Final Report

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Prepared by:	P. Green, K. Bryan, S. Fischer Greenleaf Enterprises
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Feasibility Review – Automated X-ray Beef Boning Solution

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Executive Summary

Scott's Technology in conjunction with MLA is developing a fully automated x-ray beef boning solution. This system is being developed to automate the bandsaw cuts of the beef carcase. The proposed system has the potential to improve accuracy of cutting lines and reduce OH&S issues while increasing the plants ability to manage room productivity. This report is an ex-ante review of the commercial viability of the system, including where value could be generated from and its likely magnitude.

The sections of the carcase to be affect by this system are as follows:

- Splitting of the forequarter between the 5th and 6th ribs;
- Scribing of the ribs through the point end forequarter;
- Dissection of the navel end forequarter;
- Splitting of the hindquarter between the rump and striploin;
- Refining the hindquarter boning process;

The x-ray beef solution is being designed to include four main stations that would remove a scribing saw and four bandsaws. The system is to include the following:

- X-ray system for image analysis;
- Aitch Bone puller (4 labour units saved);
- Cutting system to break the forequarter (3 labour units saved);
- Hindquarter splitting system (2 labour units saved);

The development of an automated boning solution could create new ways of breaking a carcase and to optimise value between cutting lines that has been constrained by traditional manual methods. Identifying and modifying cutting lines with image analysis that account for difference in carcase size as opposed to anatomical location could increase the saleable value of a number of cuts.

Based on the data analysis and trials conducted for a mix of grass and grain fed carcase at a beef processing plant, the proposed system is expected to deliver a return on investment in about 12 months.

Table 1 summarises the investment and likely payback across two scenarios where cut accuracy for two standard deviations from the mean are 5mm (Ex-ante 1) and 10mm (Ex-ante 2)

Ex-ante 1 is the expected performance of the x-ray beef solution for the installation, similar accuracies to this system have been observed in previous systems developed by Scott's Technology.

Table 1: Summary of benefits for ex-ante costing

SUMMARY PERFORMANCE MEASURES				
	Ex-Ante 1		Ex-Ante 2	
Hd / annum	336,000		336,000	
Production increase with equipment	7.42%		7.42%	
	From	To	From	To
Capital cost (pmt option, upfront)	$4,712,770		$4,712,770	
Gross return Per head	$12.57	$17.00	$7.77	$10.05
Total costs Per head	$1.74		$1.57	
Net Benefit Per head	$10.83	$15.27	$6.20	$8.48
Annual Net Benefit for the plant	$3,639,026	$5,129,280	$2,084,254	$2,847,915
Annual Net Benefit for the ex cap	$3,997,181	$5,487,435	$2,385,848	$3,149,508
Pay back (years)	1.18	0.86	1.98	1.50
Net Present Value of investment	$24,156,279	$34,623,200	$12,838,948	$18,202,583

Substantial benefits could be achieved through the installation of this system mainly attributable to an increase in boning room yield. The breakdown of benefits is summarised in Figure 1 and Figure 2. All product value benefits are from a reduction in bandsaw dust, increased shelf life and increased saleable yield while processing benefits include labour savings, reducing the number of bandsaws and decreasing the likelihood of OH&S incident.

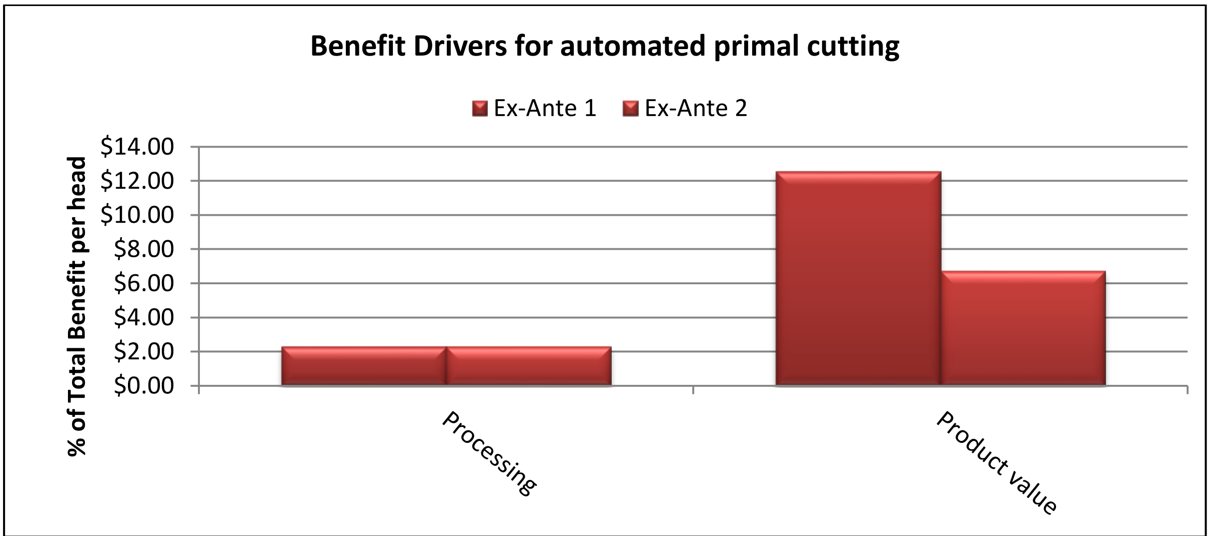

Figure 1: Broad grouping of benefits delivered for the three scenarios.

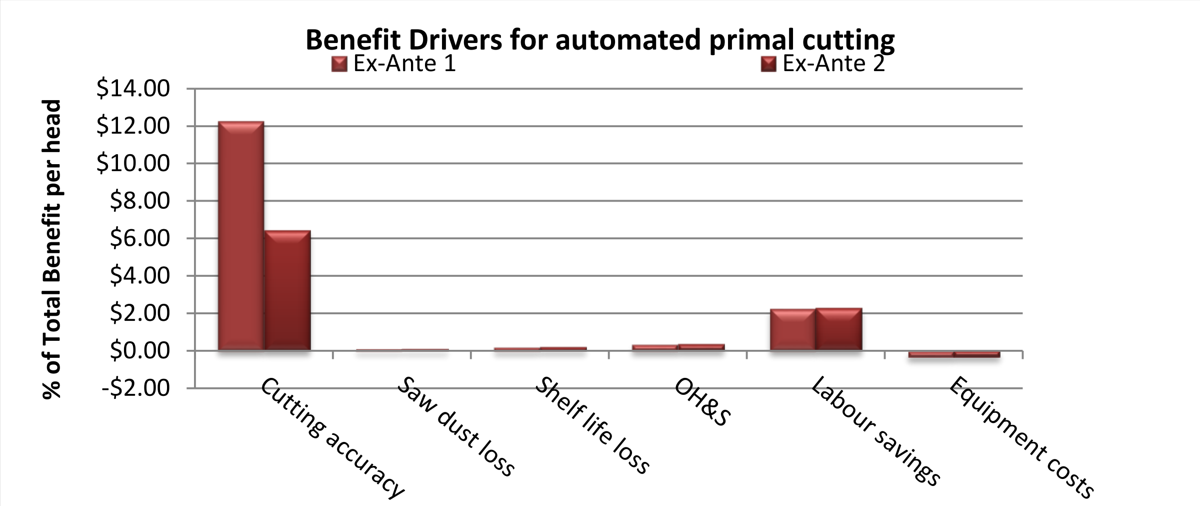

Figure 2: Detailed breakdown of benefits delivered for the three scenarios.

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)
HSCW	Hot Standard Carcase Weight
MLA	Meat & Livestock Australia
OH & S	Occupational health & Safety
RTL	Robotic Technologies Limited, the Australian subsidiary of Scott Technology who is a NZ based manufacturer of automation solutions
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 Background

Scott Technology and MLA have been collaborating since early 2002 to automate the bone-in cutting process of the Lamb sector. Although still undergoing R&D in some areas, commercial equipment is being realised with Australia's first automated x-ray lamb boning module has been installed at and commercially operated by ALC since December 2011. The successful ALC installation has resulted in ALC undertaking to install the next automated x-ray lamb deboning module and JBS installing both the existing ALC system and the new module.

Aside from fit for purpose engineering provided by Scott Technology, one of the most significant enablers has been the use of a continuous lamb full carcase x-ray system that provides the required bone cutting locations for the automated system.

Although not configured (i.e. with suitable power settings) for beef carcase side scanning, a beef quarter was scanned through a Scott lamb x-ray system with results that have demonstrated to Scott's that a x-ray driven cobotic beef deboning system is a positive future pathway (refer Figure 3) for the basis of the vision of the future of beef boning rooms.

Figure 3: Beef forequarter x-ray scan obtained from Scott x-ray Lamb System.

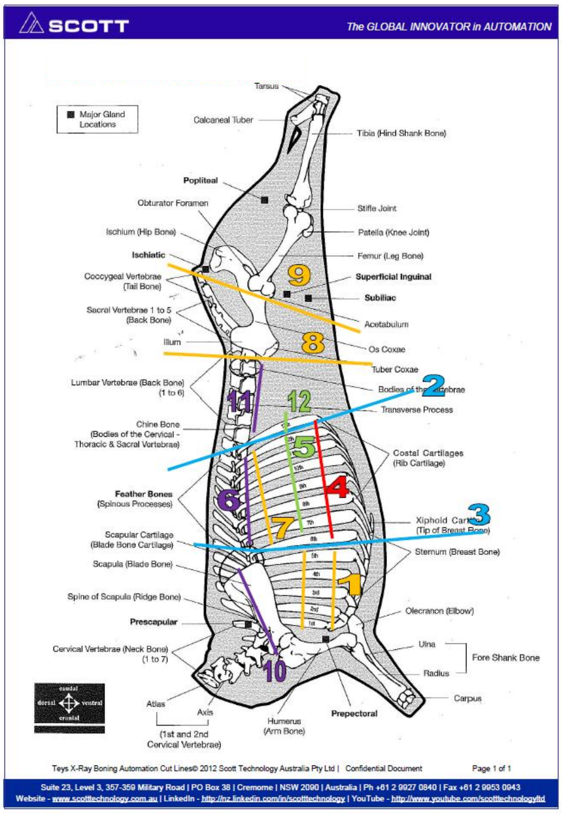

Figure 4: Cutting lines to be automated

2 Objectives

The objectives of this feasibility review were to:

1. Identity any design constraints which need consideration through the development of the beef boning solution.
2. Identify and measure value opportunities for the beef boning room.
3. Measure the expected value opportunity of an automated beef boning system when compared against a manual cutting system.
4. Summarise the value benefits and main drivers for adoption of the equipment for the Australia beef processing sector.

These outcomes were achieved successfully.

3 Methodology

This section describes the methodology used to collect data and establish measurement standards that underpin the costings and value proposition in section 4 “Results”. The methodology describes the data collection for the following areas:

- Yield loss due to variation in cuts;
- Labour Savings;
- OH & S Savings;
- Upkeep and consumables used by the current and proposed systems;

The cut lines shown in Figure 4 were included in this ex-ante study except for cuts 2 and 10.

3.1 Forequarter

3.1.1 Horizontal Cut Between 5th & 6th Ribs (Cut 3)

The green line in Figure 5 illustrates the ideal location for cut 3, which is currently conducted manually. This requires the operator to split the vertebrae and then twist the carcase to get as close to the cranial edge of the 5th rib as possible. The curved nature of this cut is required to ensure maximum yield of the cube roll, navel end brisket, short ribs, back ribs and spare ribs.

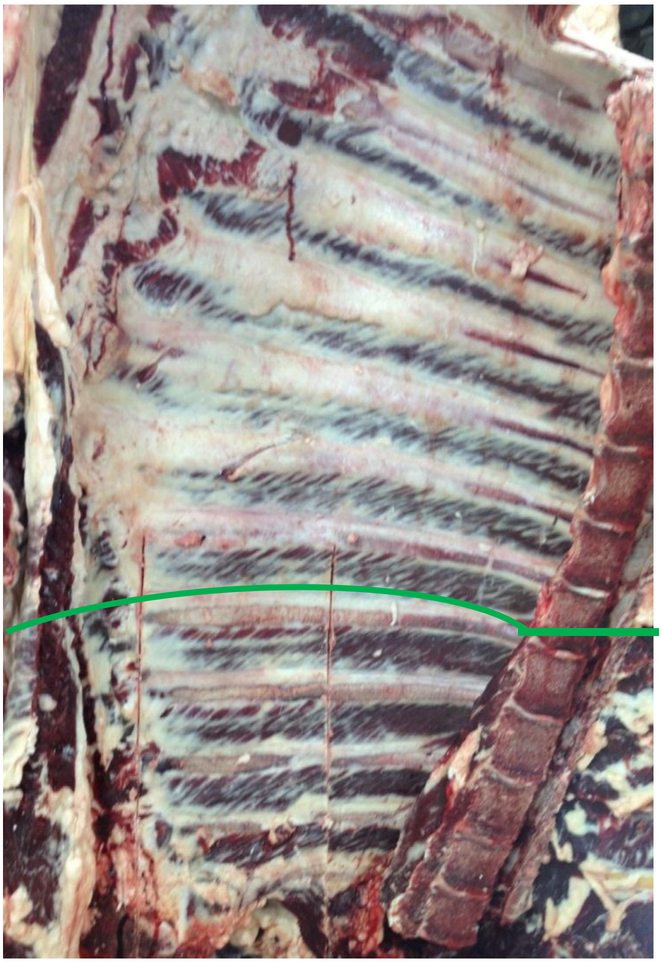

Figure 5: Location of the ideal splitting between the ribs 5 & 6.

Figure 6: Setting the 10mm standard for variation in cut 3.

The installation of the X-Ray beef solution will add value through increasing the accuracy of the cut. The robot will identify the edge of the 5th rib and guide the blade to precisely cut along the edge of the rib. This will cause all the intercostal to remain on the caudal side of the cut (attached to the 6th rib). Thus maximising the weight of intercostal sold as short ribs and back ribs.

3.1.2 Scribing Point End Brisket (Cut 1)

Cut 1 is conducted by a twin bladed saw to cut the depth of the ribs so the chuck ribs can be removed. The ideal spot for this is shown by the yellow line in Figure 7 and Figure 8, which is the knuckle between the breast bone and the 2nd rib. This ensures the chuck short ribs can be removed from the chuck forequarter.

The target location of the manual cut has been identified to account for operator variation in the scribe across the ribs. During the development of the standards it was identified that with an increase in accuracy, a robot can allow for the ideal location of this cut to be moved to 5mm past the joint towards the breastbone. The proposed changes to these cuts have been shown by the white dotted line in Figure 7.

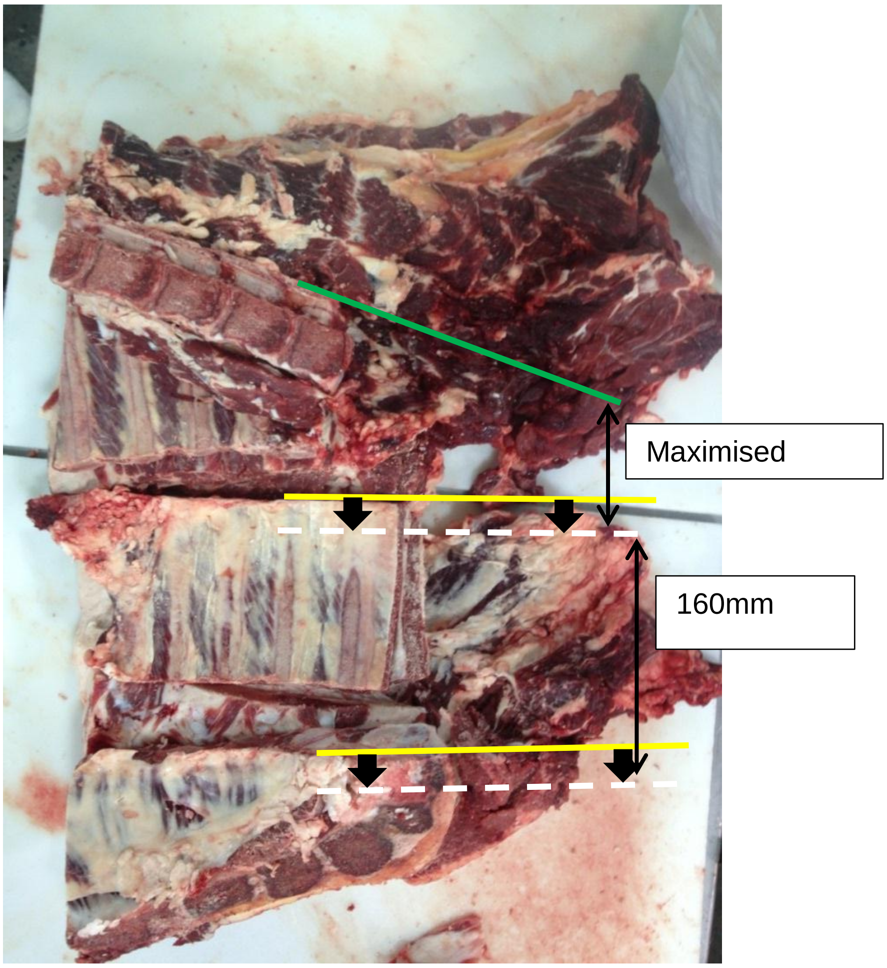

Figure 7: Current and proposed cuts for the point end forequarter

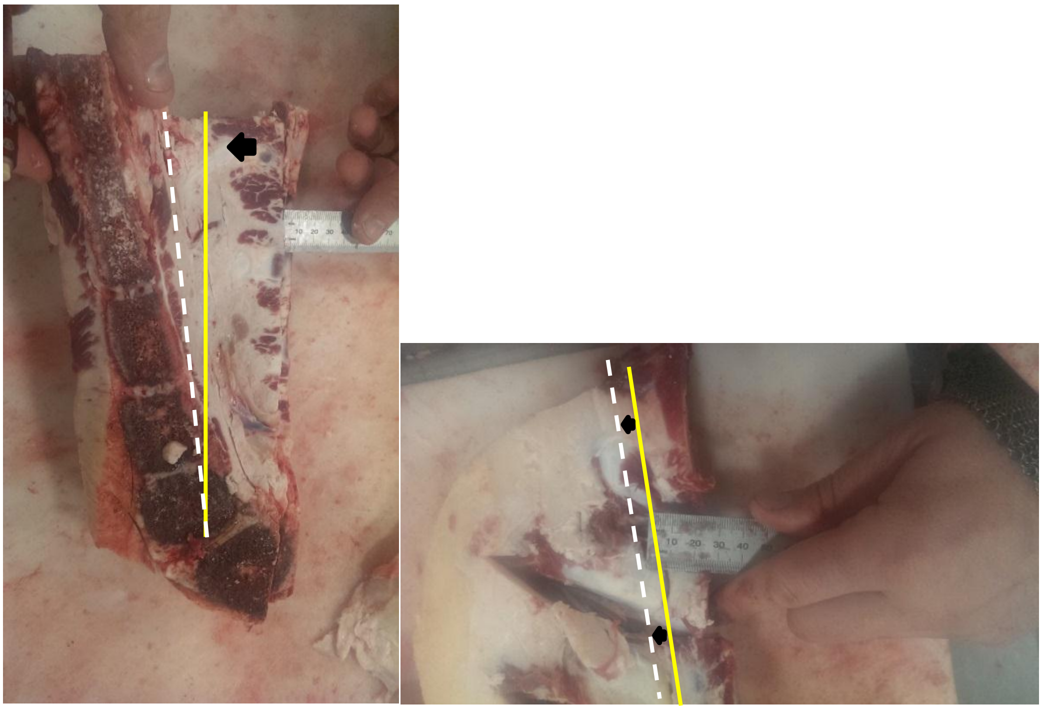

Figure 8: Variation in current and proposed cuts on the Breastbone

The variation in the ideal location of the scribes will have a positive effect on the amount of bone sold as chuck ribs, increase the number of intercostals over 150mm in length (which achieves a higher price/kg) and increase the weight of the chuck flap tail.

The standards were developed to predict the increased length and weight of the intercostal. The process involved with setting the standards for the intercostals were:

1. Weigh the intercostal and bone;
2. Take a 10mm strip off the end of the bone to calculate the weight associated with the increase in length;
3. Bone out the intercostals and measure their length;
4. Measure the length between the end of the rib and the vertebrae;

Figure 9: Length of intercostal between ribs 1 and 5

By optimising the placement of cut 1 across the width of the shoulder with the X-Ray visioning there is an opportunity to maximise the length of the intercostal (increased value) without compromising the other shoulder cuts value.

Through moving the cuts in the ventral direction it has allowed for an increase in product sold as intercostal. The yellow line in Figure 9 represents the variation in the lengths of saleable intercostal above or below 150mm. As can be seen by the three intercostals below the ruler, 1 may fit into the over 150mm specification but the other two will not. If the cuts are moved as proposed in Figure 7 then there will be two additional intercostal sold at the greater value per kg.

This scribe line sets the location of the dissection of the chuck flap tail, point end brisket and trim. Once the chuck ribs have been removed from the point end of the carcase the boner removes the brisket. As can be seen in Figure 10 as the chuck ribs are moved in a ventral direction on the carcase the meat available for the chuck flap tail increases. The blue line to the right of the image below moves towards the chuck ribs increasing the weight of the chuck flap tail.

Figure 10: Increasing length of Chuck flap tail from point end brisket.

3.1.3 Vertical Cuts across the 6th to 13th Ribs (Cuts 4, 5, 6 & 7)

The current procedure used to split the navel end forequarter into 3 sections and remove the chine is conducted in the following order (cuts are shown in Figure 11):

1. Cut 4, (brisket scribe line) to remove the navel end brisket;
2. Cut 5, to remove the short ribs;
3. Cut 6, which removes the chine;
4. Cut 7, which is removes the back rib bits from the short ribs

The manual accuracy of these cuts is relatively high as cut 4 is guided by a laser line across the navel which sets the location of cuts 5 and 7. The method does create variation in the width of the short ribs depending on the size of the carcase. The proposed x-ray solution could start cuts based on the size of carcase and maximum allowable size of all the higher value cuts, rather than a fixed anatomical location on the navel. Optimising the location of cut 4 cutting line at the cube roll rather than starting at the lower value navel end brisket could maximise the saleable value of the navel end forequarter.

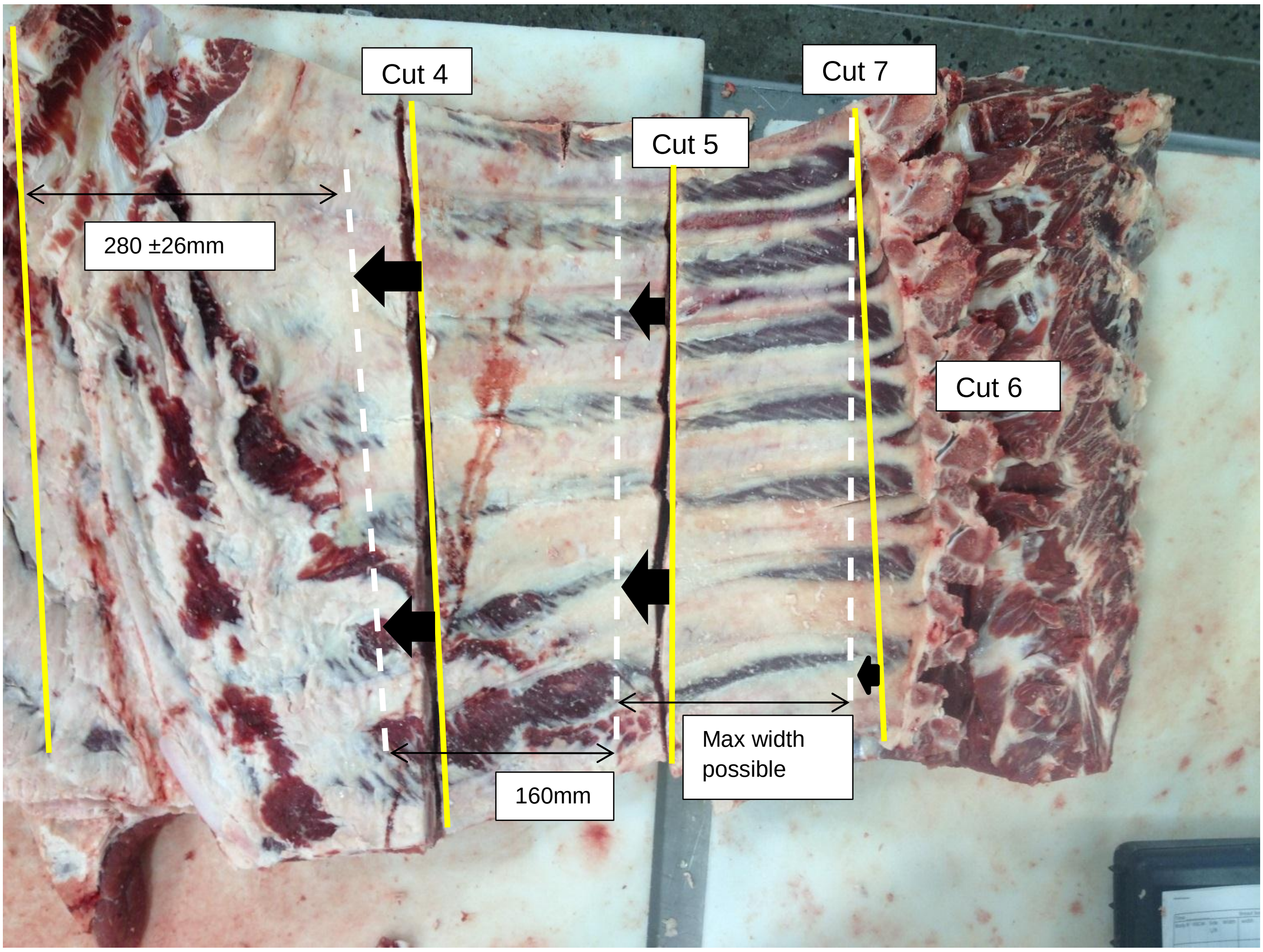

Figure 11: Navel end forequarter cuts - current and proposed

Automation System Considerations

In order to maximise the width of the back ribs the order of the cutting lines need to be modified. The proposed method of adjusting the cutting lines in Figure 11 with the installation of the robotic system is as follows:

1. Cut 5 - Remove the short ribs from the back ribs,
    a. This cut will be all the way through the ribs to split the navel end of the forequarter in two.
2. Cut 4 - The brisket scribe line,
    a. The robotic system needs to cut all the way through the ribs
3. Cut 6 - Removal of the Chine,
    a. This is to be conducted on a bandsaw with a chine guide fitted.
4. Cut 7 - Removal of the back rib bits from the short ribs,
    a. This will be completed by an operator using a bandsaw with a guide fitted.

The above process will maximise the saleable weight of back ribs by moving the cutting lines to the white lines on Figure 11.

Saleable Ribs

There is an opportunity to increase the weight of the following higher value cuts. The value proposed for each cut will be explained separately but each cut will affect adjoining cuts.

Figure 12: Ventral end of the Navel end brisket with the intercostal removed

Moving cut 4 towards the breastbone (Figure 12) will increase the bone and meat sold as back ribs or short ribs and decrease the products sold as intercostal and render. The standard to estimate the effect of variation in the length and weight of the intercostal was established by boning out the breastbone as shown in Figure 12. The weight to length ratio of the intercostal with a 10mm strip removed developed the standard.

Figure 13: Back rib width can be maximised with the robotic system

The back ribs are currently the last section of the ribs to be cut when the back ribs bits are removed. Most of the value added to this section will be to maximise the width of the back ribs by calculating the required length of all sections of the rib cage.

The location of cut 4 affects the width of the navel end brisket. The ideal location of cuts 4, 5, 6 and 7 all affect the width of the back ribs. The system will increase the amount of bone sold as back ribs by calculating the ideal locations of these cuts for each carcase, thus maximising the saleable product on every carcase. For this calculation to work successfully the Linea Alba (white fibrous tissue) or similar structures on the ventral end of the carcase would need to be identified by the x-ray solution.

Effect on Saleable Meat Products

There are currently two options available for the development of the cutting system through the x-ray beef solution. They are as follows:

Scribing the ribs only the depth of the bone - The cuts removed from the navel end brisket shown in Figure 14 will be maximised using a scribe cutting saw to only cut the depth of the bone. This will allow for the navel end brisket and short rib meat to be separated as required by the slicers and reduce the product sent to trim.

Cutting the ribs using a circular saw - The other option for this cut is to slice the forequarter completely through with a circular saw. This would reduce the weight required to be lifted by a slicer after the cuts have entered the boning room belt. The main concerns in conducting this cut with a circular saw is the white dotted line in Figure 14 (cut 4) may protrude into the Navel half. An anatomical structure will need to be identified which can be identified by the x-ray to ensure the cut is always conducted on the edge of the Navel half.

The standards to estimate the effect of value between the short rib meat and the trim were as follows:

1. Bone the ribs off the carcase and trim the short ribs. To ensure there was no weight lost off the short ribs by moving the cut in a Ventral direction.
2. Measure and weigh the weight of the trim shown in Figure 14.
3. Take a 10mm strip off the short rib meat to calculate the weight of muscle when moving the cut in a ventral direction.

These measurements were then used to calculate the value gain or loss as a result from moving this cut.

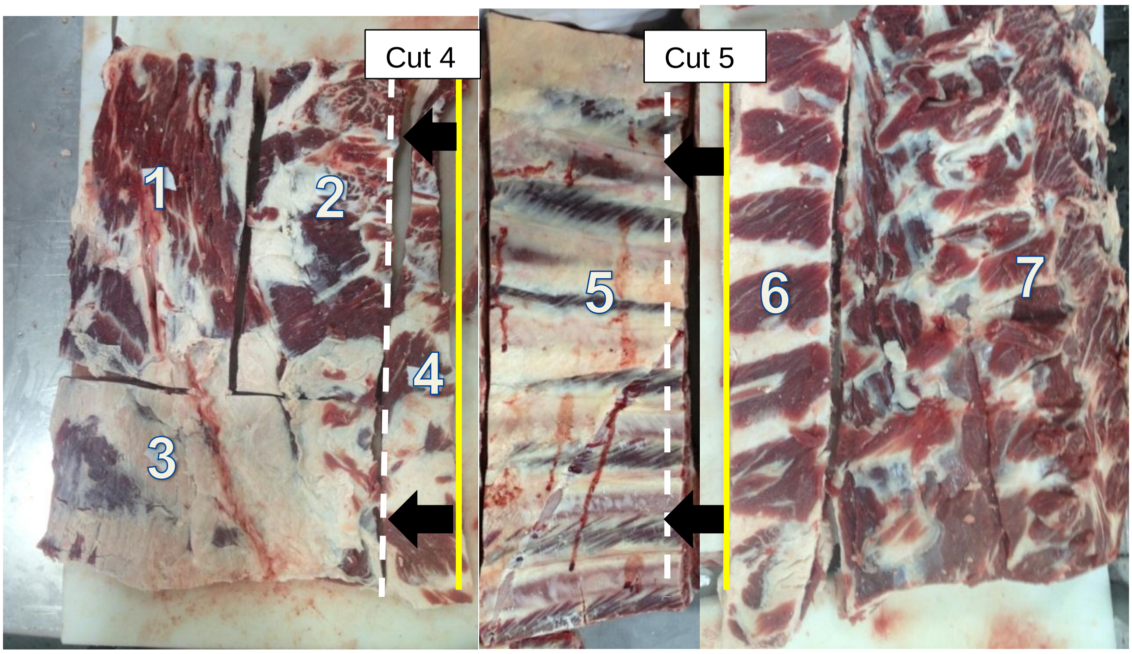

Figure 14: Cuts removed from the navel end brisket, 1) Navel end plate, 2) Navel half, 3) Rib end meat, 4) 65Cl trim, 5) short ribs (prior to trimming), 6) Short rib meat, 7) Cube roll

3.2 Hindquarter

The two cuts through the hindquarter are currently conducted on 3 bandsaws with 2 table bandsaw required on Cut 8 to maintain line speed while 1 in-line saw conducts cut 9. The proposed x-ray system will conduct cut 8 on 1 saw and replaces both bandsaw operators. An alternative boning method using an aitch bone puller is expected to give better boning yields and would replace the saw operator on cut 9.

3.2.1 Cut 8

The ideal location for cut 8 is across the face of the rump and the sirloin, thus if the saw is inaccurate muscle will be lost from either the striploin or the rump cap. Cut 8 is completed by the first operator which has to manoeuvre the shortloin into the correct position which in some cases involves leaning across the saw blade. The biggest challenge is making a square cut as the shortloin does not lie flat on the bandsaw table.

The main benefit of the x-ray solution is the increase in accuracy, reducing the yield lost from the striploin or rump. There will still need to be the same boners on the chain prior to the cuts being performed to ensure that the tip of the tri-tip is not cut off during the cutting process.

Cranial Direction

The method used to accurately gauge the loss of product from the striploin was conducted by measuring the amount of muscle left on the bone. The meat left on the bone in Figure 17 was collected off the bone belt.

Figure 15: Striploin loss to render from an inaccurate cut

Figure 16: Standards where the cut removes a section of the rump cap

Caudal Direction (Rump Cap Left on the Bone)

The method for gauging the accuracy of cut 8 in a negative direction (cut into the aitch bone) involved identifying the amount of bone and muscle removed from the end of the aitch bone. The measures used for -3, -5, -8 and -10mm can be seen in Figure 16. The effect of the cut being conducted in a negative direction cause the end of the rump cap to be sold as trim.

Angulation of Cut 8

The variation in the angle of cut 8 was collected by measuring the distance cut over or under the ideal line on both ends of the striploin identified by the 1 and 2 shown on Figure 17. Measurement 1 was taken as shown in Figure 15 and measurement 2 was taken as the distance from caudal end of the 5th lumbar vertebrae.

Figure 17: Striploin yield lost due to an inaccurate cut

The variation in angle between the samples taken seemed to vary substantially (Figure 17) when the two recordings were compared together. It appears there is as much variation in the angle as in the movement into the striploin.

Cut angle tended to vary depending on the rate at which the chain was running. The operator of the bandsaw conducting this cut is required to do the same amount of work irrespective of the speed at which the chain in operating.

3.2.2 Cut 9, Aitch Bone

The accuracy of cut 9 was largely determined by the location of the cut through the following anatomical structures seen in Figure 18:

1. The Lymph node;
2. The aitch bone to the cranial end of the femur and hip bone joint;
3. The cartilage tip;

Figure 18: Ideal location of the cut 9.

A manual assist aitch bone pulling machine is being proposed as a solution. This was designed for the removal of aitch bones and knuckles from the hindquarter. It consists of an overhead mounted pneumatic ram with a connected arm that has 2 horizontal pivot points (Figure 19) Boners place the hook on the aitch bone, and use a finger control to activate the ram and provide a controlled downward force on the aitch bone as it is pulls away from the hindquarter while marking with a knife in the other hand.

This system will eliminate the need for cut 9 and also reduce the OH & S risks associated with hindquarter boning.

Figure 19: An aitch bone pulling being used

Although leg primal boning yields were not collected in this study, Greenleaf has done considerable work on boning yields using cobotic puller systems at various meat processing plants. The results from those plants have been used in conjunction with estimated yield differences between meat processing plants. The yield benefit experienced in previous trials was calculated at $1.23/hd. This value has been included in the benefits of the automated x-ray beef boning solution.

Primals Affected

There are a number of cuts affected by boning variation. The primal and the associated yield losses can be seen in Table 2.

In circumstances where the cut is moved in the caudal direction the cut increased the amount of Silverside on the Rump and increased the amount of Knuckle sold as trim. The variation shown by this cut is minimal as 95% of the samples recorded were ±10mm from the ideal location of the cut.

Table 2: Source of yield loss for hind quarter muscle primals, caused by the variation cut 9

Primal	Location of boning loss	
Rump	Aitch Bone Top Side Trim	Knuckle Silverside
Knuckle	Rump Top Side	Silver Side Trim
Top Side	Aitch Bone Knuckle	Silverside Trim
Silver Side	Knuckle	Top Side
Tenderloin	Aitch Bone	
Shin	Silverside	

3.3 Fixed Model Drivers

The following production numbers in Table 3 were used to establish the dollar value per head of each of the costs and benefits. The table summarises the estimated performance for the manual operation as a base line and the ability of the automated system when compared to the manual process. Details for each of these scenarios are in sections 3.3.1 and 3.3.2.

Table 3: Calculation used for determining production volume base line

Processing room operation speeds			
	Manual	Ex-Ante 1	Ex-Ante 2
Carcases / min	2.33	2.33	2.33
Carcases / Statn./hr	140	140	140
Carcases / day	1400	1400	1400
Annual days	240	240	240
Annual # of hd	336,000	336,000	336,000

3.3.1 Manual Process

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

- 1 x 10 hour shift per day
- 2.33 carcases per minute
- Conducting 7 cuts using bandsaws

3.3.2 Ex-Ante

The three ex-ante scenarios have been used to demonstrate the return on investment with 3 different accuracies for the x-ray beef boning solution. This was conducted to show the payback which can be expected depending on the accuracy of the automated system. The three accuracy scenarios use different standard deviations from their means including 5mm (Ex-Ante 1), and 10mm (Ex-Ante 2).

In order to simulate the Ex-ante samples, we have produced a set of random numbers based on the manual data capture using a statistical random number generator. These random numbers are normally distributed from the mean and standard deviation of 5mm (Ex-Ante 1) and 10mm (Ex-Ante 2). Each random sample is equal in size to that of the equivalent manual sample.

The three standard deviations were set to show the estimated payback periods for different systems. Ex-ante 1 is the expected performance of the system as shown by systems previously developed by Scott's Technologies in the lamb industry. Ex-ante 2 has been used to show the estimated payback period if the system is slightly less accurate while the systems is being calibrated post installation.

The means each of the cut results data sets have been set independently for each of the cuts and ex-ante studies. The means were established by aligning the 5% percentile mark of each scenario to the most negative acceptable point. For example cut three the 5% percentile market was set at 1mm on the cranial edge of the 5th rib to minimise small pieces of bone.

The current processing speed was used for all the scenarios. However with the installation of the x-ray solution the boning rate could be increased without losing accuracy. More slicers would be required to do this. This would decrease the payback period for the system as a result of increased room efficiency.

4 Results

The data collection for the cost benefit analysis (CBA) was conducted across a number of site visits. This involved the establishment of costing standards as well as the collection of separate data to quantify variation in cutting accuracy. This included 793 observations collected.

The costing methodology involves a two part process including the setup of standard yields to quantify the cost of inaccuracy for each cut. The second part involves the measurement of cut accuracy across a number of days of operation and carcase types within the plant for each cut.

Data collection was required across a wide range of cuts and summarised into impact on value at 4 sites as follows:

1. Horizontal split between ribs 5 & 6 (Cut 3)
2. Vertical scribing through ribs 1 to 5 (Cut 1)
3. Vertical scribing of ribs 6 to 12 (Cuts 4, 5,6 & 7)
4. Splitting of the hind quarter (Cuts 8 & 9)

4.1 Cost Benefit Results

The increased value came from yield benefits, OH & S savings and labour savings. The summary results in Table 4 demonstrate the performance of the three ex-ante scenarios compared to current manual performance.

The ex-ante net benefit expected for this system was from $10.83/hd to $15.28/hd. This delivers an estimated return on investment of between 0.86 and 1.18 years depending on the accuracy of the automated system.

Table 4: Summary of benefits for ex-ante 1, ex-ante 2 and ex-ante 3

SUMMARY PERFORMANCE MEASURES				
	Ex-Ante 1		Ex-Ante 2	
Hd / annum	336,000		336,000	
Production increase with equipment	7.42%		7.42%	
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Capital cost (pmt option, upfront)	$4,712,770		$4,712,770	
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Pay back (years)	1.18	0.86	1.98	1.50
Net Present Value of investment	$24,156,279	$34,623,200	$12,838,948	$18,202,583

The payback periods displayed in Table 4 are an average of grass and grain fed carcases. Based on observations payback periods will vary between abattoirs depending on the percentage of grass and grain fed animals being processed. Plants processing higher percentages of grass fed product will experience grater benefits that displayed. The main cause of this is attributed to high chain speeds when processing grass decreasing the accuracy of the cuts.

The production increase shown in Table 4 is a result of the decrease in labour requirements of the boning room. There may be increases in throughput possible but these have not been factored into the CBA as the system is still in development. The variation used to display these results as the price paid for primals and the variation in number of carcases per year.

The benefits identified can be broadly summarised as either product value or processing efficiency with the larger portion of benefits being related to product value in Figure 20. Yield benefits due to a decrease variation in the location of the cuts contribute most of the value.

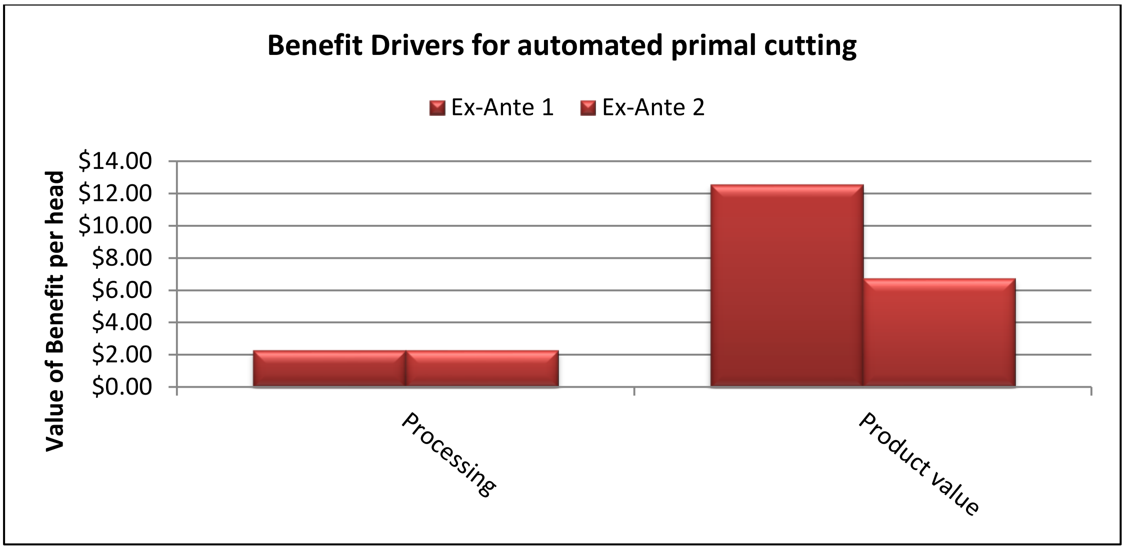

Figure 20: Broad grouping of benefits delivered by the x-ray beef solution.

The main benefits of the automated cutting technology are the increase in yield and a reduction in labour units required. Occupational health and safety costs will reduce by removing bandsaws. There may be small yield gains through reduced bandsaw dust and shelf life. The contribution of each individual benefit is summarised in Figure 21 and Table 5.

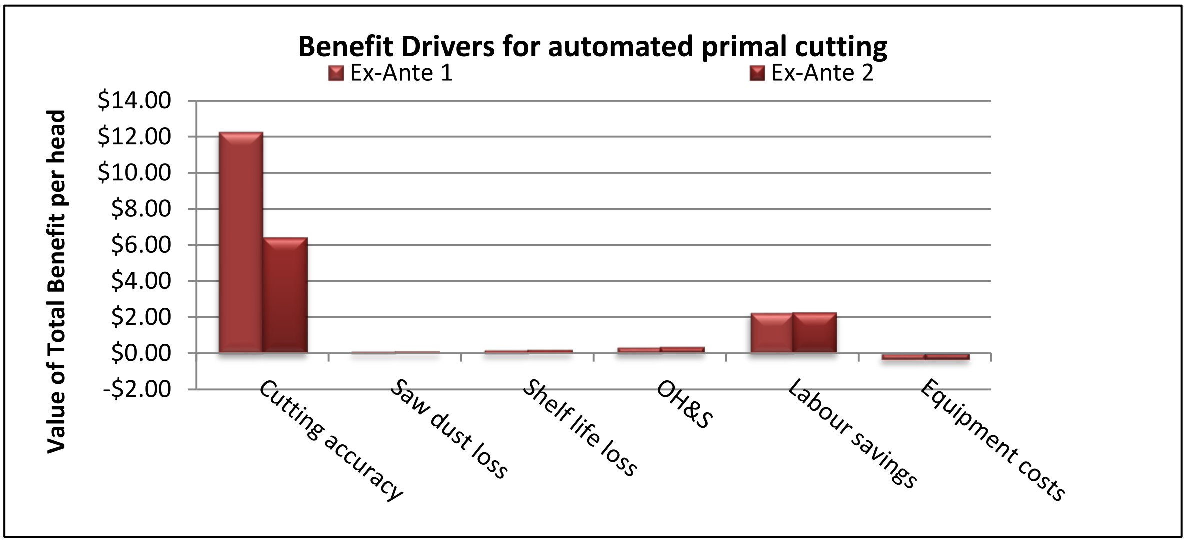

Figure 21: Summary of benefits expected to be delivered from the x-ray beef boning solution.

Table 5: Breakdown of benefits and costs by area

Benefit Drivers for automated primal cutting				
	Ex-Ante 1		Ex-Ante 2	
	$/ hd	$/ annum	$/ hd	$/ annum
Processing	$2.29	$770,636	$2.29	$770,636
Product value	$12.16	$4,084,794	$6.28	$2,110,165
	$14.45	**$4,855,430**	**$8.57**	**$2,880,800**
Cutting accuracy	$11.73	$3,942,657	$5.86	$1,968,028
Saw dust loss	$0.15	$51,391	$0.15	$51,391
Shelf life loss	$0.27	$90,746	$0.27	$90,746
OH&S	$0.36	$120,000	$0.36	$120,000
Labour savings	$2.27	$763,758	$2.27	$763,758
Equipment costs	-$0.34	-$113,122	-$0.34	-$113,122
	$14.45	**$4,855,430**	**$8.57**	**$2,880,800**

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

Table 6: Ex-ante costs and benefits breakdown for the ex-ante 1, ex-ante 2 and ex-ante

COST - BENEFIT ANALYSIS OF ROBOTIC PRIMAL CUTTING EQUIPMENT				
	Ex-Ante 1		Ex-Ante 2	
Benefit summary	$/hd		$/hd	
	From	To	From	To
$ Accuracy Benefit per head	$9.52	$13.95	$4.72	$6.99
$ Technique Benefit per head	$0.42	$0.42	$0.42	$0.42
$ Labour Benefit per head	$2.63	$2.63	$2.63	$2.63
$ Automation Costs	($0.34)	($0.34)	($0.34)	($0.34)
$ Overall Benefit per head	**$12.23**	**$16.67**	**$7.44**	**$9.71**
** 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	$1.40		$1.40	
Maintenance	$0.24		$0.12	
Operation	$0.01		$0.00	
Risk of mechanical failure	$0.09		$0.05	
Total cost per head	$1.74		$1.57	
Total cost per head (EX CAP)	$0.34		$0.17	

Table 7 shows the range in value associated with each cost of processing including breakdown of value opportunity for each cutting line. The cost is calculated as any loss from the maximum benefit possible. Throughput cost is the cost of labour for the boning process. Presenting the figures this way in the detailed section of the model demonstrates the total costs involved and highlights areas where future savings could be generated.

Table 7: Summary results of individual costs associated with the x-ray beef boning solution

VALUE OF LOSSES DUE TO INACCURACIES AND MANUAL INTERVENTION							
		Manual		Ex-Ante 1		Ex-Ante 2	
Cost summary		$/hd From	$/hd To	$/hd From	$/hd To	$/hd From	$/hd To
1.1 Accuracy	Cut 1	$0.99	$1.46	$0.76	$1.02	$1.57	$2.03
	Cut 3	$9.10	$13.00	$1.68	$2.61	$5.26	$6.81
	Cuts 4,5,6 & 7	$0.72	$3.00	$0.23	$1.27	-$0.04	$2.23
	Cut 8	$0.40	$0.51	$0.25	$0.34	$0.93	$1.13
	Aitch bone puller, Cut 9	$1.23	$1.23	$0.00	$0.00	$0.00	$0.00
1.2 Cutting Technique	Saw dust loss	$0.15	$0.15	$0.00	$0.00	$0.00	$0.00
	Shelf life loss	$0.27	$0.27	$0.00	$0.00	$0.00	$0.00
3. OH&S Costs		$0.36	$0.36	$0.00	$0.00	$0.00	$0.00
4. Labour Costs		$0.00	$0.00	-$2.27	-$2.27	-$2.27	-$2.27
Equipment costs	**Maintenance**	$0.00	$0.00	$0.24	$0.24	$0.24	$0.24
	Operation	$0.00	$0.00	$0.01	$0.01	$0.01	$0.01
	Risk of failure	$0.00	$0.00	$0.09	$0.09	$0.09	$0.09
$ Costs per head		**$13.22**	**$19.98**	**$0.99**	**$3.31**	**$5.79**	**$10.27**
$ Benefit per head		**$0.00**	**$0.00**	**$12.23**	**$16.67**	**$7.44**	**$9.71**
$ Benefit overall plant		**$0**	**$0**	**$4,110,303**	**$5,600,557**	**$2,498,970**	**$3,262,631**
$ Annual Costs overall plant		**$4,442,989**	**$6,713,240**	**$332,686**	**$1,112,683**	**$1,944,020**	**$3,450,609**

Figure 22 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.

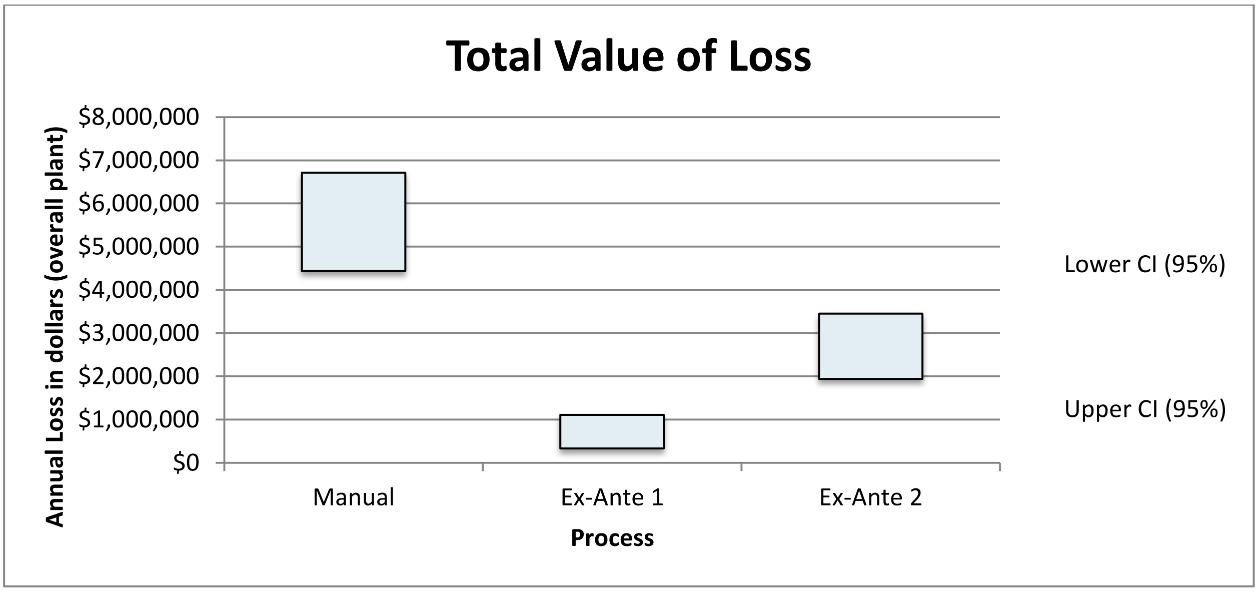

Figure 22: Graphical representation of losses captured in Table 7

4.2 Financial Viability of Equipment

Value of this equipment will vary between plants depending on market specifications and processing speeds. However based on the drivers show in Table 7 the following analysis provides a net annual return of conservatively $4,500,000 per annum. Considering an initial total cost of investment of $4,712,770 this delivers a payback period of between 1.5 and 2 years at current processing rates. Based on a 10 year life expectancy of the investment and discount rate of 7% (and all other factors being equal) the Net Present Value of investment is estimated at $12-17 million.

4.3 Yield Benefits

The yield benefits displayed in the following section are a result of the measurements collected during the site visit. The results displayed in this section a mix of grass and grain fed carcases.

4.3.1 Cut 3

The value attributed to the automation of cut 3 is shown in Figure 23. This graph displays the mean value of loss by the yellow dot and the variation in the value of loss. As can be seen by the Manual operation the value of loss varies from $9.84 to $13.68. The variation in the Ex-ante 1 is much less with the expected loss being between $2.03 and $2.90. As stated already in Table 7 the value used in the analysis is only 30 percent of this amount to be conservative.

The square around the mean demonstrates the variation of the manual systems is 4 times the variance expected by Ex-ante 1. The difference in price is also a result of a variation in the means; the manual systems mean is an estimated 19mm higher (cube roll sold as chuck roll) when compared to the Ex-ante 1 scenario.

The cuts which contribute to the decrease in loss in value seen in Figure 23 are as follows:

- Cube roll ($9.74 to $7.08/hd);
- Short ribs ($0.44 to $0.35/hd);
- Navel end plate and trim ($0.50 to $0.364/hd);
- Back ribs ($0.011 to $0.01/hd);

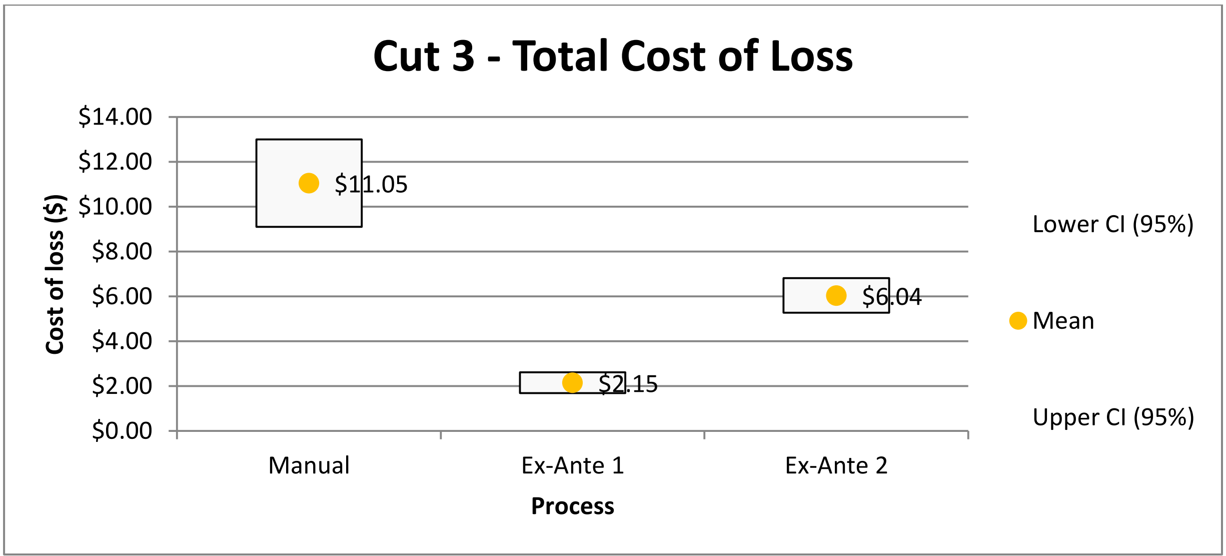

Figure 23: Cost of inaccuracy attributed to Cut 3

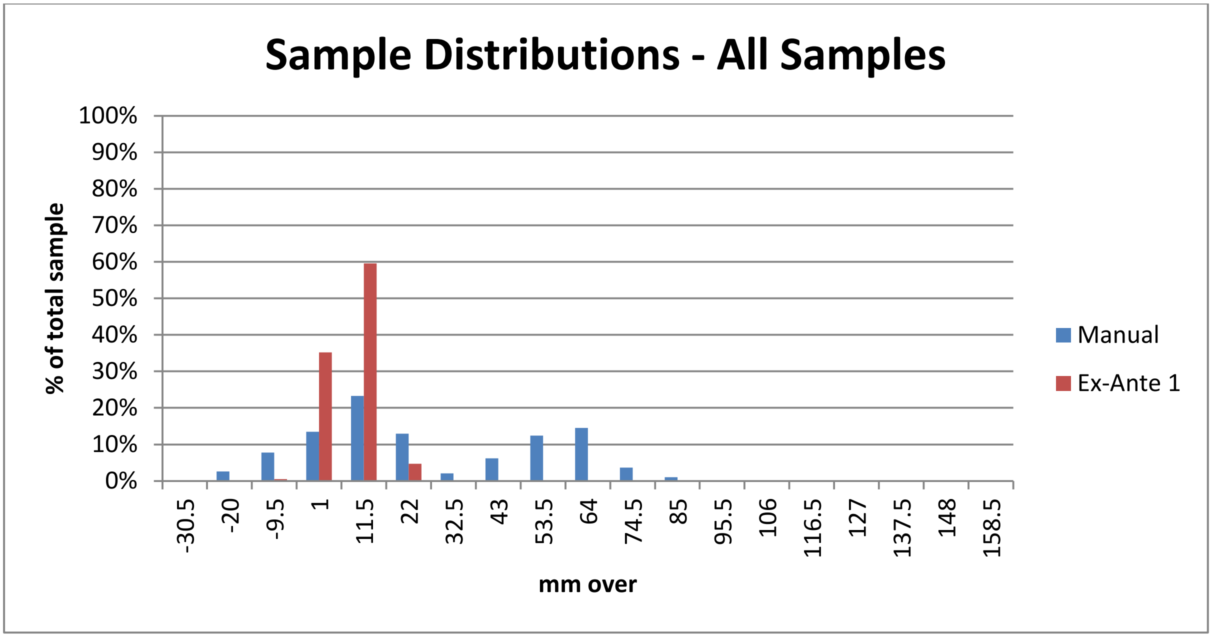

Figure 24: Distribution of samples for cut 3

The variation in the distribution of cut 3 for the manual operator has formed an abnormal distribution. The two peeks in Figure 24 for the accuracy of manual operation reflect the increase in chain speed between grass and grain fed carcases with operators having less time to complete the same job.

If the plant was to slow the chain to increase the accuracy of this cut the estimated labour cost increase to the plant is approximately $4.44 per head. Therefore if the x-ray beef solution is as accurate as estimated in the ex-ante 1 scenarios the payback will be between $10.78 and $7.81 per head. Thus maintaining current line speeds with more accuracy from the x-ray solution significantly increase savings for the plant.

4.3.2 Cut 1

The value attributed to cut 1 was calculated at $0.36/hd for Ex-ante 1. As can be seen in Figure 25 the automated system on this cut needs to have a standard deviation from the mean of less than 5mm. This has been obtained by similar systems developed by Scott's Technology.

The main variation in value of the cuts attributing to the benefits shown in Figure 25, are as follows:

- Increase in weight of Intercostals and an increase in number of Intercostals greater than 6" in length ($0.009 to $0.004/hd).
- Increased weight of bone and trim sold as Chuck ribs ($0.36 to $0.23/hd).
- Increased weight of chuck flap tail and trim ($0.10 to $0.06/hd).

There are a number of cuts which have also shown to decrease in value as a result of the x-ray system and thus the differences between the increases in value of the cuts above.

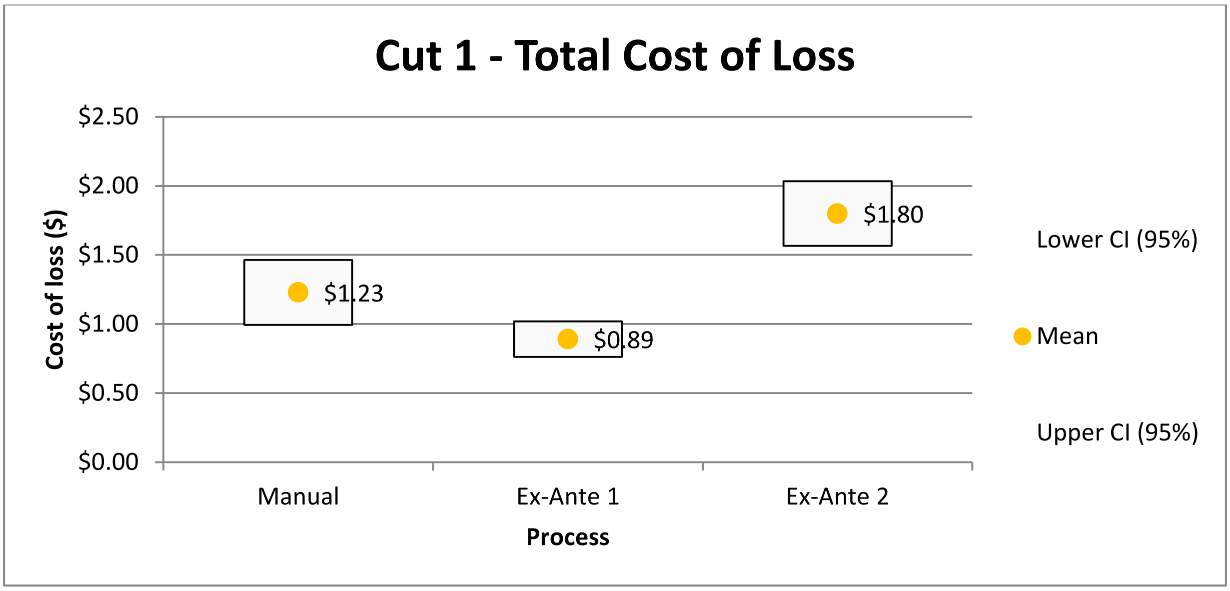

Figure 25: Cost of inaccuracy attributed to Cut 1

4.3.3 Cuts 4, 5, 6, 7

The value attributed to automating cuts 4, 5, 6 and 7 is $1.24 (Figure 26). The main value attributing to this saving is a result of reducing the variation in the width of back rib by maximising their width on every carcase by reducing the size of the back rib bits and moving cut 4 in a ventral direction.

The main variations in cuts attributing to this benefit are:

- An increased weight of Short ribs ($3.52 to $3.13/hd)
- A decreased of weight Back rib (-$1.27 to -$1.35/hd)
- A decreased weight of bone and intercostal (-$0.66 to -$0.88/hd)
- A difference in weight between trim and short rib meat ($0.02/hd)

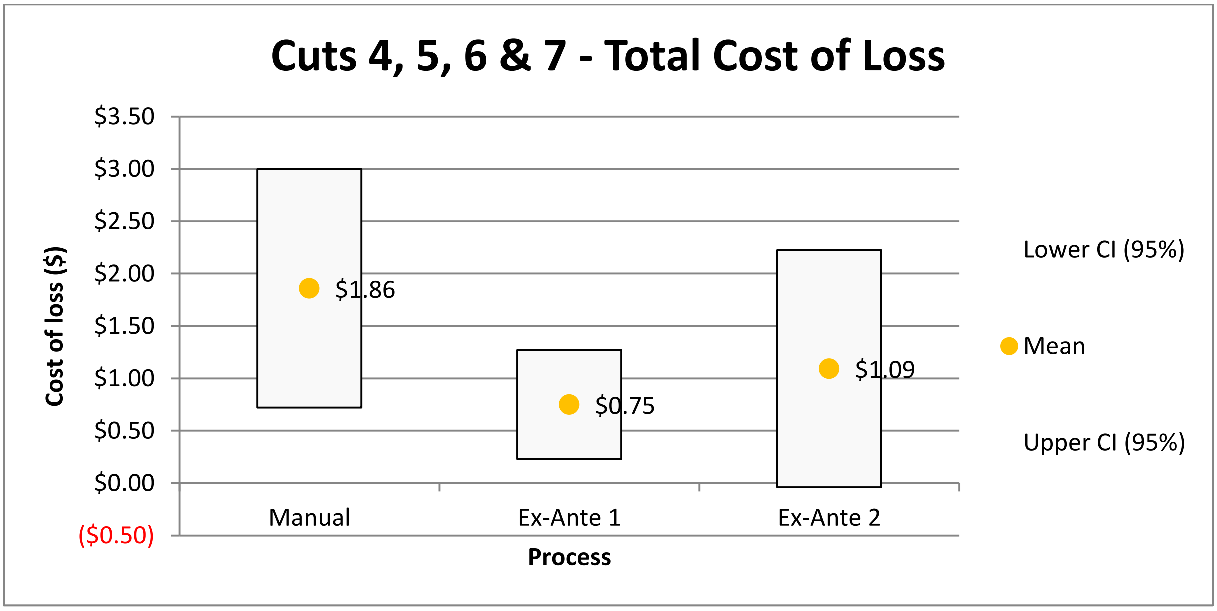

Figure 26: Cost of inaccuracy attributed to cuts 4, 5, 6 and 7

4.3.4 Cut 8

The value attributed to the automation of cut eight is affected by the chain speed. The variation shown in Figure 27 is a combination of rates between 130 and 150 carcases per hour. When the value if these cuts were assessed for the high chain speed the difference in the value between the manual and the ex-ante 1 more than doubled (from $0.13/hd to $0.37/hd). However when the automated system was compared to the slower chain speed the benefit per head was reduced to nothing.

The only cut attributing value shown in Figure 27 is the increase in the saleable weight of striploin.

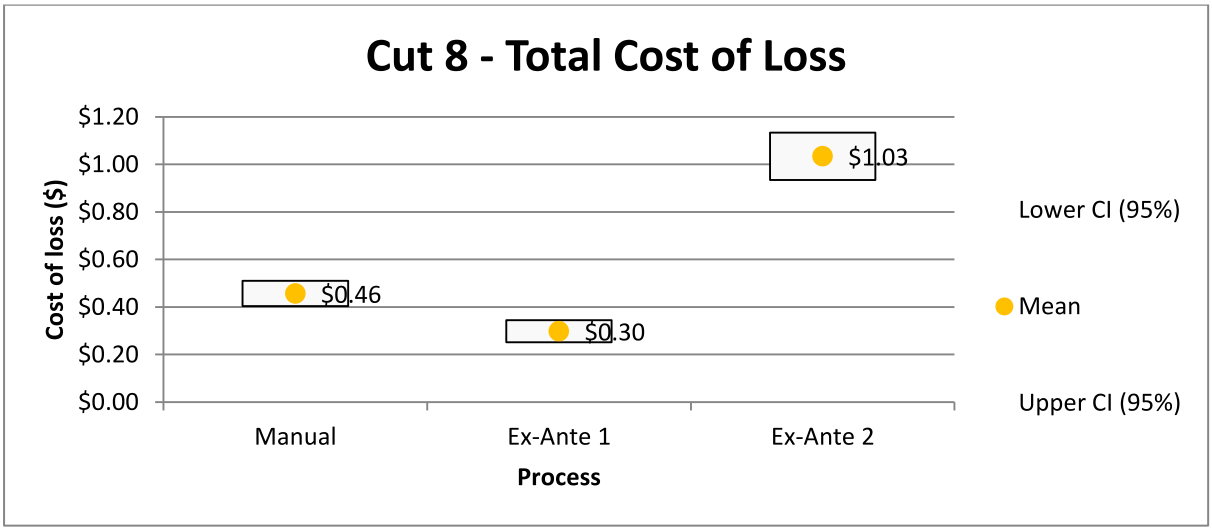

Figure 27: Cost of inaccuracy attributed to cut 8

4.3.5 Cut 9

The total saving attributed to cut 9 has been calculated at $1.23 per head which has been calculated from a previous study. This saving may be achieved through the installation of an aitch bone puller.

4.4 Labour Savings

This plant has an estimated labour savings of $2.27 per head when using the Automated x-ray beef boning solution. The number of staff saved at other plants will depend on the layout of the abattoir’s boning room.

4.5 Increased Productivity

There has been no improvement in the efficiency of the boning room factored into the cost benefit analysis as the room is already highly automated. However depending on the maximum speed of the automated system it may allow for an increased in kill capacity of the plant in years to come. The main reason of this increase in kill capacity is attributed to the automated system as the manual operator's accuracy decreases when the speed of the chain is increased from 130 to 150 carcases per hour.

4.6 OH & S Risks

The OH & S issues associated with the current processes include the full range of repetitive strain injuries, minor cuts and amputations (Figure 28).

A major benefit in the application of automation in a high risk task is eliminating the risk of serious human injury.

The following economic analysis considers the cost of limb loss at an estimated 80% chance over a ten year period with an associated total premium cost of $300,000 (NSW WorkCover, Unknown).

Based on the assumptions above, the following frame work in Figure 5 shows OH&S Benefits. The estimated OH & S savings that can be achieved through the installation of the automated system is up to $0.36 per head. These costing do not included the trauma which can be caused through amputations as this is very difficult to cost.

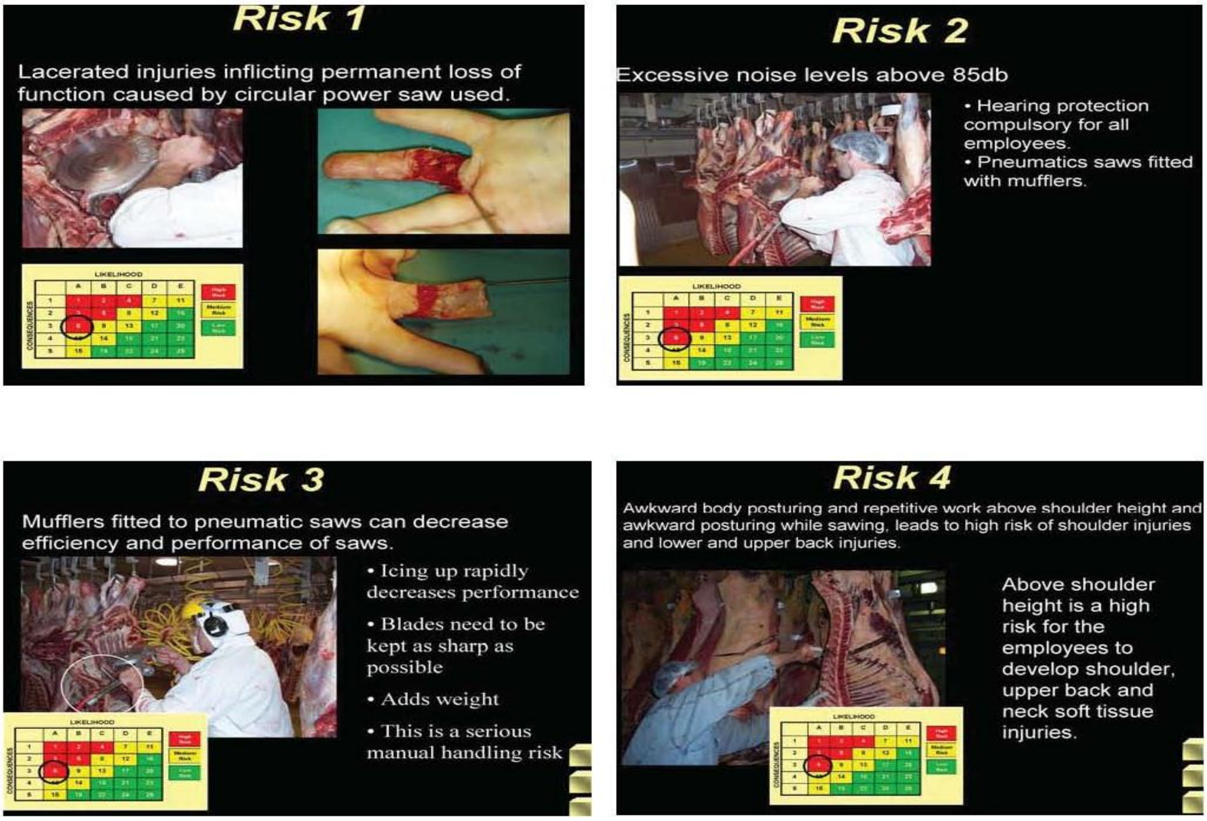

Figure 28: Potential OH&S risks associated with manual beef scribing processes source; (Red_Meat_Innovation_for_Processors, 2011).

Table 8: OH&S Benefits of the x-ray beef solution

OH&S					
	Band Saw cutting	Sprain and Strain from lifting			
Job Role Affected	Bandsaw operaters	18			
			Manual	Ex-Ante 1	Ex-Ante 2
Claims in last 10 years	2.0	30.0			
Risk / FTE / Year	5.0%	75.0%			
Annual Premium	$300,000	$20,000			
Job Annual Hours			9,600	0	0
Limb Losses per year			0	0	0
Sprains and Strains per year			3	0	0
Annual Cost			$ 120,000	$ -	$ -
Annual Cost / Head			$ 0.36	$ -	$ -
Annual saving per head			$ -	$ 0.36	$ 0.36

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

4.7 Operational Costs

Table 9 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 9: Estimated capital and operating costs of automated x-ray primal cutting equipment

Capital Cost	Manual		Ex-Ante 1		Ex-Ante 2	
	Cost	Life span	Cost	Life span	Cost	Life span
Capital Cost of the equipment			$4,006,676	10	$4,006,676	10
Essential and insurance spares			$409,094	10	$409,094	10
Other Capital install			$297,000	10	$297,000	10
Total			**$4,712,770**		**$4,712,770**	
Service maintenance	Manual		Ex-Ante 1		Ex-Ante 2	
	Units	Cost	Units	Cost	Units	Cost
Estimated - COSTS						
Electricity	6.00 KW	$0.14 /KWH	6.00 KW	$0.14 /KWH	6.00 KW	$0.14 /KWH
Maintenance labour (Daily)		744		-		-
Maintenance labour (Preventative)		10,000		-		-
Maintenance labour (Breakdown)		56,986		80,000		80,000
Maintenance labour (Training)		-		-		-
Operational		**$12,717**		**$1,973**		**$1,973**
Maintenance		**$56,986**		**$80,000**		**$80,000**
Annual Sub Total (excluding major overhaul costs)		**$69,702**		**$81,973**		**$81,973**
Combined Total: (cap ex + operating)						
Total Annual Estimated Expenses	Hours	Cost	Hours	Cost	Hours	Cost
Expected downtime hours per year	0	-	7	31,149	7	31,149

4.7.1 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 allowances have 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.

4.7.2 Maintenance and Service Costs

Maintenance and service costs are also supplied by the equipment manufacturer. Maintenance costs are additional running costs that the 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 x-ray 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.

4.7.3 Risk of Downtime

The risk of down time shown in

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

5 Recommendations

The installation of the automated x-ray beef boning solution will benefit the Australian beef processing sector as an enabling tool to increase the accuracy of cutting lines in conjunction with productivity gains. Adaptation of commercial lamb x-ray systems to beef will require significant development but the payback period of between 0.84 and 1.14 years is very positive given the benefits that could be generated beyond the current manual constraints.

Furthermore, the increase in information being extracted from each carcase will begin the evolution of processing management and decision making around carcase optimisation over the next decade. More accurate real-time information can assist decision making in the areas such as carcase yield, production planning, sales order and livestock purchasing and genetics.

It is recommended to:

- Proceed with development of all stations for the following reasons:
    - One of the single biggest costs is the x-ray so limiting cuts to one or two lines does not utilise the full value of the x-ray investment.
    - Ensure the best chance of production capacity increases across both the forequarter and hindquarter lines. If only one of systems stations were installed the other side of the room would limit future productivity gains.
- Consider the integration of synergistic technologies and processes prior to project commencement.
    - Understanding the future path of visioning technologies from medical industry advancements will help create a vision of how this technology could be used for wider purposes than just automated cutting now and in the future.
    - Identify specific areas of focus as outputs from this project that can support other aspects of the business outside the boning room now and in the future.
    - Create a context for inclusion of key people across the business as leaders and champions of this wider vision.

6 References

NSW Workcover (Unknown), Fact Sheet: Managing Ricks associated with Bandsaws in the retail Meat, Seafood and Poultry Industries, Sourced from: http://www.workcover.nsw.gov.au/formspublications/publications/Documents/managing_risk_bandsaws_retail_meat_seafood_poultry_1356.pdf

Red_Meat_Innovation_for_Processors (2011) Risks associated with Beef Scribing. Unknown **Na**, 1

7 Appendixes

7.1 List of Tables

7.2 List of Figures