FINAL REPORT

Milestone reports 8-10

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TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

1.1. Background

In this project we studied the adoption of new technologies from the competitive and sustainable automotive industry in the red meat industry.

The automotive industry, as a high volume-low margin sector, is the pioneer in automating manual tasks, by developing the most advanced and cost-effective systems. The most efficient and innovative systems have been developed in automotive companies due to the highly competitive environment in this industry. While these technologies are mainly created and developed for the auto industry, many other industries have managed to adopt and processes into their field.

Development of innovative manufacturing, processing, materials handling solutions and technologies as well as management systems and appropriate culture has helped the automotive industry to stay efficient and sustainable for many years. On the other hand, the Australian automotive industry is leaving a huge number of culturally trained and skilled workers behind.

This makes the need for an extensive research in adapting and using the already existing technologies, strategies, and systems in the automotive industry inevitable. In this project we investigated the possibilities and potentials for the red meat industry to adapt technologies and solutions in the field of automation, materials handling solutions, management of processes and procedures developed and used by the Automotive industry is proposed.

Finding the gaps in the red meat industry and linking across to relevant automotive and other food industry technologies and solutions for optimizing the procedures, mechanisms and machinery or development and implementation of technologies and solutions to automate and replace existing manual tasks.

1.2. The Objectives and Methodology

After studying both industries, we followed the below steps:

Industry Gap Identification: Finding the gaps in the red meat industry and linking across to relevant automotive and other food industry technologies and solutions for optimizing the procedures, mechanisms and machinery or development and implementation of technologies and solutions to automate and replace existing manual tasks.

Improvement Opportunities: Identifying automotive industry technologies and systems with potential usage in the red meat industry and providing guidelines and suggestions for application of required modifications to facilitate the transfer. This will be done by finding similar activities in other food industries to provide better standards of health, safety, and cleanliness before the transfer phases.

Benchmarking: Identifying ready for transfer automotive industry systems and technologies by benchmarking similar systems in other food industries and suggest strategies for smooth transfer, implementation, and integration into the red meat processing industry.

Future research: Identifying further research capacity and industry needs.

The two industries were thoroughly reviewed to enable technology mapping. Extensive literature review together with meat processing plant visits were conducted. This resulted in a detailed review of the processes and technologies in the meat industry. Multiple resources including industrial experience, books, journal papers, training videos, etc. were used to understand red meat industry processes and industry gaps. Same steps were taken to review the automotive industry and automotive manufacturing line site visit was also conducted. Processes between the two industries were mapped, management systems were compared, process improvement opportunities together with technology adaptation opportunities were identified (Figure 1).

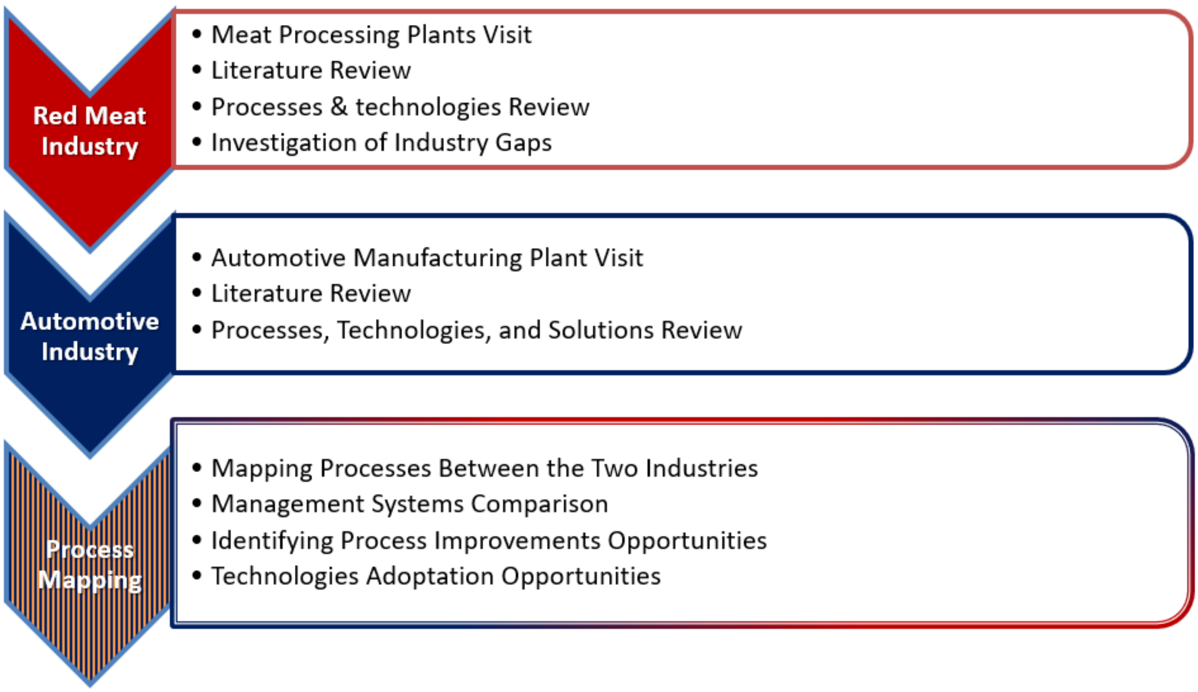

Figure 1 Methodology

1.3. Proposed Improvement Ideas

Below is a summary of the shortlisted proposed actions. Each idea should be further studied and discussed in detail for application suitability.

Lean Mindset: Implementing lean manufacturing principles will greatly help improving the plant efficiency by reducing waste and improving the cycle time. All staff in different levels require training to fully understand the lean manufacturing concepts and try to implement them in their own tasks.

Layout: Developing a detailed layout of the processing lines, including the correct dimension of each station, head counts, facilities, etc. is a crucial step to improve the plant efficiency.

Material Handling: One of the very first and obvious challenges observed in the plant was the material handling and logistics issues. This cannot be looked at as an isolated issue. Some of the below explained actions are required to be done initially to then enable the team to come up with the best solution for a smooth material handling solution.

Process Documentation: We propose that processes are documented for each station. This is referred to as "Process Illustration" or "Station Information Sheet". This document includes a description of the process for the station, illustrations to fully clarify the defined process, a list of the tools required to complete the task, the cycle time, the number of operators in the station, and finally a simplified snapshot of the layout to demonstrate where in the line this process happens.

Throughput Simulation: Throughput simulation is a type of discrete event simulation to use technical realisation of one layout to prove concept is sufficient to meet planned production capacities. Material flow, system availabilities and bottle necks will be identified and optimized in simulation. While this usually takes place in the plant design phase, we highly recommend this analysis to be done for the visited plant.

Safety & Ergo assessments: Safety and ergonomic assessment of the processes is a key to improve the processes. This will help to identify the issues which will impact the operators' performance and consequently the product quality.

Automation: In the visited plant, it was observed that there are many opportunities to improve the efficiency of the processes by the means of automation, throughout the process from the animal stunning to the flat box folding and final packaging of the product. Automation will require more initial investment compared to manual operation, but it delivers huge benefits such as long-term labour cost savings, high level of safety, and product quality improvement.

2.0 INTRODUCTION

2.1. Background

It is estimated that the world population will reach 9.7 billion by 2050 and 11.2 billion in 2100 (Gerland et al., 2014). An at least 70% increase in global food production is required to meet the increasing consumption levels, dietary changes and significant increases in costs (House). Access to raw material and resources and optimal utilization and processing are key factors in the food industry. To cope with this dynamic landscape and prosper, the food industry is required to capture competitive advantage through innovation and revolutionary strategies.

Australia is the world's largest exporter of red meat and livestock, exporting to more than 80 countries and with exports representing 74% of the industry's trade (Seo and McCarl, 2011). With an approximately $8 billion yearly revenue, the Australian red meat industry is one of the country's most prominent industries. The meat industry contributes significantly to the economics of regional Australia employing over 135,000 people (Peters et al., 2010). Moreover, the meat industry is a major component of the food processing industry, the largest manufacturing sector in Australia.

Australia's red meat industry has faced several major challenges in recent years which have brought up the importance of development and implementation of effective innovation strategies. Decline in market shares, food safety concerns and skilled labour shortage have highlighted the significance of implementation of new technologies and business strategies to improve production and overall global competitiveness in the recent years. The meat and automotive industries possess many similarities in terms of challenges they face, and the strategies undertaken to tackle them. The main concern and issue both industries face is maintaining the quality and safety without compromising the production rate. Moreover, the manufacturing process and market delivery of products should meet the requirements and regulations set by governmental, national, and international bodies.

The Automotive industry, as a high volume- low margin sector, is the pioneer in automating manual tasks, by developing the most advanced and cost-effective systems (Panwar et al., 2015). Management systems developed within and for the automotive industry are used in a variety of other industries and taught in many universities (Panwar et al., 2015). The Australian Automotive industry was one of a few in the world capable of taking an automotive design all the way from concept to production.

2.2. Research Aims and Objectives

In general, this study focuses on investigation of the possibilities and potentials, opportunities, and limitations for the red meat industry in adapting technologies and solutions found in the automotive industry. Fields of, automation and materials handling systems, management of processes and procedures, and quality assurance systems will be the main areas of focus. Specific project objectives are as follows:

- Identification of weaknesses and potentials for improvement with respect to automotive industry standards and procedures in the red meat industry processes, technologies, production management and quality assurance systems.
- Identification of ready for transfer automotive industry systems and technologies and suggest strategies for smooth transfer, implementation, and integration into the red meat processing industry
- Identifying automotive industry technologies and systems with potential to be used in the red meat industry and provide guidelines and suggestions for application of required modifications to facilitate the transfer
- Finding the gaps in the automatic processes of red meat industry and link across to relevant automotive technologies and solutions for optimizing the procedures, mechanisms and machinery or development and implementation of technologies and solutions to automate and replace existing manual tasks.
- Comparative study of the material handling systems used in both industries and investigate, and introduce improvement opportunities in the red meat industry

2.3. Significance of the Research and Outcomes

The adoption of new technologies in the red meat industry can be significantly accelerated by adopting technology and concepts from the competitive and sustainable automotive manufacturing industry. Development of innovative manufacturing, processing, materials handling solutions and technologies as well as management systems and appropriate culture has helped the automotive industry to stay efficient and sustainable for many years (Panwar et al., 2015). On the other hand, the Australian automotive industry is leaving a huge number of culturally trained and skilled workers behind. A rapid knowledge transfer between the two industries to improve red meat industry's innovation capacity on a sustained basis is essential. This will ensure quick knowledge transfer by enabling the industry to acquire skills, as well as a huge number of skilled and culturally trained, unemployed workforce.

Through this study, it is aimed to examine the agricultural livestock and red meat industry in Australia. This will include a study of the value chain, involved stakeholders, present technologies and processes and identification of industry gaps. The Australian automotive industry will also be examined in detail. A strategic plan will be developed for the transfer of technology and knowledge between the industries. This will aim to optimize the red meat industry and utilise the highly skilled and trained workforce that the automotive industry is leaving behind in Australia.

2.4. Australian Red Meat Industry

Agriculture as a resource-based industry has traditionally been a major contributor to the Australian economy. The livestock and red meat industry is Australia's largest agricultural sector, with a the total value-added revenue of the red meat industry estimated at about $23 billion (Corporation, 2016). Australian red meat is highly regarded internationally, being well known as "clean, green and safe" (Corporation, 2016). Thus, Australia, has become the world's largest exporter, targeting more than 84 countries with a large market, especially in Asia. However, the industry faces multiple issues which if not resolved pose a significant risk to the competitiveness and sustainability of the meat industry. The fiercely competitive domestic and international markets, strict regulatory compliance requirements, rapidly evolving global consumer demand patterns and climate change, all require this once traditional industry to adopt rapid transformation to survive and compete internationally.

2.4.1. The Stakeholders

The meat industry contributes significantly to the economics of regional Australia employing over 135,000 people (Peters et al., 2010). The value/supply chain of the red meat industry can be divided in to 6 distinct operating groups (Figure 2) (Jeffrey and Michael, 2000).

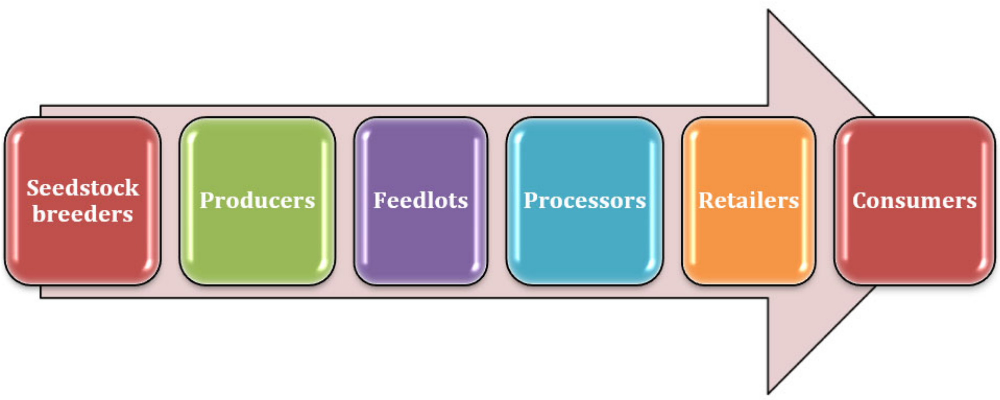

Figure 2 Australian Livestock value chain

The seed stock breeders are purebred, registered breeders that raise cattle of the same breed aiming for genetic advances and developing desirable traits of livestock. The specific targets would be based on the consumer market demand. These breeders will provide breeding animals, semen, and embryos to producers. The producers can choose to be commercial producers and/or yearling stockers. The commercial producers raise crossbred and/or unregistered cattle to a weaning age. The stock is then sold to yearling stockers where they put on weight before being sent either directly to slaughter or feedlots. Finishing rations are fed to stock at feedlots (minimum 100 days to be labelled grain-fed meat). When not aiming for direct live export, cattle are sent for slaughtering, cutting, packaging and distribution (processing segment). Sales take place in the domestic or international market. Domestically the retail groups are farmers' markets, independent butchers, and supermarkets. Consumer preferences, eating habits and demands are the last segment of the value chain which influences the previous segments in the value chain significantly.

2.4.2. Technologies in the Red Meat Industry

Innovation in technologies, when adopted by stakeholders, will result in agricultural progression. Technological advancements in agriculture can be categorised as: mechanical, biological, agronomic, chemical, biotechnological or informational (Sunding D., 2001). Innovation and technological advancements in the red meat industry are designed to be value adding and are mostly incremental in nature (Boland, 2009). Value adding advancements aim to produce more valuable products from the original material. This can be applied in various levels of the value/supply chain from production of higher quality cattle to improvement in complex machinery. This thesis will focus on innovation in automation, materials handling solutions, management of processes and procedures, and quality assurance systems in the red meat industry. For this purpose, a thorough understanding of the current routine processes in slaughter and processing plants is essential.

2.4.3. The Basic Slaughtering Process

The slaughter of livestock involves three distinct stages: pre-slaughter handling/washing, stunning, and slaughtering (Figure 3) (Encyclopædia Britannica, 1996).

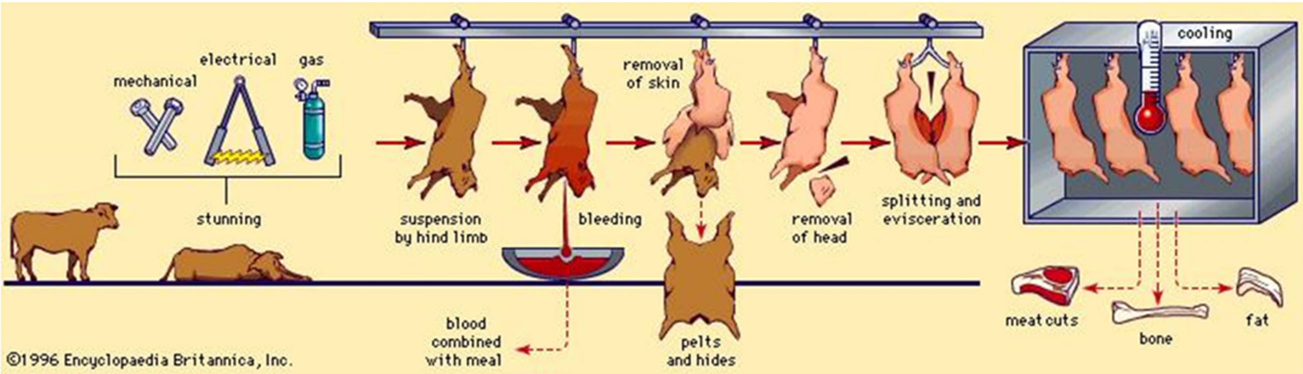

Figure 3 The basic slaughtering process (Encyclopædia Britannica, 1996)

a) Cattle Washing

After cattle are received and unloaded at the slaughtering plant pre-slaughter washing is a well-established step to reduce physical and microbiological contamination on hides which is aimed to minimise carcass contamination in the next steps (Figure 4).

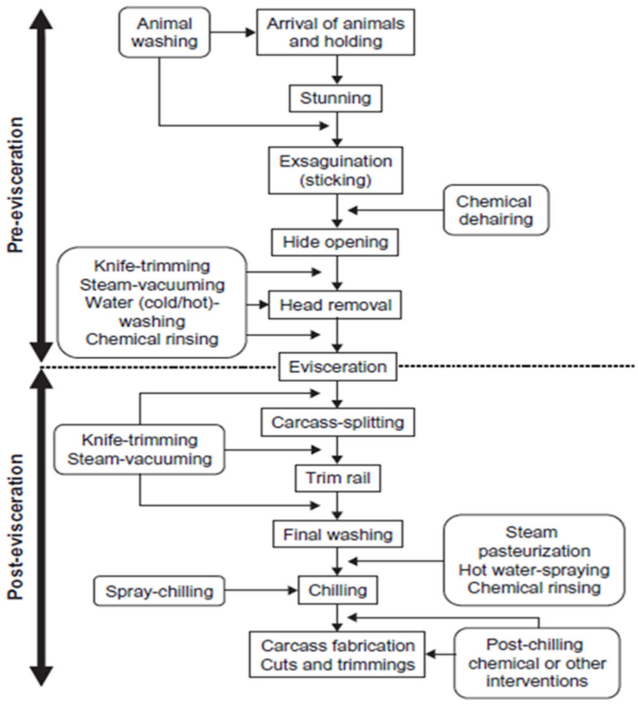

Figure 4 Main Stages of cattle - slaughtering process (12)

It is well recognised that washing the cattle reduces carcass contamination but the most efficient process to do so is not described as well (Encyclopædia Britannica, 1996). In Australia, the process varies largely between plants with some even skipping this step. While some have well dedicated washing areas with floor and back sprays others rely on hand wash using high pressure hoses on cattle in pens. A recent small scale study directed by the Australian Meat Processor Corporation (AMPC) has examined the cattle washing processes over 20 plants over Australia (AMPC, 2017). It was observed that all plants relied on a stock handler assessment to specify the time cattle needed to be cleaned (Figure 5). Only 3 plants had a formal grading system for this assessment. While 3 plants did not have, any pre-slaughter washing process, the remaining plants varied in the sophistication of their equipment. Plants that processed feedlot cattle, used recycled water to wash cattle in soaker yards using both belly and leg sprays usually taking between 20 minutes to 4 hours (Figure 6a). Grass-fed cattle processing plants used recycled water and washed the cattle using high pressure hosing (Figure 6b). All plants had a final wash and assessment step which ranged between 1-5 minutes and it was noted that all cattle were wet when entering the knocking box.

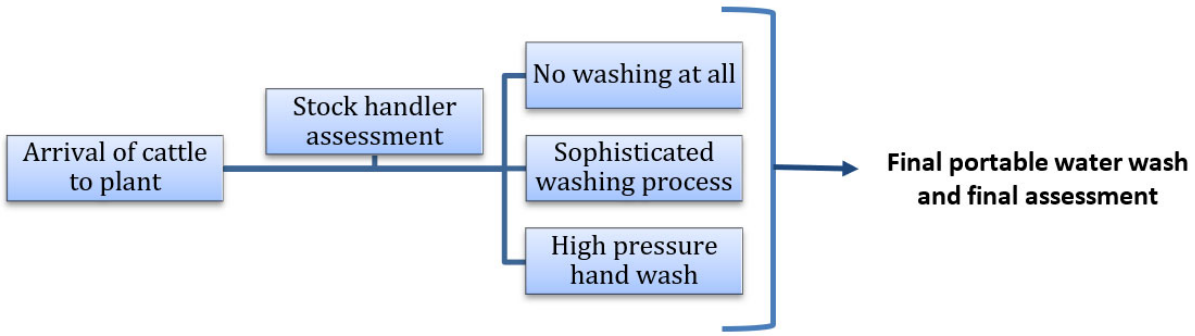

Figure 5 Usual Pre-slaughter washing process in Australia

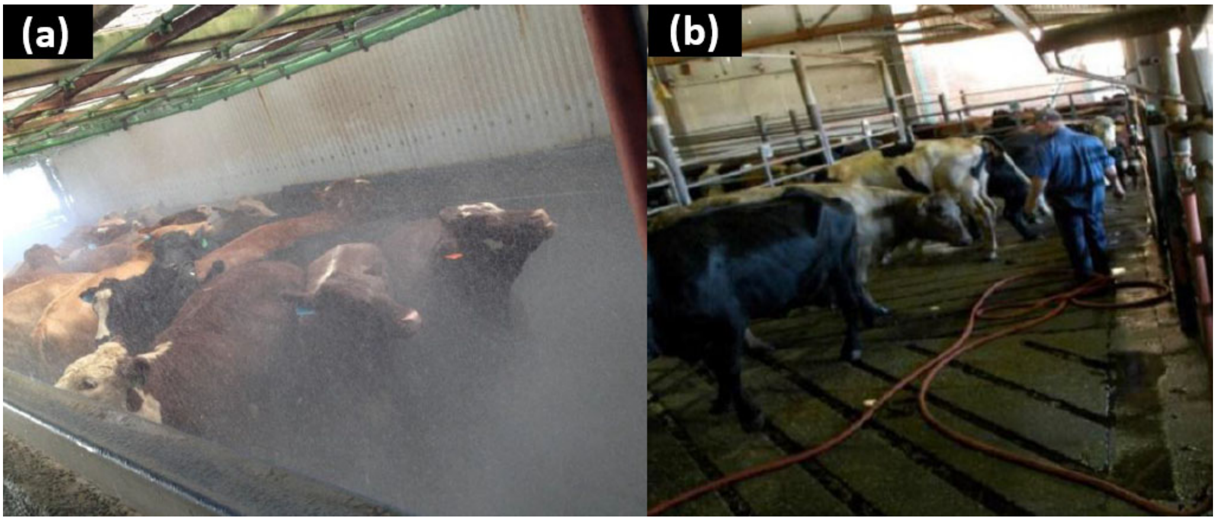

Figure 6 Routine washing processes in Australia (AMPC, 2017)

Lack of the following steps are of note:

- Customised washing step based on livestock type, hide cleanliness and microbiological results
- Formal efficacy assessment process (grading system for cleanliness prior and post washing)
- Waste assessment including time, water, electricity, and manpower

b) Cattle Stunning and Sticking Process

A mechanical bolt stunner is used in all Australian sites to produce instantaneous unconsciousness. This is a fast and minimally invasive procedure that ensures cattle are handled humanely. In general, two types of stunners are used: penetrative captive bolt (Figure 8a, b) or percussion (non-penetrating) stunner (Figure 8c). These stunners can either be powered by a cartridge, pneumatic or hydraulic power which pushes the bolt into the tissue and as the name suggests no bullets are fired in this process. As demonstrated in figure 8a, c the stunners are manually handled by an expert operator. The shotting spot in cattle is the middle of the forehead on an "X" formed between the eyes and the base of the horns (Figure 7d). This is a basic guide and the exact location for shotting will vary based on the cattle breed and shape of skull. Factors such as the proper angling of the gun, the operator expertise and the animals position all affect the bolt velocity transmitted to the brain. Plants with effective captive bolt stunning will usually achieve 96-98% of the animals rendered unconscious in one attempt. This is largely dependent of the operator expertise (T, 2005). The minimum acceptable success rate on first attempt of stunning if 95%, so a 5% limit for extra shots can enable the stunner operator to use an extra shot on a questionable animal.

The penetrative stunner has a bolt that is usually powered by an empty cartridge, air, or hydraulic power (Figure 7). Upon entry in the animal's cranium, the bolt damages the cerebrum and parts of the cerebellum. This degree of sustained damage is fatal and irreversible. This method is the most effective method in stunning as it ensures the animal is unconscious with preserved cardiac activity as the brainstem remains intact. While highly effective recent concerns have been made regarding this method as the manipulation of the brain by a foreign object causes some brain matter to enter the blood stream which is concerning as could potentially lead to spread of bovine spongiform encephalopathy (otherwise known as mad cow disease). A concave piercing end increased the damage sustained as it moves through the brain.

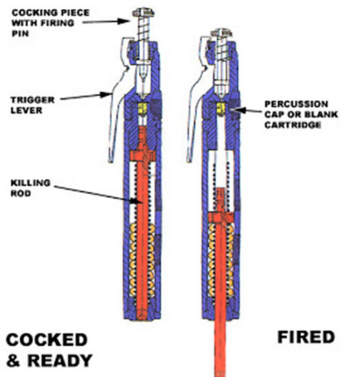

Figure 7 Penetrative captive bolt structure

Non-penetrating stunners are powered the same way as penetrative ones while the difference is in the bolt. In these types the bolt has a blunt end (mushroom shaped) which strikes the animal's forehead and retracts causing a concussion. This results in unconsciousness This method is not as effective as the penetrative method and is not permanent but minimises the risk of transmission of bovine spongiform encephalopathy and is the mandatory method in animals which are used in pharmaceutical manufacturing. The non-penetrating stunners that fracture the scull are significantly more effective than the ones that do not. The more the skull is fractured the risk spread of brain material increases. Unfortunately, effective stunning and reducing skull fracturing are two opposite goals. As the amount of damage to the skull is reduced, placement of the shot must become more and more precise to achieve instantaneous insensibility. Shooting on a slight angle may result in failure to induce instantaneous insensibility. A mushroom head with a larger diameter may be more effective with less fracturing than a mushroom head with a small diameter.

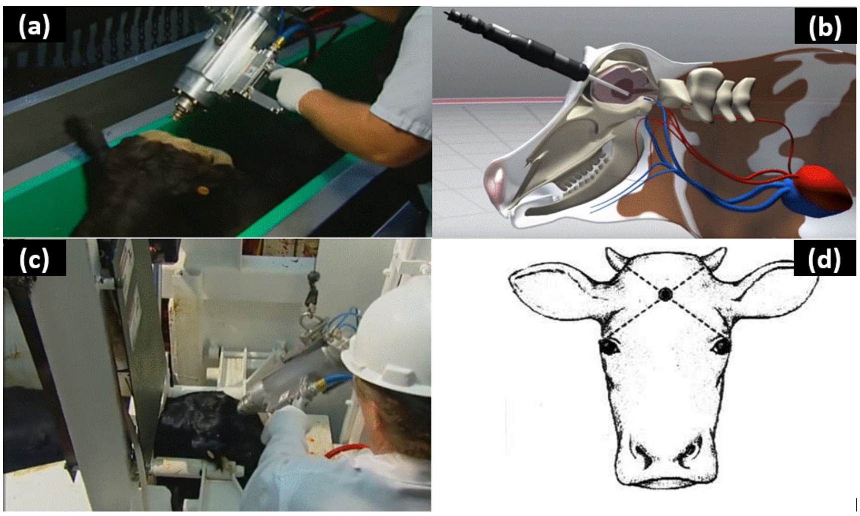

Figure 8 Stunner types. (a, b) Penetrative captive bolt stunner. (c) Non-penetrating stunners requiring head holder (d) Placement of captive-bolt device (Grandin, 1998)

Regardless of the stunning method, the animal needs to be properly restrained. Restraint of the head is essential when using nonpenetrative stunning as this requires a much more accurate aiming explained above (Figure 8c). It is essential that animal welfare is optimal during these steps as excess stress would result in low quality meat and elevated muscle pH. The cattle can be restrained either in a knocking box, V-shaped and 'ride-on' conveyor type restrainer with or without a head restraint system.

The knocking box design is important as poor animal handling will result in compromised operator safety, animal well fair and final product quality (Figure 9). It is essential that the knocking box dimensions is large enough for the animal to fit comfortably. One animal at a time should be placed in the knocking box and should be stunned immediately. It is important to note that these boxes should not be used to hold animals for long periods and should only be used during the stunning procedure.

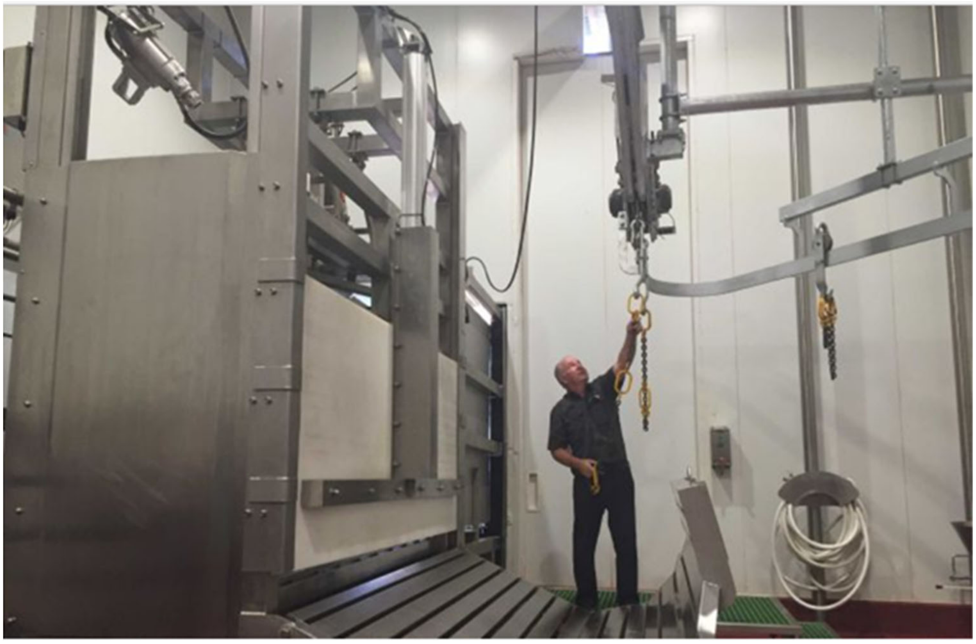

Figure 9 Knocking box (14)

Figure 10 demonstrates the stunning procedure using a non-penetrative stunner and head restraint. After the animal enters the knocking box (Figure 10a), the head is restrained using the head holder (Figure 10b) which closes automatically after the head is in the correct position. The animal is then stunned (Figure 10c) by an expert operator, the head holder is released and the animal which is unconscious is lowered to slaughter position (not dropped) and knocking box is emptied (Figure 10d).

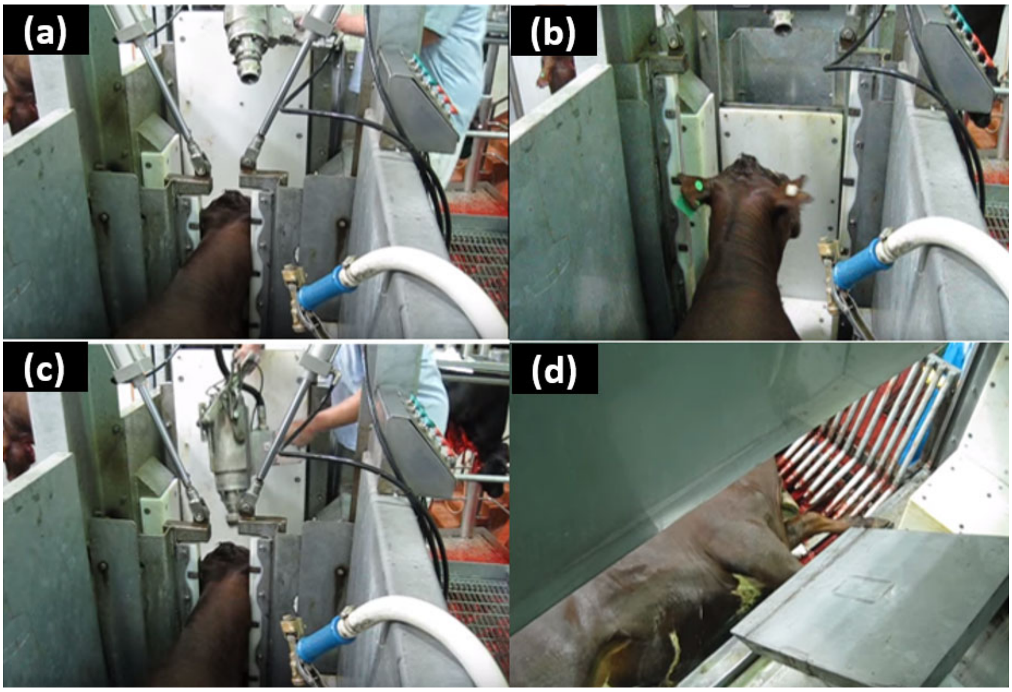

Figure 10 Knock out box and stunning procedure using a nonpenetrative stunner and a head holder (Australia, 2011)

As soon as the animal is stunned, the animal which is lowered to slaughter position, is bled ('sticking' or exsanguination process). This is usually done by cutting into the thoracic cavity, just above the breastbone at 45° pointed toward the head, and severance of the carotid artery and jugular vein in one attempt. This process aims for maximal blood removal from the body (Toldŕa, 2010). This is usually a two-step procedure carried out by 1-3 expert operators.

Figure 11 Sticking, post stunning wash and hanging. (a) Immediately after stunning happens the severance of the carotid artery and jugular vein takes place in a horizontal position "sticking". (b, c) The carcass is the lowered onto a moving stainless-steel rail where post stunning wash takes place. (d, e) Suspension by the hind leg and held in a vertical position for maximal blood removal (Foodequip, 2009)

It is obvious that as this step is largely done manually, the effectiveness of it is very much operator dependent. Based on the plan and equipment the cattle might need to be repositioned after being lowered to slaughter position so that the throat is in the best position for cutting. The most hygienic system is that bleeding is carried out on an easily cleaned stainless-steel surface. As demonstrated in Figure 11a, it is suggested that the horizontal position is the optimal position that gives faster bleeding rates and a greater recovery of blood (repository). Horn removal (if applicable should be done at this stage as well). Following this, post-stunning/bleeding hide washing +/- antimicrobial agents takes place that aims to remove as much dirt as possible from the hide (Figure 11 b, c). This step can be done automatically, manually, or both based on the plant and its available equipment. The animal is then suspended by the hind leg by an operator (Figure 11d) and held in a vertical position for maximal blood removal (Figure 11e). Important factors in this stage include: Quality and sanity of the knives used, operator experience and optimal positioning and general hygienic procedure.

Factors of note in the stunning and sticking procedures are:

- The need for further atomisation of the procedure as multiple steps are manual
- Need to cater for animal size and shape variations

c) Carcass Dressing

The cow carcass is composed of muscle, fat, bone, and connective tissue. Lean meat and muscle are the nutritive portion which is referred to as “meat”. The less the fat and connective tissue attached to the muscle, the more desirable it is. The carcass of each animal consists of about 300 muscles which vary widely depending on the body location and age of the animal. In general, only 25 muscles can be separated and used. The colour, tenderness, juiciness, and flavour of these meat are essential quality factors. The effective and maximal removal of the inedible and less desirable portions of the carcass including all the internal organs and oftentimes the head as well as inedible (or less desirable) portions of the tail and legs is an important step in achieving high quality meet. This step which is referred to as the dressing process, is aimed to produce hygienically clean and wholesome products.

Hide removal is the initial step in the dressing process. The hide is removed by making cuts at the legs and then following the natural seam along to the flank, up the back and off the rump. This can be done either manually or mechanically. It is a crucial step in prevention of direct and indirect contamination to the meat (repository). It is critical that the equipment used are sanitised and is essential that at least two sets are tools are used at each hide opening position. If done manually, the used tool should then be placed into sanitising solution and while the other is being used. Moreover, the personnel must comply to strict hand and glove hygiene based on the carried-out task. Manual hide removal is highly dependent on the operator and requires high level of skill and experience. Mechanical hide removal on the other hand is more efficient and less operator dependent. Hide pullers (Vertical, horizontal, or adjustable) are implemented to reduce operator contamination. As the mechanical hide pullers generate high levels of energy resulting in aerosol production, negative air flow is desirable to direct aerosols away from the skinned carcasses.

Figure 12 Hide Removal (Foodequip, 2009)

After hide removal is completed and the cattle are de-skinned, and head is removed, evisceration takes place. This is the process of removing viscera. It is essential that all viscera remain intact and special care should be taken to avoid any breaking of the paunch. If tissue become contaminated by visceral content that tissue must be removed immediately. In the Australian processing system, everything from the carcase is used including muscle, offal, co-products, and by-products. Edible offal most derived from a beef carcase is tongue, tripe, cheek, liver, tail, tendons, heart, and kidney.

Figure 13 Evisceration (Foodequip, 2009)

d) Splitting and Trimming

Once the internal organs are removed the body is split in two using a brisket splitter. The operator works facing the back of the carcase, splitting it down the backbone. Splitting the carcase in two makes it easier to remove the spine and any remaining organs, inspect, store, and then further break down the carcase. The splitting process can be down manually, using hand saws, but in most large-scale abattoirs it is down using a brisket splitter. Automation in the splitting process has significantly improved this laborious task. Factors of accuracy of splitting and hygiene aspects (spread of bone dust) are important to be properly addressed in this process. As demonstrated in figure 14, most plants use an operator guided mechanical band saw down the carcass spine aiming for accuracy and minimal bone dust spread. A completely automated system has the potential to eliminate variability caused by operator dependent factors and speed up the process. The structure of the beef carcass is complex and sensing of key points is a big challenge. Three main boning processes are the most used techniques in Australia. These include, Quarter boning, side boning and table boning. Quartering or ribbing down is the division of a side of beef between the eleventh and 12th ribs into fore-and hindquarters. One rib is usually left on the hindquarter to hold the shape of the loin and to make it easier to cut steaks (Figure 14). Side boning is referred to the process in which the whole beef side is taken to the boning room and same meat cuts are taken from each side. In table boning or muscle boning method the carcass is broken down into “bone in portions” and transported to individual tables by belt conveyor to obtain small sized portions later on (Starling, 2003). Currently the side boning method is the most widely used due to ease of transport, simplified product traceability and operator training and flexibility of the system.

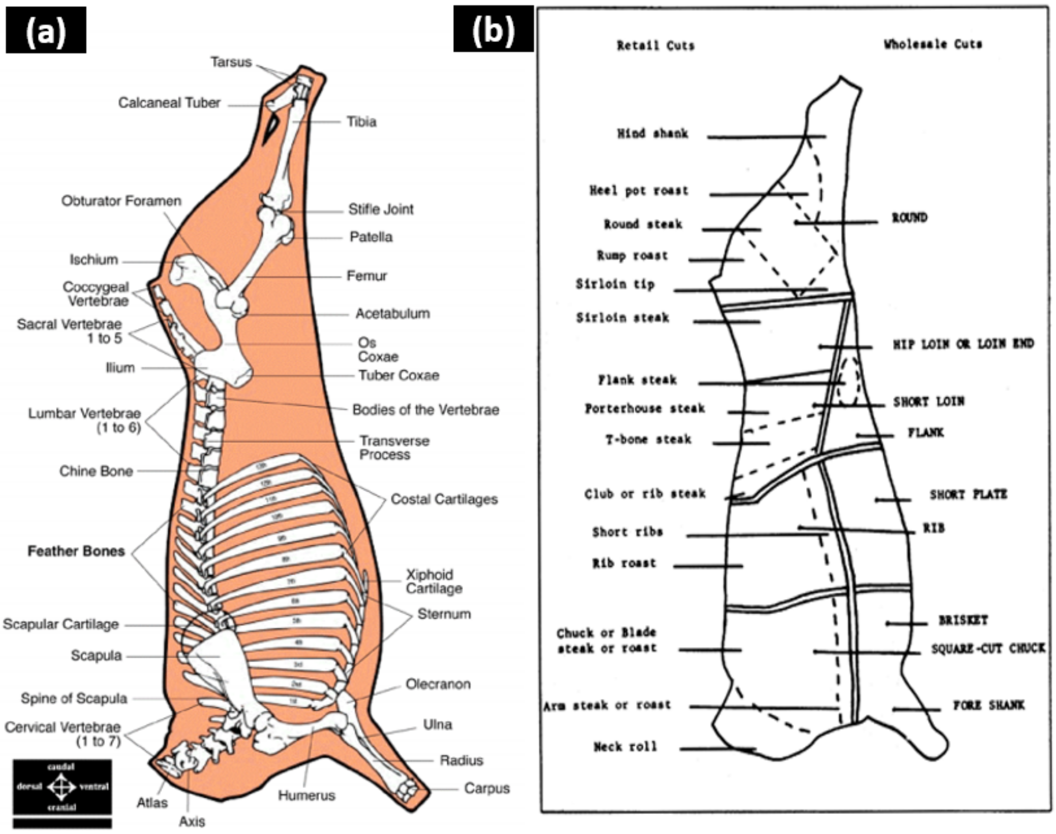

Figure 14 Beef carcass skeletal diagram (Ltd, 1998) (a) and its cuts (repository)(b)

As demonstrated in Figure 14b, the method by which the carcass is cut depends on the sale method (retail vs wholesale). The standard of cut lines is briefly outline below (Starling, 2003).

Vertical cuts: (Figure 14b) Brisket Cut – navel to point, Short Rib Cut – five ribs from the 11th to the 7th (inclusive), Various Spare Rib Cuts and Scribe cut through 11th to 7th rib between the short rib cut and the spine.

Horizontal cut: Quarter Cut which is applied through the spine between the 11th and 12th rib to produce hindquarter and forequarter

Robot guided automated bandsaws (Figure 15) that use DEXA technology to identify the cutting spot have been proposed, designed and implemented in limited capacity by Food science Australia (Funded by Meat and Livestock Australia(Starling, 2003)).

Figure 15 Robot scribing station prototype (Starling, 2003)

The technology is the world's first DEXA-enabled beef rib cutting automated system. There is a move to fast track the implementation of this technology Australia wide but currently most plants are using handheld mechanical saws (Figure 16).

Figure 16 Carcass Splitting and cutting (Foodequip, 2009)

2.5. Innovation in the meat industry

Most innovation in the beef industry has been directed at reaching sustainable advantage over international competition. The mainstay of this approach is continuous innovation focusing on increasing quality and reducing costs (Sheng Y, 2011). Innovation sources in agriculture are be one of three: agricultural practices, private or public scientific research and other industries (Daowei Sun, 2015). Due to the size and distribution of agriculture businesses direct investments in Research and Development (R&D) is usually not sustainable. This is indeed the fact with the beef industry in Australia as well. Australia is reported to have 32530 farms involved in beef production in 2012. These farms are predominantly (91%) small to medium sized and are spread throughout the country(Daowei Sun, 2015). The beef industry in Australia has been reluctant to introduce robots in the processing line due to the nature of the environment of the industry, biological variations in the animals and cost of the robots. Compared to most other industries, the working environment in the beef industry is characterized by noise, draft, humidity, low temperatures, and repetitive work. To overcome this problem, the meat industry in many industrialized countries must automate, particularly the most arduous processes, to be able to recruit sufficient labour. Uniformity in the product is the biggest obstacle in the beef industry. Due to the size of the carcasses and variability automation in beef processing has had many challenges. The pork and lamb industry have been much more successful in adopting automation. These industries have the potential to be used in the beef industry.

State and Territory Governments, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), universities, private providers, the Beef Cooperative Research Centre (1991-2010) and The Australian Meat Processor Corporation (AMPC) are the major innovation suppliers in the Australian beef industry(Daowei Sun, 2015). Fututech, Meat Training Research Centre (MTRC) (Werribee) VIC DPI, CSIRO (Cannon Hill) and Meat Industry Research Institute of New Zealand (MIRINZ) are the main 4 research initiatives that have focused on optimising the Australian meat processing sector over the past years.

In the following sections the previous local research on the optimisation of meat industry will be reviewed.

2.5.1. Past Australia/New Zealand beef research centres

a) Fututech

Fututech Australian R&D program was a 5 year program and the first initiative in the world that aimed to develop the first fully automated beef processing line with automated modules that performed the entire slaughtering tasks (White, 1994). The project was initiated by the Australia Meat Research Council in the 1970s. (Anon, 1996) and funded by the Meat Research Corporation (MRC). A commercial prototype of the proposed line was developed that had the capacity of processing 60 carcasses per hour. This radical project aimed to fully revolutionise the meat processing sector.

A brief description of the modules used in Fututech are described below.

Stunning and Sticking: Each animal was separated from the rest using a mobile floor conveyor. This transfers the animal to a moving conveyor between the animal's leg (White, 1994). The animal was then stunned using an electrical current while its neck was stabilised using two bails. The electrical current was also applied to the spine. Thereafter, using a pneumatically powered knife the aorta was severed. Horns were removed at this stage as well if present using hydraulic cutters.

Dehiding: The traditional bed-dressing position was applied in Fututech. After suspending the carcass in the supine position from four hocks, the hide was removed in a multistage automatic process. This included downward pulling of the hide, separation from the back fat and then pulling off.

Evisceration: A paddle was used to peel the viscera by pushing against the spine in the Fututech design.

Carcass Splitting: A guided bandsaw was used to automatically split the carcass in to two.

$33 million dollars was spent on the project before it was abandoned due to various issues including technical problems and rather small domestic market. The project had minimal industry input and engagement due to high level secrecy during the development stage. This resulted in lack of ownership by stakeholders and minimal commitment to implement the project into practice. Also, many engineers and technicians recruited for the project did not have experience in the meat industry which contributed to its failure. Fututech lacked sufficient research dynamics, industry engagement, appropriate project management and a true understanding of the market size and demands. The experience with Fututech has left the Australian meat industry very cautious and somehow resistant towards innovative technology.

b) Meat training research centre – Victorian DPI

MTRC which was built in 1996 as a partnership with Victoria University, Victoria DPI and Ammonia Refrigeration Industry Association. This centre included meat science laboratories, a classroom, extensive refrigeration plant, and a licensed abattoir capable of processing small stock. MTRC closed in 2014 due to ongoing financial unsustainability. While the centre was established as a research and training centre it was mostly used for teaching purposes and the abattoir was largely left unutilised. Main activities in the centre included:

1. Facility for the food science and technology course at Victoria University
2. A seven-day course per year by the Ammonium Refrigeration Industry Association
3. R & D by scientists initially on pigs and then sheep but no work on beef

The main funding source for this centre included course delivery fees and some R & D funds. The diversity in the centre projects and variability in the funds received year by year made the financial cost of the centre to be very challenging and eventually unsustainable.

Experimental work in the abattoir was very limited and in general it was left unused. The most prominent reason for the failure of this experimental scale abattoir was poor cost effectiveness. A manually operating centre will low output incurred high operational costs which eventually was deemed unsustainable. The key issues that come to sight in the establishment and operation of MTRC are lack of program management and long-term strategic planning.

c) CSIRO (Cannon Hill)

The CSIRO Cannon Hill plant was purpose built in the 1960s to further research in the meat industry and was equipped to address many aspects of the industry such as refrigerated transport, food microbiology, process engineering, meat industry services, pilot abattoir and food chemical safety testing. This site was very successful in the development and trailing many technologies in the meat industry. The Cannon Hill plant's pilot abattoir was equipped with an export approved level abattoir. Together with its proximity to major commercial abattoirs this centre was able to conduct successful commercial level R&D activity. This centre was closed after budget cuts in 2007 and due to significant costs involved with essential renovation costs. The vital factor of lack of independence in funding, high costs and poor budgeting in long term was the factor that was overlooked in this experience as well. The facility was aged and out of date, had low output and was underutilised. While it generated minimal income through commercial test products, it had very high expenses including highly qualified staff, maintenance and removal of waste products.

d) Meat Industry Research Institute New Zealand (MIRINZ)

MIRINZ was established in 1955 with significant engineering and meat science capacity. While it was initially founded as a collaboration between the government, meat producers and meat processors, MIRINZ separated from the industry in 1980s to obtain ownership and exclusivity of the research results. As a stand-alone research facility MIRINZ shifted from exclusive research on New Zealand beef and sheep and started doing projects for international clients to be able to maintain financial sustainability. Despite this MIRINZ merged with AgResearch in 1999 which enabled the facility to continue its work in meat processing research with direct industry collaboration. The MIRINZ brand has been highly effective in developing new meat processing technologies especially for sheep. While no fully automatic device for any aspect of the lamb industry has yet been developed, but mechanization that improves several arduous operations has been developed and successfully introduced. A review of such technologies will be done in the next sections.

Based on the summary above three major elements can be identified as critical factors for the success of meat research initiatives.

1. Industry collaboration
2. Independent and stable funding
3. Innovation development and transfer strategy

2.6. Automation in beef industry

Limited R&D effort has been dedicated to automatization of the beef processing industry compared to lamb and pork. In this section a brief review of these attempts will be presented, and limitation, gaps and potential improvement areas will be identified This section will be the stepping stone for the rest of the thesis which will focus on addressing industry gaps and needs.

2.6.1. Animal Preparation

The importance of cattle washing has been explained in chapter 1. A comprehensive automated visual inspection and cleaning system using RGB-D technology has been proposed and developed (AMPC, 2018). This system which utilises a nozzle matrix design, optical cameras and proximity sensors was developed, manufactured, and tested in Victoria, Australia. A sophisticated image classification algorithm was used to categories the animal cleanliness and detect the animal parts that needed washing. This then triggered automated washing through spraying of water via specific nozzles (Figure 17).

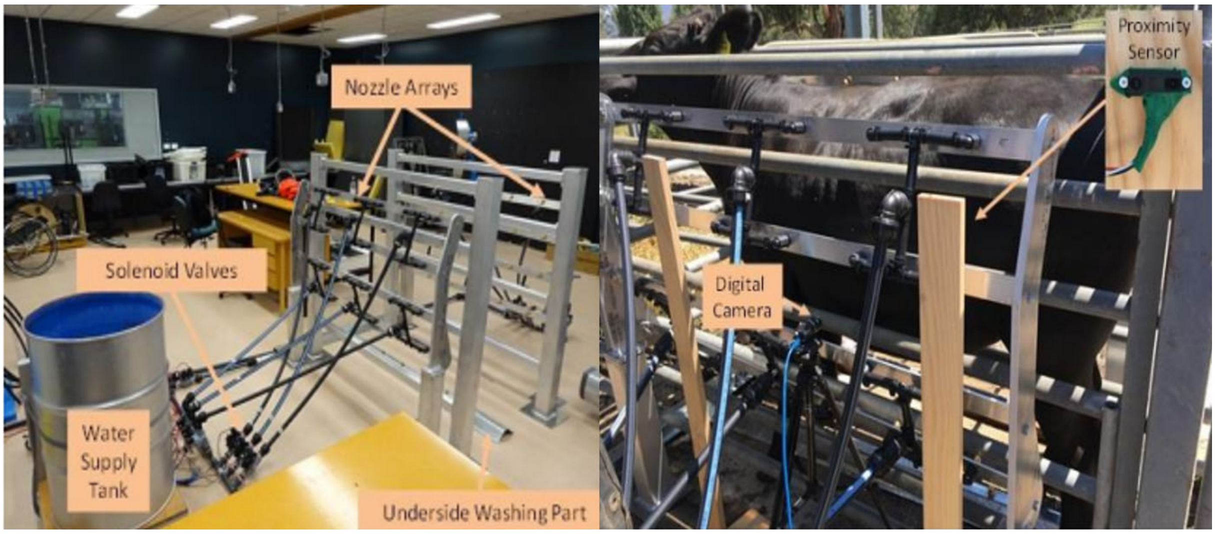

Figure 17 Automated cattle washing station prototype (AMPC, 2018)

2.6.2. Animal stunning and killing

The Fututech module as explained earlier is basically the main module for automation of this step. This is minimally developed and faces multiple barriers which the biggest is the large variability in cattle size, shape, and anatomy. This is an ergonomically difficult step due to the wide variety of cattle bread, age, and type. As the animal is still alive and mobile, effective, and humane restraint is critical as well.

2.6.3. Carcass dehiding and evisceration

The process for carcass dehiding and evisceration has been thoroughly explained. Currently most plans have dehiding machines which constitute of a horizontally mobile carcass line where the carcass is suspended by the hind legs (Figure 11) and held in a vertical position while the operator removes the hide, skin and head. As the carcass size is largely variable the operator is moved up and down by the vertically mobile platform to apply cuts and dehide the animal using manual or mechanical knives. This a potential safety hazard as any movement using these knives has the potential to cause serious the operator. Hence optimisation of this step is essential.

A fully automated dehiding step has been proposed and applied by Industrial Research Ltd. (IRL). Using an infrared laser distance sensor, the animal's belly is identified and scanned to the cutting device. A robot moves the knife which is equipped with a guidance spike, up and down cutting along the previously determined path (Templer, 2002).

2.7. The Automotive industry

The Australian Automotive industry was one of a few in the world capable of taking an automotive design all the way from concept to production. Ford Australia, is the Australian subsidiary of United States-based automaker Ford Motor Company. Geelong became the headquarters of Ford Australia in 1925 and the first Australian manufactured Ford car was produced in the same year. Ford has a legacy of innovation by expanding advanced manufacturing capabilities and introducing ground-breaking technologies that could revolutionize mass production.

Development of innovative manufacturing, processing, materials handling solutions and technologies as well as management systems and appropriate culture has helped the automotive industry to stay efficient and sustainable for many years (Panwar et al., 2015). On the other hand, the Australian automotive industry is leaving a huge number of culturally trained and skilled workers behind. A rapid knowledge transfer between the two industries to improve red meat industry's innovation capacity on a sustained basis is essential. This will ensure quick knowledge transfer by enabling the industry to acquire skills, as well as a huge number of skilled and culturally trained, unemployed workforce.

With the development of this work it is intended to learn the processes used by Ford Motors Australia as a leading global automotive manufacturer and a leader in innovation. Subsequently, it is aimed to develop a new approach and strategic plan to improve the red meat industry's innovation capacity.

2.7.1. Automobile design and manufacturing process

Ford is an American global automaker with its central headquarters located in Dearborn, Michigan. The company was founded by Henry Ford in 1903 and is well known for its commercial vehicles branded under the Ford name and luxury cars under the Lincoln brand. The company used to produce tractors and automotive components which it has now ceased. Ford's various joint ventures include China (Changan Ford), Taiwan (Ford Lio Ho), Thailand (AutoAlliance Thailand), Turkey (Ford Otosan), and Russia (Ford Sollers).

The Model T automobile was produced based on the original Model A design in 1908. The creation and development of this vehicle took 5 years. The production of this car initiated what today is known as the mass production assembly line. This was a huge revolution in manufacturing as prior to this, coaches had been hand-built in small numbers. Ford's innovative design relied on the concept of utilizing and assembling interchangeable components. This was a great leap in the manufacturing industry as it required far less parts, expert operators and much less time to produce large numbers. This gave Ford great advantage over other manufacturers due to lower costs and larger production numbers. In 1914, moving assembly lines were introduced by Ford. These methods, known as Fordism, resulted in large-scale manufacturing.

Ford reduced the assembly time for each fitter from hours to just minutes by applying the moving assembly line concept. Rather than a single fitter performing multiple tasks and assembling multiple parts on a single stationary stand, Ford used multiple stands with multiple assemblers moving from one to another performing the same task. Although this was a huge achievement, operators moving from a stand to another, still waisted time and created jam-ups in the production process. This was when the first moving assembly line was introduced (Figure 18). A conveyor moved the vehicle parts past the assemblers who were now stationary. This concept further reduced the assembly task time for each operator to under 2 minutes. The first conveyor line consisted of metal strips to which the vehicle's wheels were attached. The metal strips attached to a belt that rolled the length of the factory and then, beneath the floor, returned to the beginning area. This reduction in the amount of human effort required to assemble an automobile caught the attention of automobile assemblers throughout the world. Ford's mass production drove the automobile industry for nearly five decades and was eventually adopted by almost every other industrial manufacturer. Henry Ford introduced the lean manufacturing concept to the world through his passion for continuous improvements through scientific testing and hypotheses creation to test his production lines. Henry Ford's spirit to improve efficiency and reduce production costs kept Ford Motor Company alive and well during the hard times of the Depression. Among the top manufacturing innovations during the Depression was the introduction of the one-piece cast V8 block by Ford.

Figure 18 Ford moving assembly line 1914 (Motors, 20187)

Ford was first brought to Australia in 1904. Broadmeadows Assembly was a Ford Motor Company automobile factory operated by Ford Australia and situated in Campbellfield, Victoria. It spanned 1,973,503 square feet (45.3054 acres) and employed some 2,088 workers. On May 23, 2013 Ford Australia announced the end of local manufacture, with the last Falcon Ute rolling off the line in July 2016 and the last Falcon sedan and Territory emerging on October 7, the last day of Ford manufacturing down under. Its production history includes FG Falcon range, FG Falcon Ute range, SY Territory MkII range, Ford Performance Vehicles. It leaves back many highly qualified and trained personnel and manufacturing machinery that have the potential to be implemented in the food industry.

Automotive Product Life Cycle of a new vehicle program usually includes the below stages:

- Concept selection
- Go ahead / Abort
- Detailed design & specifications
- Development and tooling
- Manufacturing line commissioning

- Preproduction & Launch
- Ramp up and Mass Production
- Face lift
- Product retirement
- Recycling

Below is a summary of the automobile design and manufacturing process.

a) Raw Material

With rising fossil fuel prices, the use of lightweight materials such as aluminium, plastics, and vinyls in automotive manufacturing has increased drastically. The approach to shift from steel to lighter material was directed towards increasing efficacy, reducing costs and labour burden.

b) Design

Market demand is the driving factor in development of new vehicle models and designs. A 3-5 years' time interval is required for a new model to reach production. Trying to predict what the public preference would be in 5 years is challenging and crucial art that the automotive industry has mastered. This has required the manufacturers to develop high levels of market demand evaluation techniques to assess viability of the product including potential margins, restrictions, and regulations. Basic concept drawings are developed using computer-aided design systems which are then used to generate clay models. The models are then tested by market experts and aerodynamic engineers to test market viability and structural feasibility. Only after all models have been reviewed and accepted are tool designers permitted to begin building the tools that will manufacture the component parts of the new model.

The automobile assembly plant is the final phase of vehicle manufacturing. The chassis and the body together with the parts related to them are assembled separately and are put together at the final stage.

c) Chassis

Construction of a vehicle is typically from ground up. The chassis when present or the frame provides a structural base which all other parts get assembled to later. As demonstrated in Figure 19, the chassis moves down the production line to component assembly areas where complete front and rear suspensions, gas tanks, rear axles and drive shafts, gear boxes, steering box components, wheel drums, and braking systems are sequentially installed.

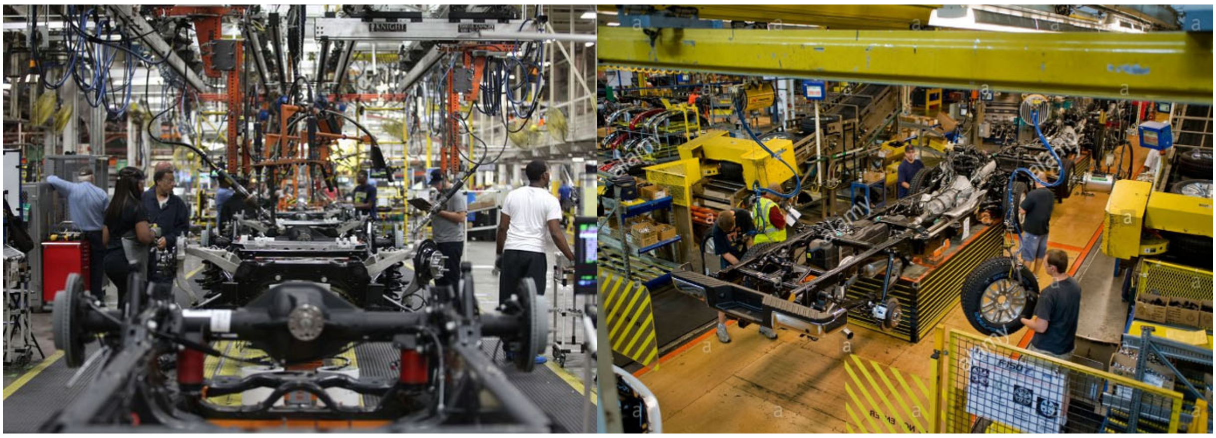

Figure 19 Chassis assembly, Ford Motors (Spencer, 2009)

d) Stamping

While assembly starts with forming the body. Stamping is the process of forming a net shape from a flat sheet metal. Sheet metal is the most used but other technologies such as hot form, hydro form tubes, cold roll form can also be used. The sheet metal is placed into a stamping press to undergo a variety of manufacturing processes as required. These include blanking, punching using a machine press or stamping press, embossing, bending, flanging, and coining (Figure 20).

Figure 20 Stamping plant (Motorolix, 2013)

e) Body Shop

As mentioned before, the body is built up on a separate assembly line from the chassis. Different joining technologies such as welding, bolting, riveting, etc. are usually used to assemble the various components (product of stamping shops) in the body shop. The parts are geo set in fixtures and welded together to form assemblies. The assemblies then come together in bigger fixtures to form major assemblies such as bodysides, floor pans, front end, etc. This later form the bodyshell in the body shop main fixture referred to as the framing station (Figure 21).

Figure 21 Panels are welded together to form the assemblies, then Bodyshell, and finally Body In White (Europe, 2015)

The shell of the automobile assembled in this section of the process, lends itself to the use of robots in most advanced production lines. This is since articulating arms can easily introduce various component braces and panels to the floor pan and perform a high number of weld operations in a time frame and with a degree of accuracy no human workers could ever approach. Robots once again perform most of the welding on the various panels, but human workers are necessary to bolt the parts together. During welding, component pieces are held securely in a jig while welding operations are performed. Once the body shell is complete, it is attached to an overhead conveyor for the painting process. The multi-step painting process entails inspection, cleaning, undercoat (electrostatically applied) dipping, drying, topcoat spraying, and baking.

Robots once again perform most of the welding on the various panels, but human workers are necessary to bolt the parts together. During welding, component pieces are held securely in a jig while welding operations are performed. Once the body shell is complete, it is attached to an overhead conveyor for the painting process. The multi-step painting process entails inspection, cleaning, undercoat (electrostatically applied) dipping, drying, topcoat spraying, and baking.

As the body moves from the isolated weld area of the assembly line, subsequent body components including fully assembled doors, deck lids, hood panel, fenders, trunk lid, and bumper reinforcements are installed. Although robots help workers place these components onto the body shell, the workers provide the proper fit for most of the bolt-on functional parts using pneumatically assisted tools.

Figure 22 Ford body shop (Europe, 2015)

f) Paint Shop

The body in white operation is referred to the process of close inspection of the body before it is painted. Hi-light oil is used to soak the shell of the vehicle. Visual inspectors examine the shell in a brightly lit white room to detect any defects. After the shell passes the inspection test, it gets cleaned and goes through the drying booth and undercoat dip. The under-coat dip (E-coat bath) is an electrostatically charged bath of undercoat paint. This coat acts as a substrate surface to which the topcoat of coloured paint adheres. After the under-coat is dried the vehicle proceeds to the final paint station. The body is then spray-painted by robots (Figure 23), specifically programmed to apply the paint. Advanced levels of programming and engineering is involved in the operation of these robots that results in high levels of precision in painting and a very clean finish. The bodies are then transferred through to the baking ovens to cure the paint at temperatures which exceed 135 degrees Celsius.

Figure 23 Ford paint shop (Europe, 2015)

g) Final Assembly

All the interior instrumentation such as wiring systems, dash panels, lights, seats, door, trim panels, headliners, radios, speakers, all glass except the automobile windshield, steering column and wheel, body weather-strips, vinyl tops, brake and gas pedals, carpeting, and front and rear bumper fascia are installed by workers after the body and chassis are assembled. The windshield is then placed into the windshield frame using robots equipped with suction cups. Seats and trim panels get transported to the vehicle by robots and installed by operators. If the vehicle has a chassis, then the semi-assembles vehicle and chassis (already fitted with powertrain) meet (Figure 24). As the chassis passes the body conveyor, the shell is robotically lifted from its conveyor fixtures and placed onto the car frame. Assembly workers, some at ground level and some in work pits beneath the conveyor, bolt the car body to the frame. Once the mating takes place the automobile proceeds down the line to receive final trim components, battery, tires, anti-freeze, and gasoline.

Figure 24 Final Assembly Shop (Europe, 2015)

The vehicle can now be started it is then quality checked and analysed. When the vehicle passes the final audit, it is given a price label and driven to a staging lot where it will await shipment to its destination.

3.0 PROJECT OBJECTIVES

In general, this study focuses on investigation of the possibilities and potentials, opportunities, and limitations for the red meat industry in adapting technologies and solutions found in the automotive industry. Fields of automation and materials handling systems, management of processes and procedures will be the main areas of focus. Specific project objectives are as follows.

- Identification of weaknesses and potentials for improvement with respect to automotive industry standards and procedures in the red meat industry processes, technologies, production management and quality assurance systems.
- Identification of ready for transfer automotive industry systems and technologies and suggest strategies for smooth transfer, implementation, and integration into the red meat processing industry
- Identifying automotive industry technologies and systems with potential to be used in the red meat industry and provide guidelines and suggestions for application of required modifications to facilitate the transfer
- Finding the gaps in the automatic processes of red meat industry and link across to relevant automotive technologies and solutions for optimizing the procedures, mechanisms and machinery or development and implementation of technologies and solutions to automate and replace existing manual tasks.
- Comparative study of the material handling systems used in both industries and investigate, and introduce improvement opportunities in the red meat industry

4.0 METHODOLOGY

The automotive industry has traditionally been the birthplace of principal productivity and quality improvement concepts in manufacturing. In this section an overview of these concepts will be presented. The review will then be narrowed down to focus on how these have been used in the meat industry.

4.1. Lean Thinking

Ford's mass production and mobile production line drove the automobile industry for nearly five decades and was eventually adopted by almost every other industrial manufacturer. Henry Ford established the foundation of Lean world through his passion for continuous improvements through scientific testing and hypotheses creation to test his production lines. Henry Ford's spirit to improve efficiency and reduce production costs kept Ford Motor Company alive and well during the hard times of the depression. While the mass production line was a huge success, over time the market changed and the need for versatility in production emerged. The Toyota Production System (TPS) was developed by Toyota after World War II with the aim to address the very different business conditions that it faced compared to Henry Ford. The mass production module was not the right answer for Toyota that was facing the very small and demanding Japanese post war market. Toyota developed the flow production system which is the basis of what we today know as lean production (Womack et al., 1990). Toyota is known as the leading Lean exemplar and has become world’s largest automobile manufacturer.

The Lean concept was first introduced in 1990 (Womack et al., 1990) with 5 principles for achieving a lean enterprise (Womack and Jones, 1996). The five principles of Lean are (Figure 25):

1) Identify the value from the end customer’s point of view (Value)
2) Identify the value stream for productions and reduce the waste steps (Value stream)
3) Make sure the remaining valued-added steps can work continuously (Flow)
4) Introduce pull between steps that are possible for continuous flow (Pull)
5) Conduct perfect management and eliminate the number of steps, the time and information (Perfection)

Figure 25 Lean Principals

Lean thinking consists of various tools which are used to implement the 5 principals of lean. A summary of some of the tool used in the philosophy of lean manufacturing are demonstrated in Figure 26.

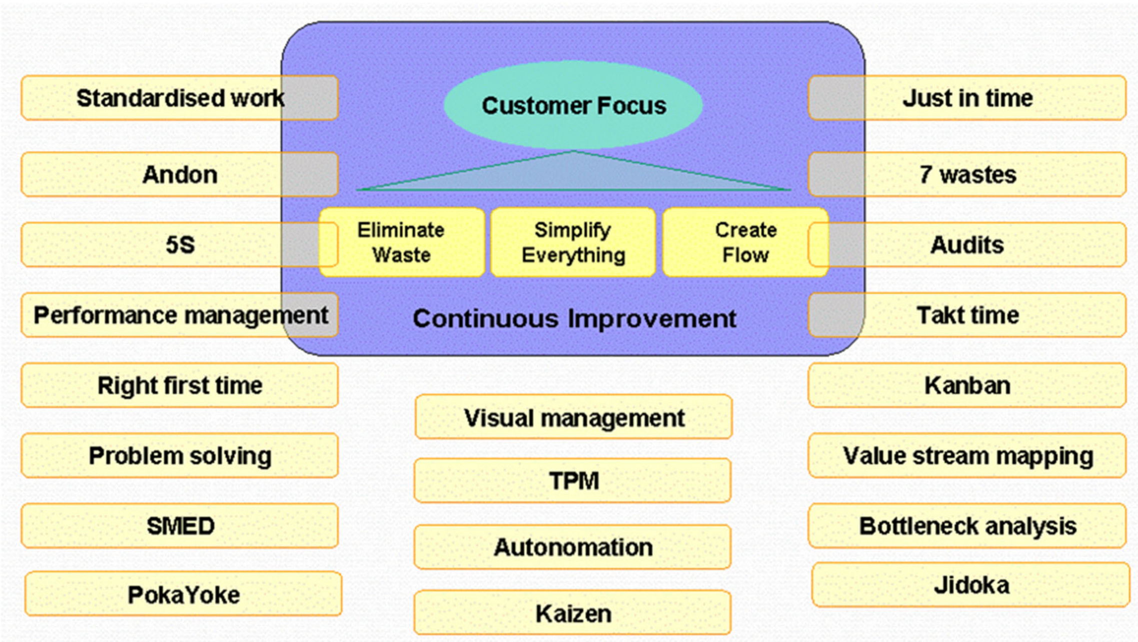

Figure 26 Lean manufacturing tools (Earley, 2019)

4.2. Six Sigma

Six Sigma consists of a group of quality control methodologies which follow a statistically based concept. These methodologies aim to recognise and decrease process defects and disparities to achieve an eventual near perfect outcome (Zhen, 2011). In the Six Sigma concept, higher levels imply presence of less flaws. Six Sigma is the near perfect result corresponding to the presence of 3.4 defects per million opportunities (George, 2002). Six Sigma like lean, applies multiple tools. Failure Mode Efficiency Analysis (FMEA), Define Measure Analysis Improve and Control (DMAIC) and Pareto Principle are three examples of the most widely used Six Sigma tools.

DMAIC consists of 5 main phases (Figure 27). These process aims to solve the problem by identification of process waste and disparities and the selection of required statistical tools:

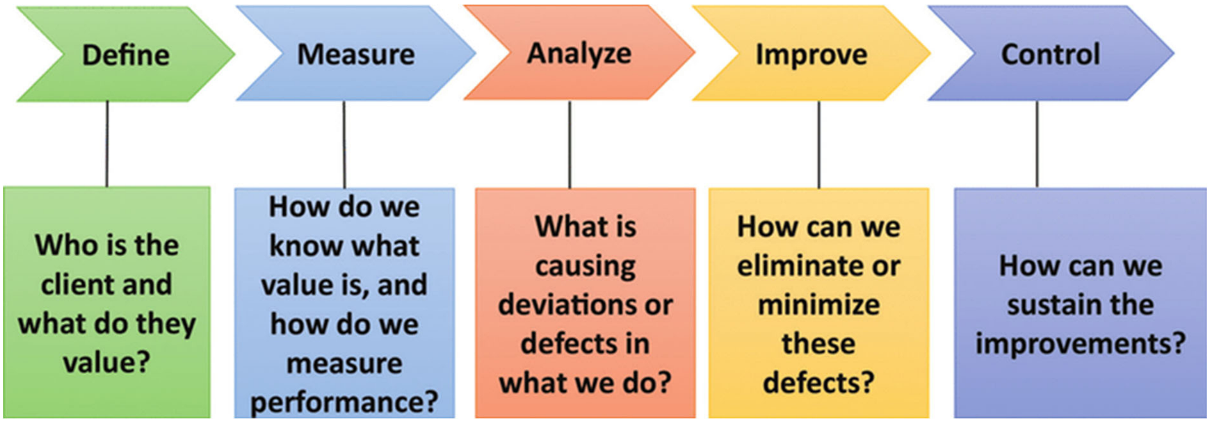

Figure 27 DMAIC phases

Failure Mode Efficiency Analysis (FMEA) analyses the possibility and risk of product/process failure modes. This includes assessment of severity, the occurrence and the detected level of each failure mode. The methodology prioritises all detected failure modes and provides with prevention strategies (Crow, K., 2002).

4.3. Applicability of lean six sigma in the food industry

Lean Six Sigma principals have not remained confined to the automobile sector only, where it originated, but it has gradually gained applicability across the food and process industry. Food and processing industries possess some barriers for application of lean principals due to various reasons such as nature of machinery, short shelf life, long setup time, resource complexity and heterogenous raw materials. In the last 10 years, application of lean manufacturing in the food processing sector has attracted significant interest due consumer demand and rising competition. A summary of relevant literature looking at the application of various aspects of lean thinking in the food industry is provided in Table 1.

Table 1 Classification of research papers according to scope of lean implementation

Scope of application of Lean	Author	Industry	Production Environment
Lean operations/manufacturing	(Dov, 1992)	Ice cream	Batch
	(Iijima, 1996)	Packaged foods	Continues
	(Jones, 1997)	Brewing	Batch
	(Simons, 2005)	Red meat	Continues
	(Lehtinen, 2005)	Sauces, and jams	Batch
	(Melvin, 2008)	Dairy	Batch
	(Jain and Lyons, 2009)	Food and drink	Batch
	(Upadhye et al., 2010)	Biscuit	Batch
	(Dora et al., 2013)	Not specified	Batch
Lean supply chain management	(Houghton, 1995)	food	Batch
	(Katz, 2000)	Beef	Batch
	(Simons, 2003)	Beef	Batch
	(Francis, 2004)	Beef	Batch
	(Cox and Chicksand, 2005)	Beef	Batch
	(Higgins, 2005)	Sugar	Batch
	(Simons, 2005)	Red meat	Continues
	(Taylor, 2005)	Food	Batch
	(Pool et al., 2011)	Coffee	Batch
Lean enterprise	(de Castro et al., 2009)	Pork	Continuous
	(Taylor, 2009)	Fresh food	

Figure 28 summarises the lean tools and their application areas in the food industry. While application of lean and Six Sigma concepts demonstrates good potential to improve outcomes in the food industry, studies on the beef industry have been limited. In General, the successes and failures of quality management initiatives are highly context dependent. We have identified a clear need to understand the problems facing implementation of such initiatives in the red meat industry.

Figure 28 Lean in Food Industry

4.4. Site Visit – Ford Broadmeadows Plant

Ford Broadmeadows site was shut down in 2016 but we had the opportunity to visit the site a few years ago. All of the processes were reviewed, and technologies and systems were observed. The visit full report was submitted to AMPC with milestone report#2 on 02/09/2018. Also, with the student experience in the auto industry, we had a good background knowledge on the car manufacturing systems and processes we could benefit in mapping the two industries.

Figure 29 Ford Australia, Broadmeadows plant

4.5. Site Visit – Meat processing plant

One of the most challenging parts of this project was visiting abattoirs. We attempted many times to get approval for site visits with no luck. After more than a year, one of the plants greatly helped us by allowing us to have a visit. Due to the confidentiality of the content, we cannot name the plant and will call it "The plant" in this report.

To get an understanding of processes and procedures in the red meat industry, we visited the a mostly manual processing plant on 26 June 2018. The plant has the capacity of processing almost 220 cattle and 2000 sheep. More than 30% of the cattle and almost 50% of the sheep are fully processed and packed in the plant and the rest of the carcasses are sent to retailers/butchers.

The visited abattoir uses the National Livestock Identification System (NLIS) tracking system. This system allows precise tracking of every piece of packaged meat to its animal and farm of origin. The NLIS system, which was first implemented in 1999, allows nationwide tracking of cattle, goats, and sheep. This system was first introduced to simplify tracing of cattle during disease outbreaks and/or food related incidents but subsequently was expanded in 2009 to include goats and sheep.

The NLIS uses three parameters:

- An animal identifier (a visual or electronic ear tag known as a device)
- Property Identification Code (PIC) to identify the animal's physical location
- A database which is accessible via internet. This stores movement data and other details

Animals are tagged with a NLIS-accredited device to be able to be traced while moving along the supply chain. With every movement, a new location entry with a unique PIC is saved on the NLIS database. This information can easily provide a history of the animal's location through their life span. The animal's contact history can also be defined using the information. The devices are also able to be allocated various statuses if required. These can represent the state of the devise, for example damaged, new, out of order and so on. The status function can also be used to describe the state of the animal.

If a device status demonstrates that an animal has a potential to pose a health risk a report is generated with would ensure testing prior to slaughter. This process has been vital in maintaining the high safety and quality standards of Australian red meat.

The processing starts at receiving and unloading the cattle & sheep in the plant. Pre-slaughter washing is a well-established step to reduce the physical and microbiological contamination on cattle hides which is aimed to minimise carcass contamination in the next steps. However, it is shown that microbiological contamination with total aerobic bacteria and Escherichia coli is greater on sheep carcases which had been washed before slaughter, irrespective of wool length. So, in the visited plant, the pre-slaughter washing is done for cattle only.

Next step is the stunning. The animal is guided through to a constrained area in which the operator performs the stunning process. The stunning is done using a non-penetrative pneumatic stunner for cattle and an electrical stunner for sheep (Figure 30). The non-penetrative stunning method is widely used to minimise the risk of transmission of bovine spongiform encephalopathy, compared to penetrative method. The animal will be unconsciousness for about 30-40 seconds and the sticking should be done in this timeframe before the animal gets conscious again.

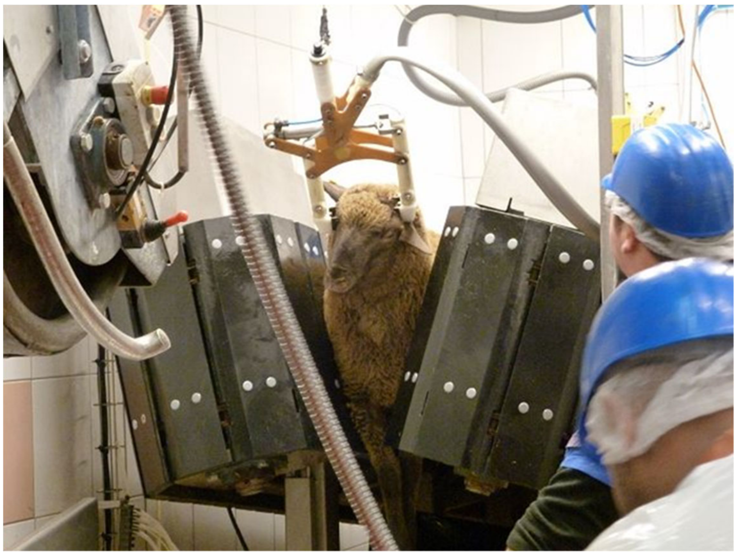

Figure 30 Sheep stunning

Then the animal, now hanging from a chain conveyor and lowered to slaughter position, is bled ('sticking' or exsanguination process). This is usually done by cutting into the thoracic cavity and severance of the carotid artery and jugular vein in one attempt. Cattle horn removal if applicable should be done at this stage as well. The animal is then suspended by the hind leg and held in a vertical position for maximal blood removal. Important factors in this stage include: Quality and sanity of the knives used, operator experience and optimal positioning and general hygienic procedure.

The next step which is head removal is automated for sheep. Due to different height for each animal, the cutting blade must be adjusted for each animal. This is done with the help of an adjustable surface (Figure 31).

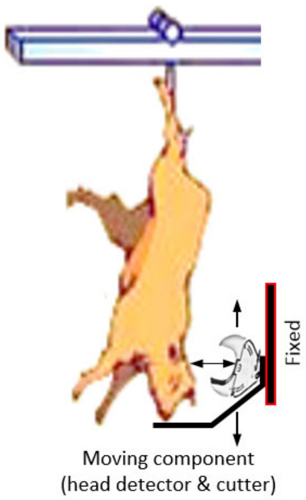

Figure 31 Animal auto head removal

The surface starts moving up from its home position, the lowest possible. The surface starts moving up till it hits the sheep head. Now, knowing the animal head is, the cutting blade which is in a fixed distance to the adjustable surface activates and cuts the animal head.

The cattle carcass is composed of muscle, fat, bone, and connective tissue. Lean meat and muscle are the nutritive portion which is referred to as “meat”. The less the fat and connective tissue attached to the muscle, the more desirable it is. The cattle carcass consists of about 300 muscles which vary widely depending on the body location and age of the animal. In general, only 25 muscles can be separated and used. The colour, tenderness, juiciness, and flavour of these meat are essential quality factors. The effective and maximal removal of the inedible and less desirable portions of the carcass including all the internal organs is an important step in achieving high quality meet. This step which is referred to as the dressing process, is aimed to produce hygienically clean and wholesome products. All knives used in the process shall be cleaned after used for each animal to prevent possible contamination transfer between animals.

Hygienic process is a Hide removal which is the initial step in the dressing process, starts by opening the brisket hide. To prevent contamination, a clean paper will be put to the brisket. The hide is removed by making cuts at the legs and then following the natural seam along to the flank, up the back and off the rump. This can be done either manually or mechanically. In the visited plant, an operator controlled pneumatic arm is used to help detaching the hide from the carcass. After the pneumatic arm detaches the main areas of the hide, the skilled operators have the task to perform the remained necessary cuts to make the carcass ready for a full hide removal.

Figure 32 Sheep hide removing

The final Hide removal machine is an automated rotary skinning machine. The operator engages the detached part of the Hide in the rollers. As the rollers rotate and move down, the Hide is removed completely from the carcass. Automating this part of the process is very efficient as it requires lots of pulling force and not very ergonomic if it was to be done manual.

After hide removal is completed, evisceration takes place. This is the process of removing viscera. The viscera are separated into different trays. It is essential that all viscera remain intact and special care should be taken to avoid any breaking of the paunch. If tissue become contaminated by visceral content that tissue must be removed immediately. In the Australian processing system, everything from the carcass is used including muscle, offal, co-products and by-products. Edible offal most derived from a beef carcass is tongue, tripe, cheek, liver, tail, tendons, heart, and kidney.

A vital quality check is required at this stage to ensure there is no contamination on the carcass and it is ready to be delivered to the customer or boning room after washing. The carcass is then sent through a washing booth. The primary object of carcass washing is to remove visible soiling and blood stains and to improve appearance after chilling. Washing is no substitute for good hygienic practices during slaughter and dressing since it is likely to spread bacteria rather than reduce total numbers. Stains of gut contents must be cut off. Wiping cloths must not be used.

Carcass spraying will remove visible dirt and blood stains. Water must be clean. Soiled carcasses should be sprayed immediately after dressing before the soiling material dries, thus minimizing the time for bacterial growth. Under factory conditions bacteria will double in number every 20 or 30 minutes. In addition to removing stains from the skinned surface, attention should be paid to the internal surface, the sticking wound, and the pelvic region.

A wet surface favours bacterial growth so only the minimum amount of water should be used, and chilling should start immediately. If the cooler is well designed and operating efficiently the carcass surface will quickly dry out, inhibiting bacterial growth.

Carcasses should go into the cooler as soon as possible and should be as dry as possible. The object of refrigeration is to retard bacterial growth and extend the shelf-life. Chilling meat post-mortem from 40°C down to 0°C and keeping it cold will give a shelf-life of up to three weeks, provided high standards of hygiene were observed during slaughter and dressing.

Figure 33 Carcasses stored in chilled room

At this point some carcasses are sent to boning room and the rest will be kept in the chilled room and later transferred to wholesales.

The carcass is the split in two using a brisket splitter. The operator works facing the back of the carcase, splitting it down the backbone. Splitting the carcase in two makes it easier to remove the spine and any remaining organs, inspect, store, and then further break down the carcase. In the visited abattoir, the splitting process is done manually using a brisket splitter.

Splitting the carcass into different known pieces requires lots of experience thus the efficiency of this part of the process hugely depends on the operators' skills. Every piece is cut to standard and put in trays. The trays then move on belt conveyors and are transferred to packaging room. In the next room, the boxes are manually folded from flat packs and ready to be used. Packing is also done manually. Then the boxes are then delivered to the chilled room and ready to be shipped to retailers. The waste parts of the animal are also processed in the plant to produce tallow and meat meal.

4.6. Mapping the two industry processes

After visiting the meat processing plant and the processes, with an understanding of the technologies and systems available in the automotive manufacturing industry, we focused on the areas we found opportunities for improvement. Utilising process concepts and design from automotive manufacturing we listed many ideas. Discussing the details later with the plant team, we shortlisted the major ideas to fill the gaps we could highlight in the abattoir process. Not every process can be benchmarked from the automotive manufacturing process, but it gave the team a significant understanding of what the gaps in the meat processes are and what options are there to rectify the issues. The next section includes some of the major shortlisted improvement ideas as a result of mapping the two industry processes.

5.0 PROJECT OUTCOME

As explained in the previous section, this study has identified seven major improvement opportunities and techniques:

5.1. Lean Mindset

Implementing lean manufacturing principles will greatly help improving the plant efficiency by reducing waste and improving the cycle time. All staff in different levels require training to fully understand the lean manufacturing concepts and try to implement them in their daily tasks.

Lean efforts are not limited to manufacturing; a lean mindset applies to any process. This is the key and most important step in making significant improvement in the plant.

5.2. Layout

Manufacturing process layouts are an important focus in Lean organizations because they are often full of inefficiencies that lead to wasted time, effort and materials. The first step in rethinking a manufacturing layout is collecting data about the existing process. Information such as machine load, takt time, equipment reliability, set-up time, yields, and staffing requirements are necessary inputs for redesigning process layouts. With data on the existing process, new layouts can be considered in order to minimize cycle time and travel distance and simulate a continuous flow process. Each scenario will present unique challenges (process flow, physical constraints and support systems) that will need to be considered as the ideal process flow is developed (Quality Training

Portal).

Developing a detailed layout of the processing lines, including the correct dimension of each station, head counts, facilities, etc. is a crucial step to improve the plant efficiency. Figure 34 illustrates a sample layout of a processing plant.

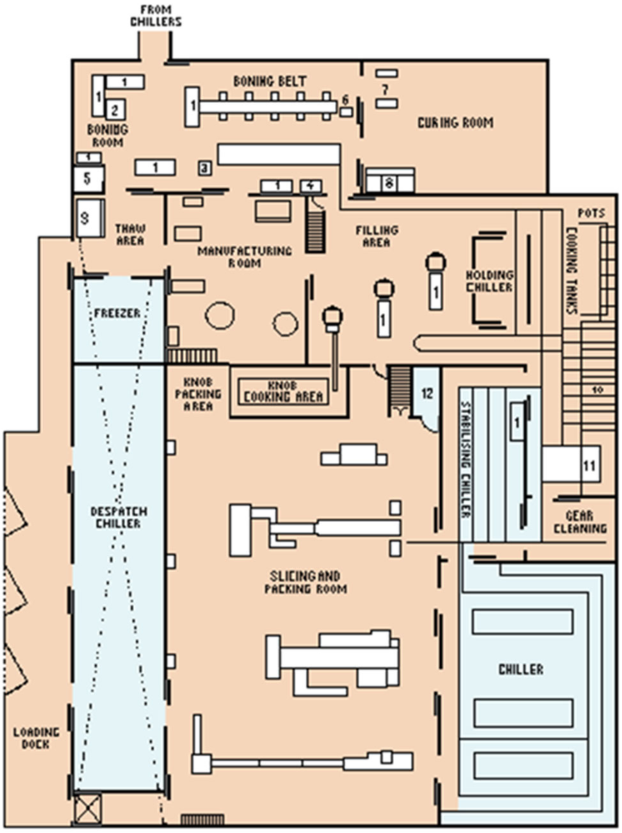

Figure 34 Sample Plant Layout

5.3. Material Handling

One of the very first and obvious challenges observed in the plant was the material handling and logistics issues. This cannot be looked at as an isolated issue. The other proposed actions are also required to be done initially to enable the team to come up with the best solution for a smooth material handling and process flow solution. Figure 35 illustrates a part of a sample automotive manufacturing process flow model.

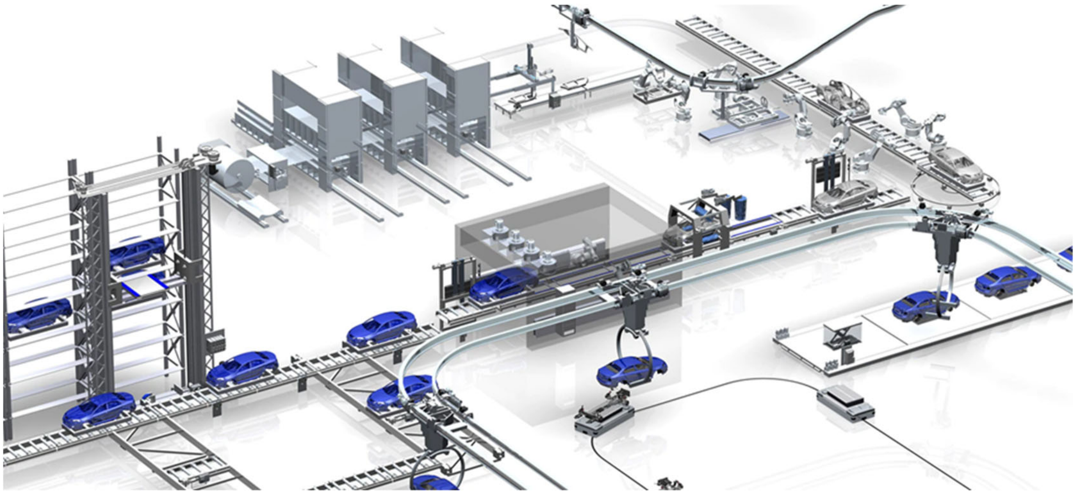

Figure 35 Sample material handling system from automotive manufacturing plant

5.4. Process Documentation

We propose that processes are documented for each station. This is referred to as "Process Illustration" or "Station Information Sheet". This document includes a description of the process for the station, illustrations to fully clarify the defined process, a list of the tools required to complete the task, the cycle time, the number of operators in the station, and finally a simplified snapshot of the layout to demonstrate where in the line this process happens. Below is a sample process sheet from automotive manufacturing plant (Figure 36).

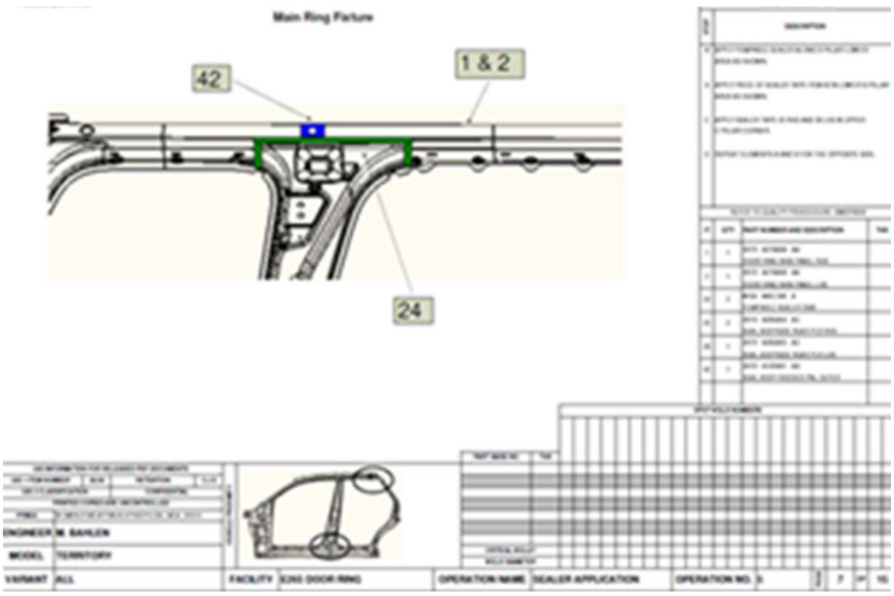

Figure 36 Sample Process Information Sheet

5.5. Throughput Simulation

Throughput simulation is a type of discrete event simulation to use technical realisation of one layout to prove concept is sufficient to meet planned production capacities. Material flow, system availabilities and process bottle necks will be identified and optimised in this simulation. While this usually takes place in the plant design phase, we still highly recommend this analysis to be done for the visited abattoir.

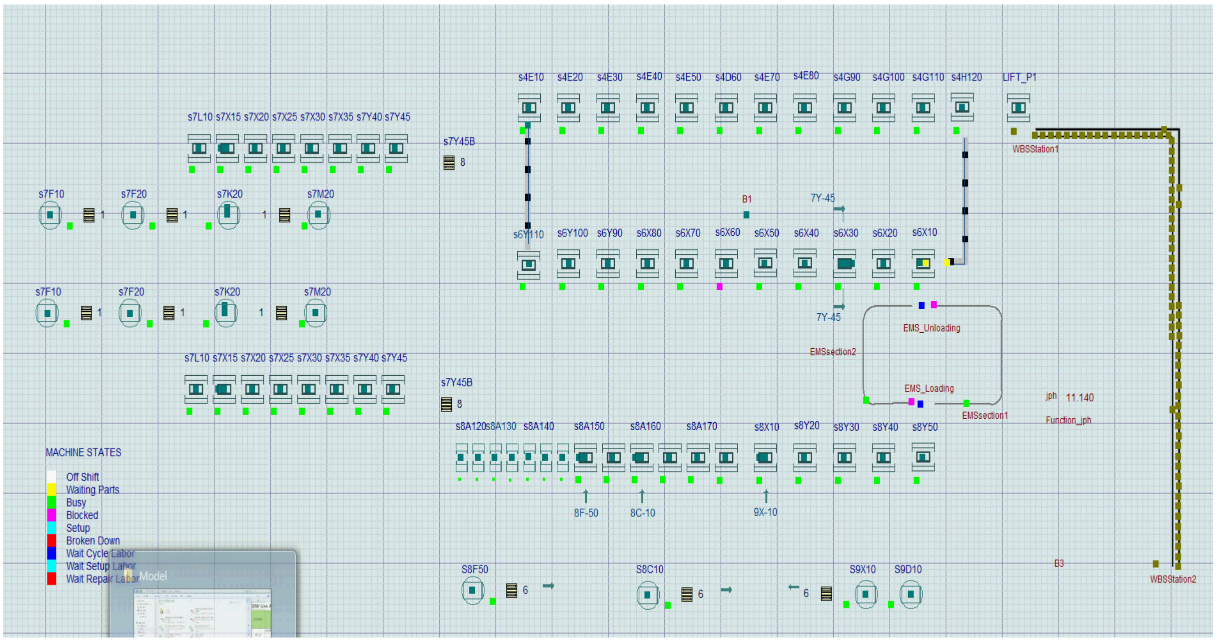

Figure 37 Sample throughput simulation

5.6. Safety and Ergo Assessment

Safety and ergonomic assessment of the processes is a key to improve the processes. This will help to identify the issues which will impact the operators' health and performance and consequently the product quality. Below figure 38 shows a sample ergo assessment.

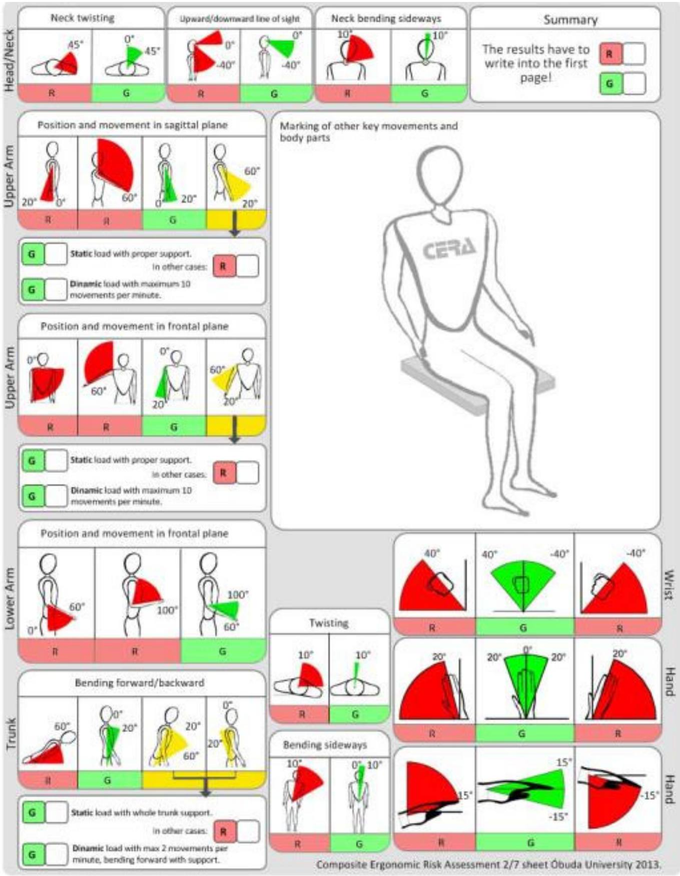

Figure 38 Sample Ergo Assessment Sheet

5.7. Automation

It was observed that there are many opportunities to improve the efficiency of the processes by the means of automation, throughout the process from the animal stunning to the flat box folding and final packaging of the product, in the visited plant. This level of manual operation requires high number of skilled operators, usually working in tough ergonomic conditions. The lack of a smooth process flow can be easily observed within the processes. This creates many non-value-adding activities and some bottlenecks in the process, all resulting in efficiency reduction and limiting the plant capacity. Automation will require more initial investment compared to manual operation, but it delivers huge benefits such as long-term labour cost savings, high level of safety, and product quality improvement. We propose future TARR study for each case to investigate whether the investment for automation is financially viable. This study will show the financial aspect of manual vs auto process and possible savings or losses over time. The quality improvement benefits should be reviewed in conjunction with the sales and marketing team as quality cannot be always converted to dollars easily.

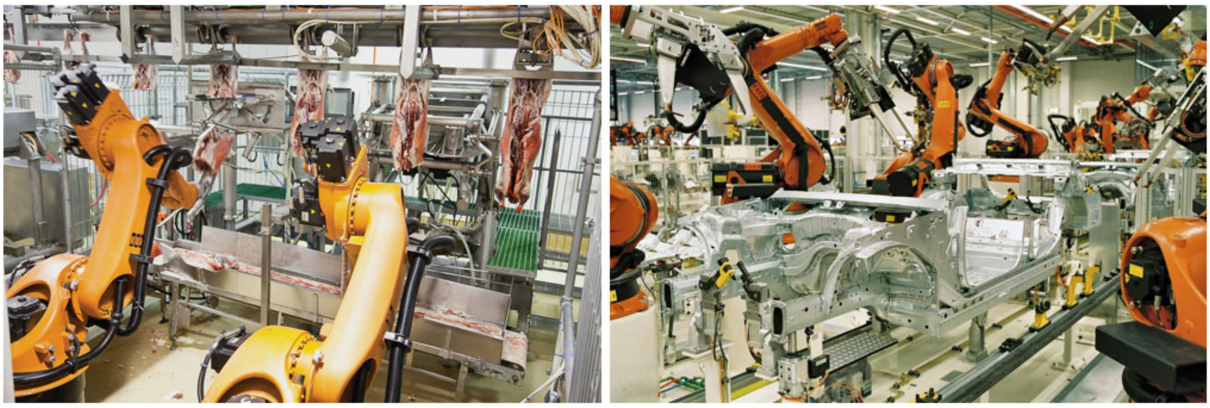

Figure 39 Automation can be widely implemented across meat processing plants

6.0 DISCUSSION

This study focused on studying the processes in the meat industry and aiming to improve processes through mapping processes across from the automotive industry as a benchmark. Investigation and study of already existing processes, technologies, and systems in the meat industry was conducted through visit to the red meat processing plant and interviews with the processing managers and staff to find out the potential or required alterations for improvement. Mapping all these activities across to the automotive industry to find similarities in the fields of processes, manufacturing procedures, facilities, and production engineering was conducted. Automotive industry technologies and solutions with a potential to be used in the red meat industry were studied and suggestions to ease the adaptation and implementation process to minimize manual tasks in the red meat industry were identified. A list of suggested actions (as explained in section 5.0) has been provided to the plant team.

We showed interest and offered full help in tuning each of the suggested ideas to make it ready for implementation in the plant. This requires the plant full participation in making the required changes to the layout and processes.

We strongly believe the potential of noticeable improvement can be achieved by implementing the suggested actions as the first step. We appreciate this can be a significant change and possibly shock to the long-established meat industry, though the industry will surely benefit from the outcome if it opens the door to the well proven technologies from the automotive industry.

With the approval of AMPC, the outcome of the project was presented in the Victorian Network

Meeting (counted for milestone 8/9 as agreed with AMPC) which was received with great interest. The presentation deck is attached in appendix 10.1.

Also, with the AMPC approval, an abstract is submitted to the IUFoST 20th World Congress of Food Science and Technology – Auckland, New Zealand (International conference and part of milestone 8 which due to COVID-19 is postponed). The conference timing is affected by COVID-19 and we are still awaiting the outcome of the abstract submission and the new dates. The abstract submission confirmation is attached in appendix 10.2.

7.0 COCLUSION / RECOMMENDATIONS

While the recommended improvement strategies have been suggested after extensive research and study of the processes in both industries, further studies are required for each item implementation and feasibility in the red meat industry.

There are great opportunities for the industry if the plants are open for changes. Being open to new technologies and systems is what the automotive industry has developed as a culture in the industry and always benefited from. Same journey can and we strongly recommend happening for the meat industry. The results and information obtained through this study can serve as a foundation for a knowledge transfer database between the two industries.

Visiting abattoirs as the major challenge we faced during this project limited the team ability to propose more specific actions. We tried 2 years through different organizations including RMIT and AMPC to get access to the abattoirs with only one chance of visiting a plant. More plant visits could greatly help the team to further tune the outcome of the project. We recommend establishing further industry/university connections and facilitating plants visit for researchers.

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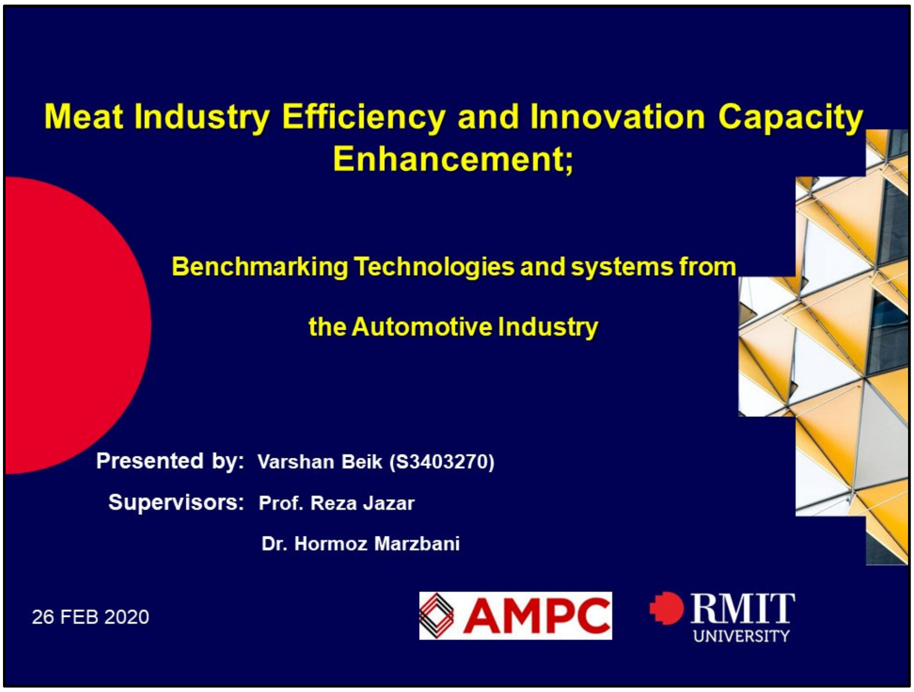
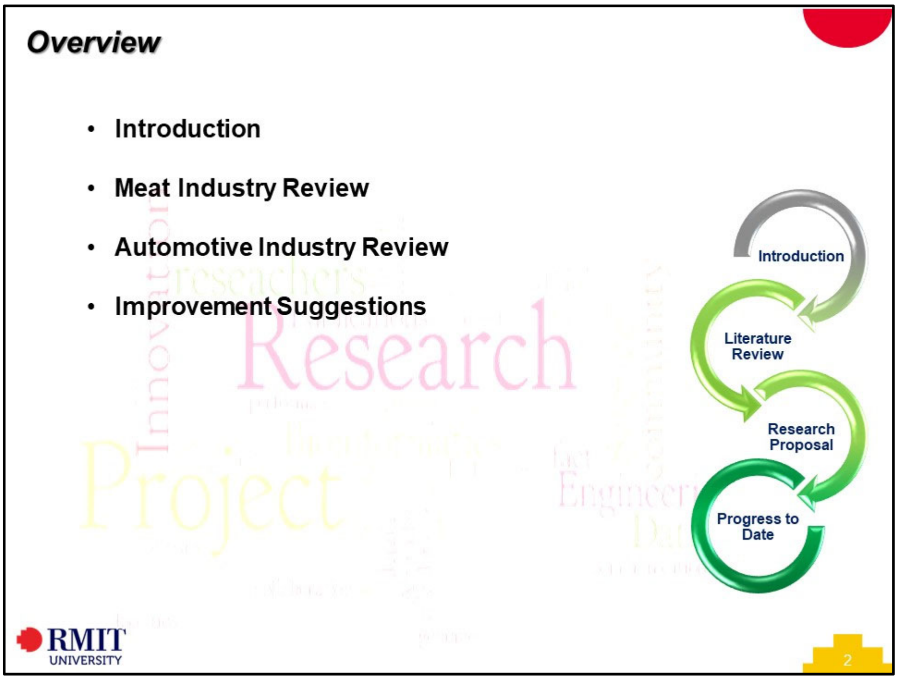
9.0 APPENDICES

9.1. Appendix 1: Milestones 8/9

Memo: Milestone 8 With the approval of AMPC, present at an international conference (or national conference of good standard). Milestone 9- Major Milestone Review, Meeting to review progress of the project including PowerPoint presentation by the student.

It was agreed that the Victorian Network meeting would count for this (Presented at the Victorian Networking Meeting on 26/02/2020)





Introduction

The *International Competition* is the first key risk reported by AMPC.

The main industry Challenges[1]:

- ❑ **International Competition**
- ❑ Changing Consumption Patterns
- ❑ Value Chain Integration
- ❑ Regulatory Environment
- ❑ Social licence to operate
- ❑ Climate Change

1- AMPC

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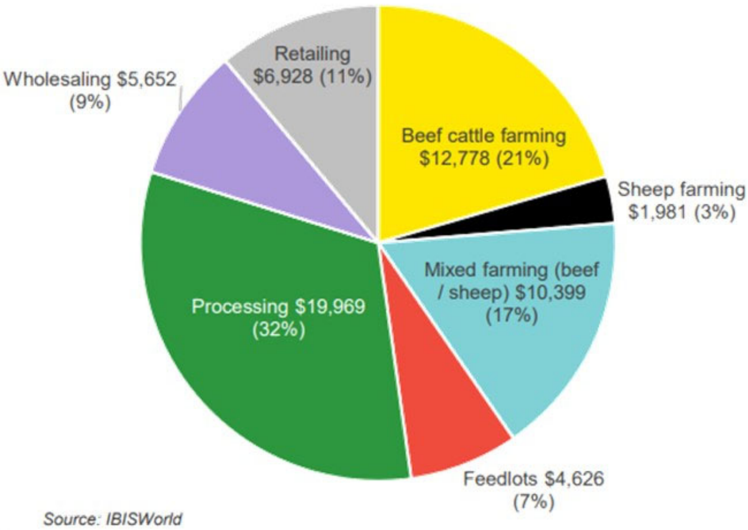
3

Introduction

The industry turnover by sub-sector: *Processing is the key element*

Industry turnover by sub-sector ($m, (%), 2015-16)



Source: IBISWorld

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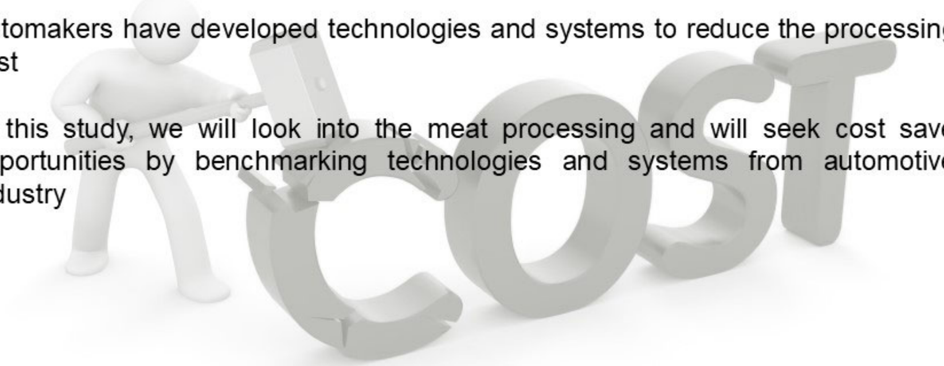
4

Introduction

To be internationally competitive, we have to minimise the processing cost.

Automakers have developed technologies and systems to reduce the processing cost

In this study, we will look into the meat processing and will seek cost save opportunities by benchmarking technologies and systems from automotive industry



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5

Red Meat Industry

Literature Review & Processing Plants Visit

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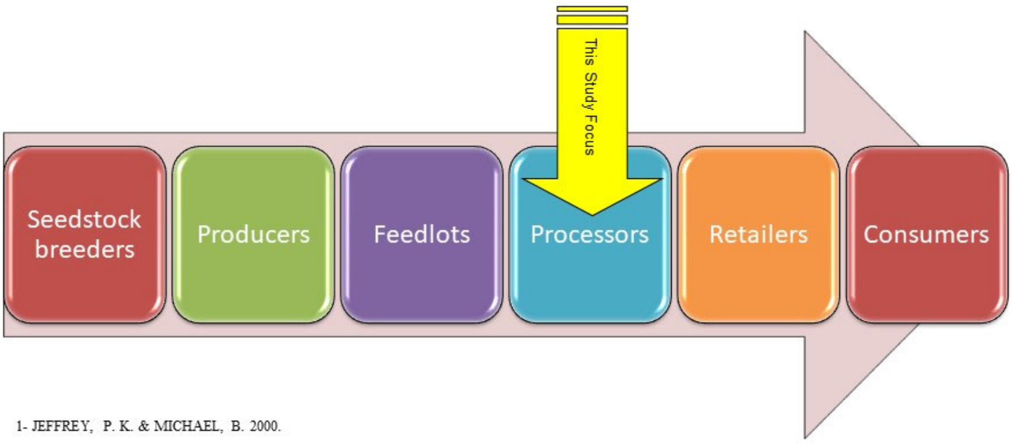
6

Red Meat Industry

The supply chain: 6 distinct operating groups[1]



1- JEFFREY, P. K. & MICHAEL, B. 2000.

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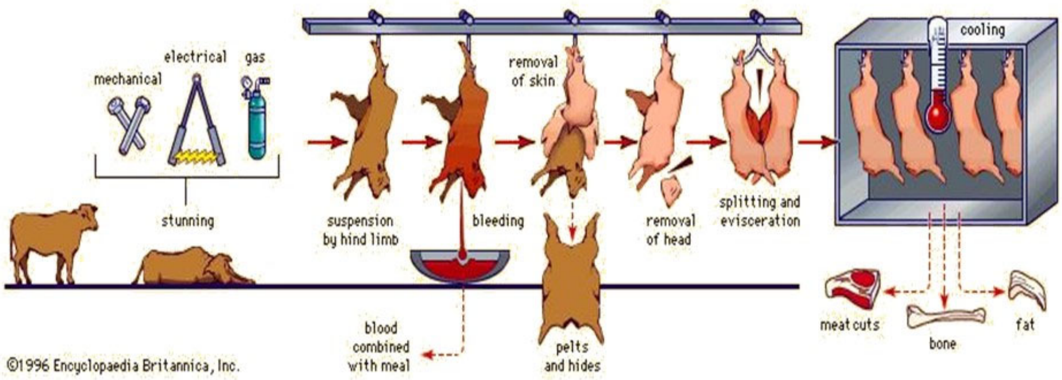
Red Meat Industry

Common stages of cattle slaughtering process



Pre-slaughter handling / washing → Stunning → Sticking → Carcass Dressing → Splitting / Trimming

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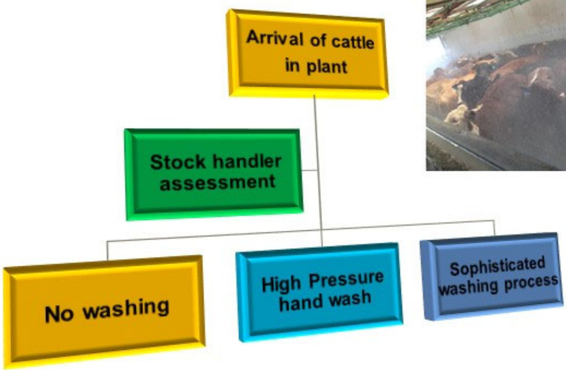
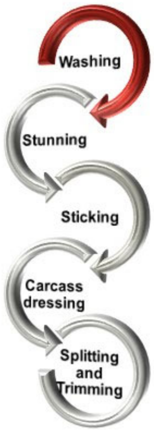
Red Meat Industry

Cattle Washing

- To minimise carcass contamination
- The washing process varies largely between plants[1]





1- AMPC, 2017

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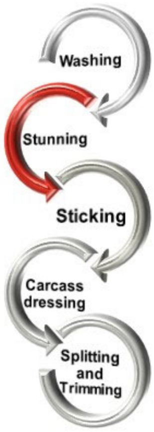
Red Meat Industry

Cattle Stunning includes:

1. Restraining animal
2. Stunning
   - Penetrating
     - Enters the cranium
     - Fatal and irreversible
     - Possibility of brain matter entering the blood stream
   - Non-Penetrating
     - Causes concussion
     - Reversible
     - Less risk of disease transmission



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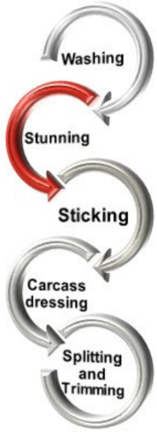
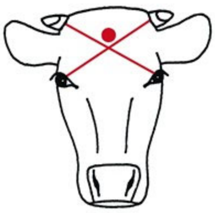
10

Red Meat Industry

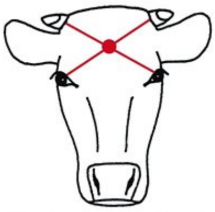
Cattle Stunning

- Force and position of impact are critical
- Can be very inhumane due to lack of skill, experience, etc.





Stunning position - Non-penetrative



Stunning position - Penetrative

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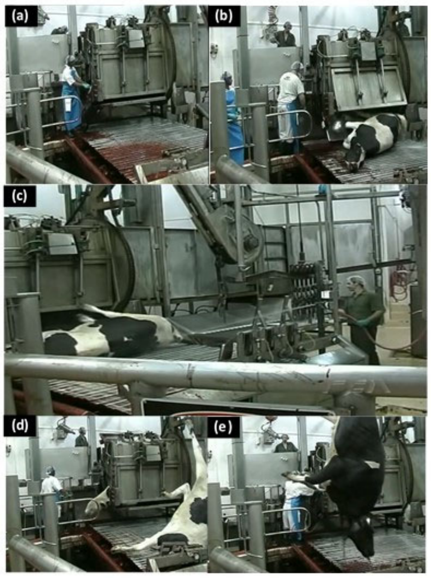
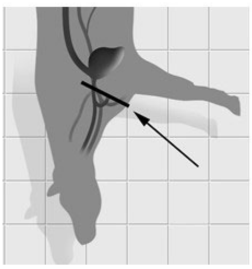
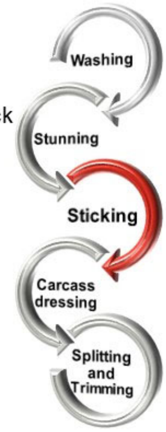
Red Meat Industry

Cattle Stunning [1]



- Severing the carotid arteries and jugular veins
- Knife positioning is critical
- Can be very inhumane due to lack of skill, experience, etc.





1- Toldrá, 2010

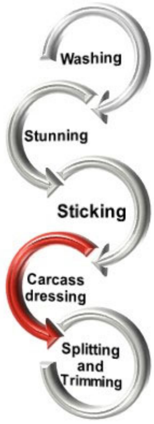
RMIT UNIVERSITY

Red Meat Industry

Carcass Dressing

Removal of the inedible portions of the carcass including all the internal organs

- Hide removal
- Head removal
- Evisceration



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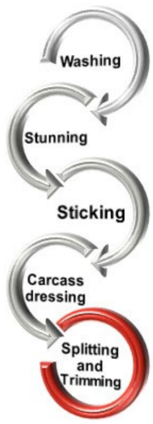
Red Meat Industry

Carcass Splitting & Trimming



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Red Meat Industry

Summary:

It was observed in the visited plants that many of the processes are still manual and relying on operators skill and experience. The visited processing plants did not seem to have structures to document the processes. Many instances of not fully efficient processes were observed.

We have learned there are some automation happening in Australia which is great to the industry. Though, still very limited and not viable for all plants due to the significant cost

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Automotive Industry

Literature Review
&
Plant Visit

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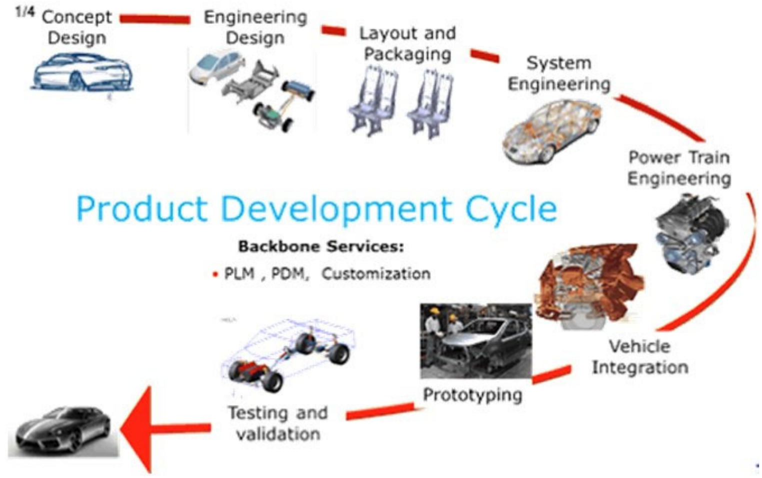
16

Automotive Industry

- The Australian Automotive industry is capable of taking an automotive design all the way from concept to production
- Ford Motor is a global leader in innovation[1]



1- Panwar et al., 2015

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17

Automotive Industry

Technologies to be looked at:

- ✓ Highly efficient product development planning and management
- ✓ Well planned engineering & feasibility study of the product
- ✓ High speed automated transfer systems
- ✓ Well developed quality systems
- ✓ Complex project management
- ✓ Highly cost effective engineering design utilising 3D simulations
- ✓ Well developed standards and procedures
- ✓ Highly regulated clean environment
- ✓ High degrees of automation
- ✓ Complex process management techniques and tools

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18

Automotive Industry

Ford Plant Visit

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Automotive Industry

Summary:

Due to the complex nature of the automotive design and manufacturing procedures, the industry is continuously becoming more challenging.

To survive in such a competitive environment, auto makers have to utilise the most cost effective solution for engineering and quality problems.

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Research Questions

&

Objectives

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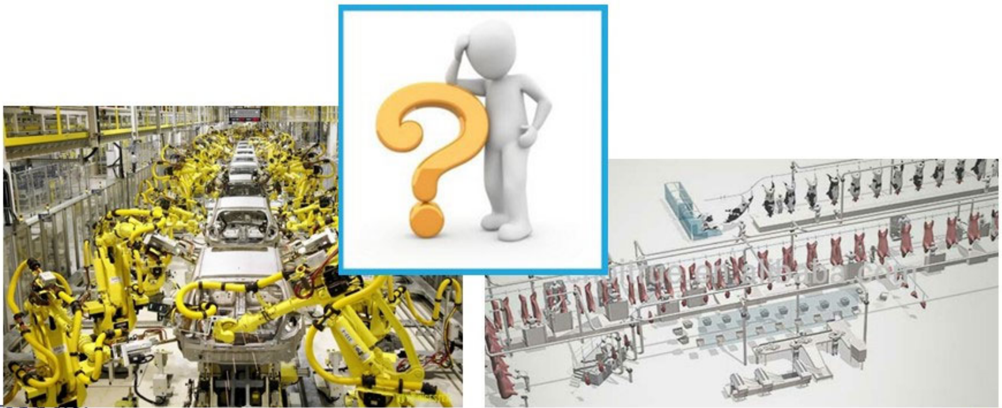
Research Questions

1. How can the red meat manufacturing process be optimised?
2. Can the technologies be adopted from automotive industry?
3. Can the adopted technologies reduce the red meat processing cost?
4. What are the limitations in adopting systems & technologies?



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Objectives

1. Identifying red meat industry weaknesses and potentials for improvement
2. Proposing cost saving ideas by adopting automotive industry's smart manufacturing processes
3. Generating a database for a rapid knowledge transfer
4. Generating more focused future research projects

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Process Mapping

Red Meat Industry
- Meat Processing Plants Visit
- Literature Review
- Processes & technologies Review
- Investigation of Industry Gaps

Automotive Industry
- Automotive Manufacturing Plant Visit
- Literature Review
- Processes, Technologies, and Solutions Review

Process Mapping
- Mapping Processes Between the Two Industries
- Management Systems Comparison
- Identifying Process Improvements Opportunities
- Technologies Adoption Opportunities

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Improvement Opportunities

Based on the findings from the meat processing plants visits and studying the automotive industry technologies and processes, we propose the below 7 improvement opportunities. We believe these will greatly improve the meat processing efficiency, as they did to the auto industry.

1. Lean Manufacturing platform
2. Process and layout design
3. Process documentation
4. Throughput simulation
5. Material handling
6. Safety and ergo assessment
7. Automation

This study is not suggesting the improvement ideas have not been implemented in any plants. This is only based on the plants visited by the team.

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Improvement Opportunities

Lean

- Rooted in Toyota's Production System
- Proven to improve the productivity and quality of red meat cutting lines[1]
  - Eliminating waste[4]
  - Improving Quality

Implementing lean manufacturing principles will greatly help improving the plant efficiency by reducing waste and improving the cycle time. All staff in different levels shall be trained to fully understand the lean manufacturing concepts and try to implement them in their own tasks.

1- Simons and Zokaei, British Food Journal 2005
2- Womack and Jones, 1996
3- Hines and Taylor, 2000
4- Vlachos, 2015

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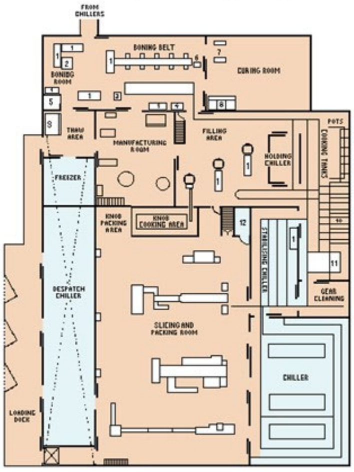
Improvement Opportunities

Process & Layout Design

Developing a detailed process with illustration and also layout of the processing lines, including the correct dimension of each station, head counts, facilities, etc. is a crucial step to improve the plant efficiency.

Designing a process with all key details in the layout, will greatly increases the efficiency.



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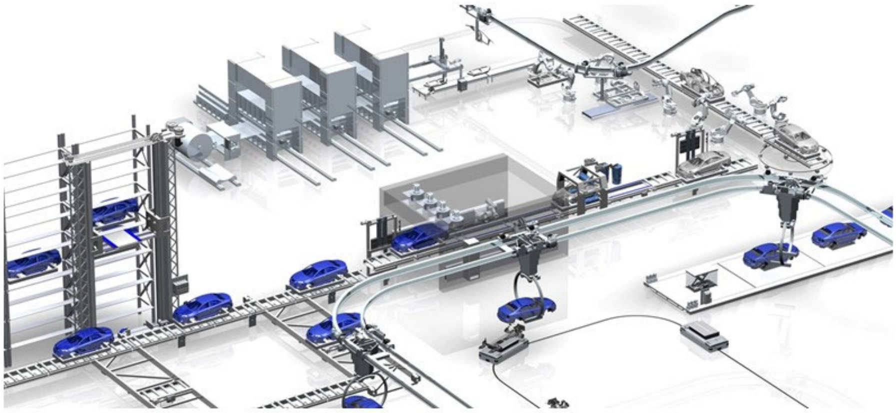
27

Improvement Opportunities

Material Handling

One of the very first and obvious challenges observed in the plants was the material handling and logistics issues. This cannot be looked at as an isolated issue. Some of the other explained actions such as a proper process and layout design are required to be done initially to then enable the team to come up with the best solution for a smooth material handling solution.



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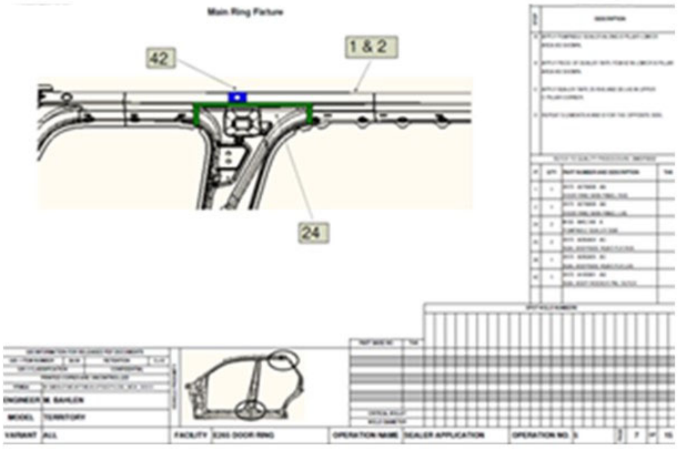
28

Improvement Opportunities

Process Documentation

The processes shall be documented for each station. This is called process illustration or Station Information Sheet. This document usually includes a description of the process for the station, illustrations to fully clarify the defined process, a list of the tools required to do the job, the cycle time, the number of operators in the station, and finally a simplified snapshot of the layout to show where in the line this process happens.



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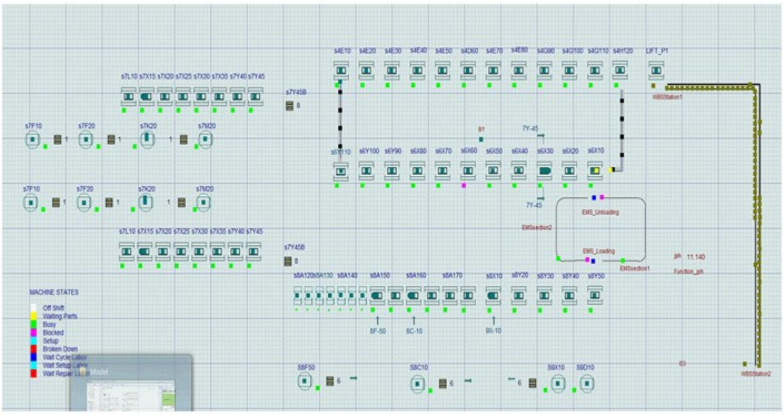
Improvement Opportunities

Throughput Simulation

Throughput simulation is a type of discrete event simulation to use technical realization of one layout to prove concept is sufficient to meet planned production capacities. Material flow, system availabilities and bottle necks will be identified and optimized in simulation. This is something usually done at the line / plant design phase but can greatly help recognizing the bottle necks of the existing lines.



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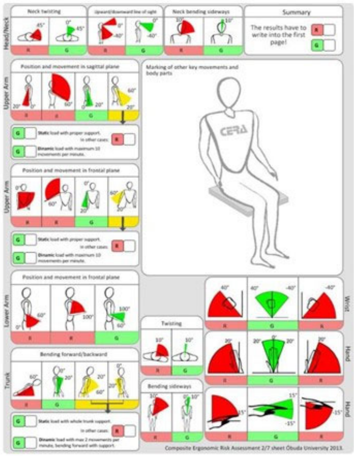
Improvement Opportunities

Safety and Ergo Assessment

Safety and ergonomic assessment of the processes is a key to improve the processes. This assessment will help to identify the issues which will impact the operators' performance and consequently the product quality.



Improvement Opportunities

Automation

it was observed that there are many opportunities to improve the efficiency of the processes by the means of automation; from animal washing to the flat box folding and final packaging of the product.

Automation surely will require more initial investment compared to manual operations but it delivers huge benefits such as long term labour cost save, high level of safety, and also the product quality improvement.

To study if the investment for automation is worth financially, a TARR study shall be done for each case. This study will show the financial aspect of manual vs auto process and possible saves or losses over time. The quality improvement benefits shall be reviewed in conjunction with the sales and marketing team as quality cannot be always converted to dollars easily.


AMPC

9.2. Appendix 2: Milestone 8 (International Conference)

With the AMPC approval, an abstract is submitted to the IUFoST 20th World Congress of Food Science and Technology – Auckland, New Zealand (International conference and part of milestone 8 which due to COVID-19 is postponed). The conference timing is affected by COVID-19 and we are still awaiting the outcome of the abstract submission and the new dates.

Abstract Submission Received - IUFoST 20th World Congress of Food Science and Technology

IUFoST 20th World Congress of Food Science and Technology <enquiries@iufost2020.com>
Sun 19/04/2020 12:27 AM
To: Varshan Beik

20/20 VISION IUFoST
Food for a Changing World
SAFE | SECURE | SUSTAINABLE
20th World Congress of Food Science and Technology
Auckland, NZ

Dear Varshan,

Thank you for your abstract submission for the programme at IUFoST 20th World Congress of Food Science and Technology.
The conference is being held at Aotea Centre in Auckland, New Zealand on 17-20 August 2020.

If you would like to edit your abstract submission or submit another session click here.

You will be notified by **30 April 2020** if your poster abstract has been accepted.

Abstract Submission(s)

Title	Meat Processing Plant Capacity Enhancement by Adopting Technologies from Automotive Industry
Presentation Type	Poster
Congress Theme	4. Contemporary food science, technology and engineering issues
IUFoST2020 Abstract Template	IUFOST 2020- VB.docx

If you have any questions regarding your the Call for Abstracts, please do not hesitate to contact the team.

Ngā mihi nui | Kind regards

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