish mm's away from target cutting line

5.3.2 Costing

The weight of the trim relative to the cutting accuracy level was averaged, and an index was established to calculate the cost of inaccuracy.

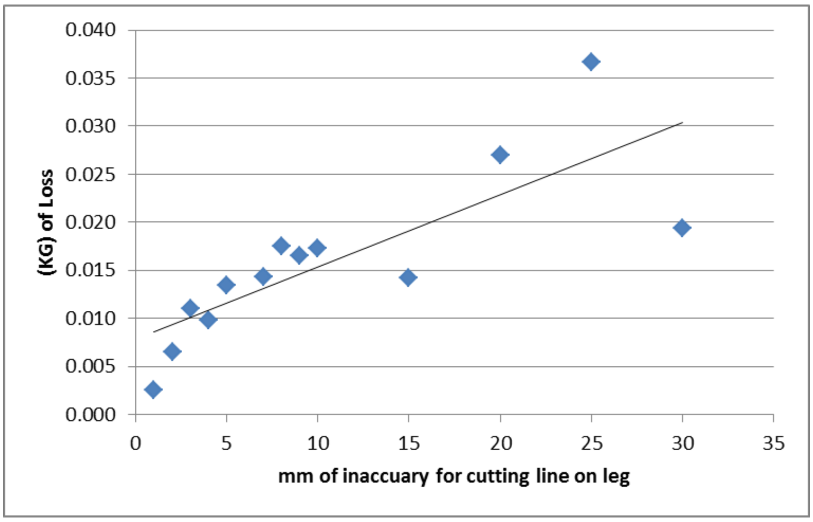

Figure 30: Average weight of loin recovered from aitch bone based on mm of cutting line inaccuracy

Figure 30 is used to illustrate the cost of inaccuracies shown in Figure 31, when the leg primal is cut long. The average amount of trim lost at a given level of inaccuracy is determined. The difference in value of this trim at loin price compared to rendering price is used to calculate the cost of inaccuracy. The per cent occurrence where the leg was long with the automated cutting system was then subtracted from the manual per cent of inaccuracy. It was not possible to pick up 100% of inaccuracy observed under manual operating conditions with the automated system. The costs for the different levels of inaccuracy were then calculated for the total daily kill population based on the percentage difference between manual and automated operation.

5.3.3 Results

The automated process had a narrower variation in cutting accuracy than manual methods as seen in Figure 31, Figure 32 and

Figure 33, which is expected.

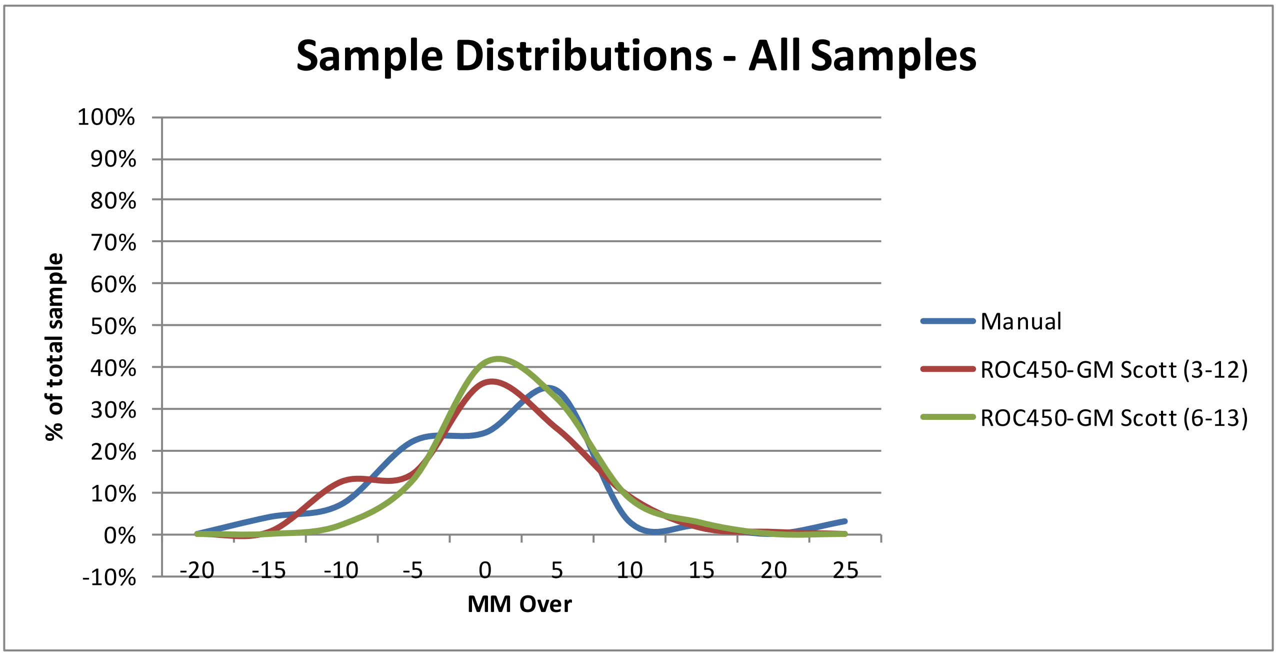

Figure 31: Survey results showing level of cutting accuracy for Loin – Leg cut for each cutting method

Given the tighter control of the cut than manual bandsaw (Figure 32), the plant would be able to target the cutting line higher into the leg to remove more loin muscle onto the shortloin pair that is left on the aitch bone as rendering. This adjustment of cutting line can be done without damaging the leg specification.

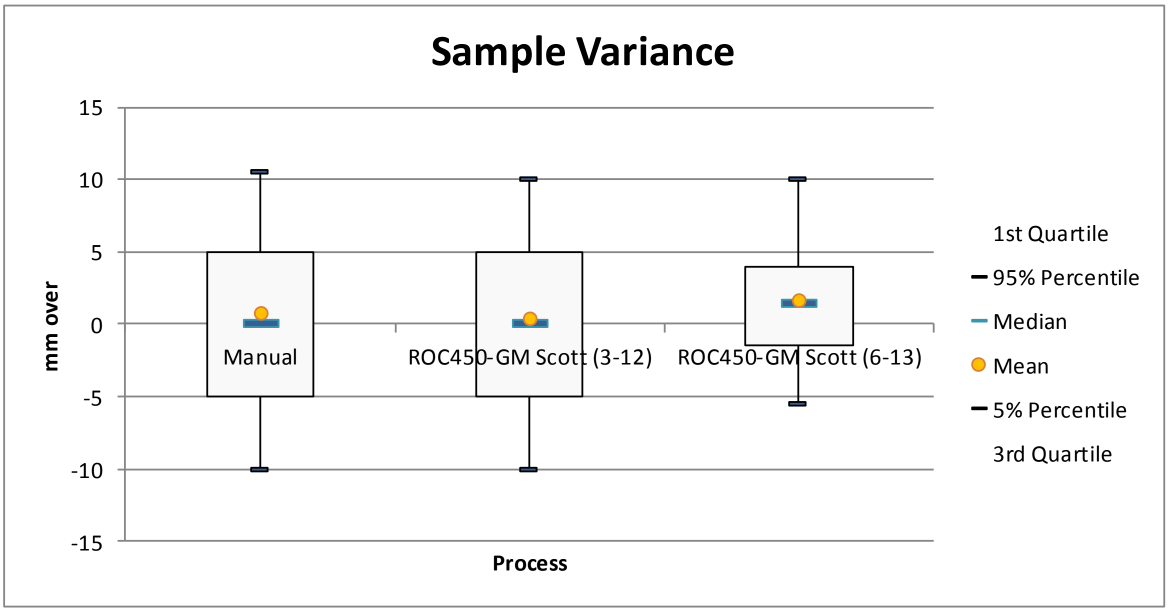

Figure 32: Leg cut sample variance between cutting processes

The variation in manual operations prevents this shift in cutting line to gain lost loin value. If the cut was to proceed too far into the leg, more rump would remain on the loin and would be lost to trim. The reduction in variance of cutting accuracy on the automated solution could allow created value on the leg cut that had not been realised during the ex-ante study.

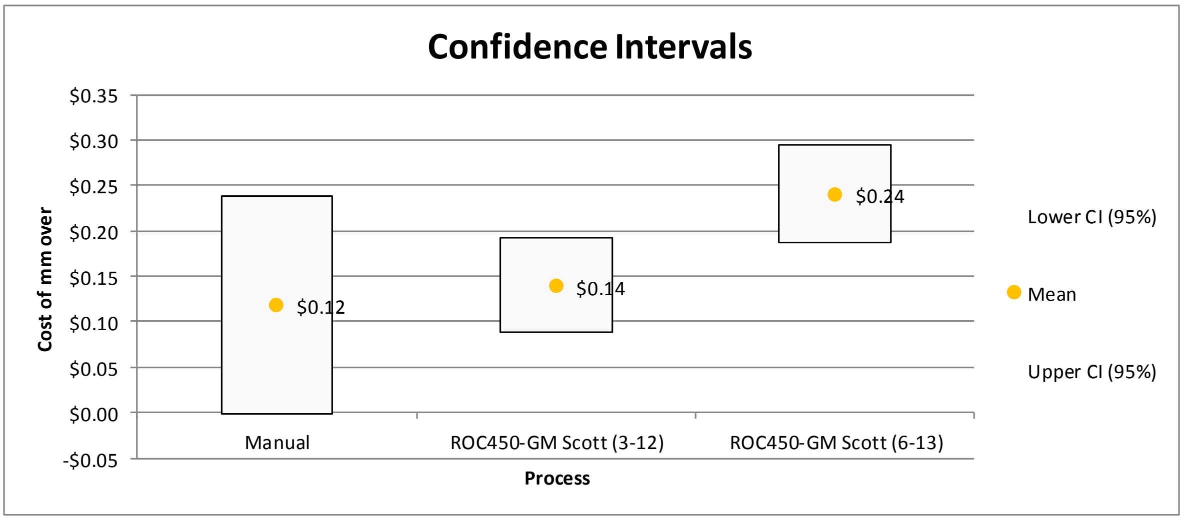

Figure 33: Cost of cut inaccuracy between leg and loin for each cutting method

5.4 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 / carcass across two different manual processing plants (Table 6). An assumption was made that there would be a 90% reduction in sawdust with the different cutting system on the Automated primal cutter. This returned a value of 39.45 kg/ day (based on production of 2200 hd), which was costed at an approximate retail carcase value of $7.5/ kg. This resulted in an achievable saving of $0.13/hd based on the automated primal cutting equipment performing 3 cuts on the carcass. An assumed reduction in savings of one third is applied if the automated equipment is operating at only two cuts; this provides a benefit of $0.09/hd.

Table 6: Value of band sawdust lost during manual cutting

Yield Savings through reduced Band Saw Dust		
Number of head processed		2,201
Time		Net amount
Band saw dust per head (kg)		0.0199
TOTAL Collected for 3 cuts (kg)		**43.83**
reduction with automated		90.00%
% reduction with automated (Kg)		39.45
Retail value of carcasses		$7.50
Value of recovered saw dust that was salable		$295.85
Value per annum		$78,400.44
	2 cuts	$0.09
Value per hd	3 cuts	$0.13

5.5 Increased Shelf Life

Increases in shelf life are expected with the use of the primal 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 current used during the cutting process
    c. Reduced human handling of meat

Figure 34: Lamb hindquarter cut with the ROC Automated primal cutting system, note cut meat surface and lack of bone dust present.

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.

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		912,000	
Current level of discounting		4.00%	
Number of items discounted	36,480	36,480	36,480
Weight of discounted (kg)	93,754	102,144	189,696
True Value	$806,281	$1,940,736	$1,705,367
Discount Value	$645,025	$1,552,589	$1,364,294
Current cost of discounting	$161,256	$388,147	$341,073
Reduction in level of discounting		10.00%	
New level of discounting		3.60%	
New number of items discounted	32,832	32,832	32,832
New quantity (kg)	84,378	91,930	170,726
New True value	$725,653	$1,746,662	$1,534,830
New Discount Value	$580,522	$1,397,330	$1,227,864
New cost	$145,131	$349,332	$306,966
SAVING	$16,126	$38,815	$34,107
Saving per head (leg reduced discounting)	$0.04	$0.09	$0.07
Number of cuts	2	$0.06	
	3	$0.13	
	4	$0.20	
Total Saving /hd	Total	$0.20	

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

5.6 Increased Efficiencies on Existing Labour

The area of improved productivity had the greatest difference between ex-ante and ex-post reviews. There had been an allowance for improved productivity in the earlier study but the observed improvement post installation was greater than expected.

The main driver behind increased efficiencies for existing labour is a result of the more consistent throughput of product. Manual processes rely on the bandsaw operator setting the speed at which the lamb carcasses enter the processing belt. While each bandsaw rotation processed the specified number of carcasses in a given time period, large variations in the processing speed occurred during the rotation. This led to labourers either operating at less than optimum speeds or build-up of product where operators were not able to keep up.

One of the main advantages of automated primal cutting equipment is the consistency of throughput through the room. Product flow into the room is now much more consistent, and has resulted in increased boning capacity of the room using the same labour and infrastructure as previously used. This improvement in labour cost per kg is shown in the middle row of Table 8 and represents a productivity increase of 15-22% compared with the ex-ante prediction of 4% labour efficiency gains.

Table 8: Manning of processing room[2]

Increased throughput through the room			Manual Process	ROC450-GM Scott (3-12)	ROC450-GM Scott (6-13)	EQUIP. MAX
Average daily hd			1536	1824	1824	2880
Average kg			21.88	21.88	21.88	21.88
Average Kg boned per day			33,608	39,909	39,909	63,014
Boning room cost / hour			$1,112	$1,112	$1,112	$1,619
Boning room cost / day			$8,893	$8,893	$8,893	$12,952
Labor cost \ per kg to bone			$0.26	$0.22	$0.22	$0.21
Labor cost \ per hd to bone			$5.79	$4.88	$4.88	$4.50
Labour productivity savings/ head			$0.00	$0.91	$0.91	$1.29
Task	Rate / hour	WW Loading 35.00%	Number labor units			
Supervisor	$35.00	$47.25	1	1	1	1
QA	$31.00	$41.85	1	1	1	1
Admin	$24.00	$32.40	2	2	2	2
Band Saw operator	$26.23	$35.41	3	3	3	5
Ticketing	$23.10	$31.19	2	2	2	3
Knife hand	$23.10	$31.19	8	8	8	12
Trimmers	$23.10	$31.19	7	7	7	10
Packer	$23.10	$31.19	4	4	4	7
General Labor	$23.10	$31.19	6	6	6	9
Maintenance	$19.00	$25.65	1	1	1	1
Total FTE's required			33.5	33.5	33.5	49.5

In the cost benefit results, no consideration is given to reduction in per head allocation of fixed costs by increasing the processing capacity of the plant due to increased cutting speed of the equipment.

5.7 Labour Savings

The data displayed in Table 9 shows a saving of 3 labour units across band saw operators and bone scrapers. This data would need to be customized for each different plant context. This resulted in labour savings of $0.29 per head using the automated primal cutting equipment.

Table 9: Labour savings achieved with automated primal cutting equipment

[2] Note Table 88 is purely for the purposes of measuring changes in throughput and labour units required to achieve faster rates. No additional staff were required to achieve the faster throughputs. It does not take into account the savings in bandsaw operators or other staff as a result of the automation. These labour savings are covered in section 5.7.

Labor	Hd / annum	456,000
Number band saw labor units saved		2.0
Hourly cost		$26.23
Plus overheads (35%)		$9.18
Total hourly rate		$35.41
Annual		$147,308
Saving in bone scrapers		1.0
Hourly cost		$23.1
Plus overheads (35%)		$8.1
Total hourly rate		$31.2
Annual cost of Bone Scraper		$64,865
$ Saved bone scraping		$64,865
Total		$212,172
Number of cuts required	2	$0.15
	3	$0.31
	4	$0.47
Saving per head		$0.47

5.8 OH&S Savings

There were two main areas 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 carcass off the rail for cutting, 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 Lamb primal cutting

OH&S			
Band Saw cutting		Sprain and Strain from lifting	
Risk of Limb Loss over 5 year period	80%	Number of occurrences per year	4
Premium Cost	$120,000	Cost of light duties claim, loss of operator	$10,000
Annual Cost	$19,200	Annual Cost	$40,000
Annual Saving per head	$0.04	Annual Saving per head	$0.09
TOTAL OH&S Benefit			$0.13

5.9 Equipment Costs

Table 11, Table 12 and Table 13 show 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 costs of automated primal cutting equipment

CAPITAL COSTS		
Based on annual product of	456,000	720,000
Item	Price	Price
Equipment purchase	$950,000	
Infrastructure upgrade	$100,000	
Total	$1,050,000	
Annual Deprecation	$105,000	
Cost per head	$0.23	$0.15

Table 12: Estimated operational costs of automated primal cutting equipment

Annual Cost	Item	Cost / yr	Cost / hd	
	Based on annual # hd		456,000	720,000
Operational	Cleaning	2,500	$0.01	$0.00
	Power	5,300	$0.01	$0.01
	Additional MAR support	5,000	$0.01	$0.01
	Ongoing Training	1,500	$0.00	$0.00
Sub Total (operational)		14,300	$0.03	$0.02
Maintenance	Blades	10,000	$0.02	$0.01
	Maintenance	4,850	$0.01	$0.01
	Materials	2,000	$0.00	$0.00
Sub Total (maintenance)		16,850	$0.04	$0.02
Total		31,150	$0.07	$0.04

Table 13: Estimated operational costs of manual primal cutting equipment

Operational Cost - Manual Bandsaw				Cost / hd	
Blades (Annual Cost)		$	37,100	$0.08	$0.05
	Blade unit cost	$	29.68		
	Blades / day		5	$0.08	$0.05
Cleaning (Annual Cost)		$	775	$0.00	$0.00
	Cleaning rate ($/hr)	$	20.66		
	Daily Time		0.15		
	Daily Cost	$	3.10		
Power			500	$0.00	$0.00
Service Contract			0	$0.00	$0.00
Ongoing Training				$0.00	$0.00
Total annual cost		$	38,375	$0.00	$0.00
Cost per head		**$**	**0.084**	$0.08	$0.05

5.9.1 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 with the existing plant. Cost of the equipment for onsite modifications and installation costs has not been allowed for. The capital cost per head processed will reduce as the total annual number of head processed increases.

5.9.2 Maintenance & Service Costs

Maintenance and service costs are also supplied by the equipment manufacturer. Maintenance costs are additional running costs that the plants 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 automated primal cutting system.

5.10 Risk of Down Time

Table 14 shows the calculation used to estimate the cost of down time. The allowance is made for 1 occurrence per week where the stoppages associated with the equipment would cause the entire room to be at a standstill for 15 minutes. The same labour cost used for calculating increases in labour efficiency 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. Breakage of bandsaw blades in the manual process is quite common and occurs more than 10 minutes per week. Depending on which saw blade breaks some product can be diverted to the other bandsaws while the blade is replaced.

Table 14: Estimated cost of down time

Risk of down time	Manual	Automatted	
Total plant down / week (hours)	0.1	0.25	
Number of head/year	384,000	456,000	720,000
Hourly labor cost for boning room	1,112	1,112	1,619
Weekly Cost	111	278	405
Annual Cost	5,336	13,339	19,428
Cost per head	$ 0.014	$ 0.029	$ 0.027

6 Cost Benefit Results

The results reported in this section are based on the model drivers summarised in the section 4.3.1 on page10. The methodology used to analyse and present the data differed between the ex-ante and ex-post studies as described earlier in this report. The increased level of detail presented in the summaries in this ex-post report, including Table 15, captures the range in vales observed in the data captured for each system.

The total ex-post benefit observed were similar to the ex-ante review but the source of benefits all came from operational efficiencies and labour savings with no benefit from cutting accuracy and yield improvement.

The summary results in Table 15 demonstrate the performance of the ex-ante machine on smaller carcases in the first trial (left), the second site visit trial with a mix of light and heavy carcases (middle) and theoretical maximum capacity of the machine assuming small carcases (right) relative to manual operations.

Variance observed across the sample data reflects a range in values expected and is reported using the upper and lower 95% confidence intervals in the Table 1 as lower (From) and upper (To) value range for each piece of equipment.

The ex-post net benefit was $0.87/hd, compared with an ex-ante prediction of $0.89/hd. This delivers an estimated return on investment of between 2 and 3 years depending on the mix of carcase weights processed and the volume processed annually.

Table 15: Summary of benefits for ex-ante, ex-post and maximum machine speed relative to manual cutting performance

SUMMARY PERFORMANCE MEASURES						
	ROC450-GM Scott (3-12)		ROC450-GM Scott (6-13)		EQUIP. MAX	
	Hd/ annum	456,000	Hd/ annum	456,000	Hd/ annum	720,000
Production increase with equipment	18.75%		18.75%		87.50%	
	From	To	From	To	From	To
Capital cost (pmtt option, upfront)	$1,050,000		$1,050,000		$1,050,000	
Gross return Per head	$1.19	$1.25	$1.03	$0.89	$1.57	$1.27
Total costs Per head	$0.33		$0.33		$0.22	
Net Benefit Per head	$0.87	$0.93	$0.70	$0.56	$1.36	$1.05
Annual Net Benefit for the plant	$394,997	$422,149	$321,266	$256,111	$976,403	$757,110
Annual Net Benefit for the ex cap	$500,993	$528,145	$427,262	$362,108	$997,644	$778,352
Pay back (years)	2.10	1.99	2.46	2.90	1.05	1.35
Net Present Value of investment	$2,537,458	$2,728,164	$2,019,603	$1,561,987	$6,025,725	$4,485,508

The benefits identified can be broadly summarised as either product value or process efficiency benefits with the larger portion of benefits being related to processing in Figure 1.

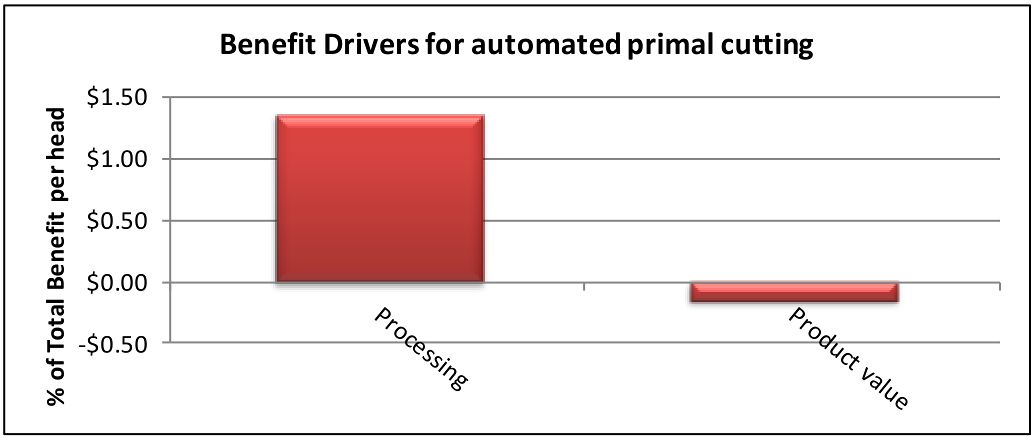

Figure 35: Broad grouping of benefits delivered by automated primal cutting solution

The automated equipment did not improve accuracy of cutting lines as compared with manual methods. Automated cutting technology delivered process improvement benefits including increased labour productivity as a result of more consistent product flows, as well as a reduction in labour units required. Occupational health and safety costs reduced as a result of reduced safety risks. Small yield gains through reduced bandsaw dust and increased shelf life were also achieved. The overall contribution of each individual benefit and its associated dollar value is summarised in Figure 2 and Table 17.

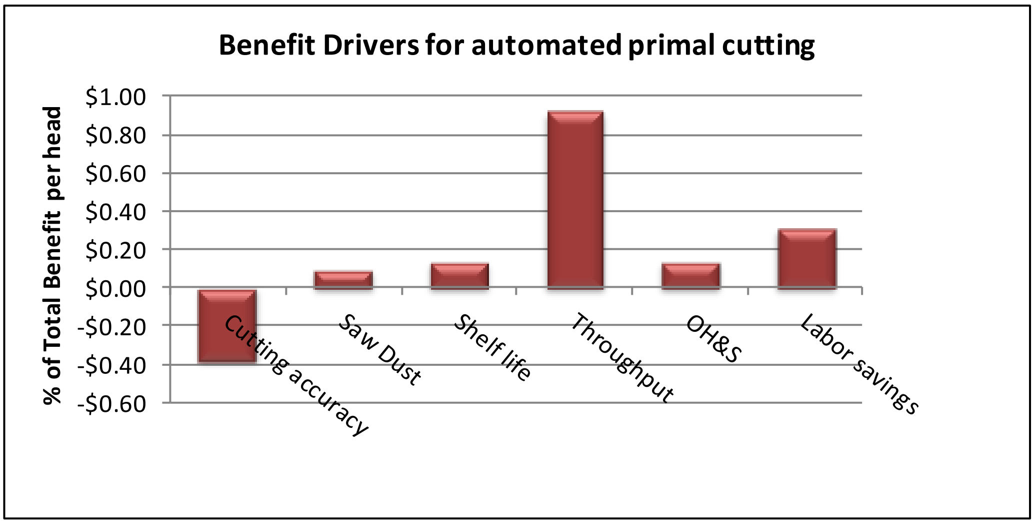

Figure 36: Summary of benefits delivered from automated primal cutting solution

Table 16: Breakdown of benefits and costs by area

Sector	% of total	$/ hd	$/ annum
Processing	113.1%	$1.35	$616,075
Product value	-13.1%	-$0.16	-$71,590
	100.00%	**$1.19**	**$544,485**
Cutting accuracy	-31.3%	-$0.37	-$170,510
Saw Dust	7.4%	$0.09	$40,149
Shelf life	10.8%	$0.13	$58,771
Throughput	76.6%	$0.91	$416,841
OH&S	10.9%	$0.13	$59,200
Labor savings	25.7%	$0.31	$140,034
	100.00%	**$1.19**	**$544,485**
Capital cost	70.24%	$0.23	$105,000
Maintenance	11.27%	$0.04	$16,850
Operation	9.57%	$0.03	$14,300
Break Down	8.92%	$0.03	$13,339
Total Cost	100.00%	$0.33	$149,489

A summary of the range in costs and benefits for each scenario are included in Table 17 below.

Table 17: Summary of benefits for the installation of MAR automated primal cutting system.

	ROC450-GM Scott (3-12)		ROC450-GM Scott (6-13)		EQUIP. MAX	
	Hd/ annum	456,000	Hd/ annum	456,000	Hd/ annum	720,000
Production increase with equipment	18.75%		18.75%		87.50%	

Table 18: Ex-ante costs and benefits breakdown for the installation at 6hd/minute

COST - BENEFIT ANALYSIS OF ROBOTIC PRIMAL CUTTING EQUIPMENT

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

Benefit summary	$/hd		$/hd		$/hd	
	From	To	From	To	From	To
$ Accuracy Benefit per head	($0.37)	($0.31)	($0.54)	($0.68)	($0.37)	($0.68)
$ Technique Benefit per head	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22
$ Labour Benefit per head	$1.35	$1.35	$1.35	$1.35	$1.73	$1.73
$ Automation Costs	$0.00	$0.00	$0.00	$0.00	($0.12)	($0.12)
$ Overall Benefit per head	**$1.20**	**$1.26**	**$1.03**	**$0.89**	**$1.46**	**$1.15**

COST ASSOCIATED WITH THE ROC450

	$/hd	$/hd	$/hd
Capital cost	$0.23	$0.23	$0.15
Maintenance	$0.04	$0.04	$0.02
Operation	$0.03	$0.03	$0.02
Risk of mechanical failure	$0.03	$0.03	$0.03
Total cost per head	$0.33	$0.33	$0.22
Total cost per head (EX CAP)	$0.10	$0.10	$0.07

6.1 Calculating Cost of Loss

Table 19 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 from.

Table 19: Summary results of individual costs associated with automated primal cutting of lamb carcasses

VALUE OF LOSSES DUE TO INACCURACIES AND MANUAL INTERVENTION

		Manual Process		ROC450-GM Scott (3-12)		ROC450-GM Scott (6-13)	
Loss summary		$/hd From	$/hd To	$/hd From	$/hd To	$/hd From	$/hd To
1.1 Accuracy	Cut 1 (FQ-Mid)	$0.50	$0.61	$0.82	$0.90	$0.86	$0.99
	Cut 2 (Rack)	$0.11	$0.15	$0.14	$0.20	$0.24	$0.43
	Cut 3 (Hind Leg)	$0.00	$0.07	$0.03	$0.06	$0.06	$0.09
	Cut 4	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
1.2 Cutting Technique	Saw dust loss	$0.09	$0.09	$0.00	$0.00	$0.00	$0.00
	Shelf life loss	$0.13	$0.13	$0.00	$0.00	$0.00	$0.00
2. Throughput loss		$5.79	$5.79	$4.88	$4.88	$4.88	$4.88
3. OH&S losses		$0.13	$0.13	$0.00	$0.00	$0.00	$0.00
4. Labor losses		$0.31	$0.31	$0.00	$0.00	$0.00	$0.00
Equipment costs	**Maintenance**	$0.00	$0.00	$0.04	$0.04	$0.04	$0.04
	Operation	$0.08	$0.08	$0.03	$0.03	$0.03	$0.03
	Risk of failure	$0.01	$0.01	$0.03	$0.03	$0.03	$0.03
$ Losses per head		**$7.16**	**$7.38**	**$5.96**	**$6.12**	**$6.12**	**$6.49**
				$1.20	$1.19		
$ Annual Losses overall plant		**$3,263,934**	**$3,364,491**	**$2,718,452**	**$2,791,857**	**$2,792,182**	**$2,957,894**

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

The Figure 37 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.

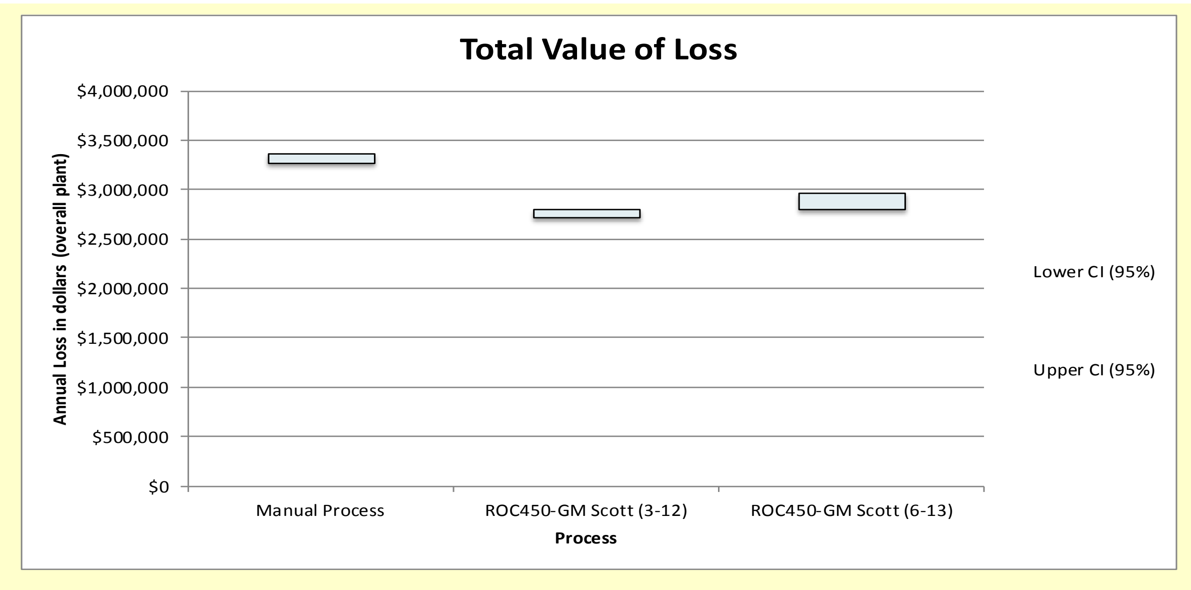

Figure 37: Graphical representation of losses captured in Table 19 showing reduction in loss using the automated systems

7 Observations

Some observations from the trials that should be considered include:

1. Quality checking processes in place at the GM Scott should be converted from manual paper records only to simple spread sheet based data entry. This will enable QA checks to report per cent accuracy to targets on a daily basis; something that was not occurring previously.
2. Further training is required to help operators understand how much the system should be adjusted by to create the appropriate change in accuracy.
    a. For example, when we notified that >80% of the cuts were 5 ribs or more on day 2, the adjustment should have been more than 2 mm (more like 15mm).
    b. Adapting the QA check sheets to measure amount of variation from target would not take any more time but could output a specific number of millimetres of adjustment required to hit target accuracy
    c. Involvement of boning and bandsaw operators in checks would create more buy-in along the chain and would enable faster adjustment without requiring additional QA controls. The boners observed during the trials were well aware of the system accuracy and some seemed proactive towards being involved in the process.
3. It is too early to tell what improvement in accuracy over manual operation could be achieved in this plant by the inclusion of a semi-automatic offset adjustment but it is clear that further training and development along with inclusion of simple process controls will provide valuable tools to support the current team.

8 References

Aus Meat (2003) “Sheep meat Language” (Sheep Meat Primal Cuts) sourced on line at Aus Meat, viewed 14 July 2010,
<http://www.ausmeat.com.au/media/3413/sheep%20meat%20language%20brochure.pdf>

9 Appendices

9.1 First Site Visit Summary

A ROC450 lamb primal cutting system has been installed and operational at GM Scott Cootamundra lamb processing plant for a number of months. Greenleaf conducted a series of trials over three days to measure the accuracy of the system for each of the 4 primal cuts the system is making.

Results from the site review were to be entered into an ex-post CBA model to provide an actual commercial operational performance for the system at GM Scott. While at the plant a number of inaccuracies were observed across the first two days of testing and with the forequarter cut between the 4th and 5th ribs in particular.

Accuracy ranged from 70% to 58% on the first and second day consecutively depicted in Table 20 and Table 21 below. This is well below the >90% accuracy observed on the system at Midfield in 2011.

Table 20: Shoulder cut measurement accuracy 7th March 2012 verse manual ex-ante

	Manual		ROC450		
Rib	# Obs	% Occurrence	# Obs	% Occurrence	**Difference**
3.00	14.00	4.73%	28.00	5.18%	-0.45%
3.50	11.00	3.72%	4.00	0.74%	2.98%
4.00	229.00	77.36%	383.00	70.79%	6.57%
4.50	7.00	2.36%	89.00	16.45%	-14.09%
5.00	35.00	11.82%	37.00	6.84%	4.99%
Total	296.00	1.00	541.00	1.00	

Table 21: Shoulder cut measurement accuracy 8th March 2012 verse manual ex-ante

	Manual		ROC450		
Rib	# Obs	% Occurrence	# Obs	% Occurrence	**Difference**
3.00	14.00	4.73%	7.00	1.64%	3.09%
3.50	11.00	3.72%	5.00	1.17%	2.54%
4.00	229.00	77.36%	249.00	58.45%	18.91%
4.50	7.00	2.36%	75.00	17.61%	-15.24%
5.00	35.00	11.82%	90.00	21.13%	-9.30%
Total	296.00	1.00	426.00	1.00	

The system has flexibility to enable adjustment of cutting lines via manual operator intervention throughout the day. The quality process in place at the plant involves physical checks of shoulder and loin cutting line accuracy at least 3 times per day or more often if required. Management staff then adjust cutting line settings up or down by a number of millimetres for each cutting line as required. Reasons for adjustment may be change in breed or carcase weight for example.

During Greenleaf's checks on the second day we noticed mainly 5 rib shoulders instead of 4 rib shoulders coming off the line. When management were notified the system settings were changed by a number of millimetres. Although this reduced the number of 5 ribs it did not completely fix the problem.

It was fortunate that Koorosh arrived at the plant in the afternoon of the second days testing. He worked with the staff at the start of day three to optimise the cutting lines. Measurements on days 3 are summarised in Table 22 below and achieved an average across the day of 81% for shoulder cut.

Table 22: Shoulder cut measurement accuracy 9th March 2012 verse manual ex-ante

	Manual		ROC450		
Rib	# Obs	% Occurrence	# Obs	% Occurrence	**Difference**
3.00	14.00	4.73%	31.00	9.28%	-4.55%
3.50	11.00	3.72%	14.00	4.19%	-0.48%
4.00	229.00	77.36%	272.00	81.44%	-4.07%
4.50	7.00	2.36%	11.00	3.29%	-0.93%
5.00	35.00	11.82%	6.00	1.80%	10.03%
Total	296.00	1.00	334.00	1.00	

Plant QA check results conducted in the previous 2 months were entered into the Greenleaf model to understand the previous shoulder cut inaccuracies. A summary of this data is included in Figure 38 below and indicates a range of between 60-80% accuracy since the start of February.

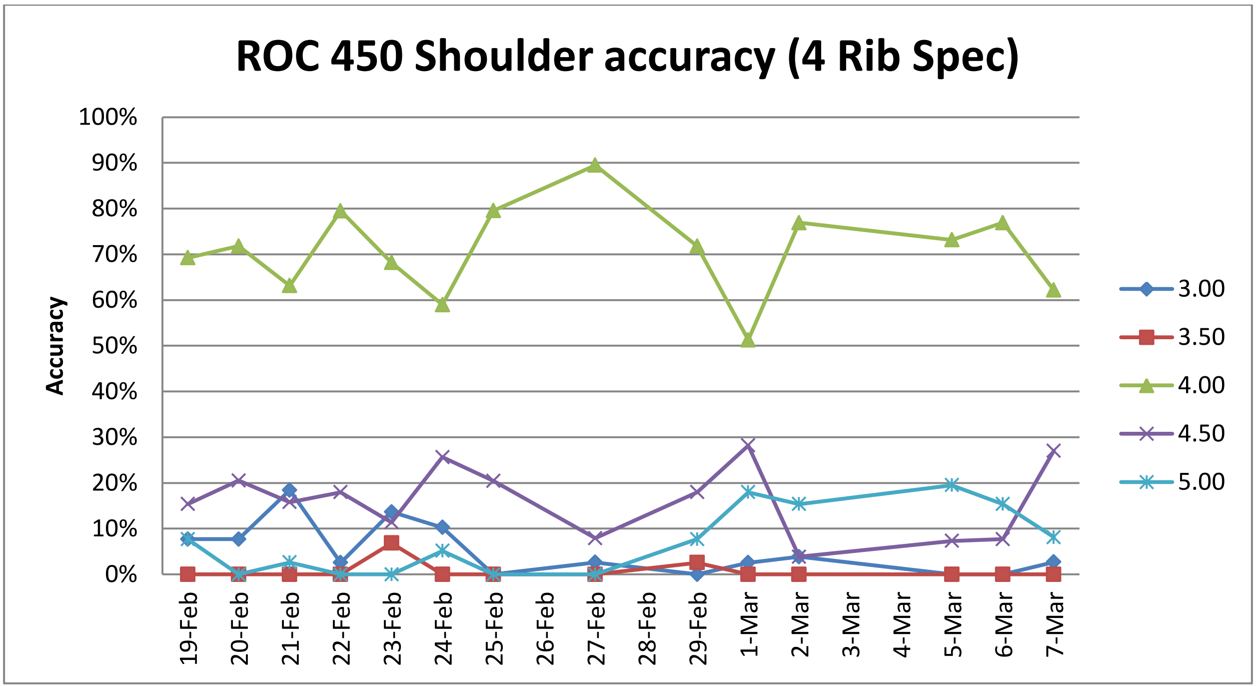

Figure 38: Plant records of daily operational accuracy

9.2 List of Tables

9.3 List of Figures