FINAL REPORT

Feasibility Study into a High Volume Cellular Processing Plant

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1.0 EXECUTIVE SUMMARY

The completed research project 2017-1054 contributes to determining the feasibility of a high volume cellular processing plant that would utilise a mix of industrial robots, collaborative robots, special purpose machines and human operators to complete various tasks of meat production. The outcome of this report builds from the findings of 2016-1033: Cellular Production and helps the industry to better understand the practical considerations that processing plants have with incorporating the new processing method and associated automation.

By investigating the practical considerations for how a high volume meat processing plant would make the transition to a cellular format this report brings forward the multiple themes surrounding group theory applied to meat processing, best application and desirability of new automation technology as well as strengths and weaknesses within organisation absorptive capacity and management capability. By assessing the enablers and disablers of Cellular Manufacturing (CM) we also identify to what extent it may be applicable within current red meat operations.

The subjects of study have been four Australian red meat processors all of which have volume levels that could potentially benefit from incorporating cellular methods. Exploration with interviews together with analysis of their feedback showed general support of the CM concept and agreed that it had potential to benefit processing operations. There was early correlation between the barriers to entry and general concerns about the costs and benefits associated with acquisition of the equipment required for transition to CM.

Based on the research presented in this feasibility study it is recommended that AMPC supports implementation strategies to adopt cellular manufacturing in the red meat processing industry.

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2.0 INTRODUCTION

2.1 Statement of research

It is hoped that this final report for the Feasibility Study into a High Volume Cellular Processing Plant will assist in building the knowledge base that will be essential in helping to develop best practice strategies to adopt cellular manufacturing processes if and when required.

2.2 Purpose

The purpose of this research has been to ascertain through a feasibility study the outcomes and applicability of applying CM to the red meat processing industry. Traditional methods of continuous chain conveying systems have had many advantages to industry since first inception with the Ford Motor car assembly lines over a century ago, but they are now gradually being superseded in many sectors by cellular based production cells.

To sustain and grow market share the red meat processing industry should always seek to be dynamic in the way that it acquires and exploits competitive advantages. Further development and investigation into CM is one such area that could assist the industry with achieving its collective strategic outcomes.

Background

The previous report 2016-1033: Cellular Production identified the following;

i. Since meat processing is a disassembly process, with the animal being separated into primal cuts and inedible by-products, it is not easily compared to other manufacturing industries that often utilise assembly or transformation processes. Nevertheless, the main principle of waste reduction of cellular and lean manufacturing can still be applied to meat processing.

ii. Almost every meat processor uses a continuous line chain with operator stations at regular intervals. Depending on the length of the line chain, there is a lot of waste caused by the physical distance each carcass travels, and the inventory required to have a carcass present at each station. There will be at least one task which is limiting the total line speed. As a result, every other task has some period of idle time waiting for the line to progress. The only way to increase production is to add additional labour to the limiting tasks without risking a decrease in quality for overloading the operator. Furthermore, stoppages or maintenance puts a halt on the entire line reducing production and profits while the issue is resolved.

iii. Cellular manufacturing has the potential to provide benefits to any process including meat processing. The potential benefit from cellular production of meat processing will be in improving quality, reliability, flexibility and increased opportunity for automation due to the ability to use automatic tool changers and work on static carcasses. However, it does require analysis of each individual meat processor to develop the best solution.

iv. CM is not a one size fits all methodology, at least not when modifying existing continuous production schemes. As such the concept designs presented here are only a guide to further research into cellular manufacturing for red meat processing.

2.4 Scope

The Scope of this report extends from previous research from 2016-1033 Cellular Production as the potential benefits offered by CM are tested by practical considerations from a group of high volume red meat processing operators. A range of surveys were developed to ascertain the level of understanding and acceptance toward incorporating cellular meat processing systems to current production methods. Particular attention was given to industry sentiment surrounding the proposed grouping of similar processing tasks as well as ratings and feedback on individual cell design.

Industry feedback has given valuable insights to the application of CM in the current marketplace and shows how it may be applied for greatest results. The survey research also identified multiple barriers to adoption as well as a greater understanding of current absorptive capacity and management capability applied to innovation that may assist in change management for integrating CM as a potential new method of production beyond the continuous chain conveying system.

2.5 Limitations

Whilst the research has been limited to a small sample size, and the smaller the sample the greater the probability of bias, it still acts as a powerful starting point in gathering information that will equip AMPC with practical know how so that the true benefits of CM can be realised and assimilated to the industry at large when required. Findings of this report can be tested against larger sample size surveys in the future.

3.0 PROJECT OBJECTIVES

The overall project objective of 2017-1054 has been to investigate the practical considerations for how a high volume meat processing plant would make the transition to a cellular format, it has achieved this by completing the following.

i. Applied group theory and other cellular manufacturing techniques to red meat processing.

ii. Examined current automation of meat industries and re-evaluated potential automation with respect to a stationary carcass in a production cell compared to a moving carcass in continuous chain system.

iii. Investigated and assessed with industry consultation;

   a. Cell design and future automation potential

   b. Barriers to adoption

   c. Absorptive capacity

   d. Management capability

4.0 METHODOLOGY

Milestone 1:

An in-depth literature review was conducted on group theory and general cellular manufacturing techniques. Internal consultation was conducted within the Strategic

Engineering project team to develop a list of realistic automated processes that could be feasibly applied within a cellular environment in the near future. A consolidated list of automated processes was decided upon so that industry participants could give their opinions surrounding application and functionality.

Milestone 2:

Due to a limited and small sample size statistical analysis and hypothesis testing has been replaced with a general qualitative focus on industry participant survey and interview feedback. The data for this study was collected by means of a two stage questionnaire survey and followed up with an industry participant interview.

The data collection process was administered online. An email requesting participation was sent via AMPC. Interested parties where then followed up with a request for general information about their operations in relation to volume, plant throughput and staff numbers. From these responses it was agreed that all interested processors had sufficient volume to undertake the feasibility study. From this point a copy of Cellular Production 1016-1033: Cellular Production was sent for review prior to surveys being sent.

In preparation for the survey design Strategic Engineering Pty Ltd undertook an internal review of collaborative robot and automation potential to be incorporated within proposed cellular designs with some extensions to previous work being made based upon new information not available at the writing of the 2016-1033: Cellular Production report.

A literature review in the relation to technology adoption was also conducted on the elements of Barriers to Adoption, Absorptive Capacity, Management Capability and Cellular Design. Further to this an extended review was conducted into how the feasibility study could be looked at from a return on investment perspective for the red meat processing industry.

5.0 PROJECT OUTCOMES

5.1 Milestone 1 - Review

The scope of this milestone was to take our current understanding of CM from the findings of

2016-1033: Cellular Production and extend its application on how the outlined techniques of group theory could be applied so that the greatest benefits can be achieved for red meat processing.

The red meat industry in Australia like other commodity based industries is subject to a constantly changing and dynamic global market place. It is subject to multiple forces beyond its control which can stagnate and weaken development. It is hoped that by exploring the application of adopting best practice CM techniques to the red meat processing industry that it will assist in creating future competitive advantages that customers will recognise as product differentials and grow to depend upon.

The empirical evidence identified within the literature review suggested that there was good reason to look beyond some of the limitations of CM applied to red meat processing as the findings identified benefits within lean/cellular approaches for most companies.

5.2 Application of group theory and other cellular manufacturing techniques to meat Processing

By the research presented in report 2016-1033: Cellular Production and from academic literature review we can see on face value the many benefits that CM can potentially bring. The potential benefits can also be limited to the barriers of adoption. The empirical evidence as outlined in a number of research papers surrounding application of cellular manufacturing (Choi, 1996) (Waterson, 1999) (Johnson. and Wemmerlov, 2004) suggests that despite its advantages the adoption of cellular manufacturing remains limited. Some of the main reasoning behind this points to the cost of organisational change and technical problems around putting machines into cell design.

In applying group theory and other cellular manufacturing techniques to red meat processing we see a number of advantages and disadvantages. Many of the fundamental benefits of cellular manufacturing in other industries are not applicable to meat processing, or not as beneficial due to the disassembly nature of meat processing. We see the main advantages of cellular manufacturing in the potential improvements with quality, reliability and the flexibility of production. The long term benefits are the potential for a greater level of automation due to the static nature of the product compared to a moving product in most continuous line chains.

Whilst there seem to be some factors that hinder the adoption of full CM, the industry should remain open minded as to how it can obtain the best advantages applied to its own particular set of dynamics. The reasoning behind this is supported through the results of a study conducted by (Waterson, 1999) where it showed that from an industry survey in the United Kingdom where 14% that incorporated dedicated cellular manufacturing practices more than 75% of the respondents claimed medium to high levels of success.

In an attempt to best apply CM to red meat processing we believe that group theory be applied to the most problematic areas in continuous line processing. To achieve this value stream mapping and value network mapping should be applied to the entire plant. Once identified these problem areas can be categorised in importance relating to productivity. Tasks can be grouped into potential work cells from which to develop an overall plan for a cellular based meat processing plant. These proposed cells could be duplicated as required to meet the specific production requirements of each meat processor.

This idea of applying cellular manufacturing to selected areas of a plant is also reported in the book "America's Best" Where it explained that most cell implementations appear to have achieved outstanding results, but only in limited areas of the plant. It went on to report that most companies chose only selected areas of their plants to implement cells. This proved particularly true with small to medium sized plants as the cells tend to be the more obvious and easiest to implement. (Kinni, 1996)

At present there is no one cellular manufacturing method that would apply to all meat processors as every plant is different in its set up and its application of automation. This is why in first instance the industry should consider applying cellular techniques using a segmented approach so that emphasis of application is given to a plants greatest bottleneck or problem area. Further cells can then be grouped and implemented when required. This method would encourage processing plants to take a first step in advancing their manufacturing mindset away from chain process and into lean thinking cellular approaches.

Group theory applied to red meat processing is categorised below.

CELL	GROUP TASKS
1	• *Stunning, Sticking, Bleed* • *Hoist onto chain*
2	• *Bung dropping, Rodding* • *Horn removal, Head removal, Head processing* • *Belly cut, Hock removal, Tail removal* • *Hide preparation and pre-dehiding*
3	• *Hide removal*
4	• *Brisket bone cut, Evisceration, Inspection of offal, Carcass splitting* • *Spinal cord removal, Fat sucking/ removal, Carcass inspection/ grading* • *Quarter cut, Scribbling, Trimming*
5	• *Chilling*
6	• *Trimming* • *Forequarter primal cutting and slicing* • *Hindquarter primal cutting and slicing*
7	• *Quality control inspection of primal cuts* • *Bagging and sealing* • *Picking and Packing*

Figure 1: Group Theory applied to red meat processing

5.3 Current automation of meat industries and a re-evaluation of potential automation with respect to a stationary carcass in a production cell compared to a moving carcass in continuous chain system

Ultimately all drivers to adopt automation have the same aim - increased profitability. If no profit or long-term benefit is foreseeable then no changes will be implemented. (Caldwell, 2013) Due to the enormous variability in the meat product, automation has been slow to develop around meat processing or cost prohibited. Whether from the differences between each animal or just the uncontrolled motion on the continuous line chain, the variability presents challenges for automation. Complex and expensive sensing systems are required as well as mechanical restraining devices or software to track the moving chain.

A list of realistic automations that could be applied to a stationary carcass in a production cell is listed below

POTENTIAL AUTOMATION
Stunning
Sticking
Hoist onto chain
Horn
Head removal
Belly cut
Hock removal
Tail removal
Carcass splitting
Spinal cord removal
Fat sucking removal
Quarter cut
Scribing
Chilling
Bagging and sealing
Picking and packing

Figure 2: Potential automation applied to a stationary carcass in a production cell

Potential new automation applied to a stationary carcass could extend to include optimised robotic tool changer and collaborative and tele robots.

5.3.1 Optimised robotic tool changer

In a static work cell, the carcass isn't moving, and can more easily be restrained to prevent any uncontrolled movement during processing. Furthermore, one sensing system can be implemented for the whole cell which is capable of providing the feedback required for multiple tasks. In the continuous line chain, automation of several tasks would require a robot, sensing system and method of tracking or restraining for every single task. With the use of an automatic tool changer, one robot with one sensing and restraining system can automate all the tasks within a work cell.

With an automatic tool changer, a standard industrial robot could potentially automate all tasks in a work cell, with an added advantage of a single sterilisation point, however the sensing requirements of all tasks might still be problematic for one complete cell. (Strategic Engineering. D. Hankins; R. Aplin, 2016)

5.3.2 Collaborative and Telerobotics

Another potential for automation in cellular production is through the use of collaborative robots. Collaborative robots can operate directly with operators. This would allow operators to oversee the collaborative robots, essentially acting as the sensing system required for industrial type robots. If there are any issues with the collaborative robot due to the variation in animals etc. the operator can resolve it or essentially take over and finish the task without having to stop or reset anything. Furthermore, the operator could be working alongside the collaborative robot on another task that is more difficult to automate or simply to decrease production time. Current collaborative robots are not advanced enough for meat processing tasks. Limitation in load capacity and hygiene protection means that the technology needs to develop over the next few years before it could be feasible in the harsh environment of a meat processing environment.

With the current limitation of load capacity of collaborative robots, a possible alternative is through the use of virtual reality technology and sensory force feedback to aid the robot, giving the robot all the senses that a skilled operator has.

Using such technology carcass processing with motion control gives all the advantages of a standard industrial robot load capacity and accuracy. This would reduce any strain related injuries or issues for the operator while maintaining the quality of product. Furthermore, the data could be collected and processed into developing a fully automated solution. (Strategic Engineering. D. Hankins; R. Aplin, 2016)

5.4 Milestone 2 – Review

Cellular Design - Survey format

1. Grouping similar processing tasks feedback. This survey asked participants to rate the grouping of similar processing tasks from a Likert scale *where 1 = Agreed strongly, 2 = Agree, 3 = Neither Agree or disagree, 4 = Disagree and 5 = Disagreed strongly*

2. General questions where then asked in relation to the effectiveness and efficiency of each of the proposed cells. Mixed Likert scales were used to assess responses. Details given in survey 1B overview

3. A future automation feedback survey was conducted on tasks that Strategic Engineering had deemed as having good potential to automate from current manual processes. This survey asked participants to rate the future automation tasks from a Likert scale where *1 = Highly desirable, 2 = Desirable, 3 = Neither Desirable or un-desirable, 4 = Undesirable and 5 = Highly undesirable*

5.5 Survey 1A: Grouping similar processing tasks

Likert scale where 1 = Agreed strongly, 2 = Agree, 3 = Neither Agree or disagree, 4 = Disagree and 5 = Disagreed strongly NB: Mean scores are calculated for each survey

CELL	GROUP TASKS	RESPONSE A:	B:	C:	D:	MEAN (µ)	DESIRABILITY
1	• Stunning, Sticking, Bleed • Hoist onto chain	1	1	2	2	1.5	Agree strongly/ Agree
2	• Bung dropping, Rodding • Horn removal, Head removal, Head processing • Belly cut, Hock removal, Tail removal • Hide preparation and pre-dehiding	4	1	2	4	2.75	Somewhat agree
3	• Hide removal	1	1	2	2	1.5	Agree strongly/ Agree
4	• Brisket bone cut, Evisceration, Inspection of offal, Carcass splitting • Spinal cord removal, Fat sucking/ removal, Carcass inspection/ grading • Quarter cut, Scribbling, Trimming	3	1	2	4	2.5	Somewhat agree
5	• Chilling	1	1	2	2	1.5	Agree strongly/ Agree
6	• Trimming • Forequarter primal cutting and slicing • Hindquarter primal cutting and slicing	3	1	3	3	2.5	Somewhat agree
7	• Quality control inspection of primal cuts • Bagging and sealing • Picking and Packing	3	1	3	2	2.25	Somewhat agree
Overall rating of cellular design grouping of tasks						2.07	Agree

Quoted feedback
Company A:
Cell 2: *"There are a lot of steps in Cell 2 which I'm struggling to see connection, I don't believe there in any sense in taking the head off before hide. I see that Hock and horns would be more automatable"*
Group 2: "*I think this may need to be broken down further, I would like to see it developed though"*

Figure 3: Grouping similar processing tasks - Survey

Grouping similar processing tasks - Interpretation

- The feedback whilst mixed, suggested that overall the industry participants AGREED with the cellular design grouping of tasks with a mean rating of 2.07. From the feedback received there may be scope to add industry insights to different aspects of cell creation. There were some opinions given against the size of cell two, whilst cell two can be simplified to be further broken down we believe that current automation technology is available to make the complete grouping of these tasks possible.

Survey results - Participant desired volume increase under current operations

NB: Company D indicated it has no need to increase current volume due to current market demand

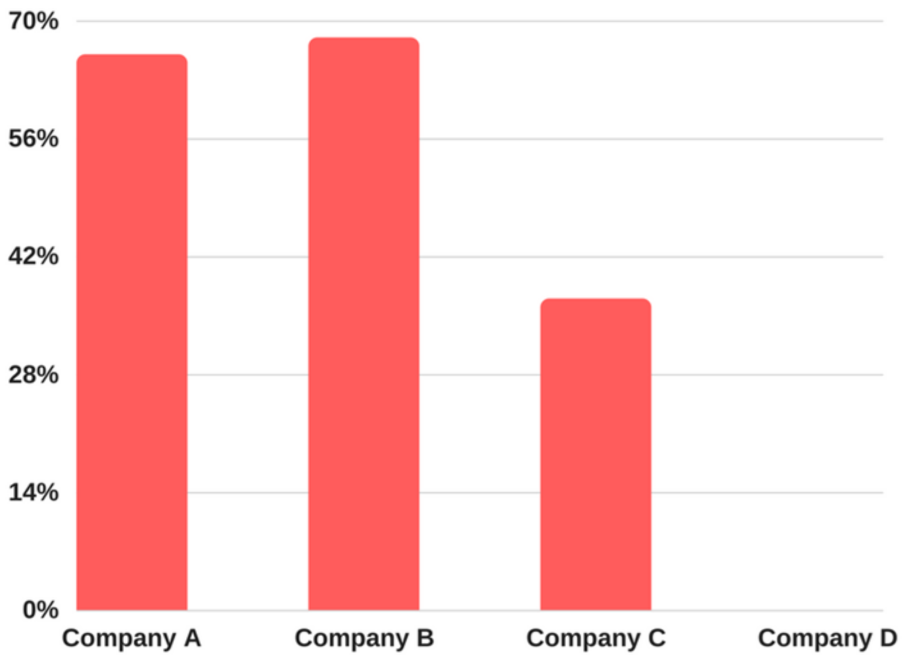


Figure 4: Participant desired volume increase under current operations - Bar graph

5.6 Survey 1B: Individual cell design

Survey format:

After rating the grouping of similar tasks participants were asked to rate the application and functionality for each of the proposed cellular designs. The following Likert scale was used

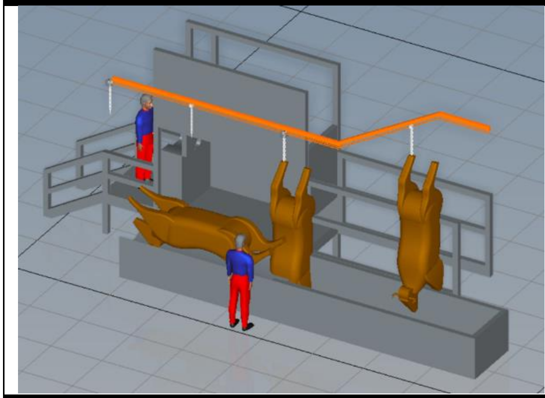
i. *Application and functionality of this cell design where 1=Very good; 2= Good; 3= Neither good or bad; 4= Bad; 5= Very bad*

The survey goes on to ascertain how efficient and effective the proposed cell would be in relation to current continuous chain production. The following Likert scale was used.

ii. *Importance of application – This cell would help efficiency and effectiveness in relation to productivity where 1=Agree strongly; 2= Agree; 3= Neither agree or disagree; 4= Disagree; 5= Disagree strongly*

Finally, the survey explored the current difficulties associated with each section in relation to the chain. For each question Mean scores are generated. The following Likert scale was used.

iii. *Difficulties with this stage of your continuous chain 1=Always; 2= Occasionally; 3= Rarely; 4= Never; 5= Don't know*

CELL 1: STICKING, STUNNING AND BLEEDING	OVERVIEW
	*Cell 1 contains the stunning and sticking processes. The cattle are then hoisted via chain to be vertically bled over the collection tank. The cell is the same general layout of existing continuous line chain architecture. This allows for easy integration into existing meat processors or modification of existing equipment into a work cell. If the production rate cannot be achieved with a single slaughter cell, the system can be duplicated to reach the required production rate.*

CELL 1: QUESTIONS	RESPONSE A	B	C	D	MEAN (μ)
A. Application and functionality of this cell design	3	2	3	3	2.75 = Good/ Neutral
B. Importance of application: This cell would help efficiency and effectiveness in relation to productivity	3	2	3	3	2.75= Agree / Neutral
C. Difficulties with this stage of your continuous chain					
• Break downs	4	3	3	3	3.25
• Bottlenecks	4	1	4	3	3
• Maintenance and cleaning	4	2	3	3	3
• Accidents/ health and safety issues	2	1	2	3	2
• Materials handling improvements	4	4	3	3	3.5
Difficulties with this stage of your continuous chain (Combined Mean)	**2.95 = Rarely difficult**				

Industry points:
Company A: *"Personally prefer bleed tables as you can go faster, with this scenario you cant stimulate the carcass long enough. I wouldn't cut throat in the vertial position."*
Company B: *"Head restraints for animal welfare must be thought about in this area. A working head restraint for multiple cells would be useful"*
"Doesn't suit our current setup, but I could see this working well"

Figure 5: Cell 1: sticking, stunning and bleeding - Survey

Cell 1: Interpretation and feedback:

- The overall design of Cell 1 was rated GOOD/ NEUTRAL indicating participants generally agreed to the application, the rating was weighted towards neutral at 2.75. The efficiency and effectiveness of this cell was also equally rated as AGREE/ NEUTRAL
- The majority of participants suggested that there was no need to automate this part of the chain under current conditions.

- A participant indicated that accidents/ health and safety issues occurred very often, the mean rating of 2.0 for this area further indicates accidents are a general issue.

- A participant indicated having bottlenecks in this area of the chain and estimated it could save them approximately (1hr) $5,500 on a difficult shift if cattle weren't going through smoothly. Whilst this didn't occur every shift it was still deemed an issue.

- A participant Suggested it would look at this technology if production was to increase 10%

- A participant believed that bleeding should be done horizontally on a bleed table before hoisting. On the current cell design there would be approximately a 30 second interval where the carcass would be horizontal.

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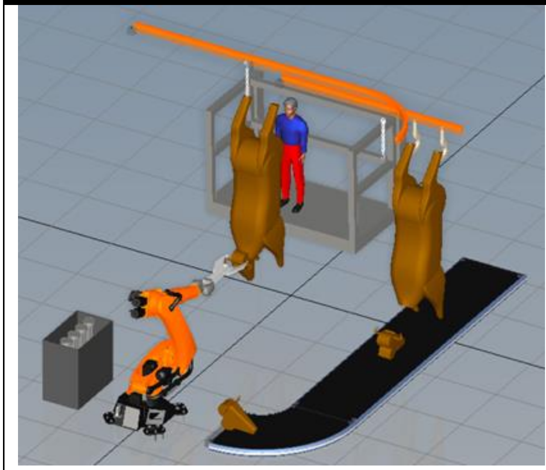
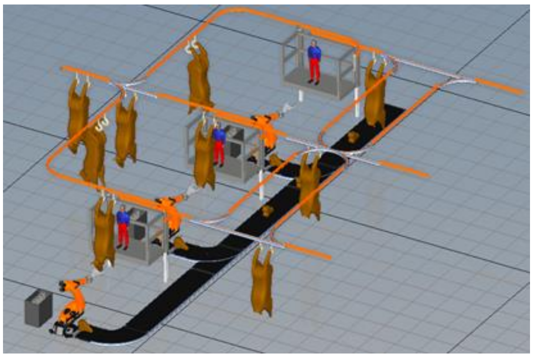
CELL 2: PRE-DEHIDING	OVERVIEW
	*Cell 2 contains all processing tasks prior to de-hiding. The cattle are transferred onto hooks to continue to the de-hiding stage. The animal should be transported into the cell by the overhead conveyor. Once inside the cell the carcass will remain stationary while each task is completed. The tasks should be completed simultaneously where possible by multiple operators or robotic automation. The hocks and head are removed with assistance from the robot and transferred out of the cell using a belt conveyor to be processed externally. A sterilisation box is situated next to the robot holding several different tools to allow the robot to complete different tasks as required. To reach a high production rate this cell should be duplicated as required.*
CELL 2 - CONTINUED BUFFERING AND CHAIN DIVERSIONS	**OVERVIEW**
	*To meet a higher production rate, Cell 2 can be multiplied and fed via splitting the chain conveyor from the sticking and stunning cell. After the cell processes are completed, each carcass can be diverted into different cells in the next stage via the chain conveyor. The heads are removed from each individual cell using a bed conveyor. These are merged into a single output conveyor to be diverted to an external head processing area. In the event of cleaning, maintenance or breakdown of a cell, the carcasses are allowed to be diverted to another cell using the chain conveyor system.*

CELL 2: QUESTIONS	RESPONSE A	B	C	D	MEAN (μ)
A. Application and functionality of this cell design	**3**	**3**	**3**	**4**	**3.25 = Neutral**
B. Importance of application: This cell would help efficiency and effectiveness in relation to productivity	**3**	**3**	**3**	**4**	**3.25 = Neutral**
C. Difficulties with this stage of your continuous chain					
• Break downs	**4**	**3**	**3**	**3**	**3.25**
• Bottlenecks	**4**	**3**	**3**	**3**	**3.25**
• Maintenance and cleaning	**4**	**3**	**3**	**3**	**3.25**
• Accidents/ health and safety issues	**2**	**3**	**3**	**3**	**2.75**
• Materials handling improvements	**4**	**3**	**3**	**3**	**3.25**
Difficulties with this stage of your continuous chain (Combined Mean)	**3.15 = Rarely difficult**				

Industry points:
Company A *"Removal of head before hide pulling not a good idea financially. If only taking head and hocks of no need to take off head. This cell would be better if it was just Hocks only."*
"This area of the chain is labor intensive at the monent, but not problematic"

Figure 6: Cell 2: Pre-dehiding - Survey

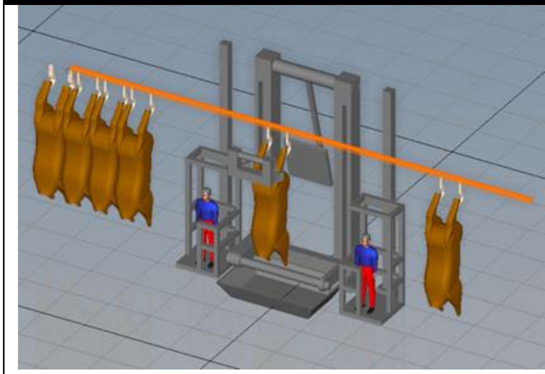
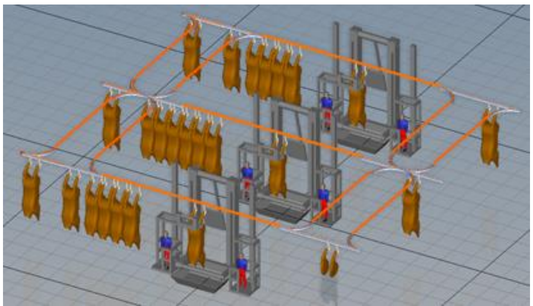
Cell 2: Interpretation and feedback:

- The overall design of Cell 2 was rated NEUTRAL indicating participants neither agreed or disagreed with its application or use. The overall difficulty currently associated to this stage of the continuous chain was considered RARELY DIFFICULT. There was some suggesting that materials handling could be reduced in this area with automation.

- A mean score of 2.75 for accidents/ health and safety issues shows that this segment of the continuous chain is an OCCASSIONAL issue for participants

- Some participants reported that they thought there was no need for this cell as it would bring no benefit to current operations

- The process of head removal before hide was also questioned by multiple participants, this may be an option that can be customised to suit what best serves the processor.

CELL 3: DE-HIDING	OVERVIEW
	*Cell 3 handles the hide removal process using a de-hiding machine with assistance from two workers. Many meat processors have existing de-hiding machines. Ideally these current machines can be easily incorporated into the cell allowing easier integration of the work cell into existing processing lines. Depending on the production rate required by the processor, multiple de-hiding cells might be needed. This would require duplication of the de-hiding machine which has already been done in large production meat processing plants.*
CELL 3 – CONTINUED BUFFERING AND CHAIN DIVERSIONS	**OVERVIEW**
	*Similar to Cell 2, the de-hiding cell can be multiplied to suit a higher production rate. The overhead conveyor chain can be designed such that each cell operates independently. Each carcass can be diverted to any de-hiding cell via the chain conveyor system with a buffering zone existing prior to each cell. After de-hiding, each carcass leaves the cell and enters the buffering zone of the next cells.*

CELL 3: QUESTIONS	RESPONSE A	B	C	D	MEAN (µ)
A. Application and functionality of this cell design	4	1	4	3	2.75 = Good/ Neutral
B. Importance of application: This cell would help efficiency and effectiveness in relation to productivity	4	1	4	3	2.75= Agree/ Neutral
C. Difficulties with this stage of your continuous chain					
• Break downs	3	3	3	3	3
• Bottlenecks	4	3	3	3	3.25
• Maintenance and cleaning	3	2	2	3	2.5
• Accidents/ health and safety issues	4	2	3	3	3
• Materials handling improvements	2	2	3	3	3
Difficulties with this stage of your continuous chain (Combined Mean)	**2.85 = Occasionally/ Rarely difficult**				

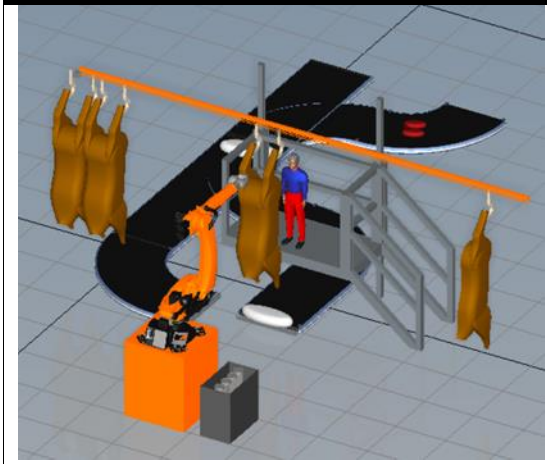
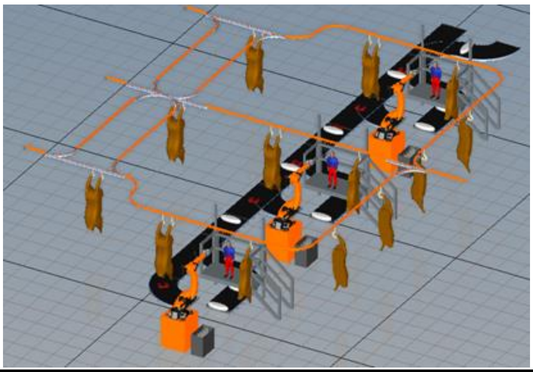
Industry points:
Company A *"An eventual goal is to take people away from working on hide pulling."*
"Labour intensive, but not problematic"
Company B: *"Hide pullers need to be dual control on the drum to resolve hand in chain issues. More robotics around this part is needed"*

Figure 7: Cell 3 De-hiding - Survey

Cell 3: Interpretation and feedback:

- The overall design of Cell 3 was rated between GOOD/ NEUTRAL indicating participants weighted the cells application and use to be slightly better than neither good or bad. The overall difficulty currently associated to this stage of the continuous chain was considered OCCASSSIONALY/ RARELY DIFFICULT. There was some indication that maintenance, cleaning and materials handling was OCCASSIONALLY difficult and could be improved.

- It was suggested that there was a need to understand what is stopping hide pullers now. A cellular application could overcome poor set up process of previous workers

CELL 4: POST DE-HIDING	OVERVIEW
	*Cell 4 contains the processing tasks occurring after de-hiding and before chilling. Quality control inspection and initial grading of the meat should be integrated with the other tasks. The offal is removed and carried out via belt conveyors to be processed externally. The carcass is then split with each half of the carcass on its own hook to be transported to the chilling cell. To reach a high production rate this cell should be duplicated as required.* *After the carcass has been split, and through the use of tool changer technology the robot is able to select a spinal fat removal tool, and carry out this task or any other tasks such as scribing.*
CELL 4 – CONTINUED **BUFFERING AND CHAIN DIVERSIONS**	**OVERVIEW**
	*Cell 4 can be multiplied to suit a higher production rate with another diverting chain conveyor system, allowing the path of each carcass to be controlled and a destination cell to be selected. The offal is removed from each cell via individual bed conveyors. These conveyors merge into a single output conveyor, which is then split into two to allow the white and red offal to be sent to their respective processing areas. As the split carcass exits a cell, the chain conveyors are merged into a single output line to send to the chilling station.*

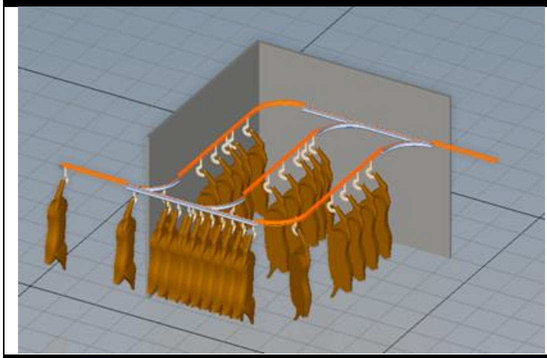
CELL 4: QUESTIONS	RESPONSE A	B	C	D	MEAN (µ)
A. Application and functionality of this cell design	**3**	**1**	**3**	**3**	**2.5 = Good/ Neutral**
B. Importance of application: This cell would help efficiency and effectiveness in relation to productivity	**3**	**1**	**4**	**2**	**2.5 = Agree/ Neutral**
C. Difficulties with this stage of your continuous chain					
• Break downs	**3**	**2**	**3**	**3**	**2.75**
• Bottlenecks	**4**	**2**	**3**	**3**	**3**
• Maintenance and cleaning	**4**	**2**	**2**	**3**	**2.75**
• Accidents/ health and safety issues	**2**	**3**	**2**	**3**	**2.5**
• Materials handling improvements	**2**	**2**	**2**	**3**	**2.25**
Difficulties with this stage of your continuous chain (Combined Mean)	**2.65 = Occasionally/ Rarely difficult**				

Industry points:
Company A: *"An Intensive area for labour for us, potential redution of ten plus staff if automated"*
Company B: *"I can see how this would benefit this part of the process"*
Company D: *"Potentially interesting – correlation with carcass inspection"*

Figure 8: Cell 4 Post de-hiding - Survey

Cell 4: Interpretation and feedback:

- The overall design of Cell 4 was rated GOOD/ NEUTRAL indicating participants weighted the cells application and use to be slightly better than neither good or bad. Mixed results were reported in relation to difficulty with this part of the continuous chain as some participants reported OCCASSIONAL difficulty with breakdowns and bottlenecks, whilst others OCCASSIONALLY reported difficulties with accidents and materials handling.
- The majority of participants could see the potential benefits of this cell.

CELL 5: CHILLING	OVERVIEW
	*Cell 5 involves chilling the carcass before the boning cells. The refrigeration contains separate lines based to allow the carcasses to be separated by grade. This also provides a buffering zone before entering the boning stage. In the majority of current processing plants, the chilling cell will not change from the existing chilling process.*

CELL 5: QUESTIONS	RESPONSE A	B	C	D	MEAN (µ)
A. Application and functionality of this cell design	**3**	**3**	**1**	**3**	**2.5 = Good/ Neutral**
B. Importance of application: This cell would help efficiency and effectiveness in relation to productivity	**1**	**3**	**1**	**3**	**2 = Agree**
C. Difficulties with this stage of your continuous chain					
• Break downs	**3**	**3**	**3**	**3**	**3**
• Bottlenecks	**4**	**3**	**4**	**3**	**3.5**
• Maintenance and cleaning	**4**	**3**	**2**	**3**	**3**
• Accidents/ health and safety issues	**4**	**3**	**2**	**3**	**3**
• Materials handling improvements	**1**	**3**	**2**	**2**	**2**
Difficulties with this stage of your continuous chain (Combined Mean)	**2.9 = Rarely difficult**				

Industry points:
Company A: *"This area is a bottleneck for the plant, wer'e already working on a continious chilling design, price of doing is expensive. If this cell can be created would save approximatley six staff"*
"Technical difficulties going from warm to cold with no condensation, this is already done with lamb and works well"
Company C: *"Our current setup of multiple chillers is somewhat like the proposed cellular method"*

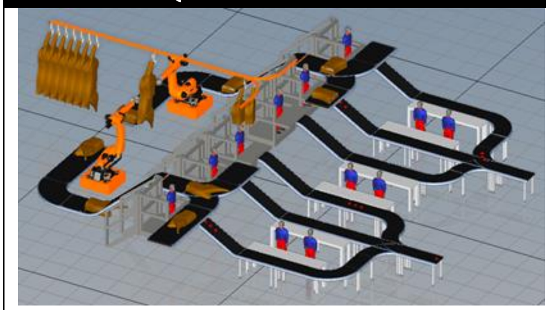
Figure 9: Cell 5 Chilling - Survey

Cell 5: Interpretation and feedback:

- The overall design of Cell 5 was rated GOOD/ NEUTRAL indicating participants weighted the cells application and use to be slightly better than neither good or bad. The importance of this cell was rated higher with participants agreeing that it would help efficiency and effectiveness in relation to productivity.

- The overall difficulty currently associated to this stage of the continuous chain was considered RARELY DIFFICULT. However, some companies did report to having high levels of materials handling as well as occasional difficulty with accidents, maintenance and cleaning.

- There was some general feedback on the concerns surrounding the expense of building chillers as the consensus was that it was very expensive

CELL 6: QUARTERING AND BONING	OVERVIEW
	*Cell 6 contains the quartering, boning and trimming processes before packaging.* *The carcass is divided into a hind section, a fore section and a middle section and are transported to individual stations. The fore and middle sections are transported to the raised boning platforms through bed conveyors while the hind section remains on the chain conveyor to the central boning platforms. The human workers then cut the sections into primal cuts which are transported via the belt conveyors.* *The cuts are then trimmed and sent to the packaging cell. Cell 6 contains multiple boning platforms for each section in order to meet a higher production rate. The bed and chain conveyors are divided to feed the separate platforms. Each platform also has its own trimming station fed via the next belt conveyors.* *Each trimming station contains two benches in close proximity to allow for cooperative work and to minimise idle time.*
CELL 6: EXTENDED AUTOMATION LAYOUT	
Extended automation and cell design of quartering and boning	

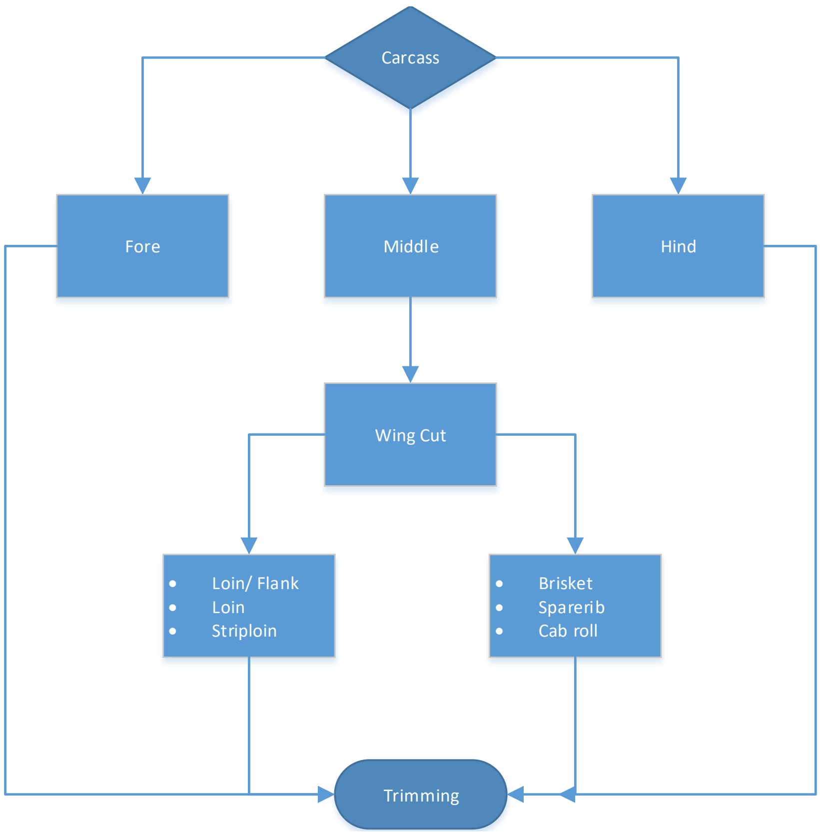


Figure 11: Extended automation and cell design of quartering and boning

CELL 6: OVERVIEW

Middle section of carcass can be further automated to extend from the Wing cut

Cell 6 contains the quartering, boning and trimming processes before packaging.

i. The carcass is divided into a fore section, a middle section and a hind section and are transported to individual stations.

ii. As automation technologies improve this cell can be further divided into individual cells, including one for dividing the carcass, one for each of the carcass sections including trimming operations or up to another three cells for trimming operations of each subset of primals from fore, middle and hind sections.

iii. These additional cells could allow for better integration of automation of tasks as they develop in the future. For example, the middle section primals could potentially be automated utilising an industrial robot with associated vision and sensing system working on a ban-saw to remove the brisket, spare ribs, cube roll, lion, thin flank, and striploin primals. If automation of the trimming of primals could be achieved this would be included in the cell. Otherwise the raw primals would progress to a separate cell for trimming as required.

iv. This design flexibility allows for production cells to be tailored to the requirements of individual processors and allow for ease of improvement or upgrading in the future, particularly with future automation as it develops.

CELL 6: QUESTIONS	RESPONSE				MEAN
	A	B	C	D	(µ)
A. Application and functionality of this cell design	**1**	**1**	**2**	**3**	**1.75 = Very good/ Good**
B. Importance of application: This cell would help efficiency and effectiveness in relation to productivity	**1**	**1**	**2**	**3**	**1.5 = Agree strongly**
C. Difficulties with this stage of your continuous chain					
• Break downs	**3**	**2**	**3**	**3**	**2.75**
• Bottlenecks	**1**	**2**	**3**	**3**	**2.25**
• Maintenance and cleaning	**1**	**2**	**2**	**3**	**2**
• Accidents/ health and safety issues	**2**	**3**	**1**	**3**	**2.25**
• Materials handling improvements	**1**	**2**	**1**	**2**	**1.5**
Difficulties with this stage of your continuous chain (Combined Mean)	**2.15 = Occasionally difficult**				

Industry points:
Company A:
"Tracbility needs to be looked at, how it would work with this layout. Accidents for us are generally related to strain of the position. There are high levels of materials handeling in this area."
Company B:
"Maybe hard to fit into our current setup, but the concept is great"
Company C:
"Would look at this if yield benefit could be proven together with labour savings"
Company D:
"The automation is good. Cut operator and tracability is a must have"
"Efficientcy without accuracy is not acceptable"

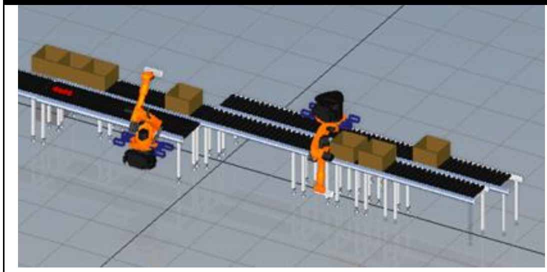
Figure 10: Cell 6 Quartering and boning - Survey

Cell 6: Interpretation and feedback:

/ The overall design of Cell 6 was rated AGREE STRONGLY/ AGREE indicating participants saw strong application and functional benefits, participants also reported strong belief that the cell would improve efficiency and effectiveness in relation to productivity.

/ The overall difficulty currently associated to this stage of the continuous chain was considered OCCASIONAL. Multiple companies did however report to having high level of bottleneck, maintenance and cleaning

/ Interesting to note that materials handling improvements rated a mean score of 1.5 which was significantly higher than any other part of the continuous chain

CELL 7: PACKAGING	OVERVIEW
	*Cell 7 involves the packaging and folding of the boxes to be sent out for distribution. The first robot packs the individual pieces into boxes from the belt conveyor. The packed boxes then travel to the second robot where the boxes are closed, then pushed onto another roller conveyor to be distributed. To reach a high production rate this cell should be duplicated as required. The primal cuts should be conveyed to the cell from the above boning cells. The packaged primals should be conveyed into a refrigerated storage facility as required by the specific processing plant.*

CELL 7: QUESTIONS	RESPONSE A	B	C	D	MEAN (µ)
A. Application and functionality of this cell design	**1**	**3**	**2**	**2**	**2 = Very good**
B. Importance of application: This cell would help efficiency and effectiveness in relation to productivity	**1**	**1**	**2**	**2**	**1.5 =Agree strongly/ Agree**
C. Difficulties with this stage of your continuous chain					
• Break downs	**4**	**1**	**2**	**3**	**2**
• Bottlenecks	**3**	**2**	**2**	**3**	**2.5**
• Maintenance and cleaning	**4**	**2**	**2**	**3**	**2.75**
• Accidents/ health and safety issues	**2**	**3**	**2**	**3**	**2.5**
• Materials handling improvements	**4**	**2**	**2**	**2**	**2.5**
Difficulties with this stage of your continuous chain (Combined Mean)	**2.45 = Occasionally difficult**				

Industry points:
Company A:
"Most plants have automatic lidding, one for chilled one for frozen Wouldn't lid it straight after, needs to be carton chilled, Case ready packaging would be needed. Potential saving of one or two staff per line."
Company B:
"This area gives our plant the most issues for downtime. Efficient automation could potentially save (2hrs) $10,000 per day (5 days per week)"
Company C:
"There is opportunity here with packing cartons"
"Good opportunity to reduce labour and OH&S issues"
Company D:
"Labour savings here in the vicinity of 140k to 350k PA"

Figure 12: Packaging - Survey

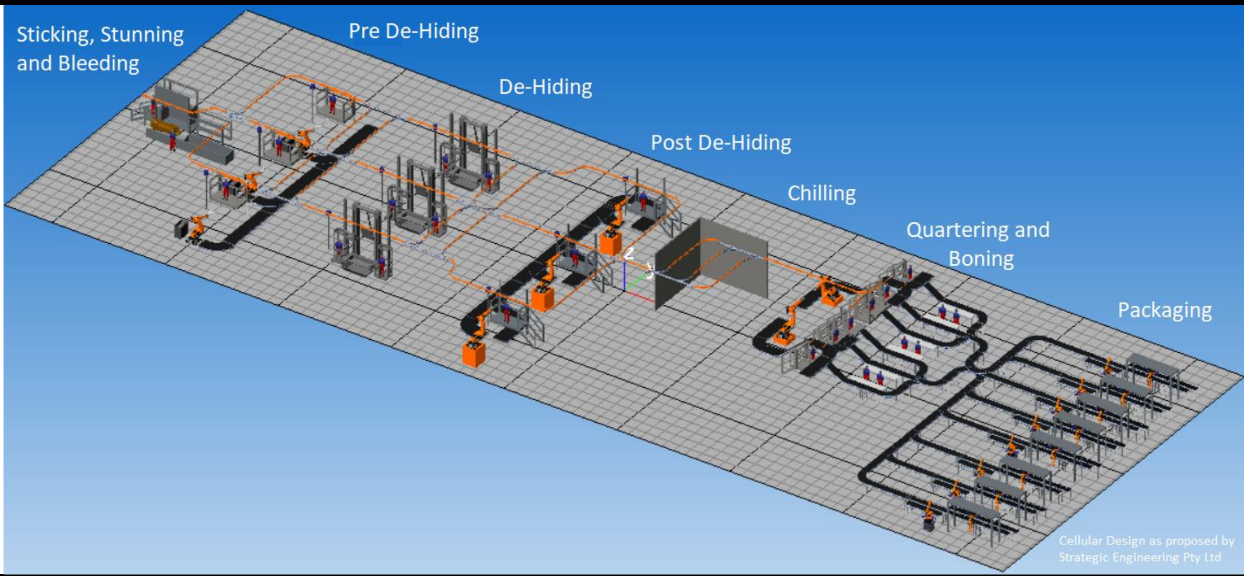
Cell 7: Interpretation and feedback:

- The overall design of Cell 7 was rated VERY GOOD indicating participants saw strong application and functional benefits, participants also reported STRONGLY AGREEING with the belief that the cell would improve efficiency and effectiveness in relation to productivity. This had a mean score of 1.5 the highest score for this question in the survey

- The overall difficulty currently associated to this stage of the continuous chain was considered OCCASIONAL. Multiple companies did however report to having high level of bottleneck, maintenance and cleaning

- Interesting to note that all companies saw potential savings around time and labour from improving this part of the continuous chain

COMPLETE LINE OVERVIEW



OVERVIEW

The complete high production line contains an increased amount of cells in order to meet a satisfactory production rate. The cells with a longer throughput time were multiplied in order to increase the overall rate of production. Cells with a shorter throughput time remained singular. The refrigeration cell also remained singular due to the increased chilling time, and acted as a buffering zone. A diversion system was created between each cell, to allow the carcasses to be transported between cells in the case of cleaning, maintenance or breakdown.

COMPLETE LINE OVERVIEW: RESULTS	RESPONSE A	B	C	D	MEAN (µ)
A. Application and functionality of overall cell design	2	1	2	3	2 = Good
B. The complete cellular design would help efficiency and effectiveness in relation to productivity	2	1	2	3	2 = Agree

Industry points:

Company A:

"In practice the overall concept is good, 99% of concepts are already operational. Big opportunity is in the boning room. As a greenfield solution this has good merit."

"The main constraint is actually developing and becoming convinced of various innovations benefits and then working out how to make them work given the existing infrastructure and need to continue to operate while changes are implemented."

Company B:

"The concept is great, would need to know if it can fit into an existing production line and the cost to transfer to cellular method"

Company C:

"I see more opportunity through boning and packaging technolgy, would need to have bang for buck"

Company D:

"Really not sure, would need a cost/ benefit analysis to be completed. Would also like to see the correlation to how it could be done on the slaughter floor as well as how a plant would transfer to cellular manufacturing whilst still operating continious chain" "For us its not about creating more volume, its about getting more out of the carass. Cattle supply is the issue, Creating blance between available cattle and sustainable markets to sell into. The business is about sustainable profitability."

Figure 13: Complete line overview - Survey

Overall cell design: Interpretation and feedback:

- The overall functionality of the complete cell line was rated GOOD. Participants agreed that cells within a complete line would help efficiency and effectiveness in relation to productivity

- The majority of participants suggested that there was no need to automate this part of the chain under current conditions.

- Labour savings varied from cell to cell 2x staff 10x staff post de-hiding picking and packing

- The overall response to the application and functionality of the proposed Cellular design was that on a whole it was rated as good. In conducting interviews, it was evident that participants held strong opinions and possible bias toward the future potential and capacity of new technology and how it could realistically be applied.

Survey results - Increased volume required for new technology consideration

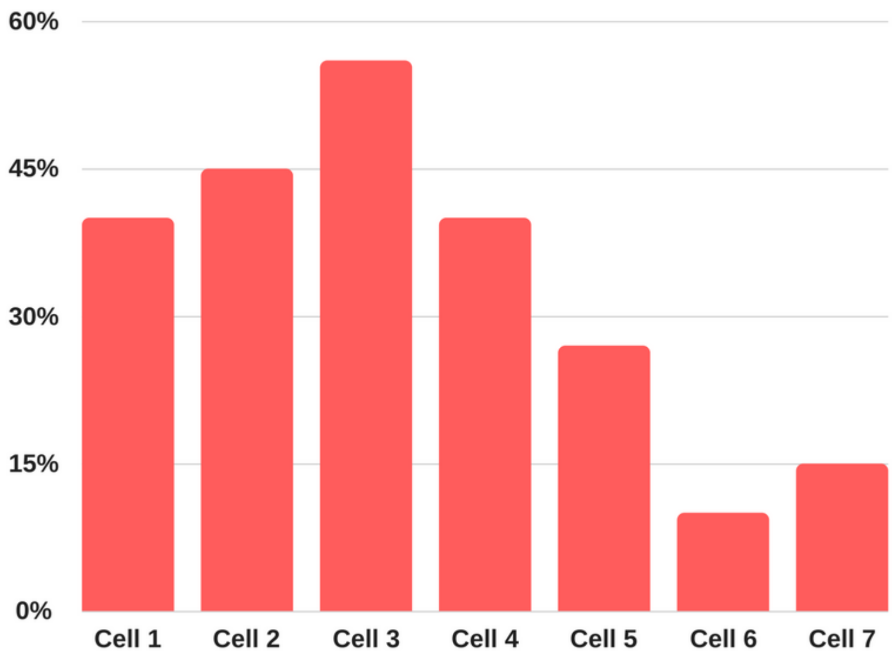


Figure 14: Increased volume required for new technology consideration - Bar graph

The graph above shows a summary of the percentage of increased demand/ volume that participants would look to new cellular technology options to assist productivity. It can be seen that there is a general open mindedness and strong inclination to incorporate technology change particularly for cells 6 and 7 as these were identified as critical areas for process improvement.

5.7 Survey 1C: Future automation

The list of potential future automation extends from previous work completed in 2016-1033: Cellular Production and gives perspective to what areas would be most beneficial to processors. Insights to how desirable an automation task is can be used for the direction of research and development for the type of industrial and collaborative robots as well as special built machines that would be most suitable for future cellular manufacturing design and application.

The following tasks have been rated as having good potential for future automation development for a stationary carcass. Participates were asked to rate the potential automations over current manual processes. The following Likert scale was used.

1=Highly desirable; 2= desirable; 3= Neither desired or not desired; 4= Not desired; 5= Highly undesirable NB: Mean scores are calculated for each survey

#	AUTOMATION TASK	RESPONSE				MEAN	DESIRABILITY
		A	B	C	D	(μ)	
1	Stunning	4	1	3	2	2.5	Desirable
2	Sticking	4	2	3	4	3.25	Neutral
3	Hoist onto chain	2	1	2	4	2.25	Desirable
4	Horn	2	1	3	4	2.5	Desirable
5	Head removal	2	4	3	4	3.25	Neutral
6	Belly cut	3	2	3	4	3	Neutral
7	Hock removal	2	2	2	4	2.5	Desirable
8	Tail removal	3	2	3	4	3	Neutral
9	Carcass splitting	2	1	2	2	1.75	Desirable/ Highly desirable
10	Spinal cord removal	2	1	2	4	2.25	Desirable
11	Fat sucking removal	1	1	4	2	2	Desirable
12	Quarter cut	3	1	2	2	2	Desirable
13	Scribing	2	1	2	2	1.75	Desirable/ Highly desirable
14	Chilling	1	3	2	5	2.75	Desirable/ Neutral
15	Bagging and sealing	1	2	1	2	1.5	Highly desirable
16	Picking and Packing	1	1	1	2	1.25	Highly desirable

Figure 15: Future automation - Survey

Future Automation – Summary table

DESIRABLE	BETWEEN: DESIRABLE/ HIGHLY DESIRABLE	HIGHLY DESIRABLE
•Fat sucking removal •Quarter cut	•Scribing •Carcass splitting	•Picking and packing •Bagging and sealing

5.8 Barriers to Adoption

Survey 2: Barriers to adoption

Participants A, B, C and D were asked to rate barriers to adoption for CM being applied to their organisation. The following Likert scale was applied to 15 potential barriers. *Never a barrier; Occasionally a barrier or Always a barrier*

#	POTENTIAL BARRIER AND OBSTACLE TO ADOPTION	NEVER	OCCASIONALLY	ALWAYS
1	Resistance from faculty and operator staff		A B C D	
2	Managers resistance	A	B C D	
3	Lack of support from various departments	A	B C D	
4	Influence of trade unions	A C D		B
5	Lack of knowledge about Group Theory/ Cellular Manufacturing techniques	A	B C	D
6	Lack of training and education in the use of Group Theory/ Cellular Manufacturing techniques		A B C	D
7	Factory floor layout			A B C D
8	Lack of advanced machinery		A C	B D
9	Lack of IT personal/ expertise within organisation		A B C	D
10	Capacity to install and implement the Cellular Manufacturing system	A	B C	D
11	Capacity to retrain staff	A B D	C	
12	Concern about the loss of productivity during transition to the new system		B C	A D
13	The amount of capital needed to acquire and implement		C	A B D
14	Lack of funds	A D	C	B
15	Uncertainty about the return on investment			A B C D

Figure 16: Barriers to adoption - Survey

The points that were deemed to always be a barrier included; Factory floor layout of current premises, uncertainty about the return on investment of CM overall and the amount of capital needed to acquire and implement the various cells

Barriers to Adoption - Summary table:

NEVER	OCCASSIONALY	ALWAYS
• Capacity to retrain staff	• Resistance from management and operator staff • Lack of support from various departments • Lack of IT personal/ expertise within organisation	• Factory floor layout • Uncertainty about the return on investment • The amount of capital needed to acquire and implement

To overcome the identified barriers to adoption of CM Rogers Diffusion of Innovation Theory (Rogers, 1995) could be applied to assist the industry to mitigate and overcome them.

This would include developing the following Diffusion of Innovation areas of Relative advantage, Compatibility, Complexity, Trialability and Observability;

/ **Relative advantage** can be examined through a cost/benefit analysis so that CM integration is identified as being a better long-term business model with greater advantages over continuous chain processing.

/ **Compatibility** could be determined by examining how CM could complement current plant configuration. CM design would be tailored to individual processor needs. Rogers Diffusion of Innovation Theory suggests that the more compatible the innovation the greater likelihood that it will be adopted.

/ **Complexity** surrounding how to integrate CM technology and automation is something that needs to be addressed if CM is to be embraced by processors. This can be done on a plant by plant basis through a method of communicating the concepts with appropriate stakeholders.

/ **Trialability** is something that would support the understanding of CM to processors. A project that would test a live cell could be used to support this.

/ **Observability** requires results of CM to be seen by processors, again a project with a live cell would be needed to show and prove benefits. During the trialability and observation stages relevant data could be collected and shown as evidence to processors.

5.10 Absorptive Capacity

Survey 3 – Absorptive capacity

Absorptive capacity is a firm's ability to identify, assimilate, transform, and apply valuable external knowledge. The following survey aims to give insight to the levels of absorptive capacity the participant companies have in their understanding and application of new market information/ technology/ R&D

Participants entered a number from 0-100 and used the following scale (as a guide) when rating their organisations absorptive capacity. NB: Mean scores are calculated for each survey

SCORE	CURRENT POSITION OF THE ORGANISATION
100	**Yes, fully practiced throughout the organisation. Continually refined and improved as 'The way things are done around here."**
80	**Yes, being practiced consistently across the organisation with further improvements being made.**
60	**Yes, being practiced across most of the organisation most of the time.**
40	**Yes, being practiced, but only in parts of the organisation, part of the time**
20	**Yes, this has just started**
0	**No, this is not in place**

1. ACQUISITION CAPACITY	SCORE	MEAN
Our management quickly identifies and acquires new market knowledge that has been formally and informally collected by the company.	**A:80**	**55**
	B:40	
	C:60	
	D:40	
Management can effectively collect internally provided market information.	**A:80**	**65**
	B:60	
	C:60	
	D:60	
Our management has the ability to readily capture and put to memory the relevant market knowledge that is made available to them and that they require to develop their work.	**A:80**	**58.7**
	B:80	
	C:60	
	D:60	

Category Mean		**59.5**
2. ASSIMILATION CAPACITY	**SCORE**	**MEAN**
Our management quickly recognise shifts in the market from the information distributed to them.	**A:75**	**73.7**
	B:60	
	C:80	
	D:80	
New opportunities to serve our clients are quickly understood by management from the information distributed to them.	**A:80**	**70**
	B:60	
	C:60	
	D:80	
Our management quickly analyses and interpret changing market demands from the information distributed to them.	**A:80**	**77.5**
	B:80	
	C:70	
	D:80	
Category Mean		**73.7**
3. TRANSFORMATION CAPACITY	**SCORE**	**MEAN**
Our management quickly recognise the usefulness of the new market knowledge that is distributed to them with regard to their existing knowledge.	**A:80**	**65**
	B:60	
	C:60	
	D:60	
Our management identifies opportunities for the company from the new market knowledge that is distributed to them.	**A:80**	**70**
	B:60	
	C:60	
	D:80	
Our management has the ability to combine existing market knowledge with the newly acquired and assimilated knowledge provided by the company, with commercial ends.	**A:80**	**70**
	B:60	
	C:60	
	D:80	
Category Mean		**68.3**
4. EXPLOITATION CAPACITY	**SCORE**	**MEAN**
Our management constantly considers how to better exploit the market knowledge that is distributed to them.	**A:80**	**75**
	B:80	
	C:80	
	D:60	
Our management are able to apply the new market knowledge that is distributed to them in their practical work.	**A:80**	**65**
	B:60	
	C:60	
	D:60	
Our management has the ability to use and exploit the market knowledge that is distributed to them to respond quickly to market changes.	**A:80**	**70**
	B:60	
	C:60	
	D:80	
Category Mean		**70**
Total Mean Score for Absorptive Capacity		**67.8**

Figure 17: Absorptive capacity - Survey

The survey data suggests that there is some room for growth with sample answers generating a combined mean score of 67.8 points out of 100

A particularly low mean score of 55 was generated to the question *"Our management quickly recognise the usefulness of the new market knowledge that is distributed to them with regard to their existing knowledge"* Themes generated from barriers to adoption may have a correlation to the levels and motivations toward absorptive capacity for CM. The Significance of this information could potentially relate to how efficient and effective the industry would be at understanding and incorporating an application like CM and the ability to transition when required.

Survey results – Absorptive Capacity

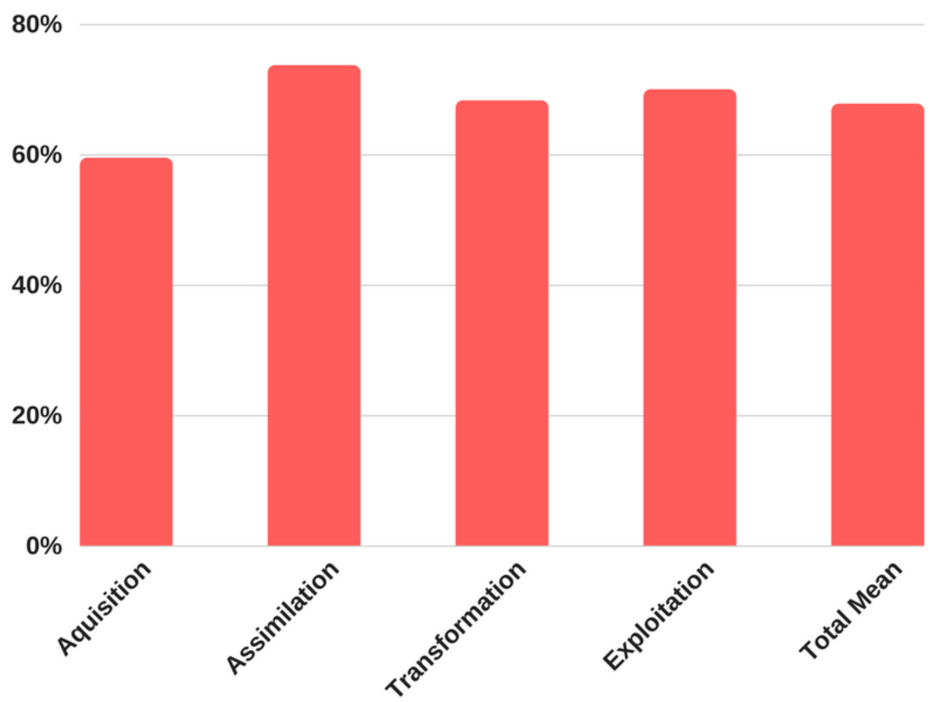


Figure 18: Absorptive Capacity - Bar graph

5.11 Management Capability

Survey 4 – Management capability

Participants entered a number from 0-100 and used the following scale (as a guide) when rating their organisation management capability. NB: Mean scores are calculated for each survey

SCORE	CURRENT POSITION OF THE ORGANISATION		
100	**Yes, fully practiced throughout the organisation. Continually refined and improved as 'The way things are done around here."**		
80	**Yes, being practiced consistently across the organisation with further improvements being made.**		
60	**Yes, being practiced across most of the organisation most of the time.**		
40	**Yes, being practiced, but only in parts of the organisation, part of the time**		
20	**Yes, this has just started**		
0	**No, this is not in place**		
1. VISIONARY AND STRATEGIC LEADERSHIP		**SCORE**	**MEAN**
Management articulates a clear and inspiring vision that is well understood		**A:75**	**83.7**
		B:100	
		C:60	
		D:100	
Management actively fosters and encourages ownership of the vision by the staff		**A:90**	**82.5**
		B:100	
		C:60	
		D:80	
The vision and supporting goals underpin and guide the managerial decisions and behaviours		**A:100**	**85**
		B:100	
		C:60	
		D:80	
Management plans with a view to growing the business while meeting the needs of shareholders/ owners, taking into account employees, suppliers, and customers.		**A:100**	**90**
		B:100	
		C:60	
		D:100	
Management demonstrates an international/ global perspective and has a good understanding of global markets and global thinking		**A:100**	**90**
		B:100	
		C:60	
		D:100	
		Category Mean	**86**
2. PEOPLE LEADERSHIP		**SCORE**	**MEAN**
Management attracts, retains, develops, motivates and leads an effective team capable of achieving company objectives.		**A:80**	**80**
		B:100	
		C:60	
		D:80	
		A: 80	**75**

Human resource planning is an integral part of the annual business planning process	B:100 C:60 D:60	
Management provides enhanced leadership - acts as a role model, is committed to developing subordinates and leading people	A:80 B:100 C:60 D:80	**80**
Management is strong on empowerment – allows scope for people to grow and contributes towards employee's growth and therefore enhancing their CV	A:80 B:100 C:60 D:80	**80**
Management maintains a culture supportive of today's employee values – not stifled by structure and hierarchy	A:80 B:80 C:60 D:100	**80**
Category Mean		**79**
3. ORGANISATIONAL CAPABILITY	**SCORE**	**MEAN**
Management builds organisations capability, a culture of innovation and research, and an organisation dedicated to continuous improvement.	A:100 B:100 C:70 D:60	**82.5**
Management brings about and maintains a 'boundary less' organisation, which is confident and effective in leading and managing a non-hierarchical structure.	A:0 B:100 C:60 D:80	**60**
Management effectively balances strong effective teams with free (independent individuals)	A:70 B:100 C:60 D:80	**77.5**
Management has a sound understanding and effective application of best management practice to achieve organisational goals and objectives.	A:90 B:100 C:60 D:60	**77.5**
Management demonstrates strong commitment to continuous learning for both individuals and the organisation	A:90 B:100 C:80 D:80	**87.5**
Category Mean		**77**
4. INNOVATION – PRODUCTS AND SERVICES	**SCORE**	**MEAN**
Management and employees create the climate for and encourage continuous innovation in products and services.	A:90 B:80 C:80 D:60	**77.5**
Management and employees recognise innovation as an important aspect of business for all the organisations processes – Innovation is part of the organisations culture.	A:90 B:80 C:80	**82.5**

	D:80	
Management and employees recognise the innovation leads the business to new dimensions of performance	**A:90**	**82.5**
	B:80	
	C:80	
	D:80	
Management and employees practice innovation to create new values for the business, customers and shareholders.	**A:90**	**72.5**
	B:80	
	C:60	
	D:60	
Management and employees practice innovation to expand the market and increase the market share	**A:90**	**77.5**
	B:80	
	C:60	
	D:80	
Category Mean		**78.5**
Total Mean Score for Management Capability		**80**

Figure 19: Management capability -Survey

Management capability refers to an organisations collective management competencies as they can be applied to achieve desired outcomes. The design purpose of this survey was to identify how effectively the management team puts into practice its combined competencies to deliver business results. Creating organisation benchmarks to rate management effectiveness may help processors be best prepared to respond to external challenges as well as maximise new opportunities.

Management capability was rated on areas including Visionary and Strategic Leadership, People Leadership, Organisation Capacity, Innovation of Product and Ideas. Overall participants rated quite highly with a total mean score of 80 out of 100 suggesting that there are sufficient capabilities within the surveyed plants to act on major decisions. However, given that cellular manufacturing represents a significant paradigm shift away from the idea of the chain, plant management would obviously require significant support and resources to implement CM.

Survey results - Management Capability

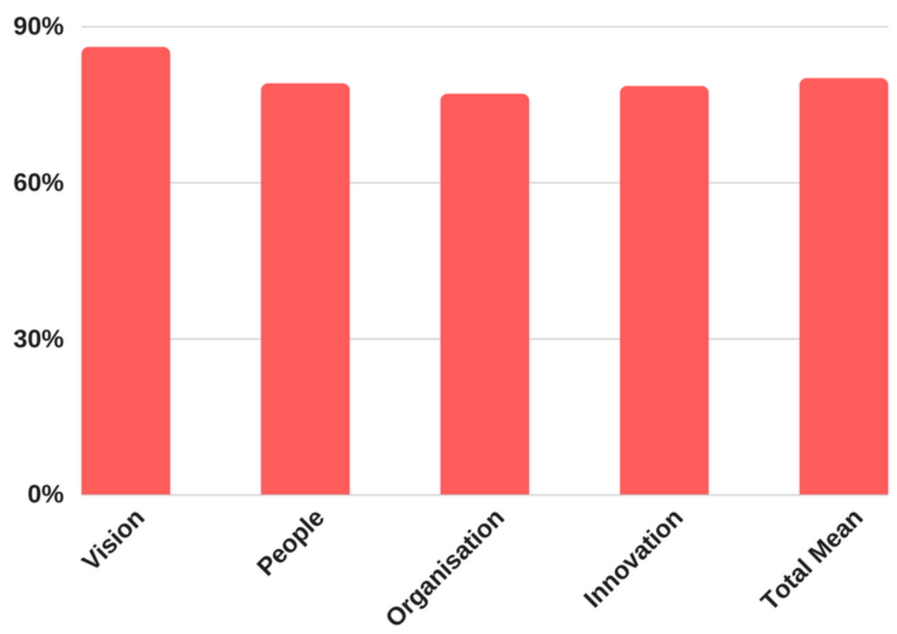


Figure 20: Management capability - Bar graph

6.0 DISCUSSION

Considerations surrounding incorporation of cellular manufacturing for the red meat industry:

6.1 Greater automation potential via Cellular Manufacturing

The largest potential benefit long term from CM is an increase in automation. Due to the enormous variability in meat products, automation has been slow to develop around meat processing and is generally cost prohibitive. Whether from the differences between each animal or just the uncontrolled motion on the continuous line chain, the variability presents challenges for automation. Complex and expensive sensing systems are required as well as mechanical restraining devices or software to track the moving chain. Furthermore, the nature of the continuous chain makes integration of automation systems challenging. Required maintenance and breakdowns cause unnecessary stoppages or can slow down production considerably as manual operation of tasks is required during the interim downtime.

In a cellular based production model, the potential for automation increases. The product is generally static and more easily restrained for multiple tasks or cutting operations. This eliminates the need for tracking software or restraints for every task being automated on the continuous line. Additionally, the complete sensing requirements of multiple tasks can be better utilised in a single cell. Whereas in a continuous line production, every individually automated task may require additional sensing feedback as the product has continued to move along the chain. CM has the potential for better utilisation of expensive automation hardware, or at least reduces the capital costs of future automation.

The cellular nature of CM is also better suited for robotic automation. The robotic cycle time is set by the speed of the continuous line production. While in CM the cycle time is more flexible, more difficult tasks can take longer if required without affecting the performance of the whole production facility. Breakdowns or regular maintenance of robots is a huge problem in continuous line production. Either the whole line has to stop, or operators have to be able to access the line to take over while the robot is down. In CM, if multiple cells are operating in production then maintenance can be scheduled to minimise the impact on production. Breakdowns should also be easier to manage as alternate cells can handle production during down time. If required operators can take over from the robot, to maintain the production level or if multiple cells are not available.

In most cases one robot is capable of completing multiple tasks with the right tools, sensing feedback and time to complete each task. With an automatic tool changer, a standard industrial robot could potentially automate all tasks in a work cell, with an added advantage of a single sterilisation point. Sensing requirements for all tasks at once might be problematic, but the cellular model makes it easier to develop automation of individual tasks. If one task can be automated, then the majority of the hardware and cost is already existing for developing and automating a second task. In the continuous line chain, automation of several tasks would require a robot, sensing system and method of tracking or restraining for every single task. Which is why currently a lot of industrial automation in the meat industry is cost prohibitive or not cost effective.

6.2 Objective carcass measurement presents added opportunity

CM has the ability to synergise well with objective carcass measurement Systems (OCM). The potential benefits of CM become more real and probable when used in conjunction with the adaptation of this new technology. Industry feedback supported the idea that OCM would assist in accelerating the advancement of potential automation for cellular application particularly in the boning area of production.

6.3 Increased access to international markets

The advantages of CM extend to its rapid flexibility to respond to changes in market conditions, where it can seize the opportunities of emerging and growing markets. An example of such an opportunity is the recent free trade agreements made with China. The Australian beef industry will now be able to potentially increase its market access for chilled meat products. The number of processors allowed to export refrigerated and vacuumed sealed cuts is set to triple and total beef exports to China are expected to now reach a billion dollars a year. Whilst the opening of this free trade agreement will also extend to other competitors including the USA, the point can still be made for CM and how we could use it to increase production efficiencies as well as strengthen our mandate to be seen as leaders in safety and quality.

6.4 Opportunities and world trends

The following opportunities and world trends can also be applied to the decision making process of whether to apply CM strategies.

- There is strong data that supports real opportunity for the red meat industry throughout the next decade. By 2030 the Asian Pacific population is expected to increase by 700 million people (MISP, 2020) During this time global real per capita incomes are expected to increase by 60% to 2030.

/ An estimated 25% increase in the demand for red meat is expected through to 2030 based upon the combined increases in population and salary throughout Asia Pacific (IBIS, 2015, p. 20)

Australia is well positioned to take advantage of this uptake as it has clear advantages over competitors in relation to geographical proximity to these markets as well as being a recognised supplier of safe, nutritious and ethically produced red meat. The introduction of CM and associated advancements in automation and robotics will only help to promote our reputation of quality assurance.

6.5 Early technology adoption applied to cellular manufacturing

There is a substantial difference between innovation and early technology adoption. In its simplest terms innovation is the use of critical thinking to improve upon current technologies, processes and management structures. Early adopters of new technology separate themselves through a conscious decision to champion new technology before their competitors.

Companies that are able to quickly adapt within a market are typically less prone to competitive threats, but being the first isn't necessarily an advantage. Ultimately, the decision comes down to when to adapt to new technologies. The red meat processing industry in relation to CM must thoroughly understand the balance between risks of the adoption and the time delay for competitors or new entrants to implement CM themselves. To achieve competitive advantage Australia doesn't necessarily need to be first to incorporate CM, but rather position itself to adapt at the right time, whether this be simultaneous to, or shortly after competitors adapt. The objective should be to promote a red meat processing industry that has a responsive organisational structure.

6.6 Cellular manufacturing beyond return on investment

Whilst a full economic feasibility study was not part of this project, it was evident from industry feedback that there would need to be further cost/ benefit analysis completed before CM would be accepted as a realistic alternative to the continuous chain. The data showed that the majority of participants would be willing to look at technology options in the later stages of processing, particularly stages 5, 6 and 7 (Chilling, Quartering and Boning and Packaging). It is here where most cost savings can be gained due to greater opportunities to automate materials handling tasks in a cellular environment.

Whilst there needs to be positive return on investment we would like to reinforce to processors that the benefits that CM brings shouldn't be focused on short term monetary gains. By incorporating elements of CM it lays the foundations to what will hopefully add to the sustainability and security of the industry as a whole, further to this it has the potential to reinforce competitive advantages over other countries contesting our markets. In particular, the elements of quality control, safety, flexibility and reliability all need to be factors that go beyond simple return on investment calculations.

7.0 CONCLUSIONS/RECOMMENDATIONS

Based on the research presented in this feasibility study it is recommended that AMPC supports implementation strategies to adopt Cellular Manufacturing in the red meat processing industry.

Justification:

/ CM is able to deliver improved quality, reliability, flexibility and increased opportunity for automation within the red meat industry. Whilst there are identified barriers to adoption it is believed that these can be overcome so that greater future benefits are achieved.

/ We believe that group theory can successfully be applied to red meat processing, giving greater potential to improve production and yield.

- Feedback from industry participants supported the presented concept of cell design overall and agreed with its potential to improve efficiency and effectiveness of production.
- There is strong evidence supporting the need to adopt new technology alternatives now so that processors can achieve desired plant volume capacity. In addition to this CM offers processors the flexibility to increase or decrease volume levels when required.
- CM has the ability to synergise with Objective Carcass Measurement Systems. The benefits of CM become more real and probable when used in conjunction with this technology.
- CM benefits would still need to be trialled, observed and quantified so that the industry will accept production changes and return on investment. Once this is achieved we expect that processors will embrace the technology.
- Whilst there are risks associated with every investment, the returns of CM are seen as worthy for the future advantages it represents. It is recommended that the industry apply a blended cellular transition approach so that CM can be utilised it in the areas of most need for individual plant requirements.

7.1 Suggested next step points of action

1. **Extended statistical analysis study (if required)**

   Project 2016 – 1054: Feasibility Study into a High Volume Cellular Processing Plant could be developed further by creating quantitative statistical analysis from a broader sample group. This would develop the research and help confirm findings as being statistically significant.

2. **A Time in motion study**

   A time in motion study of every worker within the current continuous chain. This testing could be conducted on a general high volume plant. Data collection of stoppages associated to production issues and bottlenecks within the continuous chain could also be conducted so that calculations can made to estimate the associated costs. Individual task timing data would be broken down and then re-applied to determine estimated task timings for a CM system. This would facilitate the quantification of the benefits of CM and relative comparison to the chain. Breakdowns, start-ups, shut-downs, stoppages etc. could then be factored in to give a more detailed quantitative cost comparison between CM and continuous chain.

3. **Economic feasibility study**

   A complete economic feasibility study should be undertaken so that a Cost/ Benefit analysis and Risk Assessment applied to transitioning to the proposed CM model. The study would also include a high level design and costing of the different sections of a CM plant as well as space requirements for each cell.

   Using historical data, the study could be extended to show the flexibility and scalability of CM during high and low periods of production. Such a study would include analysis of the secondary to immediately quantifiable return on investment which would assess the value of safety, maintenance, cleaning, flexibility, reliability, and stoppage factors.

4. **Design and build a prototype cell**
    a. Detailed design/ build prototype cell in workshop environment
    b. Implement prototype

   Validation through live cell testing and application within a continuous line environment.

5. **Absorptive capacity support and development**

   In conjunction with future studies we recommend that initiatives be taken to increase the general understanding of innovation Absorptive Capacity and how it can be applied to red meat processing. Whilst organisations may appreciate innovation and new technology development they need the skills to be able to identify, assimilate, transform, and apply valuable external knowledge to their individual business models. This role needs the heightened support of senior management and could be incorporated into the innovation managers job role.

7.2 Alternative options for cellular manufacturing application

Option A

A Greenfield application of CM could be designed and priced. This would serve new operations well in building a plant of the future. Survey feedback suggest that the vast majority of the industry wouldn't be in a position to stop or change operations to build a new facility from scratch.

Option B

From the industry participants surveyed all had different process issues within their respective plants, therefore a general greenfield CM approach cannot be taken for all operations. A value stream map could be developed for individual sites to identify where CM is most beneficial. Cellular designs could be directed to the identified problem and bottleneck areas of cells 5; 6; 7(Chilling, Quartering and Boning and Packaging)

Option C

A third option would be to accept the benefits of CM for the industry, but wait for the best time to apply it in practice. During this period further research can be committed to Time in Motion studies, Economic Feasibility and Competition Analysis.

The industry whilst preparing to integrate would remain collectively agile to apply CM when required so as to not allow competitors to obtain equivalent technology adoption advantages.

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9.0 APPENDICES

9.1 Appendix 1: Industry consultation - Company profiles

Company profiles:

Total sample size, n=4

Company A:

- Single plant operation
- The survey was completed by the General Manager, who's job role overseas all departments of the business including sales marketing and processing. His primary professional training and experience is 25+ years' working in meat processing and is tertiary educated with a degree in processing engineering.

Company B:

- Single plant operation
- The survey was completed by the Operations Manager, who's main job role covers all areas of operations and production for the plant. His primary professional training and experience is 35+ years' working in meat processing and has an Advanced Diploma in meat management.

Company C:

- Single plant operation

/ The survey was completed by the Innovation Coordinator, who's main job role is assisting in operations and production. His primary professional training and experience is working 10 years in meat processing with Diplomas in Meat processing and Procurement.

Company D:

/ Multiple plant operation

/ The survey was completed by the Operations Manager who sees over all aspects of operational management, project ideation and capital management. His primary professional training and experience is on the job with a long term working career in meat processing.

9.2 Appendix 2: Plant summary: Industry participants

COMPANY PROFILE	COMPANY			
	A	B	C	D
Plant Size (High, Medium, Low Volume)	Medium	High	High	High
Number of staff	480	750	700	3500
Current volume per day	600	950	800	6,250
Desired volume per day	1200	1600	1100	6,250
Plant throughput head/day	640	1000	1100	6660
Current adoption of automation and robotics	Minimal	Nil	Minimal	Nil

9.3 Appendix 3: Initial survey - Continuous chain bottleneck summary

COMPANY	GENERAL BOTTLENECKS
A	• Chillers • Boning room
B	• Backend of packing room • Chilled and frozen scales load out
C	• Materials handling issues • Management of trim CL's out of boning room • Vacuum pack off capacity
D	• No bottlenecks, but identified issues surrounding labour availability and sustainability as well as down time in production and no production