final report

Project code: A.TEC.0050

Prepared by: James Ross

Monash University

Date published: October 2006

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

Developing automation for the slaughter of sheep in Australia

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

The following study was a Mechanical Engineering final year project at Monash University for the year 2006. The study was proposed by Meat and Livestock Australia (MLA) as part of the professional development program.

The aim of the project was to design an automated slaughter floor. Each step in the slaughter process was examined to firstly investigate the potential for the task to be automated and secondly to assess the ability of the automation to work on differing species. A new system was designed for use in an existing abattoir that demonstrated increased processing time and decreased manufacturing cost.

The study investigated the current inverted dressing process for the slaughter of sheep and applied automation techniques being used for the slaughter of other species such as beef and pig. The study proved the ability of this technology to be linked between species and showed the feasibility of the technology to be available for use on sheep within five years.

Each task was looked at individually and an analysis was performed to determine time and ergonomic performance for the new and old process. A business upgrade approach was adhered to in order to analyse the results, using two alternative layouts. For each layout the study highlighted savings in manufacturing costs and the time for an abattoir to see a return on investment.

Two alternatives were devised, the first involved automation of five tasks within an existing sheep abattoir. The second was a theoretical design which proposed maximum automation of thirteen tasks.

Alternative one was set to a time standard, meaning automated steps were included specifically to speed up the slaughter process. This alternative aimed to decrease the cost of the process which was achieved by decreasing time and human labour costs.

Alternative two showed it was possible to automate 42% of a sheep abattoir slaughter floor. This is the maximum amount of automation possible at this point in time. This option was analysed as it eliminates all occupational health and safety risks for automated tasks as it decreases human involvement. While this option is ideal, it was found not to be practical due to the cost of implementation.

After analysing each of the alternatives separately, they were compared to each other as well as to current practices using manual labour only. Manual labour obviously has greater concern for employee safety and ergonomics as well as higher cost and decreased throughput. There is currently a labour shortage, abattoirs are having difficulty finding and maintaining employees so the future of the industry lies with automation.

Results from the study show that automation, through alternative one will be beneficial to sheep abattoirs. The benefits of partially automating a slaughter floor within five years include increasing throughput, decreasing manufacturing unit cost and a safer and more ergonomic environment for employees

Contents

1 Introduction

1.1 Meat Industry

Australia is one of the world leaders in the production of red meat and is "acclaimed as the largest…exporter" of meat and livestock (MLA-a, 2005). Two thirds of the meat processed in Australia is exported overseas to over one hundred countries with major recipients being France, Germany, USA and Japan. Australian beef and sheep export equates to be 2.5 million tonnes and is worth 16 billion dollars per year to the economy.

In more recent times, Australia's closest competitor on the international market Europe, has begun to creep closer with improvements in processing and the availability of good quality stock. These advances together with cheaper labour cost, means in a few years Australia will no longer be the leading exporter of red meat if improvements are not sought.

A beef abattoir processes between 45-80 animals per hour and a sheep abattoir processes 300-480 per hour. The abattoir operation starts with transporting the livestock to site and ends with packaging the final product and sending it away. For an example of the functions of a sheep processing plant please refer to appendix 1.

There are two major processes that take place in the abattoir operation. The first is the slaughter of the animal which involves 'sticking' the animal and preparing the carcass for refrigeration. The second, boning involves cutting the carcass into sections and removing the meat from the bone.

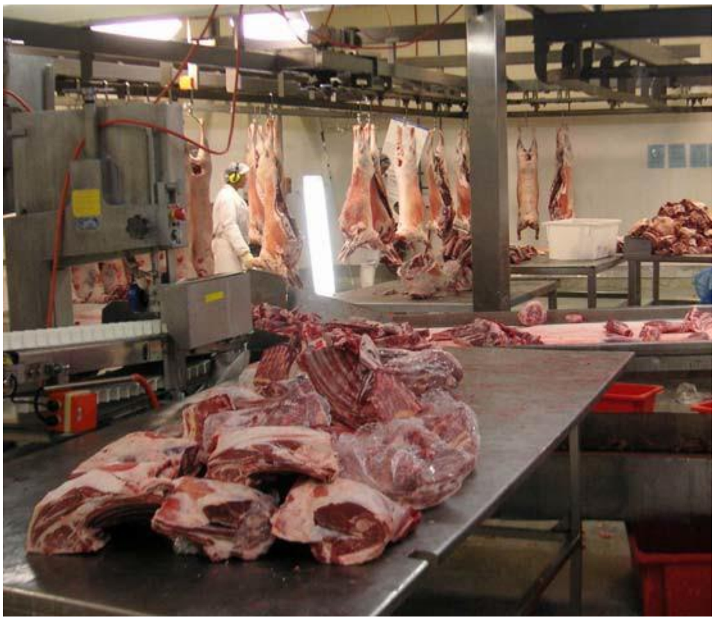


Figure 1 Sheep meat in an Australian processing plant

1.2 Meat and Livestock Australia (MLA)

To help the Australian meat industry remain assertive and competitive, Meat & Livestock Australia (MLA-b) are actively involved with assisting abattoirs. MLA fund development and encourage advancement in methods and equipment leading to improved productivity and efficiency. Meat and Livestock Australia have a vision that these tasks can be performed by robots or automation so the Australian industry will become a cut above the rest.

Recently MLA discovered that the advancements in the automated boning of sheep are also applicable to the boning of beef and so they are currently working to further develop the technology for both species.

1.3 Project Background

Abattoirs currently operating in Australia do so by a process that involves manual workers doing repetitive and demanding tasks (MLA-c, 2005). In other industries these kinds of jobs have been replaced by robots to improve performance, i.e. job made safer, reduced injuries and more competitive in trade. The reason a majority of abattoirs still use manual labour today is due to the unavailability of effective and cost efficient machines that can replace the efforts of a person.

Automation involves a machine performing a task to replace a persons operation while a robot is an automated machine which performs a task with decision making (McClain, Thomas et.al, 1992). To fast track proceedings the industry is fixing sensing technology on top of adapted robots that mimic human movement.

In more recent times considerable advancements have been made in these areas and the industry is starting to improve and move towards more modern methods. In the last couple of years the meat industry has made considerable advancements in ultrasound and x-ray sensing technology and has successfully automated some individual slaughter task. The possibility of a fully automated robot system has been limited by this type of sensing technology and so the industry is developing 3D thermal imaging which is set to be available in 2-5 years (Heidke, 2006).

In an abattoir a successful robot needs to assess the variation in an animal and perform its task with precision accuracy to prevent yield loss and contamination, it also has to be regularly hygienically cleaned and maintained (MLA-d, 2005). The reason the technology has taken so long to develop is because of the requirements to handle variation in product size and the unpredictable harsh environment in which it has to work.

This project was proposed by MLA to help further develop the slaughter process for sheep based on a theory that technology advancement between the small and large stock can be related. The purpose of this project is an attempt to convince sheep abattoir companies around Australia to invest and upgrade their current operation to improve performance and profitability.

Please refer to appendix 2 for a general process map of an Australian slaughter floor.

1.4 Aims of the Project

The aims of the project are to:

1. Investigate automated slaughter task for large and small stock.

2. Design a new system in to an existing sheep abattoir by theoretically replacing human labour with automation.

3. Perform feasibility and cost benefit analysis for theoretical automation of slaughter tasks.

2 METHODS:

The main goal of the project was to investigate and develop a realistic state of the art slaughter process for sheep that remains abreast of technology advancements. To achieve this objective the project was broken into three sections. These were as follows:

Section 1 – Investigation

- Explore engineering techniques standards and requirements
- Document manual slaughter process
- List automated slaughter tasks for all species
- Link application between species
- Explore why automation is not applicable in parts of the process

Section 2 - Detailed analysis (Inverted Dressing of sheep)

- Analyse manual labour process
    - Time study
    - Ergonomic issues
- Predict theoretical automation performance
    - Time study
    - Ergonomic
- Validate robot option

Section 3 – Business upgrade

- Analyse current abattoir performance
- Predict future performance
- Set design goals
- Finalise two alternative factory layouts
- Feasibility and cost benefit analysis

2.1 Section 1 – Investigation

2.1.1 Explore engineering techniques, standards and requirements

Engineering techniques

An investigation of engineering techniques, standards and requirements applicable to the development of the new slaughter process was performed. This background was very important to develop an understanding of the slaughter process and an engineering approach.

A review of engineering concepts was completed through research of engineering documents and journals. The key focus for the search was as follows:

- Operation management
- Optimisation of manufacturing layouts
- Facility design and materials handling
- Planning for factory automation
- Robots in manufacturing
- Financial management

Standards and requirements

The research into standards and requirements formed an understanding of the restrictions and limitations in place. As suggested by industry experts, the main reputable guidelines were sought and accessed via the web and publishing's.

2.1.2 Document manual slaughter process

With the aid of a promotional DVD supplied by MLA, the manual slaughter process (inverted dressing) was documented in the following areas, 'MLA Off Farm Automation and Technology R&D Dissemination DVD', 2005:

- Task title and detailed description
- Task requirement
- Number of human operators
- Outgoing Co/By products as a result of the task
- Special considerations of the task like sterilisation

For simplicity, the data process was broken down into three main categories of the slaughter process. These include:

1. Slaughter task
2. Hide removal and preparation task
3. Trimming and evisceration task.

2.1.3 Automated slaughter tasks for all species

A key part of the project was to assume that in concept the automated slaughter task can be linked in the future for small and large stock. To get an idea of the machinery available, it was decided to research past developments and attempts of automation and robotics in the slaughter of beef, sheep and pigs.

To analyse the available technology the machinery was split into 2 categories:

Category 1 – Automation applicable
Machinery that is currently performing in the industry and is proven, reliable and available for purchase. This information was obtained by a search via wide world web to find industry suppliers.

Category 2 – Work in progress (W.I.P.)
Machinery that has not yet been developed and/or requires alteration. This information was gathered from journals of past attempts and concepts from technology practice in other industries.

2.1.4 Link application between species

After establishing the technology possibilities for the slaughter of beef, sheep and pigs, it was assumed that the species could be linked and made applicable to the slaughter of sheep. To establish the status of the linked technology, current and operating automated sheep slaughter tasks were labelled as ‘available’, ‘work in progress’ (W.I.P.) was termed for tasks that are not yet available and ‘theoretical’ was used for tasks that are automated in pig and beef slaughter but not sheep. Smart and unintelligent sensing was investigated for all the automation possibilities.

For the purpose of this study a brief concept of the robot movement was developed via integrating concepts found for the automated tasks in question. The concepts were supplied by companies via the web and the promotional DVD supplied by MLA, ‘MLA Off Farm Automation and Technology R&D Dissemination DVD’, 2005. The result was a list of slaughter tasks that can possibly be replaced by automation.

A study was done on all the tasks that could not be classified as available, work in progress or theoretical. The study involved looking into the hurdles restricting the application of automation. The hurdles were developed by personal experience and broken in to three categories. The categories were accessibility (A), contamination (C) and intellect (I). For all tasks that did not share all three hurdles it was predicted that in ten to fifteen years the slaughter process might be able to accommodate automation and become applicable.

2.2 Section 2 - Detailed analysis (Inverted Dressing of sheep)

As opposed to guess work, it was decided to justify replacing a task with automation by means of time study and ergonomic rating. This was done by assessing video data found on the Off Farm Automation and Technology R&D Dissemination DVD supplied by MLA.

2.2.1 Analyse manual labour process

Time study

A time study was performed for each task by using video of human operators performing individual tasks. When analysing the video data it was important to remember that in many cases when a worker is being watched and timed he or she may vary their productivity. According to Carey there are three possibilities and they are as follows:

1. Flat out - increase to a level that could not be sustained over a long period of time.
2. Steady and deliberate pace - sustain a pace that would get them through the whole day without undue strain.
3. Deliberately taking longer - pretending the task takes much longer than it should to gain more time to complete task.

To eliminate this factor MODAPTS guidelines were used to estimate time to perform a task based on hand movements and the actions an employee has to make. MODAPTS stands for MODular Arrangement of Predetermined Time Standards and is used to 'judge the level of performance of the person being timed' and not the speed a person can complete the task (Carey, 2001).

For every human movement there is an equivalent MODAPTS predetermined time. According to guidelines suggested by Heyde's MODAPTS the study assessed parallel movement and allowances were made to consider factors such as fatigue, (Carey, Farrell, et.al 2001). A time study was performed for each task by weighting the MODAPT times to be within 20% of the stopwatch time.

An example of some human movements considered in the analysis is as follows:

- Hand movement
- Forearm general use
- Body trunk move
- Walk 1,2 & 3 paces
- Turn and focus
- Arm movement associated with tool use
- Extra force

Ergonomic issues

To measure the current status of ergonomic level in the slaughter process, working conditions and actual work was studied. For simplicity the working conditions were assumed to be the same for all Australian abattoirs, i.e. the number of working hours and the conditions such as lighting, heating and noise.

The actual work was broken into the following categories: posture issues, manual handling, performing a laceration and repetitive strain. Based on personal experience this data was weighted to give a degree of employee safety and comfort. It is important to note that the weightings were set individually to reflect ranking for each type of work content.

As can be seen in Table 1, the weight given for safety implies that performing a laceration has a higher margin of risk than manual lifting. And repetitive strain ranks higher than posture issues in comfort of an employee.

Table 1 - Weight given to calculate a degree of comfort and safety

Work Content Type	SAFETY Weight	COMFORT Weight
Posture Issue	0.5	1
Manual Lifting	1	3
Repetitive Strain	2	4
Laceration	5	2
Other	3	0.8

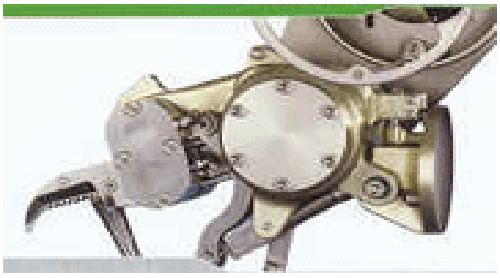
The data was calculated as a percentage per task and illustrated in a bar graph to show the degree of ergonomic level in terms of safety and comfort.

2.2.2 Predict theoretical automation performance

Time study

To theoretically replace manual tasks with automation, the project established a time using the concept that an industry robot would replicate human movement but execute much quicker. This is a viable assumption in that at present the industry are developing faster and more powerful cutting tools to attach to the end of the robot arm. Figure 2, gives an idea of the differences between pneumatic industry hock cutters used for sheep processing.

A)



B)

Figure 2 – A) Hand tool for human operator, B) Attachment for automated tasks
Accessed via worldwide web: www.machineryautomation.com

Based on the theory that automation will be quicker, an understanding of how a robot moves needed to be studied. As can be seen in Fig. 3 a robot can accelerate and decelerate into and out of motion very quickly. The only restriction to this capacity is sponge at the hinges that arises when moving so fast. For the purpose of the study a check was developed to aid in a more detailed analysis. The assumption made was that a robot moves at around 0.5 to 1 second per movement.

To calculate the automated processing time consideration needed to be given to the way a task is performed and the time to do it. The times were developed using the same theory of the MODAPTS of a predetermined time for every movement. The calculations used specifications for a medium payload robot that is already used in the meat industry.

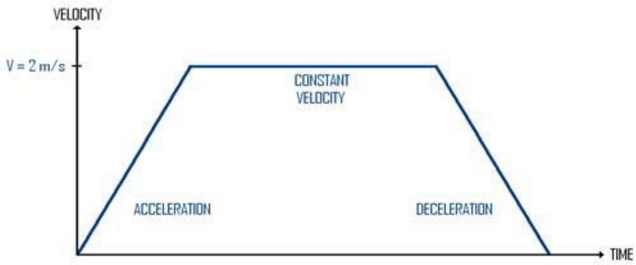


Figure 3 - Time for a robot to move

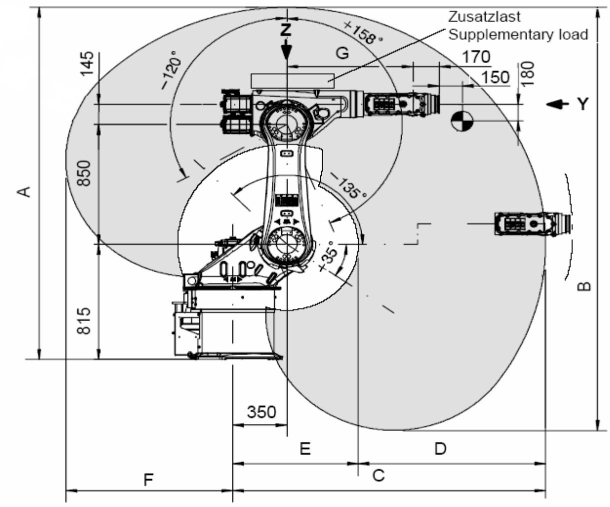


Figure 4 - Kaku KR 60 (www.kaku.com)

A time for the robot to perform its task was predicted using the break down of the MODAPT units. For every movement there was a time that was related back to the rotation of the axis. The model was based on the speed range specified for the KR60 at 128-322 °/sec, (www.kaku.com). Table 2 shows a summary of the robot times appropriate for the human movement. Also considered in the analysis were other times like computational calculations for the robot to perform in the environment. For a more detailed description of each please refer to appendix 9, Table 20.

Table 2 - Estimated computational times for theoretical robot

Computational Type	Estimated time
1 step forward (60cm)	≈ 0.3 seconds
Hand movement (5cm)	≈ 0.12 seconds
Arm movement (50cm)	≈ 0.35 seconds
Body trunk (80cm) movement	≈ 0.69 seconds
Use tool	≈ 1 second
Scan Time to think Set in motion	≈ 1 second
Retract and sterilise	≈ 1 second

2.2.3 Validate robot option

For practicality of the project, the estimated automation times were compared to existing machinery available for purchase. Emails were sent to companies that supply automated solutions in Australia. A reply was received for the readily available brisket shear and this was referred to in the analysis.

The estimated time for the brisket shear was fitted against the existing automation. It was found to be within 10% of the calculated processing time and so the theoretical estimation was approved.

2.3 Section 3 – Business upgrade

To bring the project together, it was decided to follow a business plan to resemble what would happen if engineers were working in the industry. The reason the project was structured like this is because it hopes to convince abattoirs that it is a good idea to upgrade their operation.

Good engineering practice suggests planning an improvement in a manufacturing process requires an evaluation of current performance, predicting future performance, setting design goals and an action plan to implement the change (Vanderspek, 1993).

2.3.1 Analyse current abattoir performance

The analysis for current performance was broken into present and recent past performance. The model used for present was the result of the time analysis from section 2 and the recent past involved assessing previous documents.

Recent performance was found via a statistical analysis on historical trends of sales volume. The model used data from the calendar year of 2003/04 and listed the top 25 meat processors based on the throughput estimated tonnes of carcass weight per year, appendix 3.

The following assumptions were needed to convert the throughput in tonnes per year to performance rate of units per minute.

Assumptions:

- An average carcass weight of 21kg for lamb and 30kg for sheep,
- 251 working days in a year,
- 2 shifts per day with 411 working minutes per shift, excluding breaks.

It was decided to select the top 3 processors of sheep in Australia because these companies were in the best position to afford automation.

2.3.2 Predict future performance

According to Vanderspek an increase of 20-60% in performance should be required to justify the hefty price tag of automation. Before the future performance was predicted an investigation was done into the competitive forces that restrict a better performance. The forces were established on personal experiences and documented.

A 20% increase in performance was used for the analysis and this was based on the competitive forces. An average of the upper and lower limit was selected to continue the development of the upgrade.

2.3.3 Set design goals

During the design stage of the new slaughter process it was decided that at least two alternative directions need to be established. Please note that a common trend was established in possible manufacturing goals from multiple resources (Meyer, Stephens, 2005), (Vanderspek, 1993).

The two selected goals were chosen due to their benefiting the industry the most and are specific to the area of study.

2.3.4 Finalise two alternative factory layouts

Once the design goals were established, the data from the detailed analysis of Section 2 was used to develop two alternative slaughter processes. The layouts were developed according to a time and ergonomic study.

The concept used was to replace the hardest and slowest steps with automation with no restrictions or constraints in size. This was put into a layout plan to summarise and feature the study.

For each alternative an estimation was made in the following areas.

- Product / unit rate
- Daily product throughput
- Determine number of machines needed

The alternatives were broken into the following categories:

<u>Alternative Layout 1</u>

Set to a time standard and very dollar conscious

<u>Alternative Layout 2</u>

Maximum automation with decreased ergonomic issues

The result was a basic outline of the selection and placement of automated machinery along a chain and an analysis on performance and the cost associated.

2.3.5 Feasibility and cost benefit analysis

To analyse the two alternative layouts an investigation was done into the hardware and cost associated with the automated options. As can be seen in Fig. 5 A), a 1994 study suggests that employee wages dominate sheep processing in Australia (MLA-f, 1998).

Based on the assumption that other cost in the slaughter process would not change, total cost per unit was calculated for each possibility of automation. The feasibility analysis included the predicted throughput, total labour cost based on wages and automation running cost based on maintenance and energy consumption.

To evaluate the associated cost an Australian plant and industry supplier provided the following information shown in table 3.

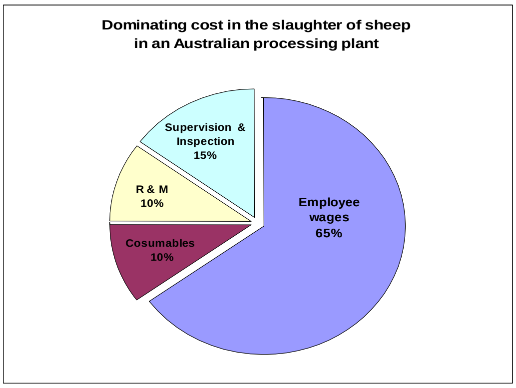
Table 3 - Details of cost of manual and automated operations

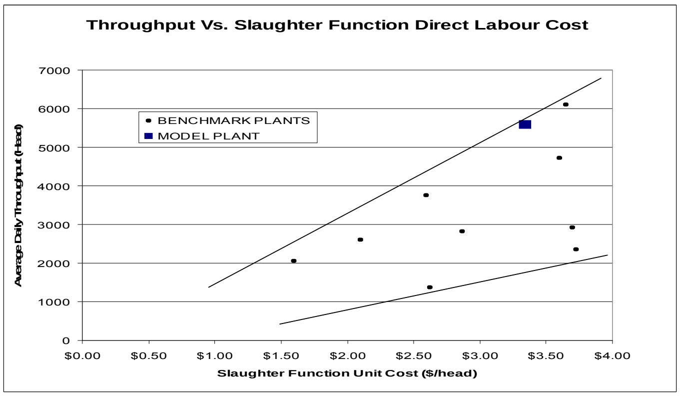
Cost type	Cost
Employee wages in an Australian slaughter floor	\$120 to \$80 per day depending on the task
Purchase price of a robot	\$250K to \$1 M depending on line rate
Running cost of a robot	60 cents per hour of energy \$12K - \$20K in maintenance per year
Outer dimensions of a robot	2 to 4 meters per robot
Predicted life span of a robot	7 to 10 years in a single shift operation

The study explored two possibilities of product rates, 7.9 and 9 units per minute. The main basis of the study worked towards the deign goal of 9 units per minute as suggested by Section 2.3.2.

Using the data in table 3, the savings in running cost were calculated and a break even (BE) calculation was performed as shown below. The cost benefit analysis was displayed on a best practice model, Fig. 3 B) to make the study realistic. The throughput and BE calculations used 411 minutes and 352 working days in the year.

$$BE = \frac{Purchase\ \&\ Installation\ Cost}{Savings\ in\ Runnning\ Cost}\ (UNITS)$$





A) **B)**

Figure 5 – A) Dominating slaughter cost, B) Best practice model for sheep, as suggested by (MLA-f, 1998)

3 RESULTS:

3.1 Section 1 – Investigation

3.1.1 Explore engineering techniques, standards and requirements

Engineering techniques

The engineering techniques used in the project were:

- Lean manufacturing
- Concurrent engineering
- Standards and requirements

These are the three most reputable guidelines used in the project for:

- Highlighting importance of a hygienic environment when processing food for human consumption (AS 4696-2002).
- Supplying awareness of hazard analysis to help assess automation applicability, (AQIS, 2002).
- Building an understanding of time restrictions in the slaughter process, (AQIS, 1995).
- Providing primal weight range of sheep according to AUSMEAT specifications, (Kitchung, 2001)
- Detailing the importance and specifications of processing HALAL meat in Australia, (Author Unknown, 1998).

Please refer to appendix 11 for details on each of the section applicable to the project.

3.1.2 Inverted dressing slaughter of sheep

Figure 6 - Flow diagram for the slaughter of sheep (inverted dressing) illustrates all the tasks in the slaughter process. For a more detailed description of each task please refer to appendix 4.

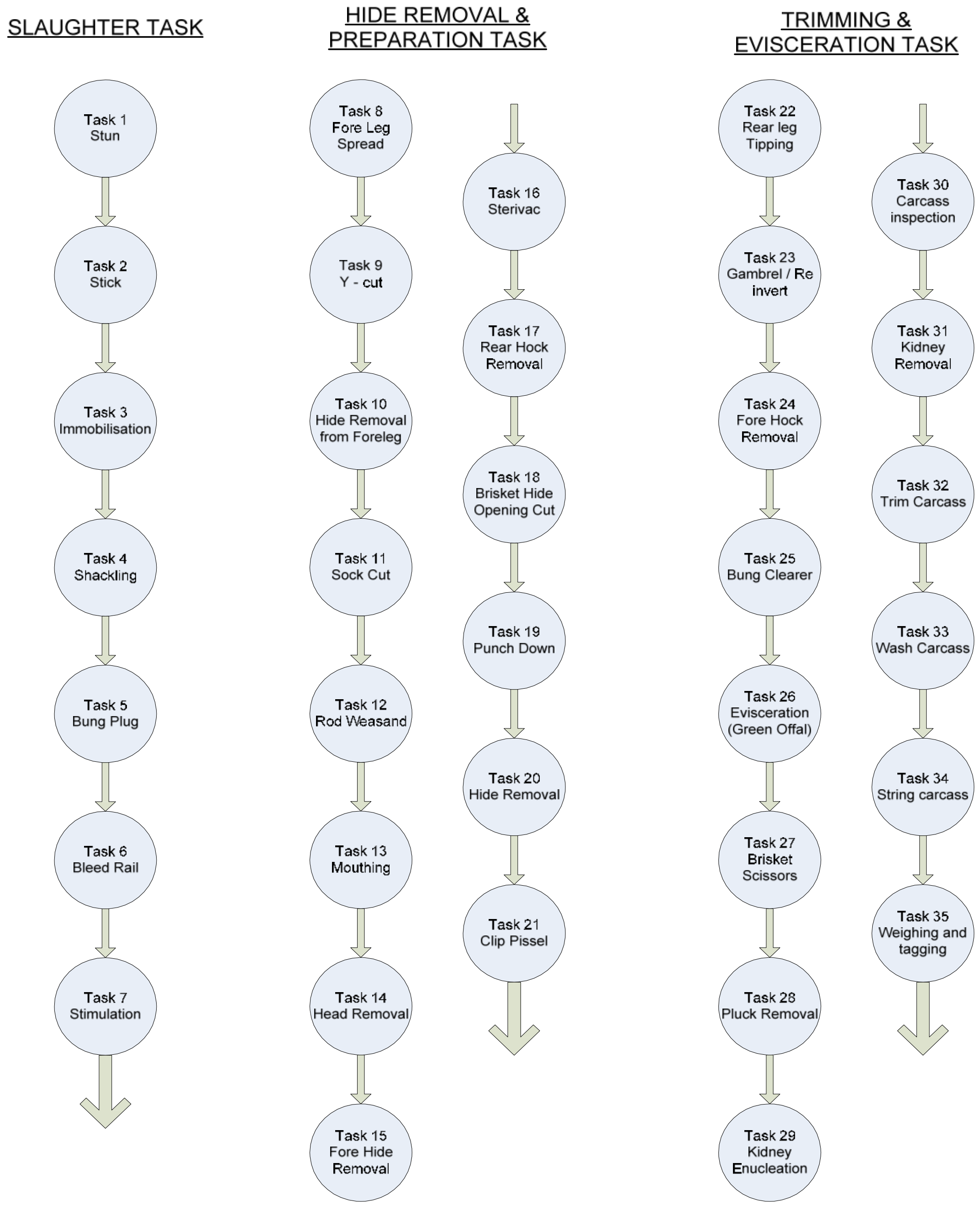


Figure 6 - Flow diagram for the slaughter of sheep (inverted dressing)

3.1.3 Automated slaughter task for all species

Table 4 below illustrates the automation available to the industry for all tasks in the slaughter of sheep, pig and beef.

✓ = Automation available to industry, **W. I. P.** = Work in progress

Table 4 - List of automation for sheep, pig and beef

Tasks No.	SHEEP	PIG	BEEF
Task 1		✓	✓
Task 2	✓	✓	✓
Task 4			✓
Task 5		✓	✓
Task 8 *			
Task 9	✓		
Task 10 *			
Task 11 *			
Task 12 *			
Task 13	W. I. P.		
Task 14	W. I. P.		
Task 15 *			
Task 16	✓		
Task 17	W. I. P.	✓	
Task 18 *			
Task 19 *			
Task 20	✓		✓
Task 21 *			
Task 22 *			
Task 23	W. I. P.		
Task 24		✓	
Task 25 *			
Task 26	✓	✓	
Task 27	✓	✓	
Task 28 *			
Task 29 *			
Task 30 *			
Task 31 *			
Task 32 *			
Task 33	✓		
Task 34 *			
Task 35 *			

3.1.4 Linked application between species

Table 5 shows the result of linking all species of automation with a brief concept for each task. Refer to appendix 5 – Automation and Robotics for detailed concept of the automated process. Please note the tasks marked available do not have a concept listed due to confidential reasons.

Table 5 - Task and concept for future sheep slaughter task

Tasks No.	Title	Status	Degree of sensing technology	Brief Concept
Task 1	Stun	Theoretical	Smart sensing	• Immobilise and stun the animal. • Restrain, locate and perform laceration.
Task 2	Stick	Available		
Task 4	Shackling	Theoretical	Smart sensing	• Locate, lift and position carcass by its legs
Task 5	Bung plug	Theoretical	Smart sensing	• Locate, cut and seal the bung area via burning.
Task 9	Y - cut	Available	Smart sensing	-
Task 13	Mouthing	W.I.P.	Smart sensing	• Locate and track the mouth area. • Assess image then performs logical thinking
Task 14	Head removal	W.I.P.	Unintelligent sensing	• Locates and secures the head. • Sever through the neck.
Task 16	SteriVac	Available	Unintelligent sensing	-
Task 17	Rear hock removal	W.I.P.	Smart sensing	• Locate and secure the leg. • Sever the hock
Task 20	Hide removal	Available	Unintelligent sensing	-
Task 23	Gambrel / Re - Invert	W.I.P.	Smart sensing	• Locate, lift and position carcass by its legs
Task 24	Fore hock removal	Theoretical	Smart sensing	• Locate and secure the leg, sever the hock
Task 26	Evisceration (Green offal)	W.I.P.	Smart sensing	• Blade cuts down the belly and makes the brisket cut. • Removes offal
Task 27	Brisket scissors	Available		
Task 33	Wash Carcass	Available	Unintelligent sensing	• Sprays water as the carcass moves along

As is shown in Table 6, there are three common hurdles to why automation is not applicable to parts of the sheep slaughter process.

Hurdle type: **ACCESSIBILITY (A) - complication to perform in a complex area**
CONTAMINATION (C) high risk area of contamination
INTELLECT (I) inability to interact like a human

Table 6 – Why automation is not applicable in parts of the slaughter process

Tasks No.	Title	Hurdle Type	Prediction
Task 8	Fore leg spread	A	Possible automation in 15 years
Task 10	Hide removal from forelegs	A, C, I	-
Task 11	Sock cut	A	Possible automation in 15 years
Task 12	Rod weasand	A, C, I	-
Task 15	Fore hide removal	A, C, I	-
Task 18	Brisket hide opening cut	C, I	Possible automation in 15 years
Task 19	Punch down	C, I	Possible automation in 15 years
Task 21	Clip Pissel	C, I	Possible automation in 15 years
Task 22	Rear leg tipping	A, C, I	-
Task 25	Bung clearer	A, C, I	-
Task 28	Pluck removal	A, C, I	-
Task 29	Kidney enucleation	A, C, I	-
Task 30	Carcass inspection	A, C, I	-
Task 31	Kidney removal	A, C, I	-
Task 32	Trim carcass	A, C, I	-
Task 34	String carcass	A, C	Possible automation in 15 years
Task 35	Weighing and tagging	I	Possible automation in 15 years

3.2 Section 2 - Detailed analysis (Inverted Dressing of sheep)

3.2.1 Analyse manual labour process

Time study

Table 7 illustrates the weighted time to perform each task when stopwatch time and MODAPTS time is considered. Please refer to appendix 6 & 7 for a breakdown of the MODAPTS calculations.

Table 7 - Weighted MODAPT times considered to be within 20% of stopwatch timeTASK	OPERATORS (No.)	STOP WATCH TIME (sec)	MODAPT TIME (sec)	DIFFERENCE IN TOTAL TIMES	TIME TO PERFORM TASK (sec)
Task 1	1	6.72	3.87	-42%	5.38
Task 2	1	8.61	8.36	-3%	8.36
Task 3	0	NA	NA	NA	NA
Task 4	1	8.87	9.23	4%	8.87
Task 5	1	-	-	-	-
Task 6	0	NA	NA	NA	NA
Task 7	0	NA	NA	NA	NA
Task 8	1	5.86	8.49	45%	7.03
Task 9	3	11.23	17.27	54%	13.48
Task 10	2	5.7	9.89	74%	6.84
Task 11	1	6.29	8.06	28%	7.55
Task 12	1	-	-	-	NA
Task 13	1	-	6.77	-	6.77
Task 14	1	-	7.9	-	7.9
Task 15	2	10.95	10.04	-8%	10.04
Task 16	1	-	9.35	-	8.87
Task 17	1	6.36	6.29	-1%	6.29
Task 18	1	7.2	7.55	5%	7.55
Task 19	2	6.5	12.46	92%	7.8
Task 20	2	9.36	12.28	31%	11.23
Task 21	1	4.5	6.77	50%	5.4
Task 22	1	-	5.16	-	5.16
Task 23	1	6.13	7.71	26%	7.36
Task 24	1	-	9.19	-	8.87
Task 25	1	-	-	-	-
Task 26	1	-	6.77	-	6.77
Task 27	1	9.57	7.21	-25%	7.66
Task 28	1	-	-	-	-
Task 29	1	-	-	-	-
Task 30	1	-	-	-	-
Task 31	1	-	-	-	-

Task 32	1	-	-	-	-
Task 33	1	-	-	-	-
Task 34	1	-	-	-	-
Task 35	1	-	-	-	-

Figure 7 & 8 demonstrates the calculated total time derived from the stopwatch and MODAPTS time calculated in Table 7. The red line in Fig. 7 displays the current rate determined by Tasks 4, 16 and 24 to be 8.87 seconds. Please note that the times greater than 8.87 use two or three operators along the chain.

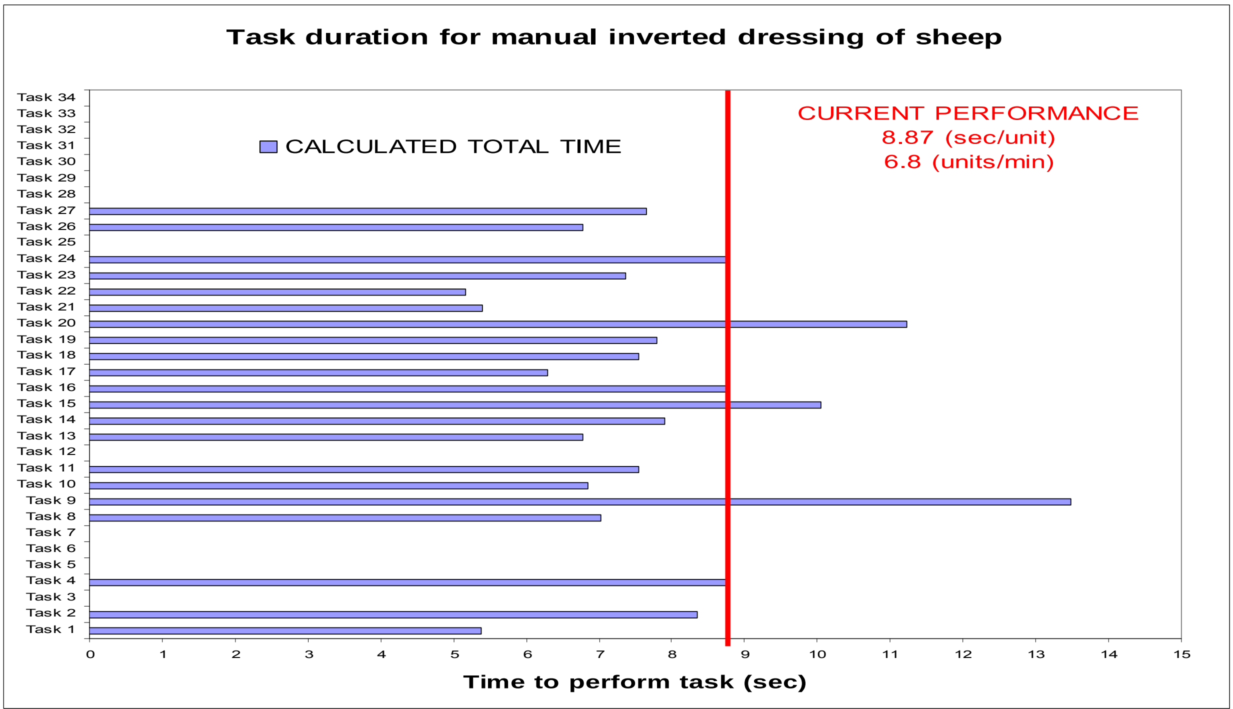


Figure 7 - Calculated total time for a human operator to perform a task

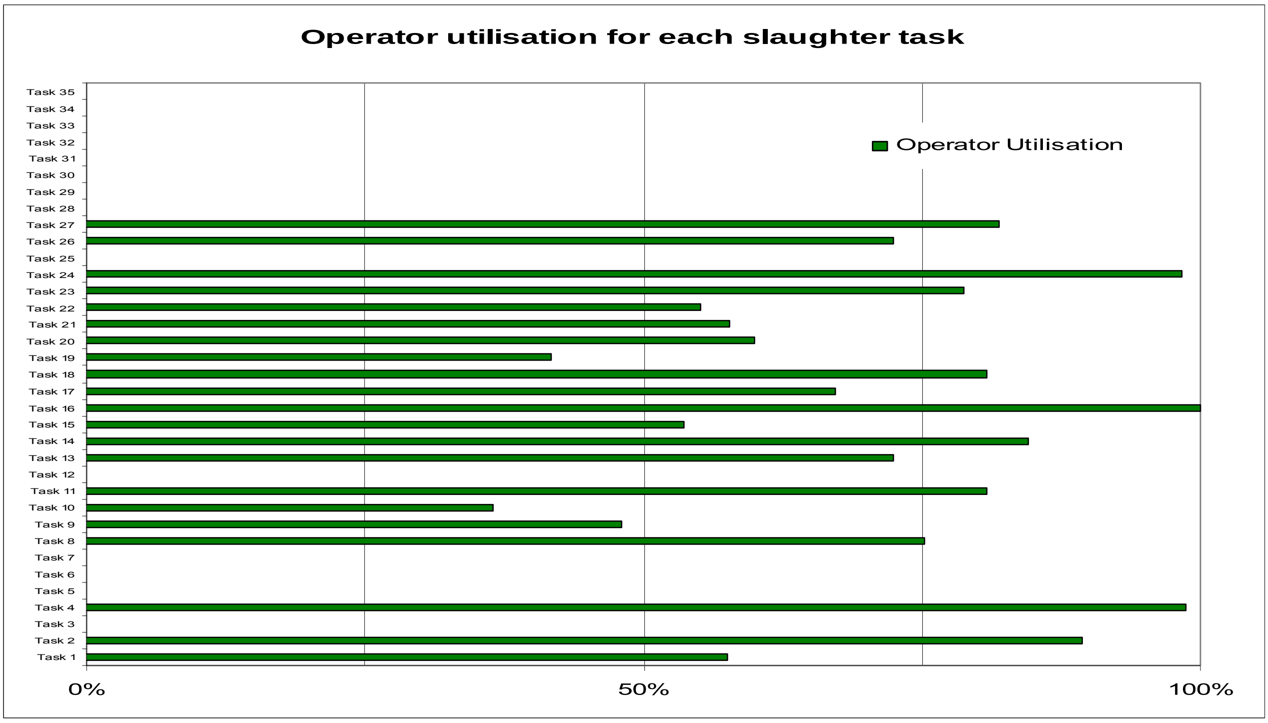


Figure 8 - Calculated operator utilisation time based on weighted MODAPTS time

Ergonomic issues

Figure 9 demonstrates the severity of the working conditions for each task in terms of safety and OH&S issues. Please refer to appendix 8 for ergonomic degree calculations.

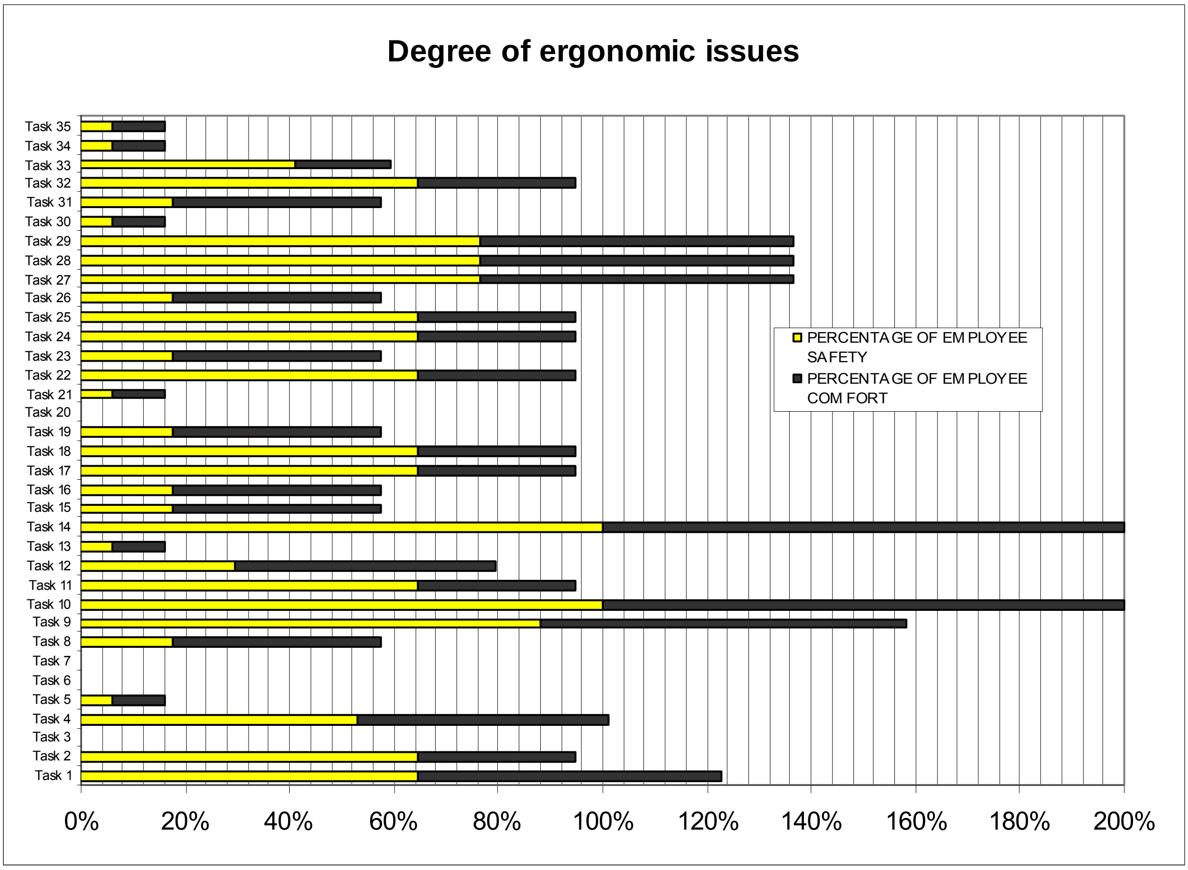


Figure 9 - Calculated degree of ergonomic issues for all task

3.2.2 Predict theoretical automation performance

Time study

Figure 10 shows the equivalent automated MODAPTS time against the total time for a operator to perform each task. As can be seen in all but one case the automation estimated time was quicker than the human time.

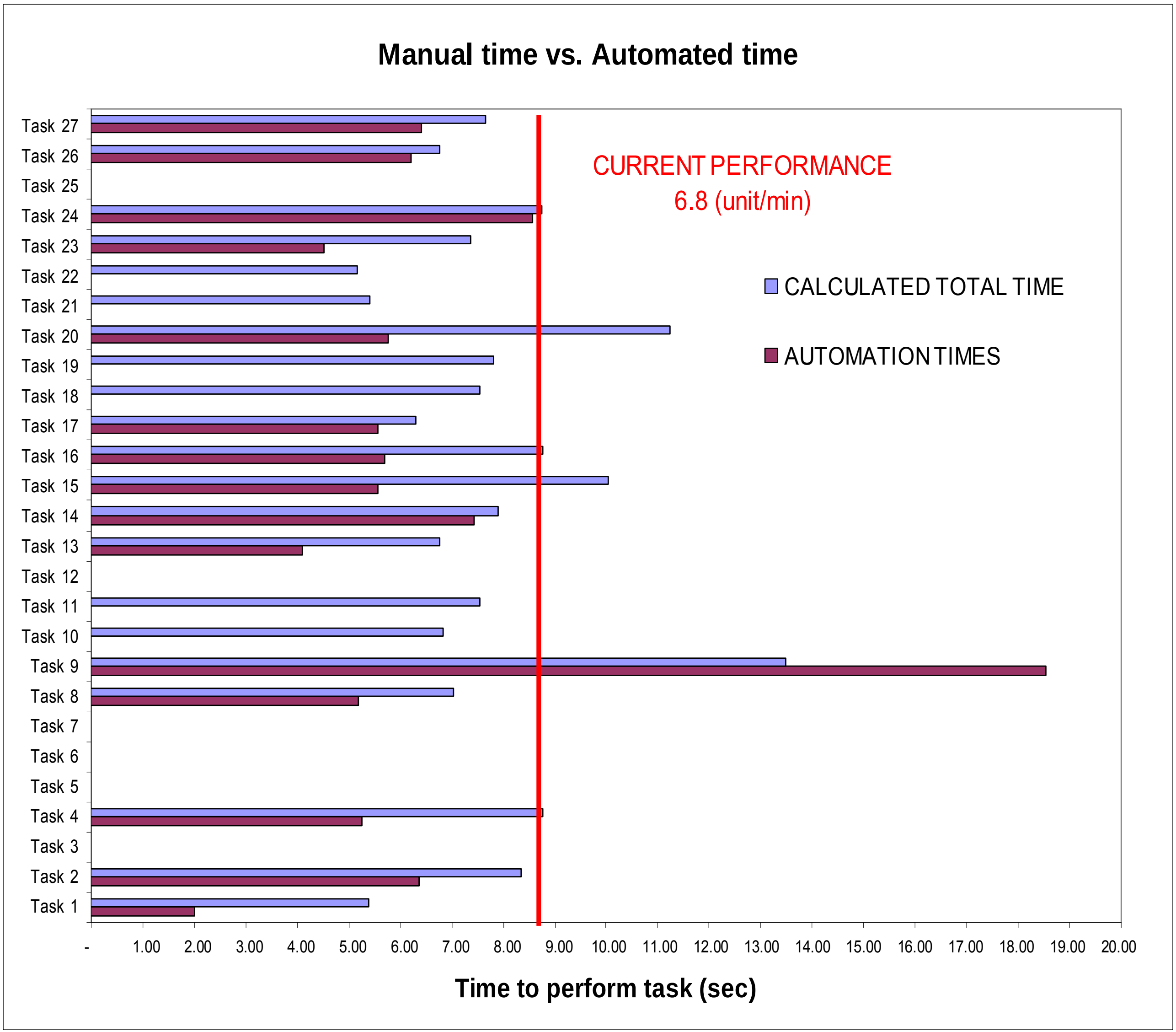


Figure 10 - Operator manual time against automated predicted time per task

After assessing the estimated time task 9, 14 and 24 was reduced to the design goal. Table 8 and Fig. 11 illustrates the selected processing times used to complete Section 3 – Feasibility and Cost benefit.

Table 8 – Weighted automation time per tasks

TASK	AUTOMATION TIME TO PERFORM TASK (sec)	TASK	AUTOMATION TIME TO PERFORM TASK (sec)
Task 1	2.00	Task 16	5.70
Task 2	6.37	Task 17	5.57
Task 4	5.26	Task 20	5.76
Task 8	5.19	Task 23	4.52
Task 9	**6.60**	**Task 24**	**6.60**
Task 13	4.10	Task 26	6.21
Task 14	**6.60**	Task 27	6.41
Task 15	5.57		

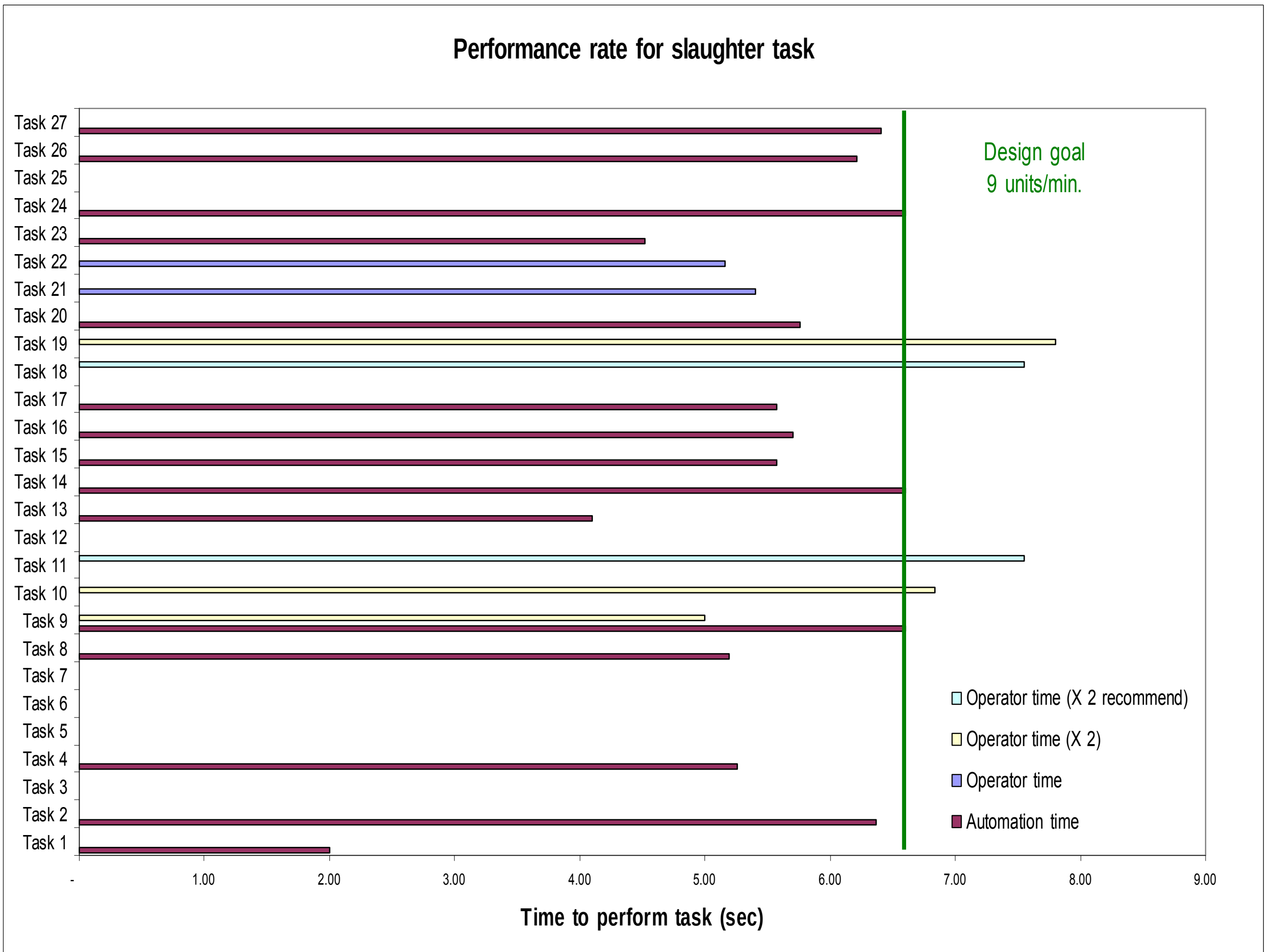


Figure 11 - Time duration for all tasks after automation is applied

Figure 12 and Table 9 shows the ergonomic level of the whole plant with no automation and alternative layout 1 and 2. The decrease in level was due to the reduction of labour.

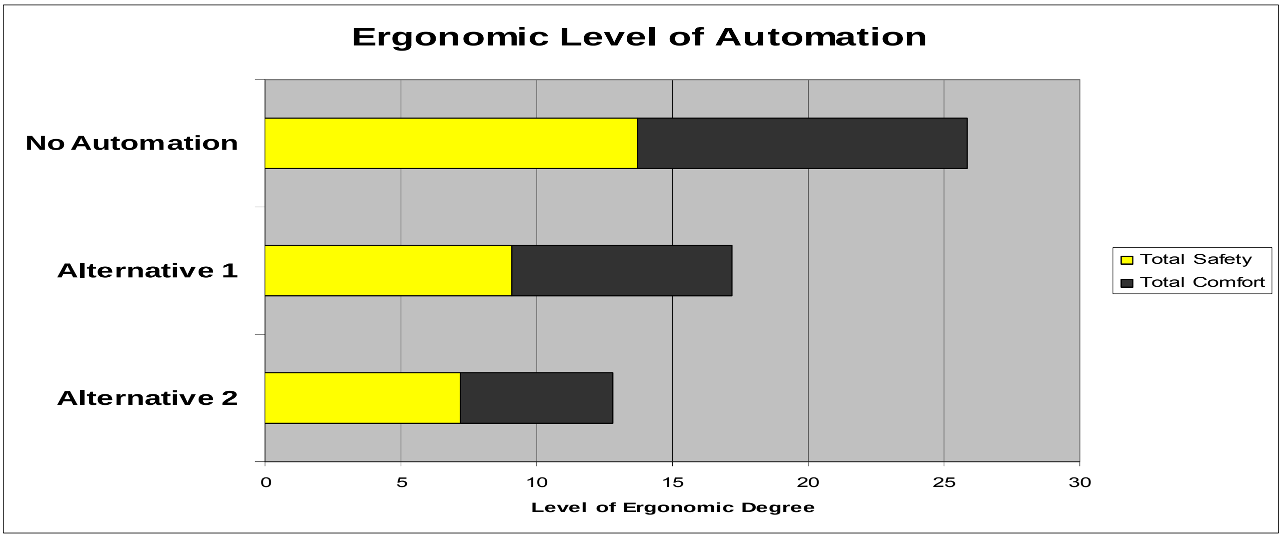


Figure 12 - Ergonomic level for automated facilities

Table 9 - Calculated overall level of ergonomic degree

	Total Safety	Total Comfort	Total (C+S)	
No Automation	13.71	12.15	25.86	-
Alternative 1	9.09	8.13	17.22	67%
Alternative 2	7.17	5.63	12.8	49 %

3.2.3 Validate robot option

Table 10 below illustrates the task that should be a priority when first introducing automation into an existing abattoir. The table shows the basis of the selection, i.e. increased product rate or decreased ergonomic issues. Also shown is the new production rate after the application of the automation.

Table 10 - Priority of tasks that should be automated based on time and ergonomic assessment

PRIORITY	TASK TITLE	REASON	PRODUCTION RATE (units/min)	MAN SAVINGS PER TASK
1	Task 24	Time Standard	6.8	1
2	Task 1 & 2	Time Standard	7.2	1
3	Task 14	Time Standard, Ergonomic	7.6	1
4	Task 26 & 27	Time Standard, Ergonomic	7.8	2
5	Task 9	Ergonomic	9.0	2
6	Task 20	Time Standard, Ergonomic	9.0	2
7	Task 16	Time Standard, Ergonomic	9.0	1
8	Task 4	Time Standard, Ergonomic	9.0	1
9	Task 17	Ergonomic	9.0	1
10	Task 33	Ergonomic	9.0	1
11	Task 23	Ergonomic	9.0	1
12	Task 13	Ergonomic	9.0	1
13	Task 5	Ergonomic	9.0	1
		POTENTIAL MAN SAVINGS		16

3.3 Section 3 – Business upgrade

3.3.1 Current abattoir performance

Based on the statistical and MODAPTS analysis the current performance ranged between 6.8 and 8.2 units per minute. Refer to the red line in Fig. 7 for the determining MODAPTS calculated time and appendix 3 for the statistical calculations.

Current performance = 6.8 to 8.2 units per minute

3.3.2 Predicted future performance

After considering the competitive forces the predicted average performance was calculated to be between 8.16 and 9.8 units per minute with a 20% increase. The mean, 9 units per minute was used in the design as a target.

Future performance = 8.16 to 9.8 units per minute

Mean performance = 9 units per minute

The competitive forces of an Australian sheep processing plant are such that:

- Stock availability and unpredictable work force changes consistency of throughput on a daily and yearly period.
- Internal efficiency is affected by the working culture, absenteeism and maintenance issues.
- The manufacturing process is restricted by a technology barrier and the requirements to access certain parts of the animal at particular times.
- Current working automation has a maximum rate of approximately 10 units per minute.
- Requirements for quality assurance and inspection increases processing time and limits application of robots and automation.
- The industry can not justify spending big on automation because a person can perform the task just as well but at a margin of the cost.

Please refer to appendix 10 for a more detailed description of the competitive forces.

Figure 13 is a chart illustrating the increased predicted future performance for the slaughter operation.

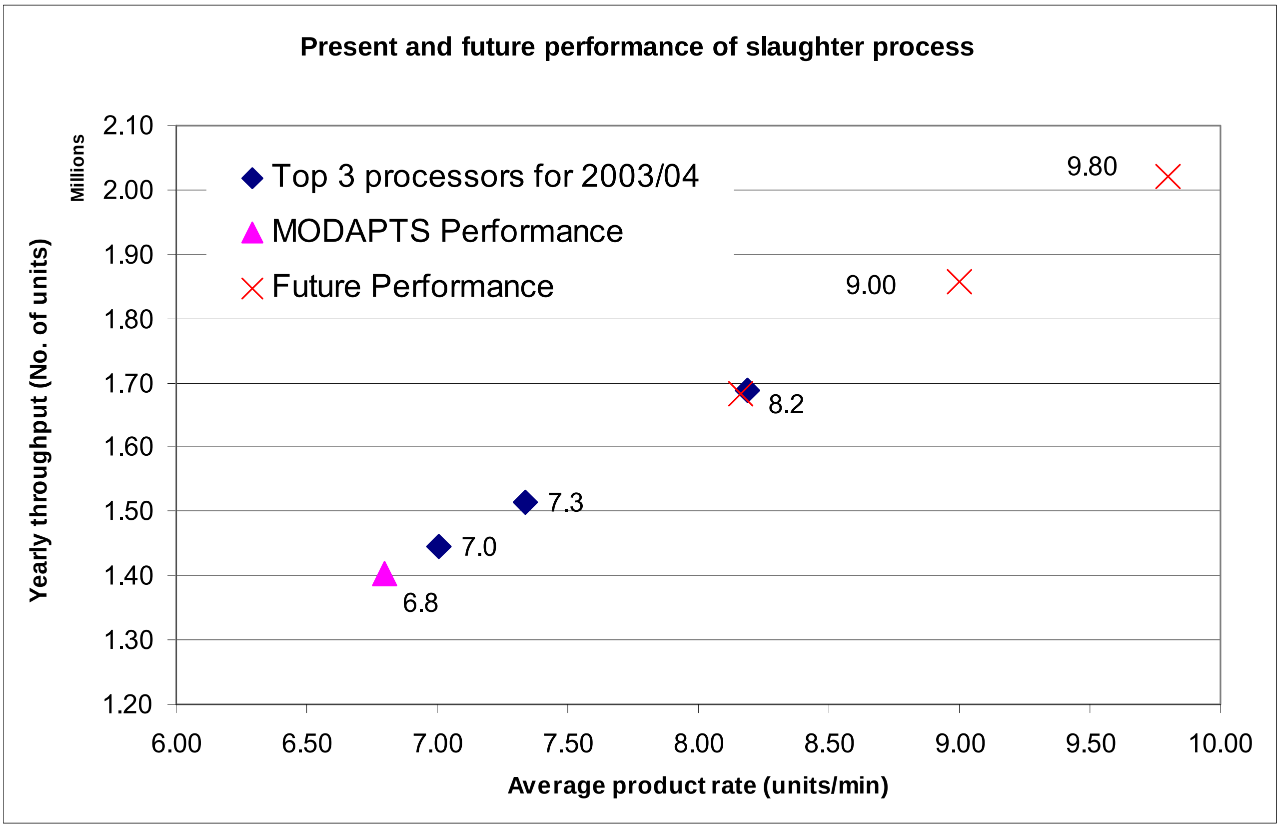


Figure 13 – Future performance above present performance based on statistical and MODAPTS calculations

3.3.3 Set design goals

The design goals that were set as a target when developing a new process are to minimise unit cost by increasing throughput and to minimise safety and occupational health and safety (OH&S).

#1 Minimise unit cost by increasing throughput.

#2 Minimise safety and OH&S issues by providing a ergonomic, safe and comfortable environment.

3.3.4 Finalise two alternative factory layouts

Based on Fig. 11 and Fig. 12 the following information for Alternative layouts 1 and 2 were developed. Please refer to drawings 1 and 2 overleaf on pages 33-34 for a factory layout illustrating the allocation of human and robots along the product chain.

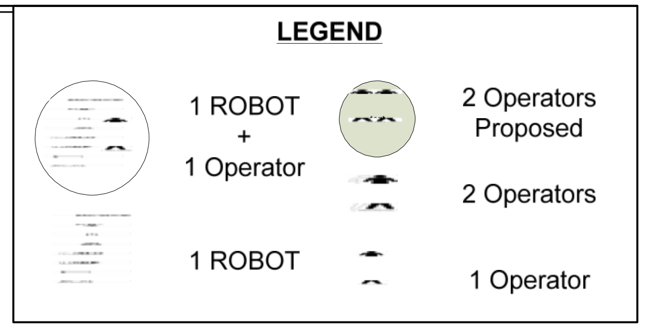
Table 11 - Summary of performance for alternative layouts 1 & 2

Alternative layout 1

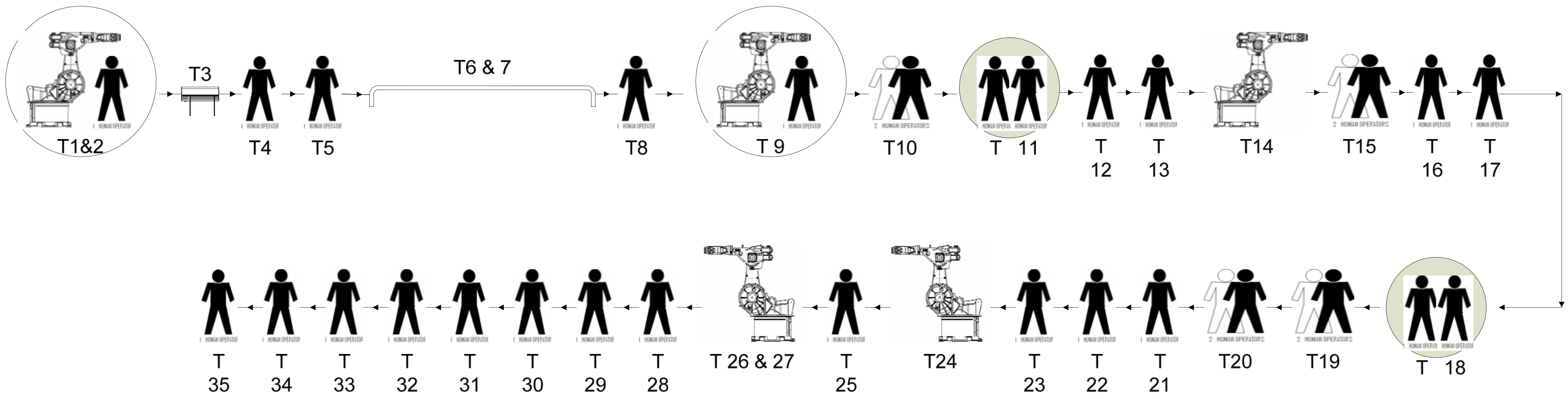
No. of robots	5 automated robots
Robot Operators	2
Maximum Product Rate	9 units per minute
Ergonomic Rating	67 % original
Manual Labour Saving (38)	5 less per shift

Alternative 2

No. of robots	13 automated tasks
Robot Operators	2
Maximum Product Rate	9 units per minute
Ergonomic Rating	49 % original
Manual Labour Saving (38)	16 less per shift



DRAWING No. 1: Sheep Slaughter Process (Inverted Dressing)
ALTERNATIVE LAYOUT 1



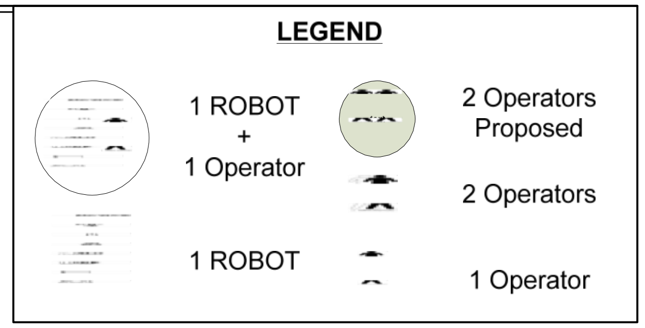
REFERENCE			
T 1	Stun	T 19	Punch down
T 2	Stick	T 20	Hide removal
T 3	Immobilisation	T 21	Clip pissel
T 4	Shackling	T 22	Rear leg tipping
T 5	Bung plug	T 23	Gambrel / re-invert
T 6	Bleed rail	T 24	Fore hock removal
T 7	Stimulation	T 25	Bung clearer
T 8	Fore leg spread	T 26	Evisceration (green offal)
T 9	Y – cut	T 27	Brisket scissors
T 10	Hide removal from foreleg	T 28	Pluck removal
T 11	Sock cut	T 29	Kidney enucleation
T 12	Rod weasand	T 30	Carcass inspection
T 13	Mouthing	T 31	Kidney removal
T 14	Head removal	T 32	Trim carcass
T 15	Fore hide removal	T 33	Wash carcass
T 16	Sterivac	T 34	String Carcass
T 17	Rear hock removal	T 35	Weighting and tagging
T 18	Brisket hide opening cut		

Comments:

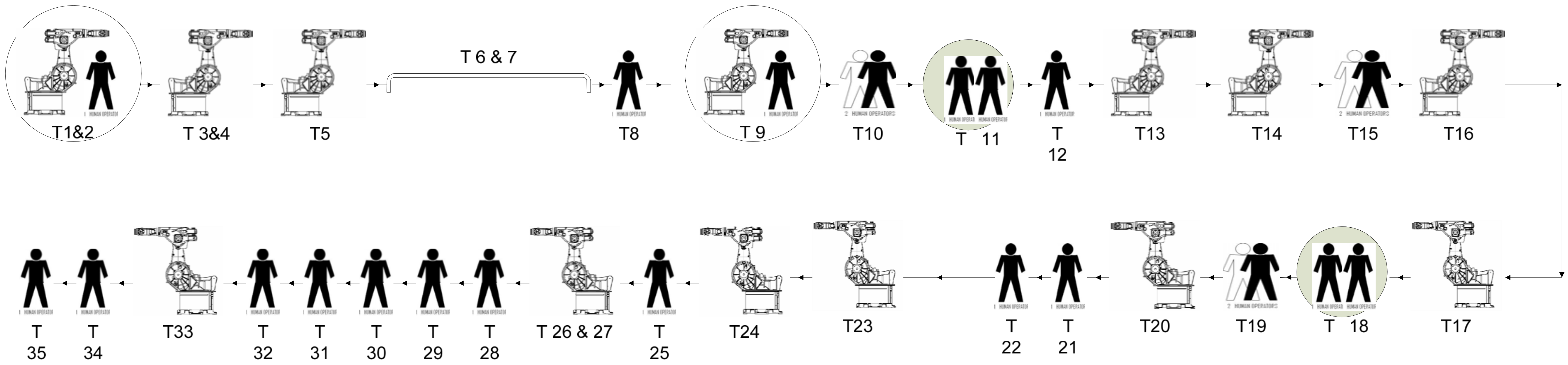
5 X Robots
2 X Robot
Operators
31 X Manual labour

Alternative Layout 1

Drawing No. 1



DRAWING No. 2: **Sheep Slaughter Process (Inverted Dressing)**
ALTERNATIVE LAYOUT 2



REFERENCE			
T 1	Stun	T 19	Punch down
T 2	Stick	T 20	Hide removal
T 3	Immobilisation	T 21	Clip pissel
T 4	Shackling	T 22	Rear leg tipping
T 5	Bung plug	T 23	Gambrel / re-invert
T 6	Bleed rail	T 24	Fore hock removal
T 7	Stimulation	T 25	Bung clearer
T 8	Fore leg spread	T 26	Evisceration (green offal)
T 9	Y – cut	T 27	Brisket scissors
T 10	Hide removal from foreleg	T 28	Pluck removal
T 11	Sock cut	T 29	Kidney enucleation
T 12	Rod weasand	T 30	Carcass inspection
T 13	Mouthing	T 31	Kidney removal
T 14	Head removal	T 32	Trim carcass
T 15	Fore hide removal	T 33	Wash carcass
T 16	Sterivac	T 34	String Carcass
T 17	Rear hock removal	T 35	Weighting and tagging
T 18	Brisket hide opening cut		

Comments:

13 X Robots
2 X Robot Operators
22 X Manual labour

Alternative Layout 2

Drawing No. 2

3.3.5 Feasibility and cost benefit analysis

Table 12 illustrates the calculation to arrive at the total labour cost per shift considering two shifts per day, i.e. AM & PM shift. Table 13 is the calculations for the running cost of a robot for the same duration but an extra one hour to warm up and cool down the robot before the slaughter process begins.

Table 12 - Model direct labour in the slaughter operation

Cost for shift 1 (AM)

Labour type	Slaughter team	Working minutes per shift	Duration of breaks per shift	Total hours per shift	Hourly rate	Base daily	Overall labour cost ($/day)
Slaughterman	38	411	45	7.6	$ 18.00	$136.80	$5,198.40
Trimmer	15	411	45	7.6	$15.00	$114.00	$1,710.00
Labourer	19	411	45	7.6	$14.00	$106.40	$2,021.60
Total on team (AM)	72				Total labour cost for AM shift		**$8,930.00**

Cost for shift 2 (PM)

Labour type	Slaughter team	Working minutes per shift	Duration of breaks per shift	Total hours per shift	Hourly rate	Base daily	Overall labour cost ($/day)
Slaughterman	38	411	45	7.6	$20.00	$152.00	$5,776.00
Trimmer	15	411	45	7.6	$16.00	$121.60	$1,824.00
Labourer	19	411	45	7.6	$15.00	$114.00	$2,166.00
Total on team (PM)	72				Total labour cost for PM shift		**$9,766.00**

Table 13 - Model automation running cost in the slaughter operation

Automation running cost (AM/PM)

	Hourly rate	Working hours per shift	Extra time for cleaning and warm up (hr)	Total hours per shift	($/shift)	Cost per day for 2 shift ($/day)
Energy consumption	$0.60	7.6	1	8.6	$5.16	$10.32
	Cost per year ($/year)	**Days per year**				**($/day)**
Maintenance	$20,000	365				$54.79
					Total daily cost	$65.11

Based on an average production rate of 9 units per minute, Fig. 14 summarises clearly the decrease in running cost for each combination of robot performing in the slaughter operation. Please refer to Table 14 which shows the calculations per robot. For full calculations please refer to appendix 12.1, Table 21.

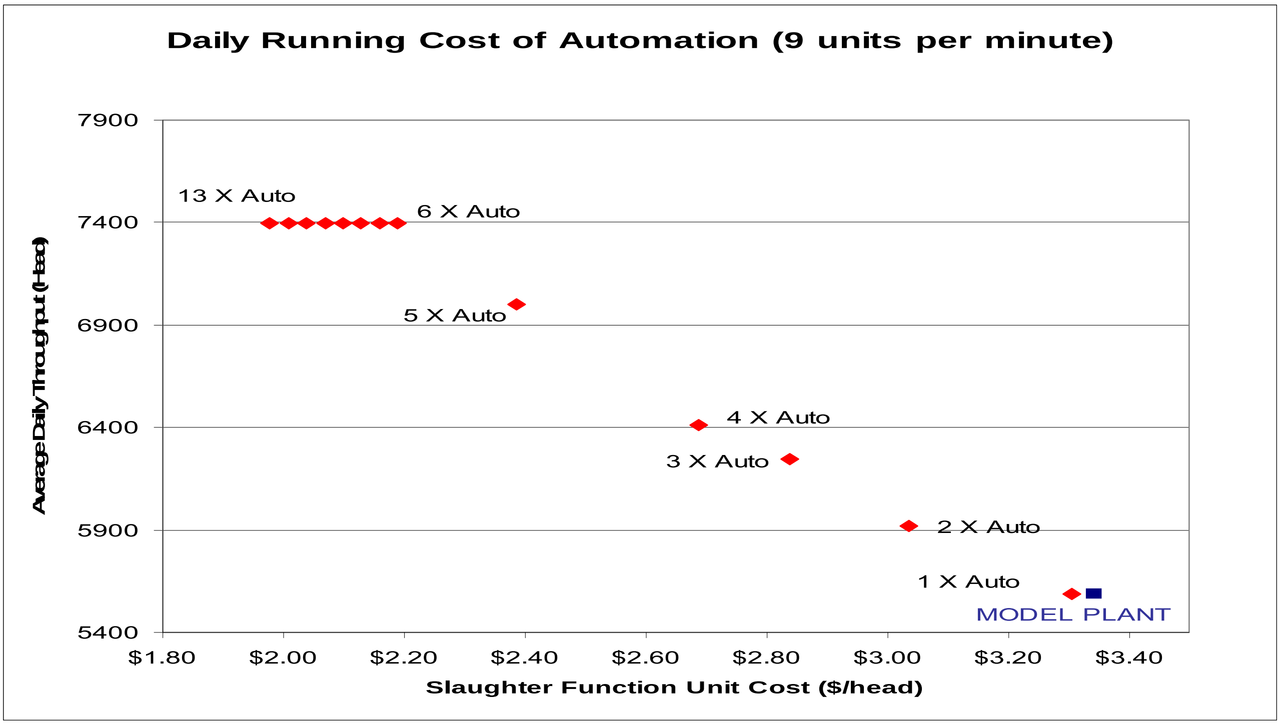


Figure 14 - Running cost per automated task

Table 14 - Calculations of running cost per robot

	0 X Auto	**1 X Auto**	**3 X Auto**	**5 X Auto**	**9 X Auto**	**13 X Auto**
TOTAL Labour cost per day	$18,696	$18,407	$17,541	$16,386	$14,942	$13,786
Automation production cost per day	-	$65	$195	$326	$586	$846
Overall daily running cost (Auto. + Labour)	$18,696	$18,472	$17,736	$16,711	$15,528	$14,633
Number of units daily	**5,590**	**5,590**	**6,247**	**7,000**	**7,398**	**7,398**
Total cost per unit	**$3.34**	**$3.30**	**$2.84**	**$2.39**	**$2.10**	**$1.98**

Developing automation for the slaughter of sheep in Australia

For all combinations of robots a calculation was done to calculate the time for a company to see a return on investment based on savings in running cost and increased throughput, Table 15. Figure 15 shows the performance of Alternative Layout 1 and 2, five and thirteen automated robots, exceeding industry best practice in terms of cost per head and daily throughput.

Table 15 - Break even calculations for automation at design goal of 9 units per minute

No. of machines	Through put in a day	Total Running Cost per Unit ($ / unit)	Cumulative Savings in Running Cost ($ / unit)	Purchase and Installation Cost	BREAK EVEN (UNITS)	BREAK EVEN (Days)	BREAK EVEN (Years)
0 X Auto.	5589.6	3.34	-	$ -	-	-	-
1 X Auto.	5590	3.3	$ 0.04	$ 2,000,000	50000000	8945	35.6
2 X Auto.	5918	3.03	$ 0.31	$ 3,800,000	12258065	2071	8.3
3 X Auto.	6247	2.84	$ 0.50	$ 5,400,000	10800000	1729	6.9
4 X Auto.	6412	2.69	$ 0.65	$ 6,800,000	10461538	1632	6.5
5 X Auto.	7398	2.26	$ 1.08	$ 8,000,000	7407407	1001	4.0
6 X Auto.	7398	2.19	$ 1.15	$ 9,000,000	7826087	1058	4.2
7 X Auto.	7398	2.16	$ 1.18	$ 9,800,000	8305085	1123	4.5
8 X Auto.	7398	2.13	$ 1.21	$ 10,600,000	8760331	1184	4.7
9 X Auto.	7398	2.1	$ 1.24	$ 11,400,000	9193548	1243	5.0
10 X Auto.	7398	2.07	$ 1.27	$ 12,200,000	9606299	1298	5.2
11 X Auto.	7398	2.04	$ 1.30	$ 13,000,000	10000000	1352	5.4
12 X Auto.	7398	2.01	$ 1.33	$ 13,800,000	10375940	1403	5.6
13 X Auto.	7398	1.98	$ 1.36	$ 14,600,000	10735294	1451	5.8

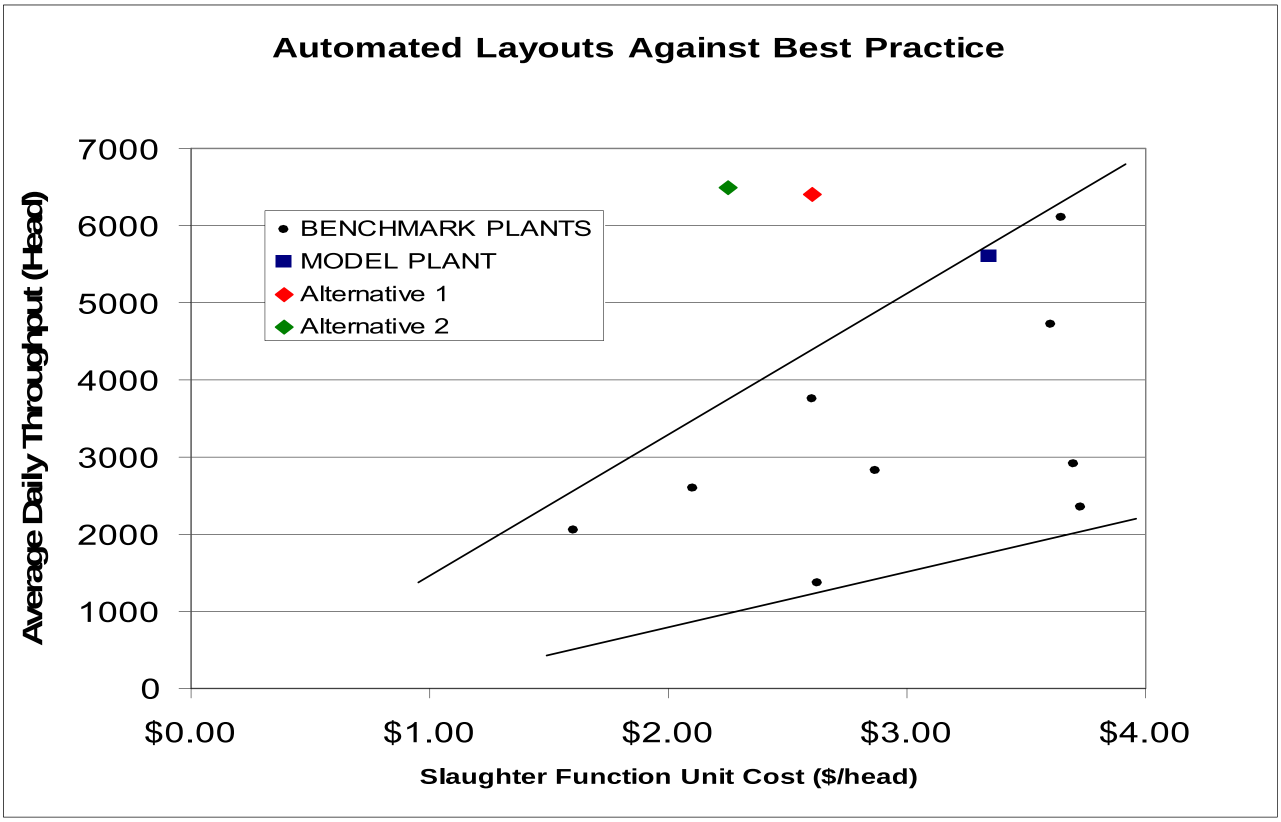


Figure 15 - Alternative 1 & 2 exceeding industry best practice

Based on two shifts per day and 256 working days in the year, the feasibility and cost benefit analysis advocates that alternative layout 1 is far more superior to alternative layout 2 with no increase in product rate, Table 16.

Table 16 - Summary of feasibility and cost benefit analysis

<u>Alternative layout 1</u>

No. of robots	5 automated robots
Installation cost	$ 8 M
Product Rate	9 units per minute
Break Even	4.0 years

<u>Alternative 2</u>

No. of robots	13 automated tasks
Installation cost	> $ 14 M
Product Rate	9 units per minute
Break Even	5.8 years

4 DISCUSSION:

4.1 Section 1 – Investigation

4.1.1 Explore engineering techniques, standards and requirements

Engineering techniques

Lean manufacturing focuses on reducing waste and expanding capacity by reducing cost and shortening cycle times (Author Unknown, 2004). These principles were applied to the slaughter process by analysing MODAPT times, determining the product rate and then calculating the savings.

Also considered in this practice was eliminating slaughter tasks. The product rate is determined by some compulsory tasks that cannot be substituted or removed, it was concluded that there was no gain to eliminating any tasks. The study focused directly on reducing cycle times and increasing throughput based on this fact.

Concurrent engineering focuses on improving quality and reducing lead times (Meyer, 2005). This affected the project by focusing the study on good working conditions leading to consistent quality and improved efficiency of the slaughter process.

To measure product quality an assumption was made that by replacing a task with automation, the machine would perform at a consistent and higher standard than a human operator. To justify automating some tasks the study looked at manual labour ergonomic working conditions, i.e. ensuring that all employees were not under stress and therefore performing at a poor standard.

The study analysed reducing lead time by assessing manual operator idle time and utilisation. The analysis used calculated MODAPT times which were based on the stopwatch and the optimal working duration per task.

Standards and requirements

The following is how the standards and requirements were interpreted:

Australian Standards (AS 4696-2002)

Australian standards demand processing meat for human consumption requires a hygienic practice to reduce product contamination at all times. Product contamination can be caused by a number of factors and the most common is contact with a contaminated surface or airborne particles. In summary all components that make direct contact or come in close proximity of the carcass need to be sterilised. Thus the robot tool needs to be sterilised after performing its tasks.

Also something that should be noted is that the exterior surfaces of the machines need to be regularly cleaned at the end of each shift in most cases twice a day. The machines body needs to be durable, corrosion resistant and allow visual detection.

The standard also highlighted the importance of stunning an animal in such a way that it can not regain consciousness prior to death, “sticking”. The rate of stunning depends on the slaughter rate which is dependant on the overall rate of the continuous chain.

Australian Quarantine and Inspection Service (AQIS)
AQIS is involved in planning and monitoring the quality of a processing operation. This includes inspection of critical control points, testing, record keeping and corrective measures that may occur at a plant. In more detail, experts are trained in quality control to detect foreign matter and grade the meat to ensure the product is of high standard.

The documentation instructs upon the maximum acceptable interval for reversible stunning to render unconsciousness of the animal. The time interval stated a maximum of 15 seconds from when the animal is stunned to the end of the sticking process of the sheep.

Also found in the document was how to perform a successful HALAL slaughter. HALAL is a Muslim ritual, a strict process of preparing food. It must involve reversible stunning and a 'transverse incision of all soft tissues on the under surface of the neck, severing the carotid arteries and jugular veins on both sides of the neck' (AQIS, 1995).

From AQIS it is concluded that the design selected for Task 1 must perform reversible stunning of the animal. Task 2 must be performed within 15 seconds of stunning and be performed by a Muslim slaughterman to special standards.

AUS-MEAT Specifications
AusMeat provides detailed specifications on how a company must categorise/grade the meat product in terms of its colour, weight range and fat content. Food safety specifications such as temperatures, packaging and labelling requirements are also available and must be adhered to before products are sent to a customer. This area was not applied to the study but was important for developing an understanding of the environment in which the workers perform their tasks.

4.1.2 Inverted dressing slaughter of sheep

At present there are two types of sheep slaughter processes operating in Australian abattoirs. The first is the traditional and conventional dressing process; the second is the improved inverted dressing process. The reason the inverted dressing process was selected over its counterpart was because it has several advantages with reduced manual labour requirements, lower worker injury and less possibility of contamination (Mittal, 1997).

The inverted dressing process consists of thirty-five tasks, Fig. 6. Each task is performed by a person in close proximity to others and is dependant on the task previous to it to continue at a steady rate. A carcass moves along a rail system and the worker performs beside and in some cases below the moving animal. All tasks are reliant on each other and if one step breaks down, all tasks following this mishap will be shut down also. This fact highlights the importance of continual assessment of machine and maintenance, made to ensure the chain runs efficiently as the process is directly affected by each task.

For simplicity all thirty-five tasks were broken into three parts, slaughter, hide removal and preparation, trimming and evisceration. During the slaughter process thirty-eight operators perform the tasks with twenty spare people to assist and eliminate fatigue. Abattoirs run two shifts per day with a team of approximately seventy-two people, labourers on the slaughter floor at any one time.

Task 3, Immobilisation, has no operator because it is a method used to prevent the person from being injured when performing shackling. Task 6, Bleed rail, represents the duration of the bleeding of the carcass and Task 7, Stimulation, is a method preferred to increase meat tenderness and quality.

4.1.3 Automated slaughter task for all species

The approach of dividing the available technology into automation accessible and work in progress highlighted proven and reliable automation, Table 4. Being aware of the technology advancements led to spending more time adapting the work in progress of sheep and the availability of pig and beef technology to sheep.

The study reviewed the technology being used overseas and adapted their techniques for the project. Research discovered that in Europe pig processing is further advanced than sheep whereas in New Zealand there are more robots used for the processing of sheep.

The study also found that the Australian meat industry in the past has attempted and succeeded to fully automate the slaughter process of beef. This was rejected by the industry because of the large price tag. The predicament has lead to the industry focusing on automating individual tasks along the chain.

Common benefits of automating slaughter tasks lead to increased yield, improved accuracy and consistency, minimised contamination and reduced injury claims by isolating personnel from dangerous equipment.

4.1.4 Link application between species

For the application of linking the species, it was assumed that an industry robot would mimic human movement and have its own sensing technology to assess the carcass.

At present there are two forms of sensing technology applicable to the process. The first is unintelligent sensing and the second smart sensing. The unintelligent sensing is repetitive and always cuts at the same spot via a trigger. Smart sensing captures an image, determines a start and finish point then tracks its path to perform a task. The most recent smart sensing currently under development uses 3D thermal modeling to determine the difference between the meat and the skin. Because of this new technology the likelihood of more automated tasks is greatly increased.

By linking the species, Table 5 shows the tasks and concepts for future sheep slaughter. It was found that fifteen out of the thirty-five tasks can be automated and in these tasks five tasks can be combined to use one robot because it has been done for the slaughter of pigs and beef.

In the cases of combining Tasks 1, 2 & 5 (Stun, stick & bung) of pig slaughter, this is not applicable to the slaughter of sheep because the person performing the shackling would have to wait for the robot to finish. In the other case of combining Tasks 1, 2 & 4 (Stun, stick & shackle) of beef slaughter, it is not restricted by accessibility like before but the product rate. Because the rate of sheep, approx 8 seconds per unit, is far greater than beef, approx 30 seconds per unit, this option is not viable for a robot to perform all three tasks at one time.

In looking for the ideal solution, Task 1 & 2 (Stun & stick) were combined. For this combination to be considered HALAL, it is stated that the Muslim slaughterman pushes the button to initiate the sticking process while he prays. This alternative eliminates two manual human operators but creates the requirement for a robot supervisor/operator if HALAL meat is being processed.

To complete the automation selection process it was essential to explore and apply knowledge to identify why automation was not applicable in parts of the process. For all the tasks hurdles of accessibility, contamination and intellect were common.

The first hurdle was accessibility of the robot to perform its tasks. In many cases the tasks were not automated because of the necessity of the robot to get access inside or around the carcass to perform the task successfully, table 6.

Contamination was brought about by the possibility of fecal and other types of contamination being predicted if a robot was to perform the task. A robot was assumed to not be able to check and ensure it was performing the task properly. A robot would just continue to perform the wrong way and many units would be affected and damaged.

Intellect was assessed by the possibility of a robot not being able to sense like a human. For example, in the case of the kidney removal, a human grasps the soft kidney with its hand unable to visualise the organ and pull it out from inside the carcass. A robot can not sense the soft tissue and make this judgment.

In assessing these hurdles, each task that did not share all three hurdles showed potential possibility for automation in the future through engineering of the slaughter process.

4.2 Section 2 - Detailed analysis (Inverted Dressing of sheep)

4.2.1 Analyse manual labour process

To analyse the time and ergonomic study, some assumptions needed to be made for simplicity. It had to be assumed that all employees were fully trained and experienced and therefore capable of performing at the most accurate for an entire shift. Given this, the times used reflect an average “normal” pace, a pace which could realistically be maintained by all employees throughout the day.

Time study

The time for each task takes to be completed was estimated by a MODAPT time which determines the ideal time to perform a task. This time was weighted to be within 20% of the actual time it takes for an employee to perform the task when videoed and timed using a stop watch. The end product was the calculated total time to perform the task which is a realistic expectation.

Table 7 – shows that in many cases the MODAPTS time over predicted the time to perform the task, this was shown as a positive difference. In many cases where the MODAPT difference was considerably higher it was due to the fatigue and other factor considered in the calculation. It was hard to predict a level of weighting that needed to result in a more accurate figure. The benefit of this exercise was to finalise a more accurate time to perform individual tasks so when it came time to replace a task with automation that performs quicker the rate would not be restricted by other tasks.

To help analyse the optimal time, Figure 5 illustrates time against the product rate. The time calculated was 8.87 seconds which is equivalent to a product rate of 6.8 units per minute. This figure was used later for the current performance in the business upgrade.
Utilisation is a term used to explain the amount of man power needed for each task. Those tasks requiring greater utilisation are obviously slower and therefore are considered to be the rate

determining tasks of the operation. Utilisation is aimed to be kept constant for ease of processing and to maximise efficiency. As can be seen in Fig. * – Calculated operator utilisation, the current manual system is not efficient because the utilisation is not even for each task. This graph brought attention to particular tasks and the necessity to replace tasks already at even utilisation with automation.

In conclusion the following tasks in Table 17 should be replaced by robots because they determine the product rate. Please note that although tasks 11 and 18 are time consuming they can not be automated via the linking of the species.

Table 17 – Tasks that should be replaced by automation based on time study

Task	Title	Priority
Task 2	Stick	Medium
Task 14	Head removal	Low
Task 16	Sterivac	High
Task 23	Gamrel / Reinvert	Low
Task 24	Fore hock removal	High
Task 27	Brisket scissors	Low

Ergonomic issues

Employee safety and comfort was a priority during the design of the new manufacturing process. The reason ergonomics is such a high priority is because it directly relates to employee comfort and safety. In a non ergonomic environment employees tend to change the way they perform the tasks and techniques are not uniform. When the technique is changed there is a possibility that product quality could decrease, the time taken to perform each task can vary dramatically depending on the operator and the likely hood of severe injury increases.

Figure 7 shows the calculated degree of safety and comfort. As can be seen there are three tasks that rate very high, i.e. tasks 9, 10 & 14. These levels are acceptable because the industry recognises this and has allocated more than one operator when performing these tasks.

Task 19 and 20 were identified to have low ergonomic levels and use more than one operator. Task 20 was concluded to be acceptable because it is a time consuming task. Task 19 was also assumed to be acceptable although in the mid range of time and the lower limit of ergonomic level. This conclusion was arrived at because of the intensity required to perform this task.

In conclusion Table 18 summarises the high scoring tasks that can be replaced by robots. Please note that task 10 and 28 are high scoring but can not be automated via linking of the species.

Table 18 – Tasks that should be replaced by automation based on ergonomic level

Task	Title	Priority
Task 9	Y-cut	High
Task 14	Head removal	Medium
Task 19	Punch down	High
Task 20	Hide removal	Medium
Task 27	Brisket scissors	Medium
Task 29	Kidney ecucleation	Low

4.2.2 Predict theoretical automation performance

Time study
Quality assurance is performed by a person in all abattoirs; rigorous inspection of carcasses takes place each day to ensure the quality of the product. Automation within the abattoir leads to a more consistent performance, requiring reduced inspection time and man hours. Unfortunately the quality assurance position must be maintained and cannot be performed by a robot, however the hours the person works can be reduced.

The assumption made was that a robot would perform at a time similar to a human time. Figure 10 estimated automation time against the total human time showing this to be true in all but one case. Task 9 was estimated to be quicker than the human time by another 5 seconds per carcass. The reason for this is because the robot was required to sterilise three times during the task, on either side of the carcass. To overcome this, the study replaced two humans with a robot and allocated one to work beside the robot to complete the tasks in a more timely fashion.

Table 8 and Figure 11 show the time for all tasks used in the feasibility and cost benefit analysis. To achieve the design goal of 9 units per minute, the robots times for tasks 9, 14 & 24 were reduced to be within the acceptable range. An assumption was made that in the future the robots would perform much quicker than the study had proved. Also shown is that task 11 and 18 are required to have an extra person to maintain the design rate of 9 units per second.

Ergonomic study
As can be seen in Fig. 12, alternative 1 has reduced in ergonomic level by 67% of the original manual level. Alternative 2 was also reduced but only by another 18% to 49% of its original level. Table 9 shows that in alternative 1 the safety and comfort decrease at approximately the same rate but for alternative 2 the comfort decreases by a further 10% of the safety. This suggests that there was a big change in ergonomic comfort and safety for alternative 1 with five robots, but only a small increase in ergonomic safety and high comfort for alternative 2 which used three times the number of robots.

4.2.3 Validate robot option

Table 10 shows the priority of a task that should be replaced with automation. This table was used to select the automation for alternative 1 and 2. The choice was based on data from tables 17 and 18 in the discussion of the time and ergonomic study. The tasks were prioritised based on the greatest benefit in time and then ergonomic level. Also shown in this table, for maximum automation there is a total man saving of 16 men for 13 robots used in alternative 2.

Table 10 can also be used as a reference by the meat industry to identify what tasks should be developed to be automated based on the benefit to an abattoir, i.e. improved productivity leading to the quickest return.

4.3 Section 3 – Business upgrade

4.3.1 Analyse current abattoir performance

The statistical analysis uncovered that current production rate for the top three Australian processors ranged between 7 and 8.2 units per minute. The MODAPTS calculation determined that the actual product rate is closer to 6.8 units per minute on average. This figure was then confirmed by the early number of 300 – 480 units per hour assumed in the project proposal.

In modelling the top three processors in Australia, these companies are the most likely to take on and be in a financial position to afford automation. It must be noted that these companies may or may not be performing industry best practice because they are the largest.

4.3.2 Predict future performance and design goal

The future performance was restricted by competitive forces to be an increase of only 20%. In industry an increase of 40% to 60% is used to justify automation. This increase was limited by competitive force. Competitive forces are factors within a work force that can not be controlled and can vary from day to day. A full list of competitive forces can be seen in appendix 10.

Taking into consideration the competitive forces and the design goals, a target was set at 9 units per minute to satisfy an increase in production rate, Fig. 13. This value is unlikely in an existing abattoir with current operator allocations, but if task 10 and 19 use two operators instead of 1 then this rate would be achievable, according to section 4.2.2 – time study.

4.3.3 Finalise two alternative factory layouts

The detailed analysis of time and ergonomic standards resulted in the selection of alternative layout 1 and 2. The layouts were placed in a factory diagram illustrating the human and robot allocation along the chain, pages 33-34.

Each layout was designed to perform at a rate of 9 units per minute. At first this was not achievable with only a product rate of 7.9 units per minute. To achieve the design target two task operators were allocated to tasks 11 and 18, sock cut and brisket hide opening. Also in the alternatives it is important to note that task 1 and 2, stick and stun, requires a robot operator to conform to HALAL requirements. Task 9, Y cut requires an operator to work with the robot to maintain product rate of 9 units per minute.

Alternative 1 was equipped with five automated robots to meet the product rate of 9 units per minute. The application of the automation reduced the number of operators performing along the chain from thirty-eight to thirty-one with two robot operators, i.e. task 1 and 2 combined and task 9. The result was a saving of 5 human operators in alternative 1. Hence for a 72 man team per shift, the team is reduced to 62 people.

Alternative 2, thirteen automated tasks does not increase the product rate further than alternative 1. This alternative reached its maximum automation because the other tasks were not able to be linked to automation of other species. The benefit of alternative 2 was the increase in worker satisfaction specific to the decrease in ergonomics by more than half, section 4.2.2. This alternative has achieved design goal #2 by minimising safety and other OH&S issues, providing a more ergonomic, safe and comfortable environment by reducing unpleasant tasks. It is important to note that their will always be a need for employees to perform tasks that can not be assigned to a machine.

4.3.4 Feasibility and cost benefit analysis

Table 12 shows the wages for the slaughter operation to be approximately $20 thousand for a day. This breaks down to be around $150 per employee per shift. This figure matched against the automation shift cost of $32.5 shows considerable savings in cost. If a robot was to replace only one human then the cost decrease is still beneficial to the slaughter operation.

Expanding on the large difference in running cost savings, Fig. 14 illustrates that as the number of robots increase, the savings are far more considerable. Installing one robot does not have a dramatic improvement in time savings leading to no real decrease in manufacturing cost, the reason is because of the initial outlay of $2 million and almost no improvement in product rate. It was more beneficial to automate two tasks but it was not until at least five tasks were automated that a decrease of 30% in unit cost was achieved.

As can be seen in table 15, alternative 1 cost $8 M to install into an existing abattoir, which consist of purchase price and set up cost. The time for the company to break even is important when considering the savings in manufacturing cost. The reason alternative 1 is better was because it breaks even in the shortest time, 4 years. This was due mainly to no real elimination of people, the performance increased considerably to a daily throughput from 6000 units to 7,400 units. This increased throughput has lead to decreased unit cost and satisfying design goal #1.

Alternative 2 had maximum automation of 13 robots and very large capital investment. This alternative is not feasible because it will take 5.8 years to break even and the predicted lifespan of a system is only 7 years. If capital investment was not an issue to the industry, then potential their is room to further improve this alternative. More robots can be allocated to the selected tasks in this study and throughput could possibly be further increased.

If a product rate of 9 units per minute was not achieved then the difference in running cost and time to break even varies considerably. The study looked into this case and assessed a product rate of only 7.8 units per minute. The difference are that if the rate was did not reach 9 then for alternative 1 it would take approximately an extra 2.5 years to break even, appendix 12.

The 20% increase in performance is not sufficient to justify spending the obscene amount of money required to set up the automated slaughter floor. After experiencing first hand, it was seen that an Australian abattoir does not adopt a new process if they do not see a return on investment within 3 years. While alternative 1 takes slightly longer than this, the extra benefit of introducing this alternative into the work place is better working conditions and employee satisfaction. This is due to the difficult tasks having been replaced by automation. It might be important to note that employees should not fear losing their jobs as labour is required and they will be reallocated within the plant to improve the process.

There are many ways to perform feasibility on upgrading to an automated process. For example looking at human labour hidden cost like super, injury claims and so forth. In industry for a yearly human wage you would expect to double this figure which would be your total cost for that person. A robot running cost needs to determine the life, initial cost and the depreciation of the machine over time. This usually results in 30-60% of the human running cost and that is where the benefit can be made.

In summary current sheep abattoirs in Australia run at an average production rate of 6.8 - 7.5 units per minute. The result shows that through automation the rate increases to 7.8 – 9 units per minute. The increase in speed and production directly affects the cost of slaughter. Overall the cost of slaughter can potentially decrease by $1.36 per head, contributed to by decreased labour and increased production.

4

5 RECOMMENDATIONS:

- This study has brought to light the fact that the meat industry can improve and be more efficient. Improvements can be made in lean manufacturing and improving work ethic and the unpleasant working environment.

- The study replaced individual slaughter tasks with automation and uncovered that a repairs and maintenance schedule needs to be set up and sustained for the life of the machine. It is important that all equipment in the slaughter operation are used and maintained in a way that reduces the possibility of down time leading to lost production.

- An abattoir replaces at least two tasks with automation. The benefits of automating are improved product rate, improved accuracy and consistency leading to higher yield, minimised contamination and reduced injury claims by isolating personnel from dangerous equipment.

- Based on increased product rate and return on investment it is recommended that an Australian abattoir introduces alternative layout 1. The tasks automated are:

    - Stun and stick the animal combined — Task 1 & 2
    - Y-cut — Task 9
    - Head removal — Task 14
    - Fore hock removal — Task 24
    - Evisceration and brisket scissors combined — Task 26 & 27

- To increase daily performance of an automated slaughter operation it is recommended that an abattoir company upon implementing alternative 1 should allocate extra manning to tasks 11 & 18, sock cut & brisket hide opening. This will reduce the level of worker fatigue and increase the chain speed to give a better return on the investment.

6 CONCLUSIONS:

Currently only two steps are successfully automated in Australian abattoirs. Other technology is primitive and runs on trial and error systems. Overseas technology needs to be embraced in Australia to improve performance and this study shows it is possible. This study shows that in a sheep abattoir up to thirteen tasks are able to be automated now or in the near future.

The work completed has indicated that by automating individual tasks in the slaughter of sheep, it results in the following benefits:

- Increased efficiency of the slaughter operation
- Increased daily throughput from 6,000 to 7,400 units per day.
- Minimised unit processing cost from $3.34 to $1.98.
- A safer and more ergonomic environment

The study looked at two alternatives layouts for automation in sheep abattoirs. Alternative 1 integrates five automated steps in the slaughter process. The manufacturing cost per head decreased by $0.95 while product rate increased from 6.8 to 9 units per minute. It has been proven that this automation is not only possible with technology advancement but can be put into an existing system and be affordable within four years time.

With this study, alternative 2 has proven not to be a viable option. Maximum automation has proved that there is a limit to the amount of automation possible, due to the throughput of the slaughtering process. The capital cost of implementing maximum automation of 42% does not give the return within 5 years required by a business. Most abattoirs in Australia are unable to afford the initial capital outlay of $14 Million.

7 REFERENCES:

AS 4696-2002 'The hygienic production and transportation of meat and meat products for human consumption'
Standards Australia International Ltd, p 21

Australian Quarantine and Inspection Service - AQIS, (2002) 'Meat safety quality assurance system for fresh meat and processed meat products 2nd Edition'
Commonwealth of Australia, 2006, via worldwide web
http://www.daff.gov.au/content/output.cfm?ObjectID=37252270-7ED7-4DEC-A5CA91BC5E29DABD&contType=outputs
accessed on 31/05/06

Australian Quarantine and Inspection Service - AQIS, (1995), 'Operational Guidelines for the welfare of animals at abattoirs and slaughterhouses 2nd Edition'
Australian government publishing service, Canberra, Australia

Author unknown, (2004) 'Lean manufacturing: SME case study'
Superfactory, TM., via worldwide web:
http://www.1000ventures.com/ads/Lean_sample.ppt
accessed on 20/04/2006

Author unknown, (1998) 'Australian HALAL meat products'
AUS-MEAT Ltd, 9 Buchanan St, South Brisbane, QLD, via worldwide web:
http://www.ausmeat.com.au/
accessed on 31/05/06

Carey, P., Farrell, J., Hui, M., Sullivan, B., (2001) 'Heye's modapts – a language of work'
Heyde Dynamics Pty Ltd, Brisbane, pp 13

Heidke, D., White, R., (13/4/2006) Food Science Australia Meeting in Brisbane
Conference room at Corner Creek and Wynnum Roads, Cannon Hill QLD

Kitching, C., (2001) 'General product requirements for meat supply specifications'
AUS-MEAT Ltd, via worldwide web:
http://www.ausmeat.com.au/standards/specification/lamb.asp
accessed on 31/05/06

McClain, J., Thomas, L., Mazzola, J., (1992) 'Operations Management'
Prentice Hall Inc, pp 479-480, 505-507

Meyers, F., Stephens, M., (2005) 'Manufacturing Facilities Design and Materials Handling'
Pearson Education, Inc., New Jersey, p 39

Mittal, G., (1997) 'Computerized control systems in the food industry'
Marcel Dekker, Inc., New York, p 461

MLA-a
Author unknown (2005) 'Paddock to Plate'
Meat & Livestock Australia via worldwide web: http://www.mla.com.au/TopicHierarchyCentre/IndustryOverview/PaddocktoPlate/default.htm accessed on 30/12/05

MLA-b
Philpott, H., (2006) 'Final Year Project Proposal'
Meat & Livestock Australia Red Meat Industry Professional Development Program, p 1

MLA-c
MLA (editor), (2005) 'Off Farm Automation and Technology R&D Dissemination DVD'
Video via link, 'Beef automation – brisket sawing in Australia (IRL)
'E:\beef slaughter task/bs_task19.htm'

MLA-d
MLA (editor), (2005) 'Off Farm Automation and Technology R&D Dissemination DVD'
Cut section of R&D report CSIRO, (2004) FSA
'E:\Beef R&D Project Reports\PIP.069 - Introduction FSA.pdf'

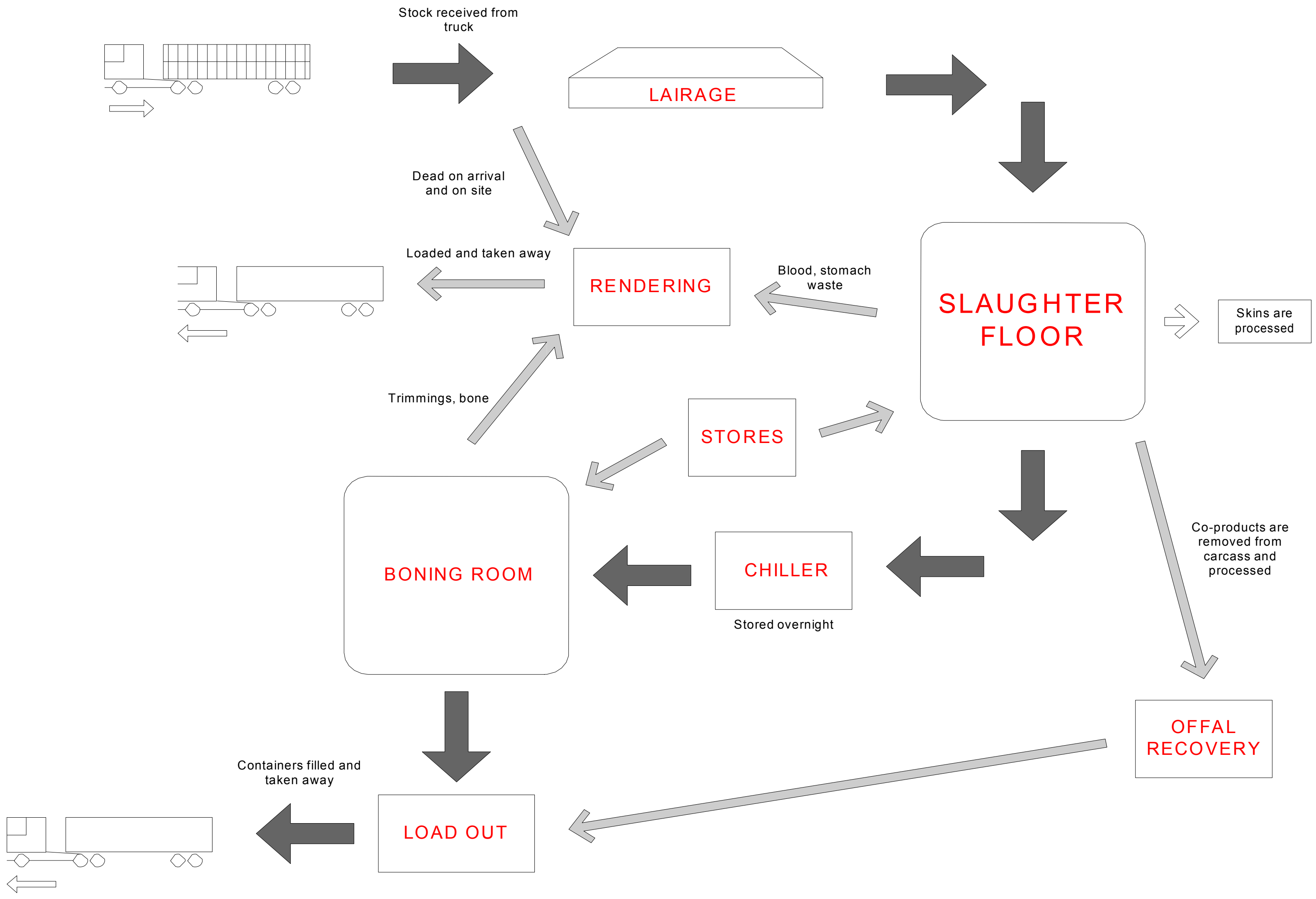
MLA-e
Author unknown (Oct 2005) 'Feedback: Top 25 red meat processors calendar year 2004'
Meat & Livestock Industry Journal Supplement, pp 1-13

MLA-f
Kearney, A. (1998) ' Benchmarking – sheep processing'
Meat & Livestock Australia Publication, pp 56 – 75

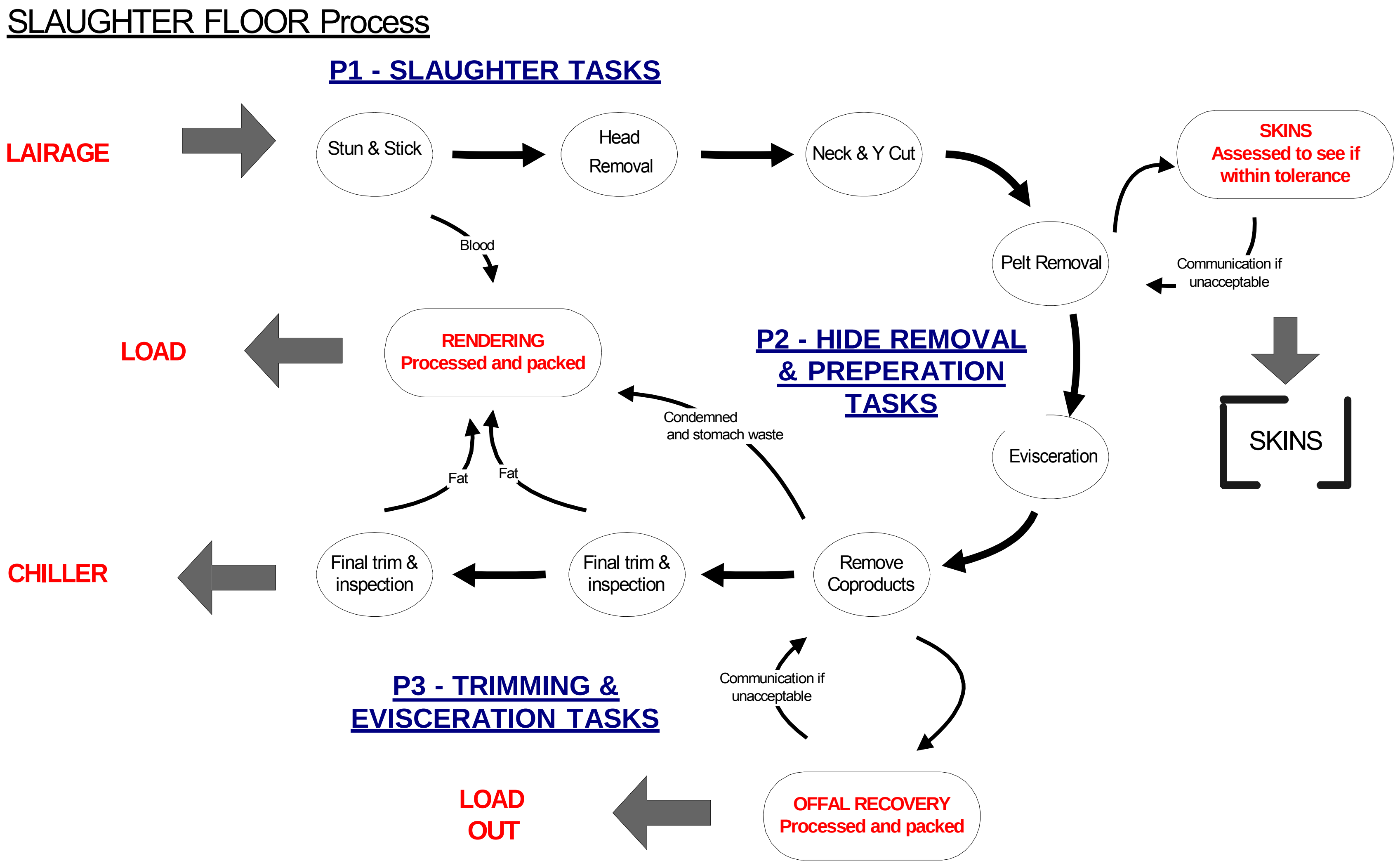
Vanderspek, P., (1993) 'Planning for factory automation' McGraw-Hill, Inc, pp 90-91

8 APPENDICES

8.1 Appendix 1: Function of an Australian sheep processing plant



8.2 Appendix 2: General process map of a slaughter floor



8.3 Appendix 3: Top 25 meat processors (2003/04)

TOP 25 PROCESSORS

Figure 1 – *feedback's* top 25 red meat processors for 2004

Rank 2004	Rank 2003	Organisation	Throughput ETCW 2004 (a)	Throughput ETCW 2003	Kill share % 2004 (b)	No. plants operated in 2004	Turnover $ million (d)	Turnover $ million prev. yr (d)	Employee Nos.
1	1	[redacted]							
2	3	[redacted]							
3	2	[redacted]							
4	4	[redacted]							
5	5	[redacted]							
6	7	[redacted]							
7	8	[redacted]							
8	6	Fletcher International Exports Pty Ltd	74,000	84,450	2.8%	2	na	na	1,150
9	9	[redacted]							
10	14	[redacted]							
11	11	[redacted]							
12	10	[redacted]							
13	12	[redacted]							
14	-22	JSA Jackson & Son Pty Ltd	50,600	34,200	1.9%	2	$185	$165	580
15	13	[redacted]							
16	15	[redacted]							
17	17	[redacted]							
18	18	[redacted]							
-19	–	[redacted]							
-19	19	[redacted]							
21	21	[redacted]							
22	24	[redacted]							
23	16	[redacted]							
24	25	[redacted]							
25	–	Tatiara Meat Company Pty Ltd	31,800	na	1.2%	1	$189		470
		Combined Total of Top 25:	**2,050,634**		**76.3%**	**48**	**$6,815**		**20,604**

Notes:

a. Throughput based on estimated tonnes carcase weight (ETCW) processed at plants under common ownership or control at 31 December 2004.

b. Kill share based on estimated national production of beef, veal, mutton and lamb for 2004 of 2,685,926 MT carcase weight (Australian Bureau of Statistics figure).

c. See company profiles for end-of-financial year details. Most figures are preliminary results for 12 months ended June 2005.

d. Turnover figures are for the year ended 30 June 2005 unless otherwise noted.

e. Data not approved by company.

** comprises entire AMH operation

In: Stanbroke Beef Company Pty Ltd; Tatiara Meat Company Pty Ltd

Out: Queensland Beef Company Py Ltd; Valley Beef Pty Ltd

Data compiled by ProAnd Australia

Organisation	Details	Ideal Throughput ETCW	Model Throughput ETCW	Ave. Throughput (ccs/year)	Ave. Daily Throughput (ccs/day)	Ave. Throughput (ccs/shift)	Ave. Throughput (ccs/min)
Fletcher	2 plants Mutton	84450	50670	1689000	6729	3365	8.19
JSA Jackson & Son Pty Ltd	2 plants Lamb	50600	30360	1445714	5760	2880	7.01
TMC	1 plant Lamb	31800	31800	1514286	6033	3017	7.34
				= Model ETCW / (0.021 tonnes for lamb)	= Ave. Throughput / 251 working days	= Ave. daily throughput / 2 shifts per day	= Ave. throughput per shift / 411 minutes per shift

If the organisation had two plants then it was assumed 60% of the ETCW would be modelled.

8.4 Appendix 4: Description of manual task for inverted sheep dressing

8.4.1 Appendix 4.1 – Slaughter Task

TASK	TITLE	DESCRIPTION	COMMENTS	TASK REQUIRED (If not benefits)	PRECEDING TASK	STERILIS-ATION	HUMAN OPERATORS	CO/BY PRODUCTS
Task 1	Stun	The animal is electrically stunned behind the head to render unconsciousness		YES	-	NONE	1	NONE
Task 2	Stick	Whilst the animal is still unconscious the head is pulled back and the throat is cut in one motion according to HALAL rules		YES	T1	YES	1	NONE
Task 3	Immobilisation	Electricity is passed through the carcass to immobilise and allow the operator to attach a shackle		NO - prevent operator being kicked	T2	NONE	0	NONE
Task 4	Shackling	Places two shackle on the rear legs and raises to the rail	Often performed at the same time as sticking	YES	T2	NONE	1	NONE
Task 5	Bung plug	Insert plug into bung to prevent contents of intestines spilling and contaminating the carcass		YES	T4	NONE	1	NONE
Task 6	Bleed rail	The blood is allowed to drain from the throat of a carcass		YES	T2	NONE	0	NONE
Task 7	Stimulation	During or after bleeding electricity is passed through a carcass to fast track the aging process and increase quality of the product	Requires two legs to be fastened	NO - increases meat tenderness and quality	T2	NONE	0	NONE

8.4.2 Appendix 4.2 – Hide removal and preparation task

TASK	TITLE	DESCRIPTION	COMMENTS	TASK REQUIRED (If not benefits)	PRECEDING TASK	STERILIS-ATION	HUMAN OPERATORS	CO/BY PRODUCTS
Task 8	Fore leg spread	Lift front legs (forelegs) and place on rail to invert	Must occur prior to dressing procedure	YES	T6	NONE	1 to 3 = 1	NONE
Task 9	Y - cut	Open the hide by cutting a Y shape down the forelegs and neck	Rotating hand tool is used manually	YES	T8	YES	1 to 6 = 3	NONE
Task 10	Hide removal from forelegs	Remove hide from foreleg in preparation for hide removal	Cut hide while pulling the skin	YES	T9	YES	1 to 6 =2	NONE
Task 11	Sock cut	Cut loose hide at the top of the foreleg	Hid hangs down	YES	T10	YES	1	NONE
Task 12	Rod weasand	Insert weasand rod up throat and apply clip to prevent contamination		YES	T11	YES	1	Co: Weasand
Task 13	Mouthing	Manually count the number of teeth in the mouth and classify the meat by age	AusMeat guidelines	YES	T2	NONE	1	NONE
Task 14	Head removal	Remove head with mechanical hand tool and place on head rail		YES	T12, T13	YES	1	By: Head
Task 15	Fore hide removal	Pull hide down from forelegs onto shoulder	Preparation for hide removal	YES	T11	YES	1 to 2 = 2	NONE
Task 16	SteriVac	A steam vacuum cleaner is used over the carcass to remove undesirable matter	Grass seeds, dust and wool	NO - Less contamination of the carcass	T15	YES	1	NONE
Task 17	Rear hock removal	Remove rear hocks from carcass with mechanical hand tool	Removing before hide will result in less contamination	YES	T15	YES	1	By: Hocks

Appendix 4.2 continued (Hide removal and preparation)

TASK	TITLE	DESCRIPTION	COMMENTS	TASK REQUIRED (If not benefits)	PRECEDING TASK	STERILIS-ATION	HUMAN OPERATORS	CO/BY PRODUCTS
Task 18	Brisket hide opening cut	Cut a strip of hide from center of the brisket		YES	T17	YES	1	By: Strip of hide
Task 19	Punch down	Punch hide with fists around the shoulder	Allows hide to be easily removed	YES	T18	YES	2 to 4 =2	NONE
Task 20	Hide removal	Remove hid from back then machine performs final removal of hide	Often performed with pulling machine	YES	T19	NONE	0 to 2 =2	By: Hide
Task 21	Clip Pissel	Clip pissel to stop contamination		NO - Less contamination of the carcass	T20	YES	1	By: Pissel

8.4.3 Appendix 4.3 – Trimming an Evisceration Task

TASK	TITLE	DESCRIPTION	COMMENTS	TASK REQUIRED (If not benefits)	PRECEDING TASK	STERILIS-ATION	HUMAN OPERATORS	CO/BY PRODUCTS
Task 22	Rear leg tipping	Remove tip of leg which still has wool attached		YES	T20	YES	1 to 2 =1	By: Tip of leg
Task 23	Gambrel / Re - Invert	Attach both rear legs to gambrel and rail	Carcass hangs from forelegs and rear legs on rail	YES	T22	NONE	1	NONE
Task 24	Fore hock removal	Remove fore hocks so carcass is hanging by rear legs		YES	T23	YES	1	By: Hocks
Task 25	Bung clearer	Cut around bung area and push inside carcass		YES	T21	YES	1	NONE
Task 26	Evisceration (Green offal removal)	Cut an opening down the center of the belly and remove offal	Required to place offal in relevant tray	YES	T25	YES	1 to 2 =1	Co: Edible offal, By: Inedible offal
Task 27	Brisket scissors	Cut/splits open the brisket using a large mechanical scissor whilst avoiding internal organs		YES	T26	YES	1	NONE
Task 28	Pluck removal	Remove the pluck and place in offal tray		YES	T27	YES	1	Co: Pluck
Task 29	Kidney enucleation	Cut the first layer of fat to expose kidneys	Check kidney for disease	YES	T28	YES	1	NONE
Task 30	Carcass inspection	Operator checks carcass inside and out for disease or contamination		YES	T29	NONE	1	NONE
Task 31	Kidney removal	Remove and peels kidneys and place in tray		YES	T30	NONE	1	Co: Kidneys

Appendix 4.3 continued (Trimming and evisceration task)

TASK	TITLE	DESCRIPTION	COMMENTS	TASK REQUIRED (If not benefits)	PRECEDING TASK	STERILIS-ATION	HUMAN OPERATORS	CO/BY PRODUCTS
Task 32	Trim carcass	Remove any excess fat from carcass	Inside, forequarter and hind quarter	NO - Better product at end of day	T31	NONE	1	Co: Fat
Task 33	Wash Carcass	Wash carcass inside and out with water	Removes blood, wool and dust	NO - Better product at end of day	T32	NONE	1	NONE
Task 34	String carcass	Thread and tie string through rear hocks	Keep rear legs together in chiller	NO - Easier to bone	T33	NONE	1	NONE
Task 35	Weighing and tagging	Measure and record fat content of carcass	Can tag and sort prior to chilling	NO - Faster to bone	T34	NONE	1	NONE

8.5 Appendix 5: Task automation and robotics

8.5.1 Appendix 5.1 – Slaughter Task

TASK	AUTOMATION CURRENTLY AVAILABLE	DEVELOPMENT TITLE	FEATURES	SUMMARY OF PERFORMANCE	POSSIBLE AUTOMATION APPLICABLE	CONCEPT	TASK REPLACED	COMMENTS
Task 1	NONE				(PIG) Automation sticking and bung dropping system	#1 Immobilises the animal by restraining (V) and electrically stunning. #2 Stretches neck and a pneumatic rotating knife locates neck above sternum. #3 Knife penetrates hide and enters the thoracic cavity severing the brachiocephalic trunk. #4 Bleeding occurs through neck and is collected. #5 Machine locates bung and places clip. #6 Release carcass	T1, T2, T5	Need to investigate HALAL/Ritual sticking
Task 2	YES	Future PIP.070 - The sticking wound neck wash (Brooks Contract)	Automatic sticks animal	-				
Task 3	YES							
Task 4	NA							
Task 5	NA				(PIG) Automatic bung dropper	#1 Locates and cuts around intestine. #2 Seals tube by clamping or burning.		Stops spreading fecal matter
Task 6	NA							
Task 7	YES	Sheep electrical stimulation	Constant (no trigger required)	Improves quality of meat				

8.5.2 Appendix 5.2 – Hide Removal and Preparation Task

TASK	AUTO-MATION CURRENTLY AVAILABLE	DEVELOPMENT TITLE	FEATURES	SUMMARY OF PERFORMANCE	POSSIBLE AUTOMATION APPLICABLE	CONCEPT	TASK REPLACED	COMMENTS
Task 8	NONE							
Task 9	YES	Automated Y-Cutter KUKA ROBOT	Reliability throughout the cutting process - tracking and sensing determines where to insert the blade and cut	Improves accuracy and consistency, reduced processing cost, minimises contamination, reduced injury claims reduced downtime - minimal maintenance N.B. 11 ccs/min				
Task 10	NA							
Task 11	NA							
Task 12	NA							
Task 13	NONE				Scanner to distinguishing lamb from hogget	#1 Robot automatically locates head. #2 Opens jaw and uses X-ray. #3 Logical thinking. #4 Approves	T13	May require tracking of carcass through process (TAG)
Task 14	NONE				Automated head removal	#1 Locates and secures (clamps) head. #2 Hydraulic tool severs neck. #3 Heads drops to a conveyor		Task maybe required to be performed after hide removal to stop contamination
Task 15	NA							
Task 16	NONE							
Task 17	NONE				Automatic hock removal	#1 Locate and secure leg. #2 Hydraulic tool grips and severe hock. #3 Hock drops to conveyor	T17	To increase speed have two cutting tools
Task 18	YES	Automated small stock brisket hide opening		-				

Appendix 5.2 continued (Hide removal and preparation)

TASK	AUTOMATION CURRENTLY AVAILABLE	DEVELOPMENT TITLE	FEATURES	SUMMARY OF PERFORMANCE	POSSIBLE AUTOMATION APPLICABLE	CONCEPT	TASK REPLACED	COMMENTS
Task 19	NA							
Task 20	YES	Pelt-O-Matic	SS, fully wash down, moves with chain thus suits all speeds, compact, work with conventional and inverted dressing	Reduced labour (replaces # 1 - requires 1 to place free end in machine), improved yield, reduced injury claims	MIRINZ two-stage automated depelting machine	#1 Removes pelt from shoulder and back region. #2 Final puller to completely remove hide.	T19, T20	Just as good as traditional system
Task 21	NA							

8.5.3 Appendix 5.3 – Trimming and Evisceration Task

TASK	AUTOMATION CURRENTLY AVAILABLE	DEVELOPMENT TITLE	FEATURES	SUMMARY OF PERFORMANCE	POSSIBLE AUTOMATION APPLICABLE	CONCEPT	TASK REPLACED	COMMENTS
Task 22	NONE							
Task 23	NONE							
Task 24	NONE				Automatic hock removal	#1 Locate and secure leg. #2 Hydraulic tool grips and severe hock. #3 Hock drops to conveyor	T24	Same as T17
Task 25	NA							
Task 26	NONE				Automated evisceration and brisket cutter	#1 Brisket cutter opens belly area. #2 Cuts brisket. #3 Extendable arm reaches in with pressure sensor and locates spine. #4 A Paddle attached to the arm follows down the spine. #5 Viscera falls on to table (removes complete gut set).	T26, T27	Will require manual sorting of green and red offal
Task 27	YES	Automated brisket shear	Uses 3D modeling laser camera for exact measureme nt of carcass (prototype)	Reduce internal organ puncture, isolates personnel from dangerous equipment, reduced labour (replaces # 1 - requires 0), accurate				
Task 28	NONE							
Task 29	NONE							
Task 30	NONE							
Task 31	NA							
Task 32	NA							
Task 33	NONE							
Task 34	NONE							
Task 35	NONE							

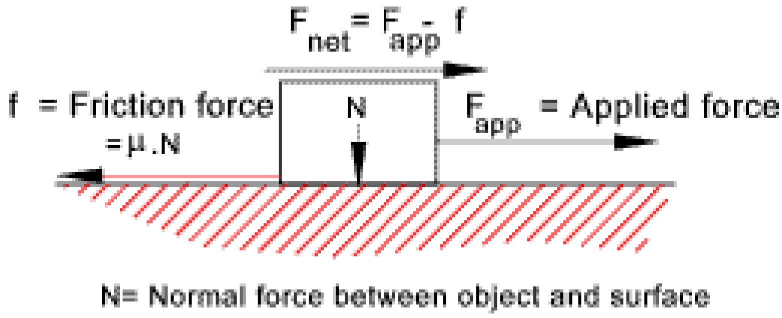
8.6 Appendix 6 : MODAPTS calculations for individual task

The following information was used according to Heyde's MODAPTS a language of work guidelines, (Carey, Farrel, et.al, 2004).

Table 19 - Description of MODAPTS used to calculate times (Carey, Farrel, et.al, 2004)

MODAPTS type	Description
Gaining Control of something	
G0	Grab with no sense
G1	Clench fist or grasp handle
G4	Two handed get
P0	Place in general location
P2	Place with tidiness
P10	Place heavy article in exact location using two hands
Finger / Hand / Arm Movements	
M1	Finger movement
M2	Hand movement
M3	Forearm general use
M4	Full arm forward from shoulder
M5	Full arm outward from shoulder
M7	Body trunk move
M9	Body trunk and feet move (feet cross)
Body Movement	
W5	Walk 1 pace
W10	Walk 2 Paces
W15	Walk 3 paces
X4	Extra force
Load Factor	
L1	Proportional to load and finger or hand movement
Mental Operations	
D3	Simple binary decision
E2	Eye travel up and down or left to right (30°)
E4	Turn and focus
E2R2	Get or put with feedback
Use Tool	
U3	Arm movement associated with tool use

Calculation of the load force required to push the carcass on the stimulation table was required to calculate the MODAPTS time for task 2. The limit was found to be within the acceptable load limit (L1) thus the appropriate MODAPTS unit could be applied.



$$\sum F_{net} = (F_{app} - f) = (F_{app} - \mu N) = ma$$

$$Static \quad \Rightarrow \quad a = 0$$

$$F_{app} = \mu N = \mu(mg)$$

$$Assume \quad \mu = 0.2 \rightarrow 0.6 \qquad i.e.\ wood\ on\ metal$$
$$mass\ of\ sheep = 25kg$$

$$F_{app} = (0.3)(25kg)(9.81m/s^2)$$
$$F_{app} = 73.57N \approx \quad lifting \quad 8kg$$

8.6.1 Appendix 6.1 – Slaughter Task

TASK	OPERATOR MOVEMENT	CORRESPONDING MOD UNITS	MODS IN PARALLEL	SUM OF MOD UNITS	MODAPT ESTIMATED TIME TO PERFORM TASK (sec)	OTHER ALLOWANCE (%)	REST ALLOWANCE (%)	STANDARD TIME PER UNIT (sec)
Task 1	Focus on position of sheep	E1	1	24	3.096	20	5	3.87
	Turn head to confirm proceeding	E1	1					
	Focus back to sheep	E1	1					
	Lunge forward from waste							
	Place hand stunner behind ears and press trigger	M7P2	7					
	Push button with left hand and return	M3G1, X4	7					
	Return	M7P0	7					
	Pause							
Task 2	Sterilise blade	M5G0	5	48	6.192	20	15	8.36
	Wait							
	1 pace to left and pull sheep sideways (Twist body with LH on head, RH on back)	W5, M7G1, M7P2	19					
	Grab and pull back head (LH)	M3P2, X4	7					
	Position right hand below neck	M3P2	3					
	Lift blade through neck	U3	3					
	Push carcass	M3G1, M3G0	6					
	Return	W5	5					
	Pause							
Task 4	Locate and grab shackle	E4, M5G1, M5P2	14	53	6.837	20	15	9.23
	Wait for sheep							
	Bend and attach shackle	W5, E4, M7P2	16					
	Lift shackle to chain rail (50cm)	M7P2, M7G0	14					
	Return and rest	W5, E4	9					
Task 5	Not Assessed							

8.6.2 Appendix 6.2 – Hide Removal and Preparation Task

TASK	OPERATOR MOVEMENT	CORRESPONDING MOD UNITS	MODS IN PARALLEL	SUM OF MOD UNITS	MODAPT ESTIMATED TIME TO PERFORM TASK (sec)	OTHER ALLOWANCE (%)	REST ALLOWANCE (%)	STANDARD TIME PER UNIT (sec)
Task 8	Wait for hooks to move			47	6.063	20	20	8.49
	2 pace and bend down							
	Grab two front feet with both hands	W15, M7G4	22					
	Pull and lift carcass to roatate (8kg)							
	Look and position feet on shakles	W10, M7P10	20					
	Return	W5	5					
	Wait							
Task 9	2 paces in and cut strip down neck	W10, M5G1, M5G0	20	103	13.287	20	10	17.27
	Locate and pull hid	M4G1, M4G0	8					
	LEFT - Cut down neck (30cm) i.e. shoulder to head	M5P2, U3, M5P0	13					
	LEFT - Cut up leg (30cm) i.e. shoulder to foot	M5P2, U3, M5P0	13					
	Reposition							
	RIGHT - Cut down neck (30cm) i.e. shoulder to head	M5P2, U3, M5P0	13					
	RIGHT - Cut up leg (30cm) i.e. shoulder to foot	M5P2, U3, M5P0	13					
	Reposition							
	Trim waste hide	M5P2, U3, M5P0	13					
	Step back and sharpen knife, rest	W10	10					
Task 10	1 pace to right and body trunk move and sterilise	W5, M7G2	12	59	7.611	20	10	9.89
	Return	M7P0, W5	12					
	Lift both arms, hold and position tool (Right)	M5G1, M5P2	10					
	Push tool and pull skin up right leg	M5P2M5P0	5					
	Re-position	M5G1, M5P2	10					
	Push tool and pull skin from chest to left leg	M5P2M5P2	5					
	Position back	M5P0	5					

Appendix 6.2 continued (Hide removal and preparation)

TASK	OPERATOR MOVEMENT	CORRESPONDING MOD UNITS	MODS IN PARALLEL	SUM OF MOD UNITS	MODAPT ESTIMATED TIME TO PERFORM TASK (sec)	OTHER ALLOWANCE (%)	REST ALLOWANCE (%)	STANDARD TIME PER UNIT (sec)
Task 11	1 pace to right and body trunk move and sterilise	W5, M7G2	12	50	6.45	20	5	8.06
	Return	M7P0, W5	12					
	Step in, look, lift both arms, grab and position blade (Right)	W5, M5G1M5P2	10					
	Slide blade across (slice)	U3	3					
	Grab and position blade (Left) then slice	M5G1M5P2, U3	8					
	Position back	M5P0	5					
Task 12	Not Assessed							
Task 13	Wait for carcass			42	5.418	20	5	6.77
	Bend down and loacate head	M7G4	7					
	Force open mouth	M4P0	4					
	Locate and count teeth	E2R2, M4P0	6					
	Return	M7P0, D3	10					
	Think and tag if not accepted	W5, M5P2, M5P0	15					
Task 14	1 pace to right and body trunk move	W5, M7G2	12	49	6.321	20	5	7.90
	Grab hand tool from steriliser							
	Return	M7P0, W5	12					
	1 pace forward, look and position tool on neck above head	W5, M7P2	12					
	Pull trigger	M1G1	1					
	Return	M7P0, W5	12					
Task 15	Step in, grab with both hands	W5, M5G1	10	62	7.998	20	10	10.40
	Pull out and down (left)	M5P0	5					
	Use blade and pull down	M5G1, M5P2, M5P0	15					
	Twist then pull out and down	M7G1, M5P0	12					
		M5G1, M5P2, M5P0	15					
	Step out	W5	5					

Appendix 6.2 continued (Hide removal and preparation)

TASK	OPERATOR MOVEMENT	CORRESPONDING MOD UNITS	MODS IN PARALLEL	SUM OF MOD UNITS	MODAPT ESTIMATED TIME TO PERFORM TASK (sec)	OTHER ALLOWANCE (%)	REST ALLOWANCE (%)	STANDARD TIME PER UNIT (sec)
Task 16	1 pace to right and trunk move to place vacuum in steriliser	W5, M5P2	10	58	7.482	20	5	9.35
	Return	M5P0	5					
	1 step in and lift vacuum	W5, M5P2	10					
	Look, focus and move down	E4, M5P2	9					
	Lift, look, focus and move down	M5P0, E4, M5P2	14					
	Return	M5P0, W5	10					
Task 17	Grab hand tool from steriliser	W5, M5G2	10	39	5.031	20	5	6.29
	Return	M5P0	5					
	Look, bend and grab sheeps legs with left hand	E4, M5G1	11					
	Hold carcass steady							
	Locate, twist and bring tool into position at knuckles	E2, M5P2, M3G1	8					
	Hold carcass and pull trigger							
	Twist back to steriliser and through away feet	M5P0	5					
Task 18	1 pace to right and body trunk move and sterilise	W5, M7G2	12	45	5.805	20	10	7.55
	Return	M7P0, W5	12					
	Step in, look, lift arm and position blade	W5, M5P2	10					
	Pull down guiding the blade	U3, U3L1	6					
	Position back	M5P0	5					
Task 19	1 pace to right and trunk move to sterilise	W5, M7G0	12	69	8.901	20	20	12.46
	Return	M7P0, W5	12					
	Step in and lift arm, clench fist	W5, M5G1	10					
	Look, place arm and push down with force	M7P2, L1	8					
	Lift, look and move down	M7P2, M7P2, L1	15					
	Lift and step out	M7P0, W5	12					

Appendix 6.2 continued (Hide removal and preparation)

TASK	OPERATOR MOVEMENT	CORRESPONDING MOD UNITS	MODS IN PARALLEL	SUM OF MOD UNITS	MODAPT ESTIMATED TIME TO PERFORM TASK (sec)	OTHER ALLOWANCE (%)	REST ALLOWANCE (%)	STANDARD TIME PER UNIT (sec)
Task 20	2 paces forward	W10	10	68	8.772	20	20	12.28
	Look and grab top of hid either side	E4, M5G4	9					
	Lunge back 3 paces and pull down	M7P0, W15, M7P0	29					
	1 pace forward and reef down	W5, M5P0	10					
	Let go and step back 1 pace	G0, M5P0, W5	10					
	Rest and wait							
Task 21	1 pace to right and body trunk move and sterilise	W5, M7G2	12	42	5.418	20	5	6.77
	Return	M7P0, W5	12					
	Step in, look, lift arm and position blade	W5, M5P2	10					
	Pull down guiding the blade	U3	3					
	Position back	M5P0	5					

8.6.3 Appendix 6.3 – Trimming and Evisceration Task

TASK	OPERATOR MOVEMENT	CORRESPONDING MOD UNITS	MODS IN PARALLEL	SUM OF MOD UNITS	MODAPT ESTIMATED TIME TO PERFORM TASK (sec)	OTHER ALLOWANCE (%)	REST ALLOWANCE (%)	STANDARD TIME PER UNIT (sec)
Task 22	1 pace, sterilise and return	W5, M5P2, M5P0, W5	20	32	4.128	20	5	5.16
	Position tool and pull trigger	M5P2, M1G1	6					
	Re-position tool and pull trigger	M7P0, M5P2, M1G1	6					
	Position back	M7P0						
Task 23	Locate and grab gambrel	W5, M5G1, M5P0	15	46	5.934	20	10	7.71
	Left hand grabs leg then right inserts gambrel (right)	M5G1, M5P2	10					
	Left hand grabs leg then right inserts gambrel (left)	M5G1, M5P2	10					
	Lift gambrel to rail	M5P2, L1	6					
	Return	M5P0	5					
Task 24	1 pace to right and body trunk move and sterilise	W5, M7G2	12	57	7.353	20	5	9.19
	Return	M7P0, W5	12					
	1 pace forward, position tool and pull trigger	W5, M7P2, M1G1	13					
	Re-position tool and pull trigger	M7P2, M1G1	8					
	Return	M7P0, W5	12					
Task 25	Not Assessed							
Task 26	1 pace to right and trunk move to sterilise blade with right hand from steriliser	W5, M7G0	12	42	5.418	20	5	6.77
	Return	M7P0, W5	12					
	Step in Look lift arm and position blade	W5, M5P2	10					
	Pull down guiding the blade	U3	3					
	Position back	M5P0	5					

Appendix 6.3 continued (Trimming and evisceration task)

TASK	OPERATOR MOVEMENT	CORRESPONDING MOD UNITS	MODS IN PARALLEL	SUM OF MOD UNITS	MODAPT ESTIMATED TIME TO PERFORM TASK (sec)	OTHER ALLOWANCE (%)	REST ALLOWANCE (%)	STANDARD TIME PER UNIT (sec)
Task 27	1 pace to right and trunk move to grab hand tool with right hand from steriliser	W5, M7G3	12	43	5.547	20	10	7.21
	Return	M7P0, W5	12					
	Look, turn and focus, left hand reaches, grasp and pulls to hold carcass in position	E4, M5G0	9					
	Right hand position tool	M4P2	4					
	Pull lever (grasp) - simple closing of finger	M1G1	1					
	Position back	M5G0	5					
Task 28	Not Assessed							
Task 29	Not Assessed							
Task 30	Not Assessed							
Task 31	Not Assessed							
Task 32	Not Assessed							
Task 33	Not Assessed							
Task 34	Not Assessed							
Task 35	Not Assessed							

8.7 Appendix 7:MODAPTS time versus Stop Watch time for individual task

TASK	OPERATORS (No.)	MODAPT ESTIMATED TIME TO PERFORM TASK (sec)	STOP WATCH TIME TO PERFORM TASK (sec)	DIFFERENCE IN TIME (%)	Fudge Factor	Weighted time to be within 20% of stopwatch
Task 1	1	3.87	6.72	-42%	-39%	5.38
Task 2	1	8.36	8.61	-3%	-	-
Task 3	0	NA	NA	NA	NA	NA
Task 4	1	9.23	8.87	4%	-	-
Task 5	1	-	-	-	-	-
Task 6	0	NA	NA	NA	NA	NA
Task 7	0	NA	NA	NA	NA	NA
Task 8	1	8.49	5.86	45%	17%	7.03
Task 9	3	17.27	11.23	54%	22%	13.48
Task 10	2	9.89	5.7	74%	31%	6.84
Task 11	1	8.06	6.29	28%	6%	7.55
Task 12	1	-	-	-	-	-
Task 13	1	6.77	-	-	-	-
Task 14	1	7.9	-	-	-	-
Task 15	2	10.04	10.95	-8%	-	-
Task 16	1	9.35	-	-	-	-
Task 17	1	6.29	6.36	-1%	-	-
Task 18	1	7.55	7.2	5%	-	-
Task 19	2	12.46	6.5	92%	37%	7.80
Task 20	2	12.28	9.36	31%	9%	11.23
Task 21	1	6.77	4.5	50%	20%	5.40
Task 22	1	5.16	-	-	-	-
Task 23	1	7.71	6.13	26%	5%	7.36
Task 24	1	9.19	-	-	-	-
Task 25	1	-	-	-	-	-
Task 26	1	6.77	-	-	-	-
Task 27	1	7.21	9.57	-25%	-6%	7.66
Task 28	1	-	-	-	-	-
Task 29	1	-	-	-	-	-
Task 30	1	-	-	-	-	-
Task 31	1	-	-	-	-	-
Task 32	1	-	-	-	-	-
Task 33	1	-	-	-	-	-
Task 34	1	-	-	-	-	-
Task 35	1	-	-	-	-	-

8.8 Appendix 8: Degree of Comfort and Safety of manual task for inverted sheep dressing

8.8.1 Appendix 8.1 – Slaughter Task

TASK	OPERATORS (No.)	POSTURE ISSUE	MANUAL HANDLING	REPETITIVE STRAIN	LACERATIONS	OTHER	OH&S RISK (5 = high 1 = low)	COMMENTS	DEGREE OF EMPLOYEE COMFORT	DEGREE OF EMPLOYEE SAFETY
Task 1	1	1	0	1	0	1	3		5.8	5.5
Task 2	1	1	0	0	1	0	2		3	5.5
Task 3	0	-	-	-	-	1	1	Large electricity - requires guard	#VALUE!	#VALUE!
Task 4	1	1	1	0	0	1	3	Moderate force required to lift carcass	4.8	4.5
Task 5	1	1	0	0	0	0	1	Bending required depending on height	1	0.5
Task 6	0	-	-	-	-	-	0	-	#VALUE!	#VALUE!
Task 7	0	-	-	-	-	1	1	Large electricity - requires guard	#VALUE!	#VALUE!

8.8.2 Appendix 8.2 – Hide Removal and Preparation Task

TASK	OPERATORS (No.)	POSTURE ISSUE	MANUAL HANDLING	REPETITIVE STRAIN	LACERATIONS	OTHER	OH&S RISK (5 = high 1 = low)	COMMENTS	DEGREE OF EMPLOYEE COMFORT	DEGREE OF EMPLOYEE SAFETY
Task 8	1	1	1	0	0	0	2	Operator is required to bend and lift above shoulder height	4	1.5
Task 9	3	1	0	1	1	0	3	Risk of being cut on the hand	7	7.5
Task 10	2	1	1	1	1	0	4	Risk of being cut on the hands and arms	10	8.5
Task 11	1	1	0	0	1	0	2	Low risk of cutting hand	3	5.5
Task 12	1	1	0	1	0	0	2	Shoulder and forearm pain	5	2.5
Task 13	1	1	0	0	0	0	1		1	0.5
Task 14	1	1	1	1	1	0	4	Repetitive strain that depends on speed	10	8.5
Task 15	2	1	1	0	0	0	2	The hide can be difficult to pull	4	1.5
Task 16	1	1	1	0	0	0	2		4	1.5
Task 17	1	1	0	0	1	0	2	Risk of amputation	3	5.5
Task 18	1	1	0	0	1	0	2		3	5.5
Task 19	2	1	1	0	0	0	2	Moderate force is required	4	1.5
Task 20	2	-	-	-	-	-	0		#VALUE!	#VALUE!
Task 21	1	1	0	0	0	0	1		1	0.5

8.8.3 Appendix 8.3 – Trimming and Evisceration Task

TASK	OPERATORS (No.)	POSTURE ISSUE	MANUAL HANDLING	REPETITIVE STRAIN	LACERATIONS	OTHER	OH&S RISK (5 = high 1 = low)	COMMENTS	DEGREE OF EMPLOYEE COMFORT	DEGREE OF EMPLOYEE SAFETY
Task 22	1	1	0	0	1	0	2		3	5.5
Task 23	1	1	1	0	0	0	2	Operator required to bend and lift rear legs	4	1.5
Task 24	1	1	0	0	1	0	2	Use two handed cutters to prevent amputation	3	5.5
Task 25	1	1	0	0	1	0	2	Risk of cutting hand	3	5.5
Task 26	1	1	1	0	0	0	2		4	1.5
Task 27	1	1	1	0	1	0	3	Scissors need to be counter balanced to handle easier	6	6.5
Task 28	1	1	1	0	1	0	3		6	6.5
Task 29	1	1	1	0	1	0	3		6	6.5
Task 30	1	1	0	0	0	0	1		1	0.5
Task 31	1	1	1	0	0	0	2		4	1.5
Task 32	1	1	0	0	1	0	2	Risk of cutting hand	3	5.5
Task 33	1	1	0	0	0	1	2	Risk of slipping	1.8	3.5
Task 34	1	1	0	0	0	0	1		1	0.5
Task 35	1	1	0	0	0	0	1		1	0.5

8.8.4 Appendix 8.4 – Summary of ergonomic levels for Alternative Layout 1 & 2

	NO AUTOMATION			ALTERNATIVE 1			ALTERNATIVE 2		
TASK	Comfort	Safety	Total	Comfort	Safety	Total	Comfort	Safety	Total
Task 1	58%	65%	123%						
Task 2	30%	65%	95%						
Task 4	48%	53%	101%	48%	53%	101%			
Task 5	10%	6%	16%	10%	6%	16%	10%	6%	16%
Task 8	40%	18%	58%	40%	18%	58%			
Task 9	70%	88%	158%						
Task 10	100%	100%	200%	100%	100%	200%	100%	100%	200%
Task 11	30%	65%	95%	30%	65%	95%	30%	65%	95%
Task 12	50%	29%	79%	50%	29%	79%	50%	29%	79%
Task 13	10%	6%	16%	10%	6%	16%			
Task 14	100%	100%	200%						
Task 15	40%	18%	58%	40%	18%	58%			
Task 16	40%	18%	58%	40%	18%	58%			
Task 17	30%	65%	95%	30%	65%	95%			
Task 18	30%	65%	95%	30%	65%	95%	30%	65%	95%
Task 19	40%	18%	58%	40%	18%	58%	40%	18%	58%
Task 21	10%	6%	16%	10%	6%	16%	10%	6%	16%
Task 22	30%	65%	95%	30%	65%	95%	30%	65%	95%
Task 23	40%	18%	58%	40%	18%	58%			
Task 24	30%	65%	95%						
Task 25	30%	65%	95%	30%	65%	95%	30%	65%	95%
Task 26	40%	18%	58%						
Task 27	60%	76%	136%						
Task 28	60%	76%	136%	60%	76%	136%	60%	76%	136%
Task 29	60%	76%	136%	60%	76%	136%	60%	76%	136%
Task 30	10%	6%	16%	10%	6%	16%	10%	6%	16%
Task 31	40%	18%	58%	40%	18%	58%	40%	18%	58%
Task 32	30%	65%	95%	30%	65%	95%	30%	65%	95%
Task 33	18%	41%	59%	18%	41%	59%	18%	41%	59%
Task 34	10%	6%	16%	10%	6%	16%	10%	6%	16%
Task 35	10%	6%	16%	10%	6%	16%	10%	6%	16%
Sum			25.86			17.22			12.8
Ave.	39%	45%	83%	34%	38%	72%	33%	42%	75%
St. Dev.	23%	31%	51%	21%	30%	46%	24%	32%	52%
Max.	100%	100%	200%	100%	100%	200%	100%	100%	200%

8.9 Appendix 9 : KR 60 Automated task calculation times

Below is a summary of the equivalent automation times to the MODAPTS unit.

Table 20 - Equivalent automation times per movement

MODAPT type	Description	Corresponding robot movement time (sec)	Automation MODAPT code
Gaining Control of something			
G0	Grab with no sense	-	
G1	Clench fist or grasp handle	-	
G4	Two handed get	-	
P0	Place in general location	-	
P2	Place with tidiness	-	
P10	Place heavy article in exact location using two hands	-	
Finger / Hand / Arm Movements			
M1	Finger movement	0.12	A_M1
M2	Hand movement	0.12	A_M2
M3	Forearm general use	0.195	A_M3
M4	Full arm forward from shoulder	0.353	A_M4
M5	Full arm outward from shoulder	0.353	A_M5
M7	Body trunk move	0.686	A_M7
M9	Body trunk and feet move (feet cross)	0.686	A_M9
Body Movement			
W5	Walk 1 pace	0.297	A_W5
W10	Walk 2 Paces	0.594	A_W10
W15	Walk 3 paces	0.891	A_W15
X4	Extra force	N/A	
Load Factor			
L1	Proportional to load and finger or hand movement	N/A	
Mental Operations			
D3	Simple binary decision	0.1	A_D3
E2	Eye travel up and down or left to right (30°)	0.1	A_E2
E4	Turn and focus	0.1	A_E4
E2R2	Get or put with feedback	N/A	
Use Tool			
U3	Arm movement associated with tool use	1	A_U3

8.9.1 Appendix 9.1 – Slaughter Task

TASK	EQUIVALENT AUTOMATED MOVEMENT	TIME PER MOVEMENT	SUM OF MOVEMENT	FUDGE FACTOR for weighted modapt human times	WEIGHTED AUTO TIMES KR60
Task 1	A_E2 A_M7 A_M3 A_M7	0.1 0.686 0.195 0.686	1.67	25%	2.09
Task 2	Sensing A_M5 A_W5, A_M7, A_M7 A_M3, A_M3 A_U3 A_M3, A_M3 A_W5	1 0.353 1.669 0.390 1 0.390 0.297	5.1	25%	6.37
Task 4	Sensing A_M5 A_W5, A_E4, A_M7 A_M7, A_M7 A_W5, A_E4	1 0.353 1.083 1.372 0.397	4.205	25%	5.26
Task 5	Not Assessed				

8.9.2 Appendix 9.2 – Hide Removal and Preparation Task

TASK	EQUIVALENT AUTOMATED MOVEMENT	TIME PER MOVEMENT	SUM OF MOVEMENT	FUDGE FACTOR	WEIGHTED AUTO TIMES KR60
Task 8	Sterilise/sensing	1	4.154	25%	5.19
	A_W15, A_M7	1.577			
	A_W10, A_M7	1.28			
	A_W5	0.297			
Task 9	Left side			25%	18.53
	Sterilise/sensing	1	5.659		
	A_W10, A_M5, A_M5	1.3			
	A_M4, A_M4	0.706			
	A_U3	0.5			
	A_M5, A_M5	0.706			
	A_U3	0.5			
	A_M5	0.353			
	A_W10	0.594			
	Right side				
	Sterilise/sensing	1	5.659		
	A_W10, A_M5, A_M5	1.3			
	A_M4, A_M4	0.706			
	A_U3	0.5			
	A_M5, A_M5	0.706			
	A_U3	0.5			
	A_M5	0.353			
	A_W10	0.594			
	Clean up				
	Sterilise/sensing	1	3.506		
	A_M4, A_M4	0.706			
	A_M5, A_U3, A_M5, A_W10	1.8			
Task 13	A_M7	0.686	3.28	25%	4.1
	A_M4	0.353			
	A_E2, A_M4	0.453			
	A_M7, A_D3	0.786			
	A_W5, A_M5, A_M5	1.00			
Task 14	Sterilise/sensing	1	5.932	25%	7.42
	A_W5, A_M7	0.983			
	A_M7, A_W5	0.983			
	A_W5, A_M7	0.983			
	Perform task	1			
	A_M7, A_W5	0.983			
Task 15	A_W5, A_M5	0.65	4.457	25%	5.57
	A_M5	0.353			
	A_M5, A_M5, A_M5	1.059			
	A_M7, A_M5, A_M5, A_M5, A_M5	2.098			
	A_W5	0.297			

Appendix 9.2 continued (Hide removal and preparation)

TASK	EQUIVALENT AUTOMATED MOVEMENT	TIME PER MOVEMENT	SUM OF MOVEMENT	FUDGE FACTOR	WEIGHTED AUTO TIMES KR60
Task 16	Sterilise/sensing A_W5, A_M5 A_M5 A_W5, A_M5 A_E4, A_M5 A_M5, A_E4, A_M5 A_M5, A_W5	1 0.65 0.353 0.65 0.453 0.806 0.65	4.562	25%	5.70
Task 17	Sterilise/sensing A_W5, A_M5 A_M5 A_E4, A_M5 Perform task A_E2, A_M5, A_M3 A_M5	1 0.65 0.353 0.453 1 0.648 0.353	4.457	25%	5.57
Task 20	A_W10 A_E4, A_M5 A_M7, A_W15, A_M7 A_W5, A_M5 A_M5, A_W5	0.594 0.453 2.263 0.65 0.65	4.61	25%	5.76

8.9.3 Appendix 9.3 – Trimming and Evisceration Task

TASK	EQUIVALENT AUTOMATED MOVEMENT	TIME PER MOVEMENT	SUM OF MOVEMENT	FUDGE FACTOR for weighted modapt human times	WEIGHTED AUTO TIMES KR60
Task 23	A_W5, A_M5, A_M5, A_W5 A_M5, A_M1 A_M7, A_M5 A_M1 A_M7	1.3 0.473 1.039 0.12 0.686	3.618	25%	4.52
Task 24	Sterilise/sensing A_W5, A_M7 A_M7, A_W5 A_W5, A_M7, A_M1 A_M7, A_M1 Perform task A_M7, A_W5	1 0.983 0.983 1.1 0.806 1 0.983	6.855	25%	8.57
Task 26	Sterilise/sensing A_W5, A_M7 A_M7, A_W5 A_W5, A_M5 A_U3 A_M5	1 0.983 0.983 0.65 1 0.353	4.969	25%	6.21
Task 27	Sterilise/sensing A_W5, A_M7 A_M7, A_W5 A_E4, A_M5 A_M4 Perform Task A_M5	1 0.983 0.983 0.453 0.353 1 0.353	5.125	25%	6.41

8.10 Appendix 10: Competitive Forces

The competitive force restricting an increase in future performance is listed below:

- Internal efficiency
  - Cut corners – The industry lacks good professional engineers, many abattoirs adapt within their own company and employ people that have worked on the floor and are committed to the company. This means that there are less educated people moving up the food chain and making decisions. Some decisions led to cutting corners and tend to be the cheaper option. This effects efficiency of performance.
  - Maintenance issues – An abattoir creates a demanding and volatile atmosphere for machinery that requires a repetitive maintenance schedule. The culture suggests the workforce just focuses on trying to get through that specific day and this leads to frequent down time during production, thus effecting overall performance and efficiency.
- External and environmental
  - Technology barrier – The industry has a barrier restricting the application of automation and robots to perform tasks. The reason for this comes down to how every animal is different. Variation in the product being manufactured requires technology to sense, think and act. This technology is just starting to be built and trialled.
  - Process requirements – The process used in many abattoirs has been engineered and can not be shuffled around to increase productivity. The reason is because of the requirements to access certain parts of the animal.
- Human and stock related
  - Lack of manual labour – The industry for the last few years have seen a considerable decrease in available and willing manual workers. At present they are training and importing casual workers from all around the world on 4 year visas. The workers from countries such as China, Fiji, Philippines and even New Zealand.
  - Ergonomic (OH&S) issues – An abattoir is thought to be high risk working area. Many of the tasks performed are either dangerous activities or in close proximity, require hard manual labour, long hours, and a poor working environment and culture. Many companies are starting to become aware of these issues and are increasing performance by tackling them.
  - Absenteeism – People not turning up to work becomes an issue when daily throughput was reduced because 5 people didn't show up without notification. The decrease in performance is caused by supervisors having to reposition certain employees where they are not most familiar or productive. Today this occurs on a regular basis in abattoirs around Australia up to 2 to 3 times a week all year round.

- Stock size - One of the biggest restrictions to consistent performance is that every sheep is different and it requires a different margin of time. This mainly depends on what species of sheep, what shape and how old it is.

- Stock availability – Depending on the season, it is getting harder and harder to predict each year when performance will differ. The main cause of change is the availability of stock is always changing, i.e. the sellers are aware of the patterns and are deliberately holding on to stock to seek the best price. Thus throughput of an abattoir varies all the time and the process needs to become a variable speed to some extent, i.e. shut down when low stock and paying twice as much.

* Financial
  - Stock availability – The price for stock varies all year round, in some cases a company can pay twice as much per animal as it would have a month prior. This adds on to variable throughput.

  - Small turn around – Many companies are not willing to spend big on automation because they don't see the benefits. The cost incurred would be significantly higher, i.e. to perform the exact same task as a person, approximately 3 times the cost.

* Quality assurance and inspection
  - Insuring product value – Maintaining quality and consistency is a large expense for an abattoir. At present this can not be performed by robot or automation and it looks like this task will always require a human element to perform this task.

  - Minimum tolerance – Export abattoirs require a zero tolerance during the process of a carcass. This requires extra processing to ensure no contamination is to occur. Because of this, the introduction of automation and robots becomes even more complex.

  - Current technology - The technology currently working in abattoirs does not perform the task considerably quicker because of the requirements to sterilise after every carcass.

8.11 Appendix 11 : Standards and Requirements

The following is a summary of the standards and requirements for the design of an Australian slaughter process.

AUSTRALIAN STANDARDS:

Below are standards applicable to the project listed in AS 4696 – 2002, 'The hygienic production and transportation of meat and meat products for human consumption'.

<u>Operational Hygiene</u>

4.2 Meat premises are cleaned before and after the operation each day (pg13).

4.5 'Meat premises and equipment are maintained in a good state of repair and working order' (pg 13)

<u>Cross Contamination</u>

5.2 'During production meat and meat products do not come into contact with any surface that is not designed for contact' (pg 15)

5.7 Inedible material is secured and removed from slaughter area as soon as possible in a manner that 'prevents contamination of the area and of meat and meat products' (pg 15)

5.20 'The process flow of meat awaiting processing ensures uniform turnover of accumulated product' (pg 17)

<u>Animal Welfare</u>

7.1 'Premises and equipment are used in a way and maintained in a condition that minimises risk of injury, pain and suffering to animals and causes them the least practicable disturbance' (pg 21)

7.10 Animals are stunned in a way that ensures that the animals is unconscious and cannot regain consciousness before dying (pg 21)

7.11 Before stunning commences the 'animals are restrained in a way that ensures that stunning is effective' (p 22)

<u>Slaughter and Dressing</u>

9.4 'Stunning proceeds at a rate which allows the carcasses to be promptly accepted for dressing and in a hygienic manner' (pg 26)

9.9 'The discharge of any material from the oesophagus, stomach, intestines, rectum, gallbladder, urinary and uterus is prevented' (pg 27)

9.15 'Pizzles are removed as completely as possible' (pg 27)

<u>POST-MORTEM INSPECTION AND DISPOSITION</u>

10.1 'Post-mortem inspection of each carcass and its carcass parts is carried out by a meat safety inspector' (pg 29)

<u>PREMISES, EQUIPMENT AND ESSENTIAL SERVICES</u>

19.9 'The premises must have sufficient natural or mechanical ventilation to minimise airborne contamination, remove excess heat and steam, facilitate the control of temperature and humidity' (pg 46-47)

19.13 All surfaces of building and equipment are durable, corrosion resistant, capable of withstanding repeated cleaning and allows visual detection of contamination (pg 47)

<u>HYGIENE AND SANITATION FACILITIES</u>

20.11 'The location of amenities does not jeopardise hygienic production of meat and meat products' (pg 49)

<u>ESSENTIAL SERVICES</u>

21.5 'There is a continuous supply of hot and cold potable water that enables hygienic practices for production of meat' (pg 50)

21.17 'Meat premises have lighting that provides sufficient natural or artificial lighting for the activities conducted on the premises' (pg 51)

AQIS – AUSTRALIAN QUARANTINE AND INSPECTION SERVICE:

The relevant information below was obtained from the AQIS homepage available to the public.

LINK:
Meat inspection division, 'Meat safety quality assurance system for fresh meat and processed meat products 2nd Edition'
Commonwealth of Australia, 2006, via worldwide web
http://www.daff.gov.au/content/output.cfm?ObjectID=37252270-7ED7-4DEC-A5CA91BC5E29DABD&contType=outputs
accessed on 31/05/06

A list of questions was obtained from Appendix A, page 80-81, applicable to hazard analysis for various plants and operations:

E. – Facility Design

1. 'Does the layout of the process line provide an adequate separation of raw materials from finished product?'

3. 'Is the traffic pattern for people and moving equipment a significant source of contamination?'

F. – Equipment Design

1. 'Will equipment provide the time/temperature control that is necessary for safe food?'

3. 'Can the equipment be sufficiently controlled so that the variation in performance will be within the tolerances required to produce safe food?'

4. 'Is the equipment reliable or is it prone to frequent breakdowns?'

5. 'Is the equipment design so that it can be cleaned and sanitised?'

6. 'Is there a chance for product contamination with hazardous substances from equipment (eg metal silvers, grease)?'

Below are guidelines for the slaughter of sheep according to AQIS(1995), ' Operational Guidelines for the welfare of animals at abattoirs and slaughterhouses 2nd Edition'.

<u>Stunning of livestock prior to slaughter</u>

4.1.1 'Animals presented for slaughter should be effectively stunned (rendered immediately unconscious) prior to sticking' (pg 9)

4.2.2 'Where reversible stunning is used, the rate of stunning should be commensurate with the rate at which animals are bled' (pg 9)

4.2.3 Effective stunning should be performed by a device that works in a humane manner, i.e. electric stunner, mechanical penetration or percussion.

4.2.8 'The placement of the stunner should be appropriate to the species of livestock being stunned and the type of equipment' (pg 10)

4.5.2 The maximum acceptable interval for reversible stunning to sticking of sheep is 15 seconds' (pg 12)

A successful HALAL slaughter involves reversible stunning and a 'transverse incision of all soft tissues on the under surface of the neck, severing the carotid arteries and jugular veins on both sides of the neck', i.e. including windpipe and weasand (AQIS, 1995, pg 34)

AUSMEAT STANDARDS

AusMeat provides detailed specifications on how a company must categorise/grade the meat product in terms of its colour, weight range and fat content. Also available is food safety temperatures and packaging and labelling requirements to send the product to a customer.

Reference 1:
Kitching, C., (2001) 'General product requirements for meat supply specifications' AUS-MEAT Ltd, via worldwide web http://www.ausmeat.com.au/standards/specification/lamb.asp accessed on 31/05/06

The following are general requirements for sheep/lamb meat supply specifications:

- Primal weight range: 18 to 22 kg.
- Fat range: Subcutaneous fat cover 2mm to 6mm.
- Meat colour: Cherry red.
- Fat colour: White to creamy white fat
- Delivery temperature maximum 5°C for chilled and -15°C for frozen product

Reference 2:
Author unknown, (1998) 'Australian HALAL meat products'
AUS-MEAT Ltd, 9 Buchanan St, South Brisbane, QLD, via worldwide web
http://www.ausmeat.com.au/
accessed on 31/05/06

The Muslim HALAL market is 'very important' to Australian processors (AUSMEAT 2). Just as important is that a company can perform the process correctly every time.

In summary the HALAL meat process is below:

1. Process must be performed by a registered Muslim slaughterman.
2. Halal and Non Halal product must be separated and identified at all times.
3. Equipment must be thoroughly cleaned and washed if Non Halal meat has been in contact.

8.12 Appendix 12 : Feasibility Calculations

8.12.1 Appendix 12.1 – Feasibility at 9 units per minute

Running cost calculations at a product rate of 9 units per minute.

Table 21 - Calculations of running cost per robot (9 units per minute)

	0 X Auto	**1 X Auto**	**2 X Auto**	**3 X Auto**	**4 X Auto**	**5 X Auto**	**6 X Auto**	**7 X Auto**	**8 X Auto**	**9 X Auto**	**10 X Auto**	**11 X Auto**	**12 X Auto**	**13 X Auto**
SL-man replaced	-	1	3	4	6	8	10	11	12	13	14	15	16	17
SL-man savings (AM)	-	$137	$410	$547	$821	$1,094	$1,368	$1,505	$1,642	$1,778	$1,915	$2,052	$2,189	$2,326
Calc. labour per day (AM)	$8,930	$8,793	$8,520	$8,383	$8,109	$7,836	$7,562	$7,425	$7,288	$7,152	$7,015	$6,878	$6,741	$6,604
SL-man savings (PM)	-	$152	$456	$608	$912	$1,216	$1,520	$1,672	$1,824	$1,976	$2,128	$2,280	$2,432	$2,584
Calc. labour per day (PM)	$9,766	$9,614	$9,310	$9,158	$8,854	$8,550	$8,246	$8,094	$7,942	$7,790	$7,638	$7,486	$7,334	$7,182
TOTAL Labour cost per day	$18,696	$18,407	$17,830	$17,541	$16,963	$16,386	$15,808	$15,519	$15,230	$14,942	$14,653	$14,364	$14,075	$13,786
Auto. running cost per day	-	$65	$130	$195	$260	$326	$391	$456	$521	$586	$651	$716	$781	$846
Overall daily running cost (Auto. + Labour)	$18,696	$18,472	$17,959	$17,736	$17,223	$16,711	$16,198	$15,975	$15,751	$15,527	$15,303	$15,080	$14,856	$14,632
Number of units daily	**5,590**	**5,590**	**5,918**	**6,247**	**6,412**	**7,000**	**7,398**	**7,398**	**7,398**	**7,398**	**7,398**	**7,398**	**7,398**	**7,398**
Total cost per unit	**$3.34**	**$3.30**	**$3.03**	**$2.84**	**$2.69**	**$2.39**	**$2.19**	**$2.16**	**$2.13**	**$2.10**	**$2.07**	**$2.04**	**$2.01**	**$1.98**

8.12.2 Appendix 12.2 – Feasibility at 7.9 units per minute

Below are the calculations for the feasibility at a rate of 7.9 units per minute. These were performed to assess benefits of achieving the design goal.

Table 22 – Calculations of running cost per robot (7.9 units per minute)

	0 X Auto	**1 X Auto**	**2 X Auto**	**3 X Auto**	**4 X Auto**	**5 X Auto**	**6 X Auto**	**7 X Auto**	**8 X Auto**	**9 X Auto**	**10 X Auto**	**11 X Auto**	**12 X Auto**	**13 X Auto**
SL-man replaced	-	1	3	4	6	8	10	11	12	13	14	15	16	17
SL-man savings (AM)	-	$137	$410	$547	$821	$1,094	$1,368	$1,505	$1,642	$1,778	$1,915	$2,052	$2,189	$2,326
Calc. labour per day (AM)	$8,930	$8,793	$8,520	$8,383	$8,109	$7,836	$7,562	$7,425	$7,288	$7,152	$7,015	$6,878	$6,741	$6,604
SL-man savings (PM)	-	$152	$456	$608	$912	$1,216	$1,520	$1,672	$1,824	$1,976	$2,128	$2,280	$2,432	$2,584
Calc. labour per day (PM)	$9,766	$9,614	$9,310	$9,158	$8,854	$8,550	$8,246	$8,094	$7,942	$7,790	$7,638	$7,486	$7,334	$7,182
TOTAL Labour cost per day	$18,696	$18,407	$17,830	$17,541	$16,963	$16,386	$15,808	$15,519	$15,230	$14,942	$14,653	$14,364	$14,075	$13,786
Auto. running cost per day	-	$65	$130	$195	$260	$326	$391	$456	$521	$586	$651	$716	$781	$846
Overall daily running cost (Auto. + Labour)	$18,696	$18,472	$17,959	$17,736	$17,223	$16,711	$16 198	$15 975	$15,751	$15,527	$15,303	$15,080	$14,856	$14,632
Number of units daily	**5,590**	**5,590**	**5,918**	**6,247**	**6,412**	**6,412**	**6,494**	**6494**	**6494**	**6494**	**6,494**	**6494**	**6494**	**6,494**
Total cost per unit	**$3.34**	**$3.30**	**$3.03**	**$2.84**	**$2.69**	**$2.61**	**$2.49**	**$2.46**	**$2.43**	**$2.39**	**$2.36**	**$2.32**	**$2.29**	**$2.25**

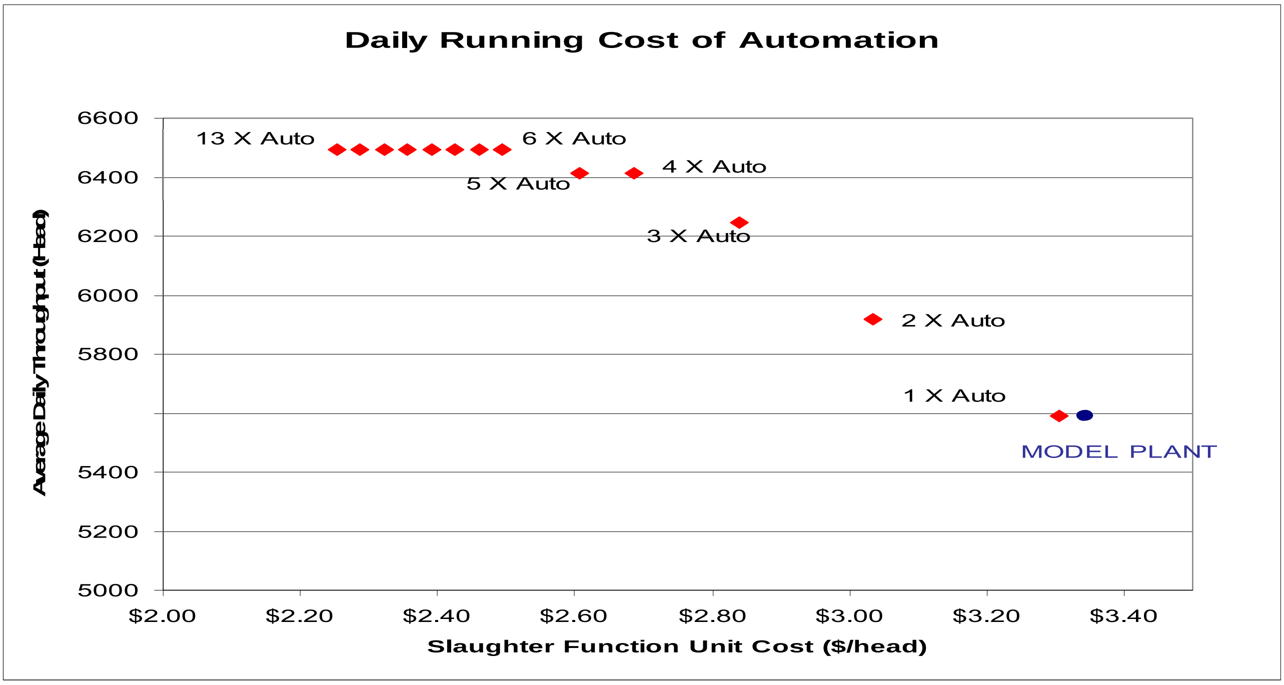


Figure 16 - Calculated daily running cost of all automated possibilities

Table 23 - Break even calculations for automation at maximum 7.9 units per minute

No. of machines	**Throughput in a day**	**Total Running Cost per Unit ($ / unit)**	**Cumulative Savings in Running Cost ($ / unit)**	**Purchase and Installation Cost**	**BREAK EVEN (UNITS)**	**BREAK EVEN (Days)**	**BREAK EVEN (Years)**
0	5560	3.34	-	$ -	-	-	-
1	5900	3.3	$ 0.04	$ 2,000,000	50000000	8992	35.8
2	6243	3.03	$ 0.31	$ 3,800,000	12258065	2078	8.3
3	6439	2.84	$ 0.50	$ 5,400,000	10800000	1730	6.9
4	6532	2.69	$ 0.65	$ 6,800,000	10461538	1625	6.5
5	6532	2.61	$ 0.73	$ 8,000,000	10958904	1678	6.7
6	6532	2.49	$ 0.85	$ 9,000,000	10588235	1621	6.5
7	6532	2.46	$ 0.88	$ 9,800,000	11136364	1705	6.8
8	6532	2.43	$ 0.91	$ 10,600,000	11648352	1783	7.1
9	6532	2.39	$ 0.95	$ 11,400,000	12000000	1837	7.3
10	6532	2.36	$ 0.98	$ 12,200,000	12448980	1906	7.6
11	6532	2.32	$ 1.02	$ 13,000,000	12745098	1951	7.8
12	6532	2.29	$ 1.05	$ 13,800,000	13142857	2012	8.0
13	6532	2.25	$ 1.09	$ 14,600,000	13394495	2050	8.2