AUSTRALIAN MEAT PROCESSOR CORPORATION

FINAL REPORT - Innovative Race and Knocking Box Design Concepts

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1.0 Executive Summary

The objective for this project was to improve the welfare of cattle immediately before and during the event of slaughter at commercial abattoirs. There is growing pressure from consumers, regulators and society to ensure that animals suffer as little as possible, and regulations are becoming more stringent. Unwillingness of an animal to enter a stun box or restrainer is an indicator of stress and is therefore potentially compromises its welfare. If the animal has to be prodded to enter and/or vocalises, its welfare is being compromised even further. This project aimed to identify ways stun boxes and restrainers could be made to appear more inviting to cattle, to improve welfare and plant efficiency.

Milmeq consulted with industry experts to begin generating concepts for improved stun boxes, restrainers and races. Concepts were based on this consultation and existing animal welfare guidelines, such as the work of Temple Grandin. AgResearch were then commissioned to complete a review of existing literature around cattle vision and perception of images. This led to the generation of concepts for using imagery techniques to move cattle forward. A trial protocol was established by reviewing the key measures that animal welfare is currently judged by.

The first milestone focussed on the development of restrainer and stun box concepts. Stun box concepts included features such as imagery on the rear wall to draw cattle in, non-slip concrete flooring for underfoot security and consistency with the race, and smooth sides with no protrusions to distract or injure animals. The main improvement devised for restrainers was a method of mechanically lowering cattle down onto the conveyor rather than forcing them down a dark ramp. Enclosing the top of races to reduce the noise and aroma experienced by the animals was considered, along with imagery along the walls of lead-in races leading into restrainers.

Investigation into cattle vision suggested that they are able to be manipulated using both static and dynamic imagery. Concepts generated for methods of displaying imagery to the animals in an abattoir setting included projection, display via LCD panel, and presentation of static images. A small amount of published research was uncovered that presented results that demonstrated that animals' attention and movement could be positively influenced by both static and dynamic (moving) images of similar animals, as well as open scenes that represented escape of flight paths. A company offering life-sized photo-realistic images of sheep for assisting in the movement of animals into yards and along races, supported by anecdotal evidence, was also identified.

A picturesque horizon scene and photo of a cattle rear were some images considered for use in drawing cattle in. Industry guidelines indicated that prod use and vocalisation are the variables that processors are judged by, so these would be focussed on during trialling. Time to enter, flapper use and use of the point of balance could also be used to determine system performance. Remote video monitoring was determined as by far the most suitable method for monitoring and evaluating any trial.

The concepts generated in this project seem feasible at a conceptual level, and meeting with plant managers to discuss them confirmed this. Site visits showed that there is a need in industry for the proposed improvements, and processors are enthusiastic to trial them in the near future. It is recommended that the next stage of the project focus first on undertaking imagery trials to quantify the potential impact at various stages from yards to stun box.

In particular, these could be incorporated in existing races and stun box designs to fully evaluate the likely improvement in throughput and animal welfare and would contribute to an improved stun box design.

At the same time, the development of a working restrainer prototype would allow the concepts developed to be evaluated in an industrial situation alongside an existing restrainer system to fully evaluate the impacts of the identified design improvements.

2.0 Introduction

The Australian industry is facing increasing scrutiny to monitor animal behaviour and welfare as the animal passes along the race and through the knocking box. Every year millions of cattle are handled through the ramps, holding pens and raceways of the Australian meat industry. The degree to which animals need to be physically prompted to move forward into restrainers and knocking boxes, along with the degree of animal vocalization and active reluctance are considered active indicators of animal stress and welfare and are the primary indicators by which customers and consumers will judge processors.

Animals are very specific in how they perceive their immediate surroundings and events around them and are easily mistreated and spooked by unfamiliar surroundings, noises, the contrast in light and other environmental factors. The benefits of correct animal handling, especially in these areas immediately prior to slaughter, are known to be of great importance to both animal welfare and the quality of meat produced.

3.0 Project Objectives

In current knocking boxes and restrainer designs, the transition from a concrete floor race to a metal floor represents a significant change in under-foot feel to animals. Changes in the both the visual aspects and the texture of floor surfaces all contribute towards animals hesitating at transitions from one under-foot material to another. Developing new restrainer and knocking box designs that minimise changes in under-foot material while maintaining the required functionality will minimise animal stress and ensure more compliant animal behaviour, resulting in less active encouragement, vocalisation and improved animal welfare.

Current beef restrainers require animals to walk down an incline, often causing the animal to baulk at this downward slope. By eliminating this ramp, the animal will experience less stress, resulting in more relaxed behaviour. Removing the incline will also positively impact the following animals as they will not witness the change in level of the animals before them.

Animals are also known to hesitate at the entry into a knocking box, primarily because they see that there is nowhere to go. The visual environment works against their natural desire to have somewhere to walk to, or escape to. Cattle are flight animals and have good vision. It is commonly observed that animals can be misled by virtual reality – almost all of us have been amused at some time in our lives by family pets responding to television broadcasts as if it were actually happening in the room. Similarly, the use of realistic static images, as well as reflections and mirrors, can also be effective in creating an optical illusion. There is mounting evidence that animals other than humans can fall prey to optical illusions.

Integrating one or more of these techniques to create an optical illusion that encourages animals to enter into the knocking box could well result in a much lower stress environment, improved animal welfare and less active intervention to maintain throughput and maintain carcass quality.

This project will develop and evaluate new approaches to moving bovine animals through the race and up to the point of stunning with reduced animal resistance, thereby reducing the use of electric prods, flappers and various other techniques currently in use.

It will address the approach and entry to ride-on restrainers and knocking boxes through the introduction of three new innovations:

1. A restrainer that does not require cattle to walk down a steep ramp as the animal transactions from standing to riding on the restraint conveyor.

2. A novel knocking box to provide the animal more assurance underfoot in order to reduce baulking and stress, reducing noise and controlled airflow to reduce blood-related aroma, and lighting designed to be less conscious to the animal immediately prior to stunning.

3. Artificial reality imagery to encourage animals to enter the knocking box through the appropriate projected still or dynamic imagery.

4.0 Methodology

Progress began by consultation with industry experts and generation of concepts for innovative races, stun boxes and restrainers. This focussed on reviewing current designs on the basis of animal welfare as well as practical operation. Guidelines for best practice in terms of animal welfare were reviewed, such as the work of internationally renowned animal behaviourist Temple Grandin (www.grandin.com). Industry experts in animal processing were also consulted and their observations and experience incorporated into some of the aspects of new design.

The level of lighting in and around races and stun boxes is well known to be an important factor when considering cattle movement through a race and into a stun box or restrainer (Grandin 1989, 1994, 2010). Shadows and contrasts in colour can cause animals to baulk, slowing movement through the race. Cattle are hesitant to move into a dark area from a light area, and are best moved through diffuse light (Blackshaw, 1996). Light shining directly into the animal's eyes can cause the animal to baulk, while bright strips of light or colour under doors and through cracks and gaps can create a distraction for cattle, causing them to lower their heads, which can cause problems when trying to apply the stunning technique to the animal. Therefore, good lighting design is a necessity to ensure consistent and reliable animal movement.

AgResearch (www.agresearch.co.nz) was contracted to perform a literature review on cattle vision and perception of images. The report identified plenty of studies relevant to this project that have been completed over the years. The findings from the review were used to inform choices around image techniques and selection. Again the work of expert animal behaviourist Temple Grandin was used to guide decision making.

The decision-matrix method was used by the author to evaluate performance of different image display techniques over a range of variables. The advantage of using this method is that subjective opinions on the suitability of each image creation technique can be replaced with objective estimates of how each will perform in the real world. The method involves first generating a set of criteria, and assigning each with a weight based on its perceived importance. Each alternative is then scored across the criteria, and each score is multiplied by each criteria weight. The multiplied values are summed to give a total score from which the options can be ranked.

Finally three processing sites in Australia were visited by Milmeq in order to verify design concepts and trial protocol.

The visits enabled critique of the proposed designs and methods by those who will potentially be end users of the equipment in future. The meetings also initiated conversation on the potential for site trials at some of the visited plants.

5.0 Project Outcomes

5.1 Stun Box and Restrainer Concepts

The overall objective for this project is to produce design concepts for improved ways to move cattle through the race and up to the point of stunning. Reducing animal stress prior to slaughter is known to be important for both meat quality and animal welfare. Specifically this will involve:

- Identifying and developing initial concepts for trialling including:
  - More inviting working surfaces
  - Adjustable floor heights to reduce animal body height changes
  - Controlled illumination and lighting
- Reviewing various image creation and projection techniques
- Researching techniques for improving the visual environment to minimize human intervention
- Selection of designs for proof-of-concept prototyping and development of a trial plan

An improved race concept was created, featuring high smooth sides and openable top hatches. The point of this is to isolate cattle from potential distractions outside the race. A concept stun box was designed to be as enticing as possible for cattle. Current stun boxes look like a dead end to cattle, so the concept incorporates imagery at the far end to give the illusion of an escape route. The concept replaces steel flooring with concrete, for consistent underfoot feel and better slip resistance.

For restrainers a concept system to better load the conveyor has been devised. This involves replacing the ramp with a rise/fall box that lowers animals directly onto the conveyor. This will eliminate baulking at the downhill slope and problems with cattle climbing on each other's backs. The benefit to industry from these concepts are greater conformance with animal welfare standards and reduced damage to carcasses.

5.1.1 Baseline of current systems

A review of international animal standards revealed very few objective measures to accurately assess animal stress. It is important to consider international regulations because of the export focus of the Australian beef processing industry.

Most regulations tell the operator "what to do" or "what not to do" rather than "it may be possible to do it provided the animal is not put through unnecessary stress and this is what to look for". For example WOATAK 2015 states "No person may lead or drive an animal over ground or floor, the nature or condition of which is likely to cause the animal to slip or fall".

The Australian Industry Animal Welfare Standards for livestock processing establishments (2009) is probably most prescriptive of the relevant international standards and provides some performance measures relating to each standard and an example audit checklist.

This is similar to the Cattle Slaughter Audit Form based on the American Meat Institute (AMI) Guidelines created by Temple Grandin.

The AMI Guidelines focus on the following metrics:

- Percentage of cattle stunned correctly on the first shot
- Percentage of cattle that are insensible on the bleed rail
- Percentage of cattle prodded with an electric prod
- Percentage of cattle that slip and fall during handling in the crowd pen, single-file chute, or stunning box
- Percentage of cattle that vocalize during handling or stunning in the crowd pen, single file chute, and the stunning box or restrainer.

5.1.2 Design Concepts

As part of our review, Milmeq consulted with John Hughes, an expert in the beef processing field and consultant to the industry. John was able to share with us his knowledge from many years working with cattle in Australian abattoirs. From his experience with knocking boxes and restrainers he was able to suggest improvements that could be made to optimise animal welfare and carcass quality.

The design concept work was categorized into three areas; races, stun boxes and restrainers.

Stun Box

Figure 1 illustrates what a cattle beast will likely see when looking into a current electric stun box. One can imagine that the animal would perceive this as a dead end, and be hesitant to enter. The steel flooring also presents cattle with a change in underfoot texture, which may cause them to baulk.

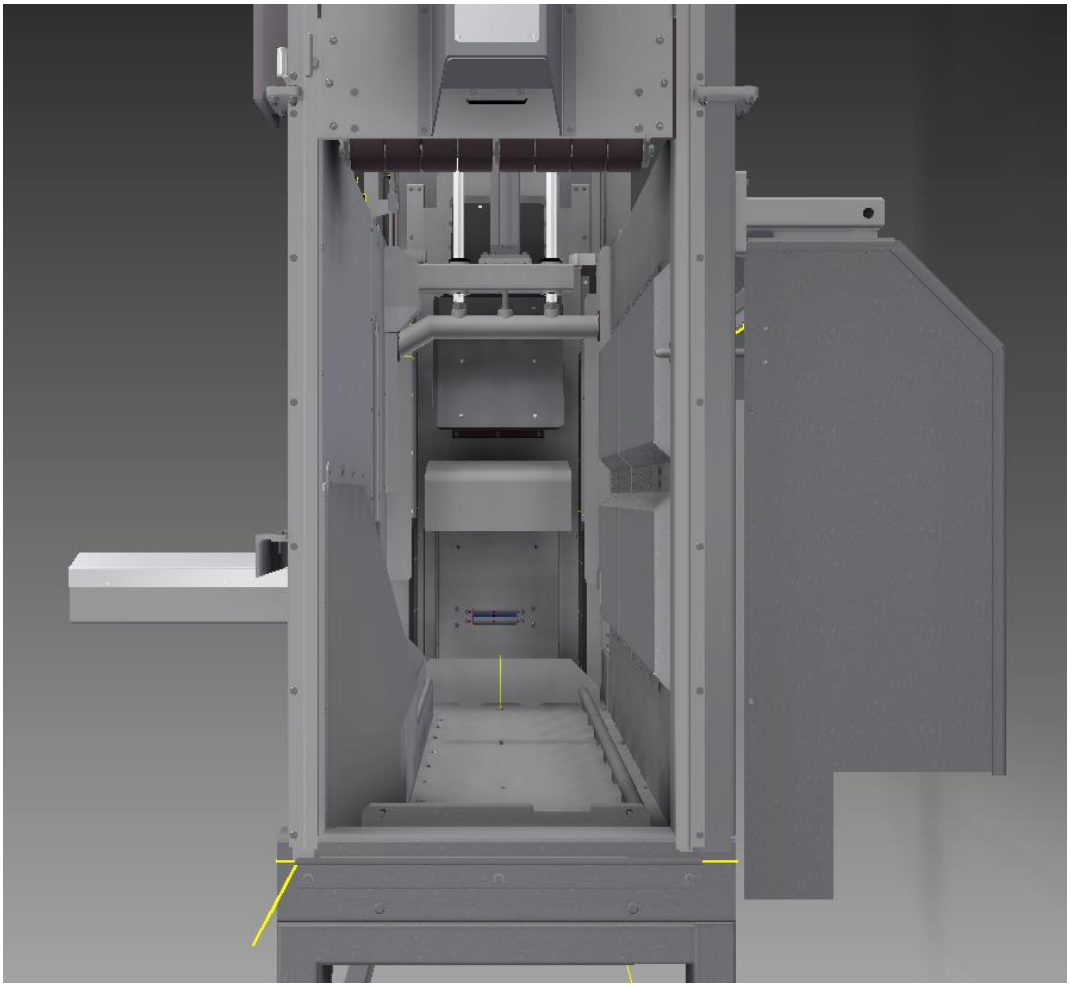

Figure 1 – Cattle eye view of current Milmeq electric stun box

Figure 2 shows an animals view of a conceptual stun box that has been optimised to be as appealing as possible for cattle. The floor is the same deep grooved concrete as used in the races for consistency. This should eliminate both baulking at the change in underfoot texture and panic due to slipping on steel flooring. This flooring would be achieved by either pouring concrete into the floor of the knocking box or placing in precast slabs. An image (either static or projected) designed to be appealing for cattle is displayed on the far wall of the stun box. This is intended to entice the animal right into the stunning position without any human or mechanical intervention. Once in position, the animal can then be captured and stunned quickly as possible. Ideally the stunning should happen immediately after capture so that the cattle beast does not have time to stress about being held. This reduction in stress should have a positive effect on both meat quality and animal welfare.

Figure 2 – Cattle eye view of concept stun box

Research conducted in the United Kingdom suggests that, while the level of lighting is an important factor to consider when assessing cattle movement leading into a stun box, an image of a horizon had greater success at enticing cattle into the stun box than an image of a cow rear or a mirror (Jones, 2011). In this research, two experiments (one under normal lighting conditions and a second under enhanced lighting level), using three treatment groups (plus a control to provide a baseline) were performed. The treatment groups involved:

1. No imagery (control)
2. A mirror placed at the end of the stun box
3. A picture of a cow's rear placed at the end of the stun box
4. A picture of a pastoral horizon placed at the end of the stun box.

The configuration of these treatment groups is illustrated in Figure 3.

Groups of beef animals (20 in the first experiment and 80 in the second), were then passed through the stun box and the three treatments scored based on the ease of movement, number of animals that baulked, and the time taken to enter the stun box. The results indicated that treatment 3 was the most effective in improving the movement of animals through the stun box, as evidenced by a reduced number of electric goad applications and improved overall ease of movement. Treatment 3 also "significantly improved the orientation of the animals' head to aid accurate captive bolt positioning and significantly reduced non-social vocalisation and tail swishing" (Jones, 2011).

Figure 1. Images of treatment groups in place in the stun box: 1. Control (top left), 2. Mirror (top right, 3. Cow rear (bottom left) and Horizon (bottom right).

Figure 3 - Photographs of the three treatment groups, reproduced from in Jones (2001).

In the research undertaken by Jones, the gate at the end of the stun box was characterised by a number of vertical bars, with a solid wall almost a metre beyond the bars. During the first trial, the treatments were applied to the wall beyond the vertical bars while in the second experiment they were brought forward to the vertical bars. However, the results of these two experiments were combined prior to analysis. As a result, there was no comment or conclusion on the effect of the placement of the mirror and images on the results.

Therefore, an important consideration in the use of images is that cattle may realise the picturesque scene in front of them is false as they near the image on the far wall. The stun box may have to be lengthened to add space between the stunning position and the wall, to help maintain the illusion. This would have flow-on effects to how the restraint and stunning equipment inside the box operates.

As shown in Figure 2, the sides of the stun box are to be kept as flush as possible. This reduces both bruising from impact injuries and distractions that may cause the animal to baulk. The aim is for cattle to perceive the stun box as an extension of the race that they will happily walk up into. Adjustable width side panels were also considered for use in the knocking box. The purpose of these would be to allow smaller cattle to be stunned in the box without having too much space to potentially thrash around or turn in.

The top of the stun box could potentially be enclosed in a similar manner as proposed for the races in Figure 5. This could help reduce distraction to the cattle caused by the sights, sounds and smells of the slaughter floor. In this concept image mechanisms such as the neck bales are not shown, but these would be mounted externally in a way that maintains flush inner walls. The existing chin lifter could be modified to mould to the animal's chin and more precisely present the head for mechanical stunning. This could help facilitate automatic mechanical stunning in the future.

Guillotine style vertically acting doors are the most common type of gate in existing abattoir races and stun boxes. Alternative gate designs were considered, such as horizontal sliding gates or saloon style doors. However, these would likely not be suitable for the stun box entry door, as a rump pusher device needs to be mounted to the back of it. More investigation would need to be done to determine if the entry door action is critical to improving animal welfare before trying to change it.

Restrainers

Existing ride on restrainers require cattle to walk down an incline to enter the conveyor. Cattle tend to baulk at the downward slope, and have to be driven down onto the restrainer. This is both labour-intensive for operators and stressful for the animals. The concept shown in Figure 4 involves the cattle being mechanically lowered onto the conveyor. In the concept an animal will straddle a leg spreader bar and walk into the rise/fall box. The door behind it closes and the box lowers, the front doors opening as it does so. The conveyor then moves the cattle beast forward, and the box rises again to pick up the next waiting animal.

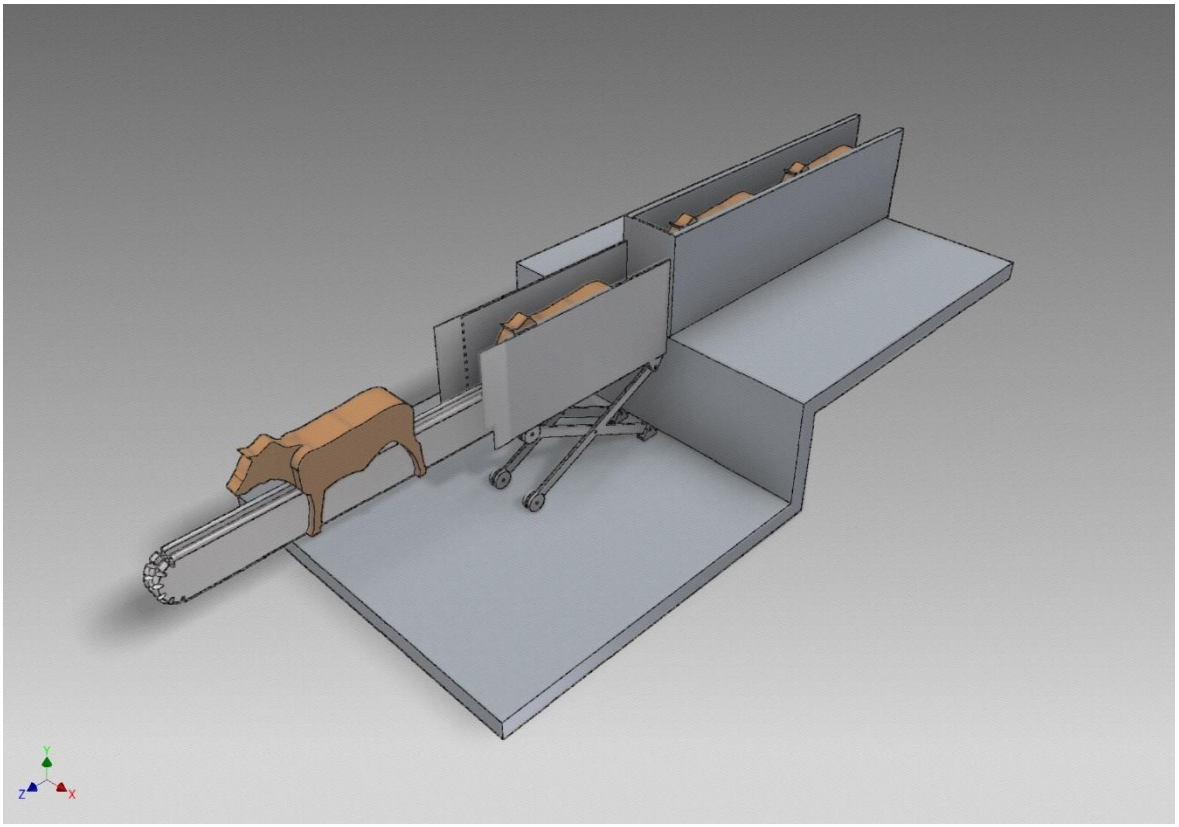

Figure 4 – Ride on Restrainer concept model

As with the stun box concept, this rise/fall box would have non-slip concrete flooring consistent with the race. Imagery could also be used on the inside of the front doors as enticement.

In addition to eliminating the downward slope causing cattle to baulk, the mechanical rise/fall feeders have the advantage of controlling animal spacing on the conveyor. With existing systems animals can enter the restrainer very close together, and issues arise where cattle climb onto each other's backs. These mechanical feeding concepts eliminate this problem by only placing one animal at a time on the restrainer.

Races

It was identified that race design could be improved to reduce baulking and enhance the flow of animals. This would reduce the amount of human intervention necessary and improve animal welfare. The reaction of cattle to all forms of sensory stimuli in the race was considered, with the exception of taste.

Cattle have wide angle vision and are easily distracted (Grandin, various), so it is recommended all races have solid sides to minimize this. In addition to solid sides, the top of races could be enclosed to further minimise distraction (as shown in Figure 5 below). The concept involves adding openable hatches with windows to the top of races. These windows would be tinted in such a way that they are largely directional, allowing operators to see into the race but preventing animals from seeing out. These hatches would also facilitate control of lighting within the race to prevent cattle being spooked by bright light and shadows.

In the case of a downer or a stubborn animal, the operator can open the hatches and deal with them as usual.

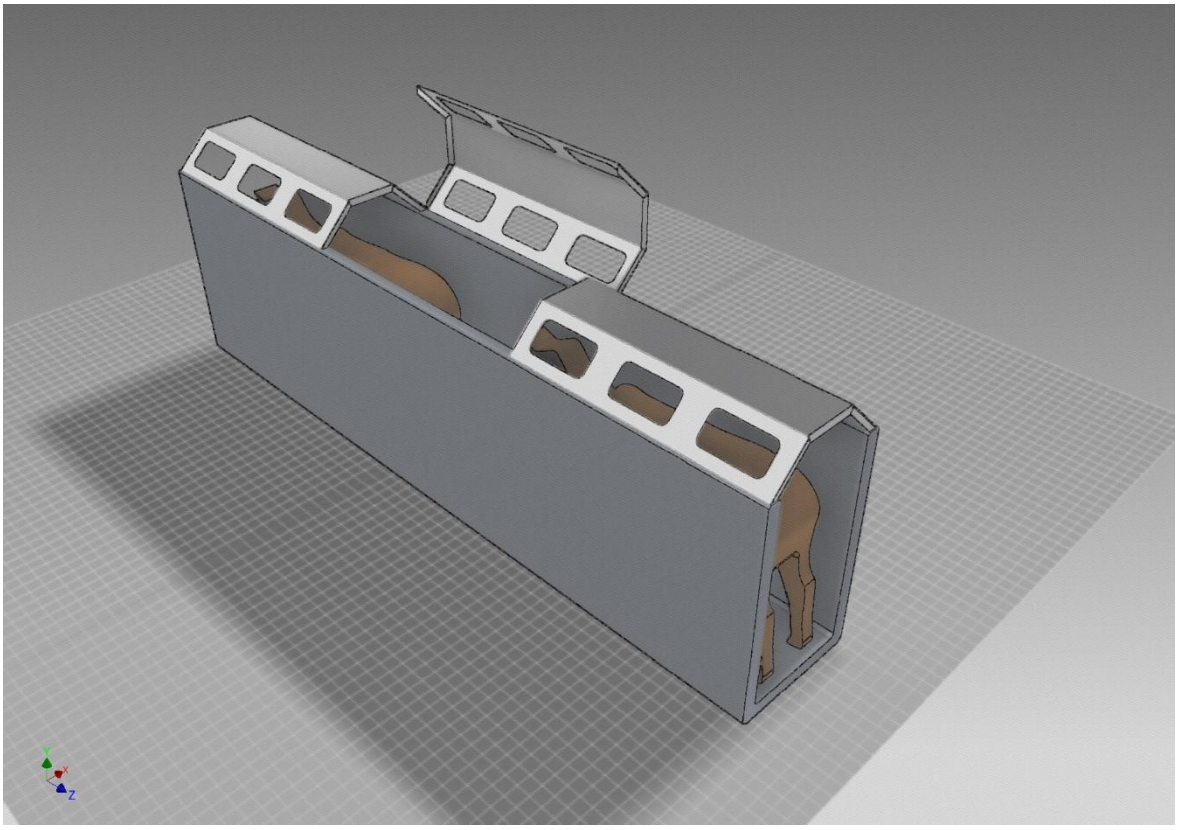

Figure 5 – Concept modification to races

Loud noises are known to agitate cattle, so a noisy slaughter floor will likely cause the animals to stress. Enclosing the top of the race will reduce the sound levels experienced by cattle in the race, likely improving their compliance and welfare. The hatches will likely help block aroma (such as blood) from the slaughter floor, which cattle may find unpleasant. If aroma was still considered a problem, it would be relatively straightforward to implement a ventilation system to bring fresh air into the races. Such a system would have to be carefully designed to not spook cattle with air blowing from vents.

Cattle panic if they slip at all (Grandin, various), so it is important to consider the floor surface in the race. Changes in underfoot texture may also cause cattle to baulk, so a consistent material should be used from the start of the race right to the stun box/restrainer. Concrete with deep groves and a rough surface finish is known to work well. It should be ensured that race sides are flush to prevent animals being jabbed and startled by protrusions. Saloon and horizontal sliding style doors have been considered as alternatives to the guillotine style currently found in races. These would have less distance to travel than the guillotine door, so could operate more slowly, which may reduce spooking of cattle. These door concepts will require further investigation to identify an effective solutions that meets the functional requirement without being unnecessarily complex to manufacture and maintain.

5.2 Image Techniques

The analysis performed into image techniques was mostly carried out from the context of a stun box, but many of the ideas could also be applied to a restrainer. The first part of the stage was to investigate how lighting and imagery techniques could be utilized to entice cattle into the stun box. The second part was to develop a trial protocol for testing the effectiveness of these techniques.

5.2.1 Cattle Perception Review

Milmeq commissioned AgResearch to complete a review of existing literature relating to cattle vision and perception of images. AgResearch is a Crown Research Institute of New Zealand servicing the agriculture and biotechnology fields. This review was undertaken by Dr Jim Webster (Science Team Leader Farm Systems –North). Dr Webster's team seeks to improve farm performance by understanding the impact of new farm technologies and operating requirements, such as animal welfare, on production and quality outputs. The team is therefore well-placed within the animal welfare and behavioural area to provide expert commentary and advice on the use of imagery to lead animals.
The main points of this review are summarised as follows:

- Cattle have a good visual field and colour vision which may be limited in the dark blue spectrum.
- As a prey species, cattle are vigilant and sensitive to motion but the ability to distinguish detail and fluid motion is less than that of humans meaning that they can be easily startled.
- There is good evidence that cattle recognise static and moving images as representing the items they depict and display appropriate emotional responses to the images content. There should be caution however as individual responses to images may vary with the animal's experience.
- Most studies have involved periods of habituation or training for image recognition therefore responses might not be applicable to novel presentation.
- Moving images are likely to catch and hold attention more than still ones but there is a greater potential to startle with moving images.
- There is potential to use images (still or moving) to influence the behaviour of cattle.
- The choice of imagery and how to present it to achieve a desired, and consistent response within a short time frame may be challenging.

5.2.2 Lighting and Image Creation

Cattle are flight animals, they possess a natural desire to have somewhere to escape to. Current stun boxes contravene this instinct, appearing as a trap with no way out. An improvement that may remedy this issue is the addition of imagery to the stun box. The purpose of the imagery would be to create an illusion that entices cattle to enter the box without operator intervention. Also the lighting leading up to and inside the stun box could be optimised to be as inviting as possible to the animals.

5.2.3 Image Display Techniques

Displaying images to cattle in the stun box comes with a unique set of challenges. Devices installed on the slaughter floor are exposed to regular wash down, so electronics need to be well shielded against water entry. An image creation device would also have to be well protected from shock, as stun boxes get a battering with cattle kicking around inside them.

Static Image with Spotlight

This concept would involve imagery printed onto plastic board (or similar) and mounted to the back wall of the stun box. The image would then be illuminated by carefully positioned spotlights. The lighting would have to be arranged so that light is not shining into animal's eyes as they approach, as this could cause them to baulk. Lighting would need to be positioned so that cattle do not enter the beam of the spotlight as they approach the stunning position, as this could throw shadows up onto the image and spook the animals.

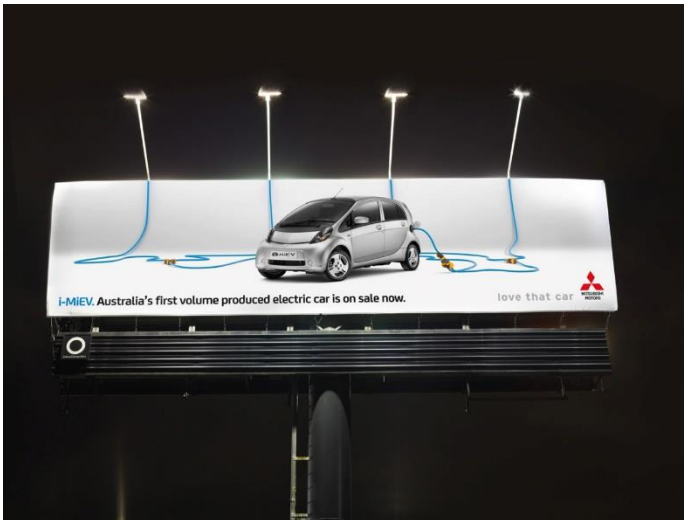

Figure 6 – Example of spotlight illuminated imagery on an advertising billboard

Backlit Static Image

The backlit static image would be very similar to the spot-lit concept, the only difference being method of illumination. The chosen image would be printed on a sheet of acrylic or polycarbonate plastic and mounted at the end of the stun box. Behind the image would be lighting such as fluorescent tube bulbs. The opaque plastic material would cause diffuse, uniform lighting of the image, and there would be no shadows to spook cattle. One disadvantage with this concept is that if cattle were allowed to charge at the image, it could break the plastic and lighting system behind.

Projector

Imagery could be added to the stun box wall using a data projector. This would involve mounting a projector in a waterproof enclosure, and applying an appropriate surface finish to the end wall to project onto. This would allow trialling of dynamic imagery and easy testing of many different static images. However most projectors work best in low light conditions, so it may be difficult to source a projector that can create sufficiently bright and clear images. The electronics would have to be carefully projected from moisture and vibration or the projector would likely fail in a very short time. There could also be issues with cattle obstructing the images as they approach the stun position, and startling themselves as a result.

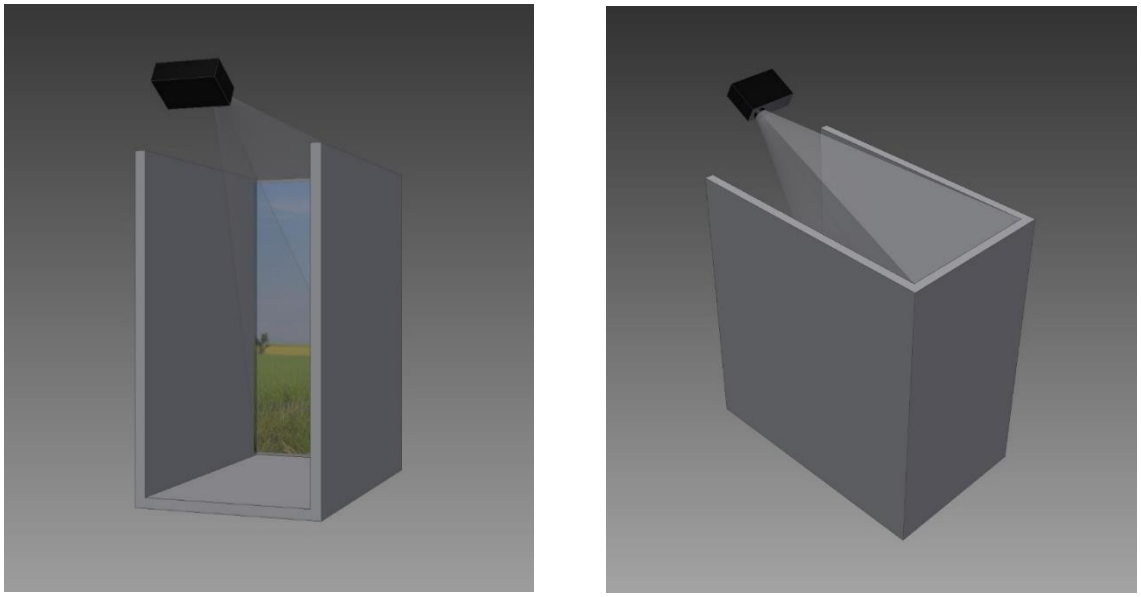

Figure 7 – Potential stun box projector layout

Television

An alternative method of displaying dynamic imagery to projection could be the use of a LCD television in the stun box. The TV would have to be mounted in a water/shock proof enclosure at the end of the box, and cooling would need to be considered. Bulletproof or prison-spec glass may have to be used to protect the TV in case an animal charges the end of the box.

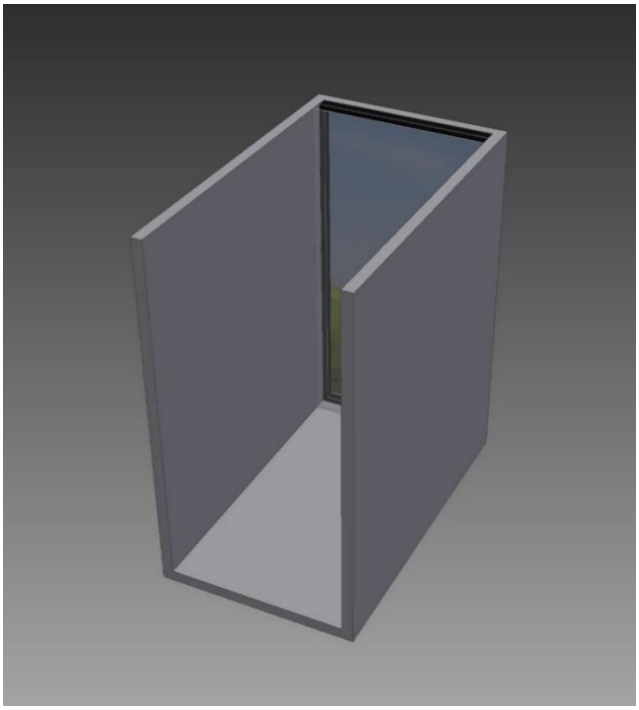

Figure 8 – Model of a television mounted on a stun box end wall

Comparison of Display Techniques

The four image display techniques given above all have their merits, and any one of them could prove to be the most fit for purpose. An evaluation matrix has been used to get a provisional idea of how the methods compare to each other. Each of the four options was scored against seven criteria, which have each been assigned a weight based on their relative importance as perceived by the author. These criteria as given in order of descending importance are:

- Gives clear bright images – the ability of the display technique to produce imagery that can be easily seen by cattle
- Durability – the likelihood that the imagery system will last in the slaughter floor environment for the foreseeable future
- Images easily interchangeable – the technique allows the trialling of several different potential images
- Value for money – the method has a favourable benefit to cost ratio
- Enables dynamic images – the display technique can show video in addition to still imagery
- Not obscured by animal in race – operation of the imagery method is not affected as the animal nears the end of the stun box
- Low cooling requirements – ventilation or other cooling methods will not be needed for the display technique

The performance of each technique is estimated for each of the criteria, and given a score from zero to ten. These scores are then multiplied by the weight for each criteria, and summed over all seven criteria to give a total score for each method. The evaluation matrix is shown in Table 1 below.

Table 1 – Image display technique evaluation matrix

Criteria	Weight	Option Score (0-10)			
		Static image w. spotlight	Backlit static image	Projector	TV
Gives clear bright images	15	8	9	6	8
Durability (water, shock etc.)	10	9	8	5	3
Images easily interchangeable	8	7	7	10	10
Value for money	7	10	9	7	7
Enables dynamic images	7	0	0	10	10
Not obscured by animal in race	5	5	10	4	10
Low cooling requirements	3	10	9	4	2
Totals		**391**	**411**	**371**	**405**

The result of the evaluation is that a backlit static image seems the most fit for purpose, followed by the TV, then the spot lit static image and finally the projector. An evaluation matrix is no substitute for field trials however, so the best technique may prove to be different from that determined here.

5.2.4 Image Selection

In addition to the method of presenting imagery to cattle, the content of images shown also needs to be considered. Cattle are flight animals and are attracted to an escape route, so this instinct could be exploited. Cattle can also stress when isolated, so imagery of other cattle may be beneficial. Both static and dynamic images could be trialled to investigate which is best at enticing animals into the stun box.

Static Images

One potential static image could be a horizon scene consisting of a green pasture meeting blue sky. This image may be location specific for each abattoir, so that a familiar environment is shown to the animals. There could be other cattle included in the scene – either close by or grazing in the distance. The horizon scene could be full size on the end wall of the box or displayed in a perspective 'light at the end of the tunnel' style. One disadvantage of the horizon scene may be that it encourages cattle to charge the end wall of the box, causing damage to themselves and equipment.
Another image that could be shown in the stun box is a picture of a cattle rear in a race. This would hopefully dupe cattle into following the artificial animal in front of them. It would have to be investigated whether or not the breed of cattle shown in the image is important, e.g. an image of an Angus may spook a Brahman. The literature review uncovered a study that found that ewes can discriminate between photos of different sheep breeds (Bouissou, Porter, Boyle, & Ferreira, 1996). Due to the similarities between cattle and sheep, it could be assumed that cattle may behave in a similar way.

One advantage that a cattle rear image may have over a horizon scene is less encouragement for cattle to charge at the image under the illusion they are escaping.

The use of decoy sheep to facilitate sheep movement was evaluated in experiments in the 1980's (Franklin & Hutson, 1982). Live decoy sheep were found to be effective at enticing sheep out of a pen and up a race, but sheep responded with fear when the live decoy was replaced with a model animal.

This suggests that care will need to be taken not to spook cattle when presenting them with images of their kind.

In a Master of Science (MSc) project, Jones (2011) found that cows moved more easily towards a stun box with a picture of a horizon at the end of it than a picture of another cow. This suggests that changing the appearance to that of an open space may have encouraged movement into what is a bond-ended stun box. Placement of a mirror in the stun box did not appear to help movement, perhaps because the apparent appearance of an animal approaching head on may be sufficient to stop the animal moving forward.

More recently, an Australian-based company called Livestock Lures have developed life-size printed images of domestically farmed animals. According to their website, "Livestock Lures are a very cheap, effective and low stress tool for moving all herding animals in foreign environments. Such environments are not limited to what we have already trialled but would also include livestock selling yards, abattoir killing pens and live export ships." Based in Bakkuklla, NSW, this company currently offers images of Merion and Dorper sheep, with lures for crossbred sheep, goats, pigs and cattle "coming soon". The company as a provisional innovation patent application pending (PCT/AU2014/000993, WO 2015058240 A1, An Animal Decoy, granted 12 Nov 2013). This is an Innovation patent that has a lifetime of 8 years and still requires examination to prove an innovative step before being commercially enforceable. The company have posted videos on YouTube demonstrating these lures in action (https://www.youtube.com/watch?v=_TSCpB6jucU). These videos demonstrate sheep moving right up to the image and sniffing these images, providing anecdotal evidence that the animal interprets these images as representative of other animals. This evidence supports the use of such images to draw animals forward under an illusion.

Figure 10 – An example of a livestock lure, reproduced from www.livestocklures.com

Collaboration with this company would be an obvious next step to evaluate different static images in various locations (races, stun box, yards).

Dynamic Images

The AgResearch report found that moving images are likely to catch and hold attention more than still ones, but there is a greater potential to startle with moving images. If imagery is displayed with a projector or television, then dynamic enticements are possible. Moving images may be more convincing to cattle due to their extra degree of realism. Conversely care would have to be taken not to spook excitable animals with sudden movements. Possible dynamic scenarios to display are a cow walking forward up a race, a cow walking out of the stun box into a paddock, or a pasture scene with grass blowing in the wind and cattle moving in the distance.

The literature review also uncovered some preliminary research, as part of a Scotland-based Masters thesis as yet unpublished, where the response to a projection of dynamic images (on the internal wall of a barn) by a beef animal was videoed. Two videos from the study have been posted on YouTube (https://youtu.be/AvkHxM1V__E and https://youtu.be/VbTNurkNSjA), and appear to show cattle interpreting projected images as representations of the real world. Still images from the videos are shown below.

Figure 10 – Cattle observing projected dynamic imagery

5.2.5 Lighting

Temple Grandin states on her website that *"cattle have a tendency to move from a dimly illuminated area to a more brightly illuminated area, provided the light is not glaring in their eyes"*. This behaviour could be used to help encourage cattle into the stun box. The box could be illuminated with uniform and diffuse lighting, slightly brighter than the race to entice cattle into it. The entrance to current restrainers could also receive illumination to help stop animals baulking at the dark slope down onto the conveyor.

5.2.6 Image Evaluation Trial Protocol

Trial Apparatus

The performance of different visual enticements would need to be tested to verify which works best. Other variables (such as lighting, smell, noise levels, floor material etc.) would have to be carefully controlled to ensure that differences in animal response are due to the effect of the imagery rather than some other factor. To best replicate the circumstances of a stun box, cattle should only be subject to the test apparatus once. If one animal was tested multiple times, experiences from previous trials would begin to influence its response to the images.
Using a cattle crush on a local farm could be a cost-efficient method of testing the effectiveness of visual enticements. The interior dimensions and neck bales of a crush would both be similar to a stun box, so for testing purposes a crush could be a good substitute. Plywood or similar side walls could be added to the crush to mimic the walls of a stun box. Imagery would be added onto a door in front of the neck bales that would open to let the animal out. The distance of the image from the neck bales could be varied to investigate how close cattle can get to the image before realising it is not genuine. Once proven in a farm setting, further testing could occur in an actual abattoir.

While this approach has a number of advantages in terms of cost and animal welfare, the major risk is that objective results become biased by the animals developing a level of familiarity and training that results in behaviour modification.

Operator Intervention

The performance of a visual enticement can be measured by recording levels of operator intervention at the stun box entry. Jones (2011) assessed individual animal compliance with a scale for the degree of persuasion required, as given below:

1. No persuasion required
2. Use of the point of balance
3. Touching/patting rump of animal
4. Use of electric goad

This scale could be used to assess animal compliance before and after addition of a visual enticement. A simpler measure is the percentage of cattle that require electric prodding to enter the stun box. The American Meat Institute's Animal Handling Guide (written by Temple Grandin) states that "*Reducing the use of electric prods will improve animal welfare. Shocking livestock with electric prods significantly raises heart rate, open mouth breathing and many other physiological measures".* The guide also lists that an acceptable cattle prodding level is 25% or less, and it is excellent to have 5% or less of animals prodded.

Animal Response

In addition to recording the level of operator intervention required, responses of animals entering the stun box could be used to judge effectiveness of an enticement. The guide mentioned above states *"Vocalisation is an indicator of cattle discomfort during handling, restraint and stunning".* It is considered excellent to have 1% or less of cattle vocalising, and acceptable to have 3% or less. When using a head holder for stunning/slaughter, it is acceptable to have 5% or less vocalising. Vocalisation scoring is a well proven method of assessing animal welfare, and it would be easy to implement in testing the performance of visual enticements.
The time taken for each animal to enter the stun box after the entry door is raised is a factor that could be recorded to evaluate the effectiveness of an enticement. Longer entry times would imply a reluctance to entering the stun box, and shorter entry times vice-versa. Tail swishing is another sign in cattle that suggests fear or stress.

Cattle have been known to swish their tails at a growing rate before performing an act such as kicking or trying to leap out of a race. Jones (2011) used both tail swishing and time to enter as measures to determine performance of stun box treatments. Tail swishing rates and times to enter could be recorded along with vocalisation scores in testing of the proposed visual enticements.

Cortisol is a hormone that is released into an animal's bloodstream in response to stress, and levels can be determined by testing a sample of blood. It is a more useful measure of determining stress at slaughter than adrenaline levels, as both captive bolt and electric stunning cause large adrenaline releases. Measuring cortisol levels would be far more difficult and expensive than observing vocalisations or tail swishing however, so would likely not be suitable for the purpose of this investigation.

Provisional Trial Protocol

From the above information, a two-staged evaluation appears to be a logical next step, with the first stage involving the evaluation of image type and projection technique. To avoid using the same animals repeatedly and biasing results to due animals becoming familiar and modifying their behaviour to comply with repeated trials, installation of such a device in a meat processing setting would be preferred, such that each mob of animals only passed through the device once. This would require greater numbers for each different technique employed in order to prevent the effects of breed, age, sex and mob overshadowing any preference to image or image projection technique. Formal statistical experimental design will therefore need to be deployed when undertaking any trial in order to generate statistically significant results in the presence of variations in noise, lighting, animal, environment etc.

As discussed previously, key variables that need to be monitored include:

- Number of persuasions required
- Use of the point of balance
- Touching/patting rump of animal
- Use of electric goad
- Lighting levels
- Background noise
- Time to enter the box
- Throughput
- Vocalisation
- Tail swishing
- Head positioning or lowering

The vast majority of these are easily discerned visually and the authors strongly support the use of a multiple camera video recording device as the primarily method of monitoring and measuring any animal trials.

5.3 Concept Verification

During the final milestone three processing sites were visited to examine their stunning areas during operation. This enabled stun box and restrainer concepts to be evaluated from a functional point of view, and feedback to be gained from plant operators.

It was agreed that the trial protocol should involve measurement of key welfare measures vocalisation and prod rate. Video record of all trials was also agreed upon as the best way to establish a baseline and ensure that results are not skewed by changing perceptions over time.

5.3.1 Stun Boxes

Conventional

One site visited featured a conventional stun box, where cattle were stunned with a captive bolt gun before being ejected out onto a bleed slat table. Animals entered this box freely, with only a small percentage requiring prodding to enter. Here a single operator was able to both load and operate the stun box, whereas the previous plants visited required two people to perform the same job. A rump pusher was used on the few that did not move far enough forward on their own accord, and this did not cause any obvious signs of stress. Once in the correct position, the animal was captured in neck bails and its head was raised with a chin lifter for stunning.

Some general observations of the stun box were made. The overall construction was quite heavy, and the box did not make any clanging noises as cattle moved through it. Flooring was steel tread plate, which would have provided the cattle with better underfoot security than flat steel. A fluorescent tube light was hung above, illuminating the stun box without shining into the animal's eyes.

Rotating

The second site visited featured a slaughter floor with a rotating knocking box. Milmeq had been contacted by the plant's Engineering Manager after he learned of this project through AMPC. The rotating box in question had quite a specific issue – cattle would enter the box freely enough but would often not extend their heads out through the end for capture and stunning. It was believed that cattle were being startled by their view of the slaughter floor, and this was causing them to baulk.

The plant has trialled a number of measures to remedy the issue, such as the addition of imagery, spotlights and visual barriers. They had some success with shining spotlights directly into the approaching animal's eyes, which would seem counterintuitive. One principle that Temple Grandin highlights is that cattle have a tendency to move from a dimly illuminated area to a more brightly illuminated area, providing the light is not glaring into their eyes. It was thought that at this plant the blinding lights may have been preventing cattle from seeing the slaughter floor ahead, and therefore reducing the incidence of baulking.

A partition made from plastic sheeting had been added to the platform in front of the stun box to help block the animal's view of the subsequent slaughter floor. The partition was painted matte black to prevent reflections and was reported to reduce the rate of baulking. However, the partition did not block the entire field of vision of the cattle, and they could still see platforms, a control panel and shiny white wall panels. Review of video footage taken at the plant shows cattle looking to their left at these distractions as they near the stunning position. It is the author's opinion that further visual barriers need to be added to fully block the animal's view of objects that may startle them. Feedback has been provided to this plant by separate communication.

The company responsible for installing the stun box had tried printing a photograph of a local paddock and fixing it to the partition in front of the stun box.

The stun box operator reported that this did not measurably reduce baulking, which is an interesting contrast to the findings from Jones (2011). In that study, an image of a cow rear at the front of the stun box improved animal movement into the stun box, and an image of a horizon improved movement even further. It is important to note however that Jones conducted her experiment in a conventional stun box with a closed front. It is likely that at the plant visited by Milmeq, the image was not effective as there were too many other distractions for it to have a positive effect. The next improvement to be trialled on this stun box is the addition of a rump pusher. It is hoped that this will encourage cattle to move up the last part of the box and put their heads out far enough for the restraint to operate.

5.3.2 Restrainers

A centre track restrainer was observed operating at a high throughput beef processing facility. Animals move along a race before straddling and walking down onto the conveyor. The conveyor supports them by the brisket and belly and they travel off to be stunned. The major baulking point in this particular system was the entrance ramp to the conveyor. Animals freely approached the top of the ramp, but would then baulk at the downward slope. Most animals had to be encouraged down the ramp, and electric prod use here was higher than preferred. Spotlights were used to illuminate the ramp as recommended by animal welfare expert Temple Grandin. The ramp had originally been installed with cleats, but these were removed after problems with baulking, and throughput increased as a result.

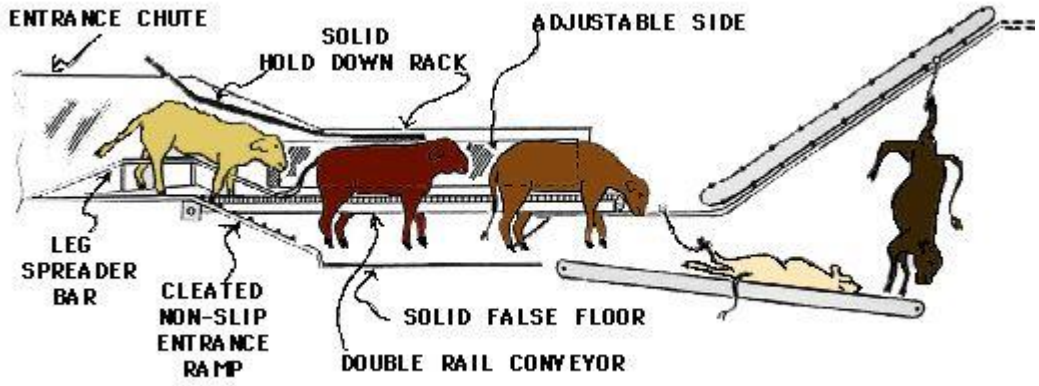

Figure 11 – Temple Grandin's centre track restrainer design

Plant management suggested that if an improved restrainer prototype were to be trialled, their abattoir would be the ideal site for it. It was pointed out that there was plenty of room adjacent to the current restrainer to install a second one in parallel. This would enable testing of a concept system in a commercial abattoir setting without the risk of impairing production. Vocalisation and prod use are the measures that stun area performance is judged by at this abattoir, so these would be the key indicators of the performance of a prototype restrainer.

5.3.3 Yard and Race Design

Other areas with potential to be improved were the yards and races leading up to the restrainer. It was suggested that being able to see through the pipe steel yards may confuse cattle, as they are not presented with a single obvious route to follow. If solid panels were added to the steel railing, animals would be more drawn to the route that they are meant to be following. This would hopefully lead to less human intervention required, and less stress for the cattle. One issue with enclosing the yards however may be gas build-up.

Gases produced by the cattle (such as methane and ammonia) can build up to unpleasant levels inside the covered yards, and the natural draught through the building is the main way of controlling this. Adding panels to the pipe yards could inhibit airflow through the building, and subsequently lead to more problems with animal gases.

Another issue highlighted was the entry to the race from the forcing pen, where animals transition from a group to walking in single file. The stockman was observed working hard to get some cattle up the race, and it was suggested that the entrance to the race could be improved to appear more attractive to the animals.

Although the races appeared to be constructed to modern animal welfare guidelines, cattle flow may be able to be improved through methods such as addition of imagery or enhancing lighting. The abattoir has a parallel backup race from the forcing pen to restrainer, for use when an animal goes down in the main race. The secondary race could be used to test concepts without the risk of holding the plant up.

Ideas were discussed of what imagery in particular could be used to entice cattle into the single file race. The concept of the 'Judas goat' was brought up, where a trained goat leads sheep from the yards up to the slaughter floor and escapes out a side door at the last minute. It was proposed that this technique could be replicated for cattle, using imagery rather than a live animal. One way of achieving this could be to use static or dynamic images of cattle displayed on the race wall, to lure animals in the forcing pen. Another way could be to move a static image of a cattle rear up the race on a board, enticing animals up behind it.

Figure 12 – Judas goat leading sheep (image from https://en.wikipedia.org/wiki/Judas_goat)

6.0 Conclusions and Recommendations

The investigations outlined in this report have uncovered a number of improvements and technical developments that offer significant potential to improve animal movement from yards through to the stun box or restrainer. The project has produced concepts with potential to improve animal welfare and increase stun area efficiency. These concepts have been developed alongside animal welfare experts, abattoir managers and experienced engineers.

A review of relevant studies has found that cattle can be manipulated with both static and dynamic images. Different methods of displaying images in the stun box have been explored, and possible image content has been considered.

The preliminary design concepts appear feasible at a conceptual level. The outcomes of investigations into using visual cues to lead animals will be incorporated into these designs and these final designs reviewed by external experts for comment. Any development of an actual prototype will be dependent on further trials on the effectiveness of visual cues for leading animals.

The visits to processing sites verified that not only is there a use for the concepts developed in this project, but there is a real need. Plant managers were supportive of the initial concepts they were shown, and were enthusiastic about incorporating them into their operations as soon as possible. Speaking to plant operators during the visit confirmed aspects of the proposed trial protocol. In a practical context, vocalisation and prod use rates were identified as the key measurements upon which they were judged. Video recording was also agreed to be a useful tool in the evaluation of prototype performance.

The next stage is to test them on cattle in a controlled environment. While anecdotal evidence has been documented that demonstrates the potential for static and dynamic images to positively influence the movement of cattle, further experimental work is required to quantify the conditions under which static and/or dynamic images deliver sufficient positive impact to justify implementation. Investigation of possible trial methods has identified a number of objective measures that can be recorded to determine how well an enticement performs.

The authors propose that the project should continue in two parts; image technique evaluation followed by prototype development.

1. Visual Image Cue Evaluation

Imagery could be trialled in a number of scenarios, such as stun box ends, curved race walls and forcing pens. Imagery may be displayed by either static or dynamic methods, and a variety of content such as photos of cattle (from different angles) and horizon scenes would be trialled. Trials would be video recorded, and measurements taken off the subsequent footage. Such measurements could include throughput, vocalisation, prod use, goad use, time to enter, use of point of balance and baulking.

Specifically, separate scenarios are considered worthwhile of further investigation:

a) Images at the end of the stun-box to draw animals into the stun-box

   Investigation of static and dynamic images in this configuration needs to be undertaken with careful consideration to all other negative impacts on animal movement, particularly:

   - Noise
   - Underfloor footing

- Lighting
- Smell

While it may be possible to implement such a trial in an existing stun box installation (one of the sites visited has some of the attributes required), more objective results could well be achieved by developing a physical, race-based mock-up of a stun box to ensure trials fully separate the effects of the images from other variables.

b) Entrance into races from forcing pens

Plant visits demonstrated that animals often baulked from entering a narrow, single-file race from a forcing pen. The use of static and/or dynamic images along the sides of the entry to the race, showing animals heading up the race, could well provide additional incentive for animals to head up a curved race, creating more uniform and regular animal movement for high-throughput processing facilities.

The outcomes of imaging trials will then provide the definitive functional and structural requirements of a prototype stun-box and restrainer, reducing subsequent technical risk and providing a clear target outcome and performance expectations.

2. Prototype Development and Trialling

The next step would be to take the most promising concepts and begin detailed design to create prototypes. Plant operators have already expressed interest in having improved systems trialled at their abattoirs, so the project would have support from industry.

a) Stun Box
The prototype stun box would incorporate the suggested improvements to animal welfare. An estimation of the cost for full design and construction of the concept box would then be produced, along with a detailed trial plan for construction and trialling of a prototype.

b) Restrainer
An improved centre track restrainer with an alternate loading method would be designed and costed in full. The details (including costs) of a trial at the abattoir discussed earlier in this report would be figured out in conjunction with plant management. After construction and installation, performance of the existing and prototype restrainers would be recorded by video and analysed to measure welfare improvements.

A suitable site to test these concepts was identified at the high throughput site (restrainer-based) visited as part of this project. This site has the necessary throughput, existing curved race design and room available to implement animal trials without impacting negatively on their existing processing operations.

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