# Final report

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Prepared by: Graham Treffone

JBS Australia Pty Ltd

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JBS2 - Beef Loin Deboning Manual Saw Semi-Automation – Stage 1

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# 1 ABSTRACT

This report details and outlines the development and commercial trialling of a prototype saw (modified from existing equipment) for the processing of beef striploins. Currently, striploins are processed manually by an operator using a standard bandsaw. This leads to yield losses and occupational health and safety hazards. The investment has demonstrated that the newly designed semi-automatic saw allows the operator to process striploins efficiently with increased yield output with lower personal risk. It is recommended that a smaller more robust unit be designed to ensure reliability and decrease maintenance costs. Furthermore, a fully automated design of the system would eliminate operator safety issues and would potentially increase yield output.

# 2 Executive Summary

The Australian red meat industry is continually looking at ways to improve bottom line results by increasing revenue and reducing operating costs.

The concept of looking outside the square at different production methods as a solution to these problems is continual.

The use of purpose built bandsaws to achieve additional yield and consistency, whilst protecting the operator from the cutting mechanism is one such method that provides a solution to both problems.

The R&D completed so far during this PIP 0271 suggests that commercialisation of this equipment will deliver a process that will add value and reduce OH&S costs to the beef industry.

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# 3 Background

Since 2010 JBS has been looking for bandsaw solutions that can improve yields and revenue in its beef processing facilities. At the same time JBS was investigating what could be incorporated to increase bandsaw operator safety by removing the ability to interact with the moving saw blade.

Typically all Australian beef processors use side or quarter boning or table boning methods to produce boneless loins. Neither of these methods can adequately maximise the loin yield from the complex skeletal vertebrae at current process line speeds.

JBS conceived an idea that by using a 3 wheeled bandsaw with a triangular configuration the perfect angle for removing chime bones could be achieved to maximise boneless loin yield. The outstanding question that remained, was how to make it safe to operate?

In conjunction with Scott Technology, JBS developed a beef loin saw MK I, PIP 0271 was designed and built in an attempt to provide the following features:

1. Maximise the yield by removing the chime bone at the optimal angle.
2. Use a guided carriage with hand held grippers to hold the loin in position during the sawing process.
3. Install electrical interlock on the gripper handles which only allow saw blades function while the operator has both hands on the grippers.
4. Has laser guidance which enables the operator to align the loin and the saw blade to maximise loin yield.
5. Mount a circular saw to remove excess rib bones during the cutting process.

Excluding full automation that would require the development of a new machine from scratch no other alternatives have been investigated or are currently available. No other meat processing sector processes the loin in this configuration

Scott Technology Australia and Swift have conducted a preliminary investigation of different processing options for developing a safer operator system with improved yields (over current manual systems requiring direct equipment and operator contact), including taking various photographs and videos and consultation with ‘vision’ experts.

This project proposed to remove the operator away from a bandsaw by automating the sensing and 'driving' of the meat primal (the loin) through the bandsaw on a newly developed moving table. The system will be semi-automatic and requires the operator to place the meat primal into a cradle, activate 'two' clamps and then the system will determine the best cut profile and drive the loin through a bandsaw.

# 4 Project Objectives

Overall objectives of the project were:

1. To improve accuracy of the chime bone removal & improve loin yield plus reduce whiz trim, hence increasing overall revenue and costs.
2. Remove operator interaction with the saw blade, hence removing the risk of cuts, soft tissue & nerve damage & ultimately the risk of amputation.
3. To measure the difference in yield between side boning of the loin against table boning (including what whiz meat is left on the bone) plus a comparison of table loin boning versus the loin saw method (including wiz residual).

# 5 Outcomes

There is significant yield and operator safety issues associated with current processing methods for deboning beef loins.

The angle of cut is critical to achieving optimal yields. Whilst companies have experienced improved yields using trial make-shift saws in order to remove direct interaction of operator and the equipment.

This project PIP 0271 developed and trialled a prototype sensing saw (modified from existing equipment). The system is semi-automatic and requires the operator to place the bone-in beef loin into a carriage, align it with the saw blade using laser guidance to determine optimal cut profile, position the 'two' holding clamps, activate the bandsaw then drive the loin through a bandsaw to remove the chime bone.

This project will remove the operator's hands away from a bandsaw during the cutting process.
The project has delivered:

1. Operator safety.
2. Yield & revenue increases.
3. Line speed capability.

# 6 Methodology & Design

## 6.1 Concept

It was proposed that the process flow be:

1) Product will be placed on the machine
2) Clamped by a device
3) Aligned by lasers to the correct line of cut
4) Then passed linearly through the bandsaw

Each step would have an included safety feature where the operator would be required to perform an action (press a button) to indicate advancement through each step.

## 6.2 Design of bandsaw, housing and table

JBS's (3 wheel) bandsaw was to be modified to meet the required objectives. The new design would have to incorporate the existing shape and structure of the 3 wheel pullies but a redesign of the table was required.

After 3-4 iterations of preliminary designs a final design was approved by all. Throughout the iterations, additional design modifications, which exceeded the minimum requirements (stated in objectives) of the machine were also included. This included adding a rotary saw to remove rib bones simultaneously during the cutting process. This was not a preliminary objective of the proposal but was added at an attempt to reduce process cycle time.

## 6.3 Vision and sensing

The most challenging step in the processing of the strip loin was by far the correct aligning of the product relative to the bandsaw. This is because every product (animal) is different and there is no uniform size, weight or height to use as a reference. A small error in alignment could significantly reduce product yield and require reprocessing, which is time consuming and costly.

Currently the operator aligns the product to the blade using his/her vision. The spinal bone column of the animal is placed on top of a metallic groove, which acts as a guide when moving the product through the bandsaw blade. However, this relies heavily on the operator's experience and vision.

On some occasions the operator would line up the loin then midway through the cutting process, realise that it had been misaligned so he/she, in order to avoid reprocessing, would reach in and realign the product during the cut. This is a dangerous process, as the operator's hand is usually only millimetres (mm's) away from the bandsaw blade.

To eliminate the possibilities of the above two aforementioned issues, a laser system and clamping system were designed. The laser system was targeted at removing the reliance on the operator's vision in predicting the line of cut on either side of the loin; the clamping system was aimed at eliminating the operator's ability to shift the product during the cutting process, whereby indirectly eliminating the opportunity for the operator to get his/her hands near the blade.

A laser projected a line on each side of the product. This line corresponded with the position and angle of the bandsaw blade, which made it the predicted cut trajectory. Therefore the operator could visual exactly where the cut would be made, allowing him/her to correctly align the product.

The clamping system consisted of two pneumatic handles, which were held together using a pneumatic cylinder and a pneumatic foot pedal. The handles included two pneumatic thumb switches, which were a vital part of the cutting and clamping process.

The clamping mechanism worked as such:
To clamp;

1. Both thumb buttons had to be activated (pressed) simultaneously
2. Then the foot pedal had to be pressed
3. This would then allow the pneumatic cylinder holding the clamps to move freely.

Once the operator had clamped the product, all the buttons and pedals were released and the clamp positions would be locked, not allowing any product movement.

To release: ***ONLY*** a foot pedal has to be pressed once to release the clamp.

Once the machine was clamped the operator was required to push a button, which indicated that the cycle was ready to start. To start the cutting process, the operator had to simultaneously press (and hold) down on the thumb buttons located on the pneumatic handles. This was an extra safety feature, because it meant that, the machine could only be run when both hands of the operator where gripping the handles and pressing the thumb buttons.

## 6.4 Safety Features

With occupational health and safety (OH&S) a key driver for the project, the design had to ensure that the operator's safety would not be compromised in anyway shape or form. Multiple safety features had to be put into place, which included (but was not limited to) an array of buttons, visual indicators and sensors, which were all connected to a hub of safety controllers.

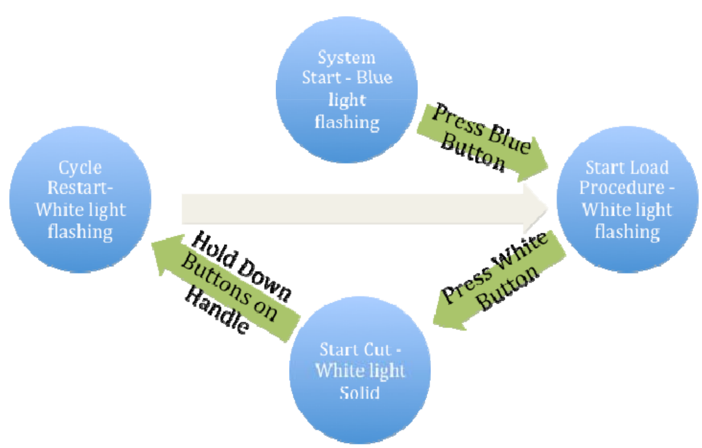
The biggest risks to operator safety were the bandsaw and rotary saw blades and in order to mitigate the risks involved with both, a number of advance safety systems were employed. Both the bandsaw and rotary saw had quick stop procedures in place, where each had a stopping time of less than two (2) seconds. This would ensure quick stopping of both blades if any issues were to arise.

The biggest safety feature of this system is the pneumatic handles with the thumb buttons. In order for either of the saws to be run, both the thumb buttons had to be pressed. This feature ensured that both hands (of the operator) had to be constantly placed on the handles when either saw was engaged.

The safety system in place constantly monitored the position of the bandsaw housing to ensure that the internal pullies were never exposed during machine operation.

As an additional safety measure, through each process step a sequential pattern of buttons needed to be pressed to allow continuation to the next process. This was designed to eliminate mental fatigue and to ensure the operator stays alert and focused.

The operation process was as follows:



## 6.5 Commissioning and Production trialling

The modified/redesigned bandsaw was sent to the industry partner's production site for trialling.

Within the first few weeks of trialling the safety features of the machine were very apparent. The difference between the existing machine and the newly designed one were paramount. The operators soon became familiar with the machine and its processes.

However during the trialling phase of the project some unforseen issues arose which needed to be resolved.

The primary issue was due to water damage to electrical components. To ensure the real-time monitoring of all the safety features of the system a large number of smart electrical systems were put into place. These systems were housed below the table top of the machine, roughly about knee height to the operator.
The low positioning of the electrical cabinet caused a number of issues, as meat processing plants are heavily washed down using high-pressure water. This high-pressure water caused problems as it sporadically entered the electrical cabinets and caused damage to some components.

The electrical sensor systems located on the outside of the machine also acquired some damage, as a result of the heavy wash down environment of the processing plants.

The solution was to minimise the number of external electronics of the machine, which would directly minimise the amount of internal electronic 'smarts' that would be required to monitor them. The electronics were replaced with mechanical solutions, which would not be affected by moisture or water ingress.

The second major problem faced was caused by the rotary saw. The rotary saw, was designed to cut off the rib bones simultaneously as the strip loin was being cut. The design of the saw blade proved to be difficult as different profiles had different attributes and caused a number of different issues.

The processing plant operated with a maximum allowable noise level of 85dB. Therefore in order to avoid the introduction of hearing protection to all employees, the noise level of the process could not exceed 85dB.

The rotary saw produced the highest amount of noise reaching 95dB at times. The majority of the noise was produced by the blade cutting the rib bones and this lead to a search for quieter blade profiles.

Multiple low noise blade profiles were trialled, only to determine that the blade profiles grabbed onto the bones and tossed them out the back of the saw with the saw dust. This was of major concern, as the bones were potential missiles which could cause harm to anyone person(s) nearby.

The use of the rotary saw also required modifications to be made on the machine. Additional chutes and tracts needed to be put into place to remove rib bones as they fell. This would eliminate the risk of the operator removing them manually.

The high-levels of noise, large amounts of saw dust coupled with additional modifications required to the overall system and the general violent nature of the rotary saw, lead to a decision to remove the rotary saw from the system completely.

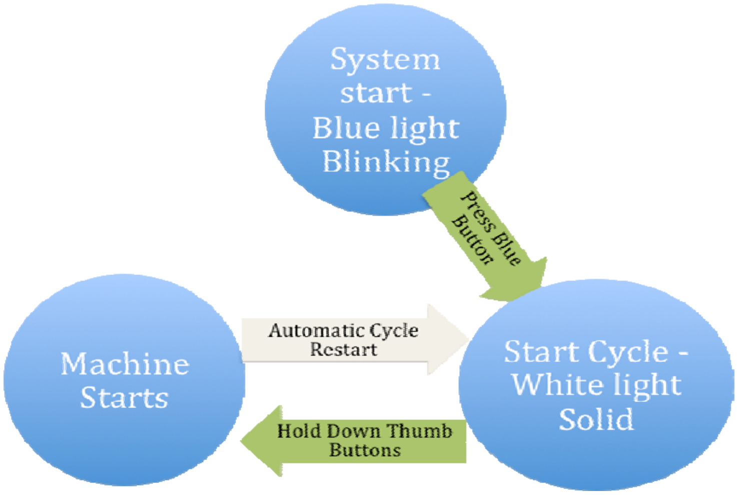
Another issue with the machine came with the cycle time of the process. The current method of processing (manually operated bandsaw) operated with a cycle time of between 15-18 seconds. The newly designed strip loin saw had an operating cycle time of 25-28 seconds. This meant that the operator was unable to keep up with production.

The most time consuming processes were the aligning and clamping processes. The aligning process could not be minimised through a standard procedure, because each product was different, and no universal rule could apply to all.

However, the clamping system of the machine involved the same procedure for all product variations. The operator holding down two thumb-operated buttons (simultaneously) while pressing the foot pedal. This process, when done correctly, would slowly compress the pneumatic cylinder and clamp the product.

The procedure was slightly complicated and to increase time efficiency the clamping system needed to become less cumbersome and more intuitive. The pneumatic element of the clamping step was removed, which lead to a more natural movement for clamping, where the clamps on either end were not restricted to the speed of the air in the pneumatic cylinder. This significantly reduced the clamping time by 6-8 seconds.

The second most time consuming tasks were the (Safety) button procedures, which required 3 button presses per product cycle. With the initial setup, the button press procedure consumed between 3-5 seconds. The original procedure was reprogrammed to a more efficient one:




This reduced the cycle time by another 2-3 seconds. Making the full cycle time between 15-18 seconds, allowing the operator to keep up with production.

Once all the changes were completed the machine was put into its permanent location for production and the operator could successfully keep up with production.

# 7 Results

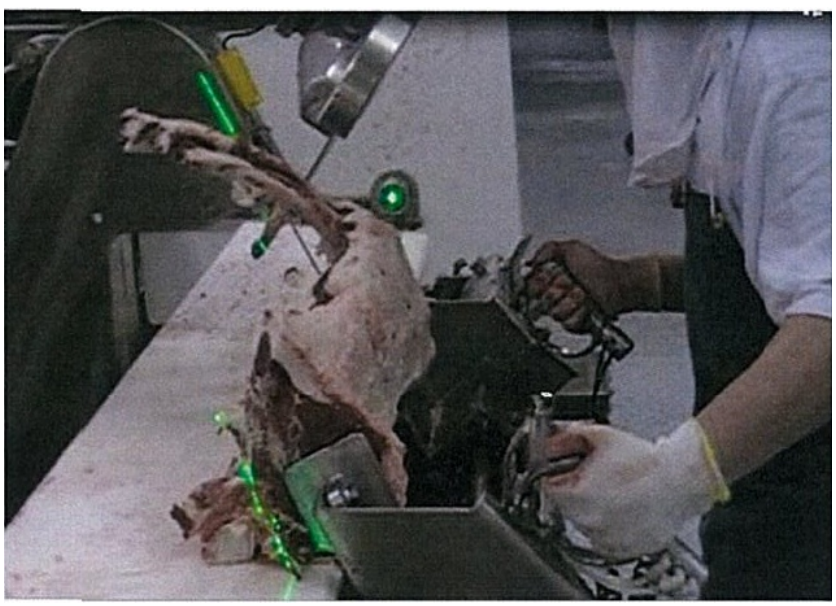
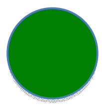
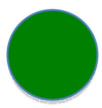
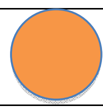


Photo 1 – Beef loin saw in operation.

With stage one (1) of the proposal completed, the outcomes of the project look promising.

The design aims of the project were:

| Result | Design Aim |
|---|---|
|  | Simple sensing/visioning hardware and software can reliably and repeatable be used to find the relevant information points in each end of a left and right loin that would enable a cut trajectory path to be established. |
|  | Develop a simple yet robust product clamping mechanism. |
|  | Develop a method that can incorporate sensing and clamping developments and robustly drive the product through the saw. |

Design aims one (1) and two (2) were successfully implemented; utilising simple laser lines to reliably and repeatedly ascertain cut trajectory, and using free moving linear mounted handles to clamp the product.

Preliminary research indicated that the full implementation of Design aim three (3) would greatly increase the costs of the project and as a result, the decision was made to incorporate the sensing aspect of the aim in the next phase(s) of the project. The clamping was implemented and worked successfully.

Referring back to the objectives, the aim of the project was to develop a simple yet robust machine for the processing of strip loins, which would increase yield and operator safety.

By introducing visioning technology into the aligning process, the operator error was greatly reduced, and reliability of the process increased. And by developing a hand-operated bandsaw clamping system, the operator's risk of blade injuries was eliminated. Increasing the technological 'smarts' and removing operator error in the processing of the strip loin, lead to increased operator safety and improved yield output.

# 8 Conclusion

No other alternatives have been investigated or are currently available. Note this proposal is for development and commercial proving of a prototype saw by modification of an existing JBS saw including adding sensing and safety systems.

A comparison of existing manual equipment and the modified sensing saw has been conducted at the JBS Beef City plant as part of this project. A cost benefit analyses will be undertaken specifically for operator safety and yield improvements.

Additional phases have been recommended, subject to the successful proving of the saw prototype and proven cost benefit. An additional proposal (for recommended stages 2-4) may be developed at the conclusion of this project once reviewed by JBS and MLA to be commercially viable.
When the commercial system is developed, JBS may purchase up to 15 units straight away to meet their immediate needs for operator safety and improved yields.

# 9 Commercialisation / dissemination strategy

Note this proposal is for development and commercial proving of a prototype saw by modification of an existing JBS saw including adding sensing systems. An additional proposal (for recommended stages 2-4) may be developed at the conclusion of this project once reviewed by JBS and MLA to be commercially viable.

At the conclusion of the project if successful, JBS will roll out the technology within other JBS beef processing plants.

MLA & Scott will disseminate to wider industry general communications, videos and practical demonstrations.

At the conclusion of this Project, JBS, Scott and MLA will have delivered:

- A report detailing the impact of the technology on yield, quality aspects of the product processed by this technology, potential labour savings and anticipated economic impact will be completed at the end of the project.
- A video of a system in trial operation will be produced in conjunction between MLA, JBS in the course of the project.

# 10 Recommendations

Note this proposal is for development and commercial proving of a prototype saw by modification of an existing JBS saw including adding sensing systems. An additional proposal (for recommended stages 2-4) has been developed at the conclusion of this project to take the MkI learning and develop a commercial unit (known as MkII). Following stages are depicted below.

- Stage 2 – Refine anything needing refining and apply to the second JBS saw (the current Beef City unit) (JBS 25%: AMPC 25%: MLA 50%)
- Stage 3 – Development from scratch with the learning from above a machine from scratch and install into a non JBS site. This will enable a value engineering iteration to take place. (Scott Technology 50%: MLA 50%)
- Stage 4 – Global commercialisation through Scott Technology and subsidiary companies with royalties flowing back to JBS Australia and MLA.