final report

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Prepared by: Geoffrey Parker

Invetech Pty Limited

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

Bladestop technical review

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Abstract

Invetech was commissioned by Meat and Livestock Australia (MLA) to review a new technology known as Bladestop, which is aimed at reducing injury that could arise from bandsaw operation in meat processing facilities.

The purpose of this review is to help MLA to objectively assess the likelihood of technical and commercial success of the Bladestop technology in the market place, before committing to further investment.

Bladestop has the potential to offer significant benefits to the fresh meat processing industry due to the demonstrated potential to reduce the degree of injury with some bandsaw incidents. Estimated cost is currently greater than the target cost; impacting expected industry acceptance and take-up.

The approach to date appears to have been a technology driven push to find a solution. There is now a need for market research to understand injury data and the needs of the industry to enable evaluation of the commercial viability and if improvements or changes are warranted. A revised costing is required that identifies all costs, assumptions and the cost structure for manufacturing the current Bladestop design.

The challenge may be finding an appropriate balance between safety, functionality, ease of use and cost for differing sector needs.

The cost of development for Bladestop is beyond the means of individual businesses. By MLA taking on the project, the cost is shared and all stand to share in the potential benefits.

Executive Summary

Bladestop is a bandsaw designed to reduce the degree of injury to operators who come in contact with the blade. There is definite need for a product like Bladestop.

The purpose of this review is to help MLA to objectively assess the likelihood of technical and commercial success of the Bladestop technology in the market place, before committing to further investment.

Bandsaws are used extensively within the meat and wood industries, but unfortunately are a major contributor to serious injuries, including amputations. Meat and Livestock Australia (MLA), in a drive to improve operator safety within the meat industry, has been supporting a new technology for a bandsaw safety stopping system, named Bladestop. Machinery Automation and Robotics (MAR) has been carrying out the development of this technology and has tested a prototype system in a meat processing plant in Casino, NSW.

For the fresh meat industry it is generally considered not practicable to reduce all bandsaw hazards by means that distance the operator from the blade. This is due to the variety of products a given bandsaw may need to handle, variations within a given product, potentially slower production cycle times and capital costs. The dexterity of the human hand is still required for much of the bandsaw work in the meat industry.

Invetech inspected two versions of Bladestop, discussed their use and development with a user and MAR, and conducted technical review and ideas sessions. The report is based on the most recent prototype at MAR.

It is important to understand:

- Bladestop does not eliminate hazards associated with operating bandsaws.
- Bladestop is being promoted as an operator ‘aid’; it is not a failsafe safety system.
- Bladestop is intended to reduce the severity of injuries; not eliminate injuries.
- Bladestop is designed to operate after an injury has commenced. It requires an operator’s skin to be in contact with the blade before it can trigger to stop the blade; it is assumed that in general this will mean an operator is being cut before the system is triggered.
- The degree of protection achieved is related to operator speed of movement towards the blade.

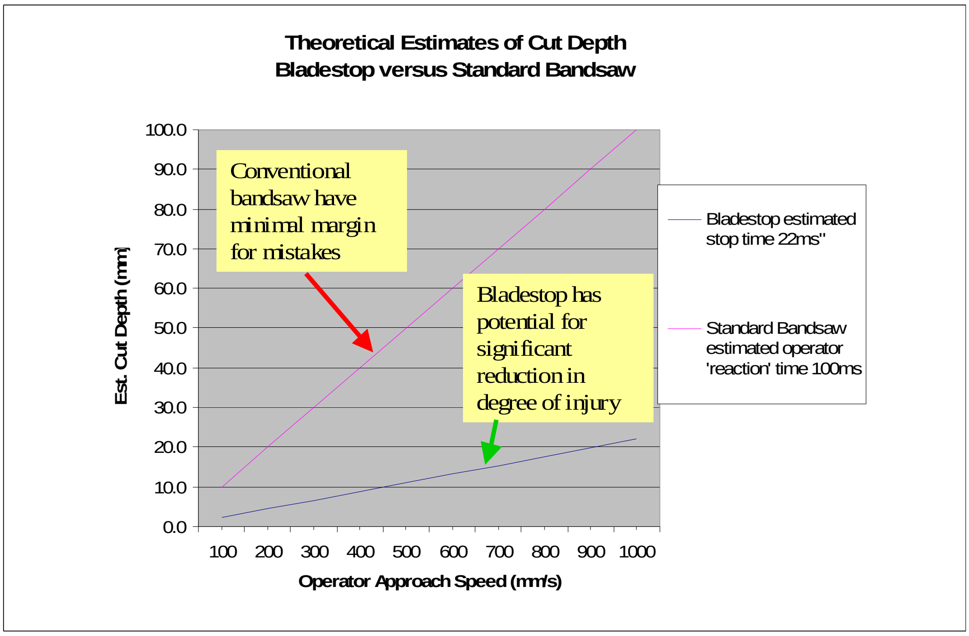
Theoretical estimations based on limited preliminary blade stopping time estimations under workshop conditions indicate Bladestop has the potential to limit cut depth as follows:

- Between 1.5 to 2.2mm for an operator approach speed of 100mm/s.
- Between 3.4 to 5mm for an operator approach speed of 227mm/s.
- Between 9 to 13mm for an operator approach speed of 600mm/s.

By comparison ***if*** an operator’s reaction time to an incident on a regular bandsaw without Bladestop was 100ms, the potential cut depth, based on the estimate method used above would be 10mm, 22mm and 60mm respectively. The potential benefits of Bladestop are significant.

Whilst at some approach speeds finger and fingertip amputations may occur, Invetech expects that amputation of larger limbs i.e. wrists could be reduced when Bladestop is operating correctly.

The graph below is provided to illustrate the importance of blade stopping or operator reaction time.



This report identifies concerns and potential improvements for Bladestop.

There is limited data available on bandsaw injuries in meat processing operations; MLA advised. Injury data is required to better understand the range of injuries occurring and in which sectors of the industry. Such data would enable performance requirements or objectives for Bladestop to be formally defined, allow the system to be evaluated against them and assist in understanding the commercial viability of the system.

The target customer buy price of $40,000 to $60,000 appears challenging for initial low volume production; based on the MAR current build estimate of $72,550. This estimate does not include all costs.

A review of parts and labour costs and the cost structure to build a defined number of replication machines may help to ensure any development costs are appropriately identified and not confused/included with component costs.

Project management, administration, profit, marketing and reseller mark-up costs etc need to be identified and included in cost estimates. Any past unfunded or future development work may also impact costs and need to be understood and dealt with. Costs to be amortised need to be identified and a strategy/timeframe agreed. Reseller mark-up costs may significantly increase the final cost and we understand are not included in current estimates. A transparent approach is required to ensure all costs are understood.

Anecdotal comments suggested the total cost of a serious incident to a business might be in the order of $80,000 to $160,000. Depending upon the rate of injuries in particular sectors, this may make Bladestop more affordable, with better ROI, than is currently perceived.

The potential take-up of a Bladestop type machine may initially be for activities with the highest risks and or incident rates. Depending upon performance and operator experiences, owners may progressively purchase additional units for other activities. As a reputation is created, prospective customers may decide they can't ignore the potential benefits of Bladestop or the liability of not having it.

The meat processing industry stands to gain from a Bladestop type of device that achieves defined performance requirements at an acceptable price to the market. Raising the awareness of the market about injury statistics may be an important part of the successful deployment of a suitable Bladestop device.

Meat process workers, their families and the broader community stand to benefit from an appropriate Bladestop type of machine.

Recommended next steps are provided in the body of the report.

Contents

1 Background

1.1 General

Bandsaws are used extensively within the meat and wood industries, but unfortunately are a major contributor to serious injuries, including amputations. Meat and Livestock Australia (MLA), in a drive to improve operator safety within the meat industry, has been supporting a new technology for a bandsaw safety stopping system, named Bladestop. Machinery Automation and Robotics (MAR) has been carrying out the development of this technology and has tested a prototype system in a meat processing plant in Casino, NSW.

For the fresh meat industry it is generally considered not practicable to reduce all bandsaw hazards by means that distance the operator from the blade such as moving tables, conveyors, magazines, robots etc. This is due to the variety of products a given bandsaw may need to handle, variations within a given product, potentially slower production cycle times and capital costs. The dexterity of the human hand is still required for much of the bandsaw work in the meat industry.

The Bladestop design aims to detect when an operator is in contact with the blade then stop the blade quickly. It does this by clamping the blade above the throat of the machine and removing drive tension on the blade so that the clamping system only needs to stop the momentum of an un-driven blade and not the drive wheels. It is important to understand:

- Bladestop does not eliminate hazards associated with operating bandsaws.
- Bladestop is considered an operator ‘aid’; it is not a failsafe safety system.
- Bladestop is intended to reduce the severity of injuries; not eliminate injuries.
- Bladestop is designed to operate after an injury has commenced. It requires an operator’s skin to be in contact with the blade before it can trigger to stop the blade; it is assumed that in general this will mean an operator is being cut before the system is triggered.
- The degree of protection achieved is related to operator speed of movement towards the blade.

There is definite need for a product like Bladestop in the fresh meat industry.

There may be approximately 1000 bandsaws in use in Australian meat works and butcher shops (MLA). It is not known how many of these are fitted with hazard reduction devices. MLA and MAR suggested there may be 6 to 10 ‘nasty’ accidents per year in Australia and that New Zealand may have a higher injury rate with many being wrist amputations. If 10 incidents were evenly distributed across the 1000 saws, that could mean 100 years between incidents on a particular saw! Some saws will be used much more than others and there will be a ratio of butcher saws to meat plants. A butcher saw may do 2 hours per day whereas a meat plant with 10 saws may do 10 saws x 15hrs = 150 hours per day. Injury data is required to understand the type and degree of injuries and in what sector of the industry they occur.

The potential take-up of a Bladestop type machine may initially be for activities with the highest risks. Depending upon performance and operator experiences, owners may progressively purchase additional units for other activities. As a reputation is created, prospective customers may decide they can’t ignore the potential benefits of Bladestop or the liability of not having it.

1.2 Bladestop Development

The general Bladestop concept and design has been arrived at as a result of significant investigation by MAR into the current state of knowledge in bandsaw safety and the manufacture and testing of a range of concepts to reduce the hazards associated with bandsaws. A U.S. company called SawStop has developed fast blade stopping systems for both circular saws and bandsaws for use with timber. The bandsaw device is not currently available for purchase. MAR has met and discussed the meat industry needs with SawStop. A licence or royalty agreement may be required or may already have been negotiated to enable the Bladestop concept to be marketed. The MAR and Invetech investigations have not found any other commercial solutions suitable for the use of bandsaws in the fresh meat industry in situations where others have determined operators need to work close to the blade.

MAR's work done with Bladestop is of high quality and there is significant documentation showing a high level of professionalism.

2 Project Objectives

The purpose of this review is to help MLA to objectively assess the likelihood of technical and commercial success of the Bladestop technology in the market place, before committing to further investment.

3 Program of Work

Site visits were conducted by Jim Atkin and Geoff Parker of Invetech to NCMC and MAR on 20 and 21 August respectively. At NCMC Greg Williams and Nathan Connellan were key staff explaining the system and experiences; there was no production on this day. At MAR, Clyde Campbell and Roland Painter explained the development history and current situation. David Doral was present at the MAR meeting.

Invetech carried out a technical review of the current system and conducted ideas sessions looking for improvement opportunities and alternative concepts. Some of the suggested improvement opportunities and alternative concepts have previously been trialled by MAR.

4 Results and Discussion

4.1 Bladestop Functional Requirements

There is limited data available on bandsaw injuries in meat processing operations; MLA advised.

Injury data is required to understand the range of injuries occurring and in which sectors of the industry. Such data would enable performance requirements or objectives for Bladestop to be formally defined and tested against, identify potential likely market segments, and hence assist in determining the commercial viability of the system.

A functional requirements specification for Bladestop has not been finalised by MLA. MLA advised the main performance requirement is to stop bad injuries from occurring. MLA also advised that the limits around this are not formalised but if amputations (including finger amputations) could be eradicated that would be a very positive achievement. Informal discussions noted that ideally cuts would be limited to 2mm and that cuts above 5mm may make it hard to justify the system. The conflict in these requirements needs to be resolved.

The requirements specification may be developed in an iterative process considering the performance Bladestop or variations of it can potentially achieve, and information about past injuries. Equipment and injury costs are other factors that may influence the specification. Bladestop can be better assessed when the requirements are better defined or finalised.

4.2 Injury Factors

Many factors are likely contribute to injuries from bandsaws including lack of safety systems or aids, training, level of experience, familiarity, location, surroundings, floor and lighting, distractions, not following or inappropriate procedures, fatigue and boredom. Some of these can at least in part be addressed and minimised by a range of procedures and are not considered in this report.

A key factor in the degree of injury when an incident does occur is the operator approach speed to the blade. If the operator is moving slowly towards the blade there is a greater likelihood of the operator reacting to limit the degree of injury. If the operator is moving quickly towards the blade there is a greater likelihood of the operator being more seriously injured before they can react to limit the injury.

A simplistic theoretical estimation of potential cut depth is:

Cut Depth ≈ Operator Approach Speed x (Blade Stopping Time or Operator Reaction Time)

Without the Bladestop system, the blade stopping time is typically in excess of several seconds after someone has initiated the machine stop; presumably too late to limit the injury. In this case the degree of injury is fundamentally dependant on the operator’s reaction time in responding to the injury. It is easy to understand that serious injuries can be expected with standard bandsaws.

4.3 Protection Offered by Bladestop

In workshop tests conducted by MAR, Bladestop nominally stops the blade within 200 to 265mm of travel from when the operator is detected by the system. This is made up of 9 to 10ms from detection of the operator touching the blade until the system has removed blade drive tension and applied the brake. As the blade operating speed is 16,500mm/s, this 9 to 10ms period corresponds to 148.5 to 165mm of blade travel. There is between 50 to 100mm of travel (slip or run on) from the application of the brake until the blade stops. Hence the nominal 200 to 265mm stopping distance.

As stopping time is a useful method of evaluating performance, the time from applying the brake until the blade stops was estimated using motion formulas assuming constant acceleration. This resulted in estimates for the 50 to 100mm slip of 6 and 12ms respectively. Adding these to the 9 to 10ms brake application time results in an estimated nominal blade stopping time of between 15 and 22ms.

Using the 15 to 22ms blade stopping time in the simplistic theoretical estimation of potential cut depth,

$$\text{Cut Depth} \approx \text{Operator Approach Speed x Blade Stopping Time},$$

indicates Bladestop has the potential to limit cut depth to between 3.4 to 5mm for operator approach speeds up to 227mm per second (5mm = 227mm/s approach speed x 22ms stopping time). At a faster operator approach speed of 600mm/s, between 9 to 13mm deep cuts and hence small diameter finger or fingertip amputations may occur. At higher operator approach speeds the degree of injury would be worse however the potential exists to avoid some potential amputations.

If some injuries occur when not cutting meat i.e. reaching across the saw for any reason, this could occur at higher speed than when cutting meat and hence result in more serious injury.

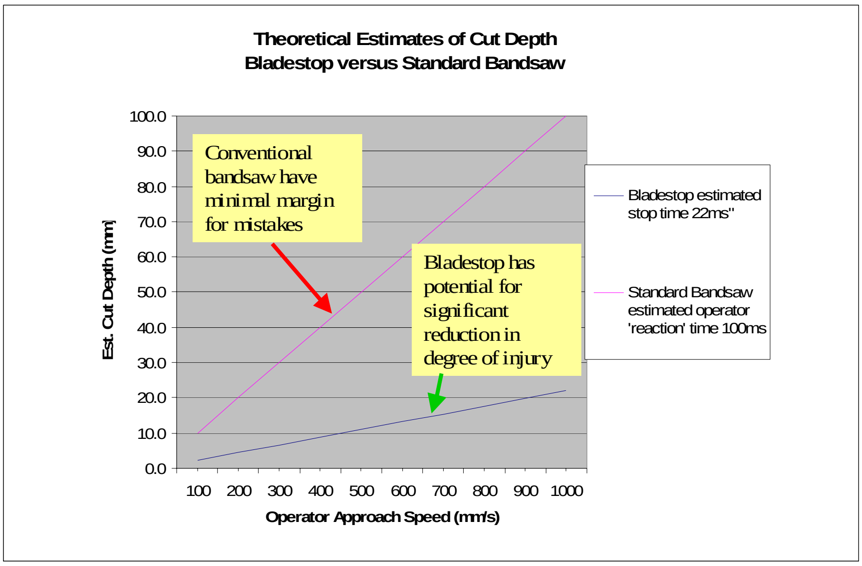
Adequate testing under production conditions is required to determine the validity of these estimations and industry data is required on operator approach speeds.

Other factors may influence the degree of injury compared to this simple estimation method. Friction of the blade in the product being cut may reduce stopping time; hence reducing the degree of injury. Potential acceleration of the operator as the blade breaks through sections of product being cut means the operator speed may be higher than an assumed nominal speed; thus a more severe injury could result compared to the estimated method.

If an operator's reaction time to an incident on a regular bandsaws without Bladestop, was 100ms[1], the potential cut depth based on the estimate method above at an approach speed of 227mm/s would be 22mm and at 600mm/s would be 60mm! The potential benefits of Bladestop are apparent.

[1] 100ms an estimate (optimistic?) derived from this link that suggests human response to 'touch' can be approximately 155ms refer http://biae.clemson.edu/bpc/bp/Lab/110/reaction.htm#Kinds)

The graph and table below were created for comparative purposes; they are based on Invetech's estimates and partial test data from MAR. More formal data is required to determine their validity.



The graph above shows the *estimated* difference in cut depth between Bladestop and a standard bandsaw for different operator approach speeds.

Operator Approach Speed mm/s	**Stopping Time ms**						
	5	**10**	**15**	**18.5**	**22**	**25**	**100**
	Could this be achieved?		**Bladestop *estimated* performace range. To be confirmed by testing.**				**Std Saw Operator Reation Time est.**
100	0.5	1.0	1.5	1.9	2.2	2.5	10.0
200	1.0	2.0	3.0	3.7	4.4	5.0	20.0
300	1.5	3.0	4.5	5.6	6.6	7.5	30.0
400	2.0	4.0	6.0	7.4	8.8	10.0	40.0
500	2.5	5.0	7.5	9.3	11.0	12.5	50.0
600	3.0	6.0	9.0	11.1	13.2	15.0	60.0
700	3.5	7.0	10.5	13.0	15.4	17.5	70.0
800	4.0	8.0	12.0	14.8	17.6	20.0	80.0
900	4.5	9.0	13.5	16.7	19.8	22.5	90.0
1000	5.0	10.0	15.0	18.5	22.0	25.0	100.0
	Theoretical Cut Depth mm						

The table above shows the *estimated* cut depths for a range of blade stopping or operator reaction times.

4.4 Results and Discussion

4.4.1 Robustness, Effectiveness, Integration & Reliability of Design

The following subsections provide some comments on particular aspects of the current Bladestop design. A subsequent section tabulates concerns with the current system, the effect of these on equipment and outcomes, general comments and potential system improvements.

4.4.2 Robustness and Effectiveness of the Mechanical Design

The general mechanical construction appears to be of a high standard with good workmanship. There are some elegant solutions incorporated in the design such as loss of pressure in the hydraulic system should remove drive to the blade.
Whilst the construction appears robust, there are mechanical issues that may benefit from additional attention including:

- Large forces and reactions, consider:
    - Impact / effect on components when the system is triggered – consider component design / selection, fatigue and other effects of these forces on total system; modifying the design to include over-travel and shock absorbers may assist here.
    - Brake system bounces due to drive mechanism shock. This may limit the potential performance achieved by the system.
    - Large forces on trigger mechanisms – consider wear rates / material selection. MAR predicts that in normal operation wear on these parts, would lead to the system false tripping, not failing to trip.
    - Hazards when opened for maintenance, cleaning etc.
- Reliability and consistency of performance, in particular blade stopping time. Is there sufficient relevant test data to demonstrate this is not an issue?
- Methods and or equipment available or required to set-up, test and maintain the system.

4.4.3 Robustness and Effectiveness of the Electronics Design

The general electronics / electrical construction appears to be of a high standard with good workmanship. It was evident in discussion with MAR, a great deal of development effort has been undertaken to get to the current situation and many obstacles have been overcome.

MAR explained, as a high level overview, that much of the control system has been designed to provide a significant level of redundancy. Much of the control system utilises dual circuits including dual microprocessors. The code for the separate processors has been mainly written and tested by different people. This approach is similar to the general principles for development of electronic programmable safety equipment. The Bladestop printed circuit board control system has in general been designed with the objective of failing to a safe mode (stopping the drive motor), however, it has not been certified to any standard; to do so would be an expensive exercise. This is in line with the system claiming to be an operator aid rather than a 'safety system'. The Bladestop system does not offer complete redundancy and thus is not a fail-safe system. Single component failure can lead to the loss of the system performing when required.

Some key concerns with the overall control system include:

- Single trigger coil does not provide redundancy yet experiences substantial shock and vibration each time the system is fired.
- Trigger coil only tested at daily test and fitting armband test. Failure could go undetected between these tests; a significant time. It may be possible to more thoroughly/frequently test the coil with enhancements to the control system.
- Operator screen displays important performance information on part of the system performance but not total blade stopping time. Potentially, this could fail to indicate significant degradation in blade stopping time and provide a false sense of security.
- The control circuit for the basic bandsaw motor appears not to achieve Category 3 or 4 safety status which is likely to be the preferred category. Whilst it may not be practicable for the nominal Bladestop control circuits to achieve Category 3 or 4 safety status, that should not impact the basic motor control circuit where it may be practicable.

Operators have requested an alternative quick release armband connector that is easier to use with gloves on.

4.4.4 Integration of Components

The Bladestop components generally appear to be well integrated with the Thompson bandsaw. The facility to swap out the top mechanical section of the equipment provides an ability to help ensure systems are correctly setup if manufacturer change-over units are utilised.

Wiring of the electrical terminal strip located near the main trigger mechanism appears awkward to work on with the potential for wires being trapped between the machine frame and cover. Potential shock and vibration issues should be considered particularly with respect to terminations.

The potential for water entry and / or condensation in the trigger mechanism area are issues MAR advised they would evaluate with future work. A simple resistive heater was fitted to the machine at NCMC to combat moisture in the trigger mechanism area.

4.4.5 Overall Reliability and Adequacy to Operating

The current Bladestop design has the potential to significantly reduce the degree of injury incurred with some hazardous events of operators contacting the blade. Data on past injuries and operator approach speeds is required to enable more specific evaluation to be provided.

A system like this requires significant testing under both workshop and production or simulated production conditions to understand and demonstrate consistency of performance, number of safe cycles before components wear or failures occur. Reliability calculations may aid in understanding the potential reliability.

Whilst some significant testing has been undertaken, the actual blade stopping time may not have been monitored for consistency. This is ultimately the parameter that directly impacts operator protection, so it important to have adequate data on it.

This report identifies a range of issues and opportunities for consideration in future Bladestop activities. The achieved, required/desired performance and cost issues should be considered in determining the adequacy of the current system.

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4.5 Issues, Effects, Comments, and Opportunities for Improvement

This table captures concerns with the current system, notes the potential effect on the equipment or project outcomes, provides comments to expand on the situation and lists potential improvements to the system.

Whilst reviewing the table below, the reader should remain aware of the performance already demonstrated by the current Bladestop system and the substantial benefits it offers over a conventional bandsaw.

Concern with current Bladestop system	Effect on equipment & outcomes	Comments	Potential improvement to system
o Equipment functional requirements (objectives) not formally defined. o Acceptance (test) criteria not defined.	o Can't assess if equipment meets requirements.	o Define functional requirements. o Create acceptance test plan. o Gather data on past injuries and operator approach speeds.	
o Is there adequate performance data? o Lack of a test rig to trigger the system in a controlled manner & measure blade stopping performance.	o Ability to know machines are in specification?	o Is there adequate performance data? o Develop a test rig to do the sausage (simulated finger) test at a controlled speeds & measure the actual blade stopping performance; time & cut depth?	
o Time for the blade to stop after a person detected. Potential degree of injury at some operator approach speeds.	o Degree of injury. o Ability to meet requirements.	o This issue depends on data of past injuries and operator approach speeds, and performance of Bladestop.	o Review/optimise mechanism and brake design. o Eliminate bouncing of brake mechanism. o Sticky eccentric wheels or wedges that grip blade and self tighten on blade? Consumable components. o See other notes in this column re shock & mass.

Concern with current Bladestop system	Effect on equipment & outcomes	Comments	Potential improvement to system
o Repeatability of stopping performance. o Blade stopping distance or time is not directly measured. o Can deterioration of (some of) the brake system go undetected, leading to increased blade stopping distance? o Is there adequate data on actual blade stopping distance rather than proximity sensor actuation time? Does data include actual production conditions?	o Potentially reduced operator protection? o Potentially lack or indication of reduced performance? o Ability to meet specification?	o Display shows time for mechanism to lower but this is not the blade stopping time. o Stopping time depends on blade & brake interaction that could vary over time or cycle to cycle. o If not already done, consider measuring and assessing data on actual blade stopping time (rather than proximity sensor time) over substantial cycles for production and possibly workshop conditions. o Some tests have been done with lubricant on the blade to simulate production conditions.	o IF this is an issue, consider measuring blade stopped time as well as wheel down proximity sensor. o This may not be a trivial task. Induce & detecting eddy currents in the blade? o See other brake notes.
o Shock loads due to mass of mechanical parts & forces applied. o Video shows brake components bounce, therefore contributing to blade stopping distance/time.	o Negatively impacts stopping time? o Reliability, longevity and maintenance costs of equipment.		o Reduce weight of components? o Use shock absorbers and longer travel / over-travel to reduce shock, bouncing & fatigue.
o Shock loads of daily firing tests may prematurely wear components or cause failures. (Trigger coil is subjected to significant vibration.. Mechanical trigger mechanisms wear.)	o Potential failure to operate or false triggering.	o Failure of trigger coil could go undetected. Refer elsewhere in this table. o False triggering may pose a hazard during maintenance or cleaning. o Some mechanical wear could lead to false triggering and a fail to safety situation. o MAR did considerable work regarding materials used in trigger system.	o See other comments on mass & shock. o As not Cat 3 or 4, regular testing is desirable/required. This potentially works against having consumable items that need replacement when system fired.

Concern with current Bladestop system	Effect on equipment & outcomes	Comments	Potential improvement to system
o Potential hazards (i.e. crushing) if the system is mechanically triggered when a rear top or front door is open.	o Injury to staff during maintenance or cleaning.	o Procedures may address this item.	o Consider mechanical interlocks to make system safe when guards open. o Provide adequate signage. o Other?
o Lack of redundancy in critical components i.e. trigger coil, cocked detection pressure switch.	o Potential failure to operate.	o Could the design be adapted so coil is not carried on the moving plate? Could consider replacing trigger coil with explosive charge type device – any advantage as still need to fire it?	o Add redundant trigger coil? o Add 2nd means of detecting cocked (a top proximity sensor?)
o Period between testing trigger coil not open circuit (o/c) or short circuited (s/c). Some tests done daily others done more frequently when armband fitted.	o Potential failure to operate.	o A key concern is if coil fails after daily test, it is not tested for a long time; possibly the next daily test. Does testing confirm coil definitely connected, not s/c and not o/c?	o Modify control circuit & software to test coil more frequently and thoroughly – (like CAT 4 safety relays) but not by firing the mechanism.
o Basic bandsaw motor control safety circuit. Appears to use single contactor without feedback to safety relay, single channel kick-stop switch. o Understand Bladestop electronics is not Cat 3 or 4 but motor circuit is practicable to be.	o Saw may not stop if emergency stop kicked or pressed. o Future distributors and/or manufacturers may not accept safety circuit.	o Persons modifying equipment take on responsibility for safety aspects of that equipment. Must do own hazard identification & risk categorisation. Expect bandsaw would be assessed as Cat 3 or 4. Does basic motor control, estop/kick switch achieve this Category?	o Review & upgrade bandsaw motor safety circuit?

Concern with current Bladestop system	Effect on equipment & outcomes	Comments	Potential improvement to system
o In general, requires person to be cut before system takes action.	o Degree of injury.	o Is there a way to trigger system earlier? o If some form of laminated thicker glove with a conductive layer just under the outer surface and say 2 to 3mm between that & inside of glove, would injury be reduced by that 2 to 3mm? o Alternatively wear an inner conductive glove or conductive gel so system is triggered as glove is cut. o Availability of such gloves & practicality of gloves or gels on the job?	
o Quality of components	o Reliability	o This is not saying the current components are not suitable, it just raising it as an issue for consideration. o The use quality parts and or overrated parts may help the system achieve its objectives.	o Consider using UL rated and/or over sized components particularly for non-redundant parts eg proximity & pressure sensors, relays etc. Also consider diversity of components.
o Project Specific Risk Register may need update/review to ensure data and assessment is current.		o Relates to MAR document 23426-PM-100.xls	

4.6 Alternative Concepts

Bladestop works by removing blade tension and hence drive to the blade and then applying a brake to stop the blade. This enables a faster stopping action than leaving the blade tensioned and trying to stop the complete motor, drive and idle wheel assemblies; a significantly higher mass/inertia load than just the blade.

4.6.1 Shear and Trap the Blade

An alternative concept has the potential to stop the blade even faster. The concept is to shear and trap the blade below the table so it is stopped extremely quickly with minimal slipping or run-on, whilst at the same time clamping the blade above the throat of the machine so that it does not travel down into the operator area. Shearing the blade removes the tension and hence drive to the blade. The bandsaw drive or idle wheel does not need to be lowered in this concept; thus potentially reducing the mass of components to be moved rapidly.

MAR has worked on this concept but was disappointed with results so the current design was developed. If there is consideration given to revisit and extend the previous shear, trap and clamp work, it would clearly be prudent to understand the issues encountered with the previous work before launching into variations of it or alternative methods. SawStop's U.S. Patent No. 7,000,514 notes that a bandsaw blade stopping time as short as 3ms was achieved by the shear method.

Energy sources other than or in addition to hydraulic could be considered for the current or alternative concepts. These could include sources used in seat belt pre-tensioners, Ramset concrete fastener systems and nail guns; this includes explosive charges. This may lead to a system a little like the SawStop product for circular saws where after being triggered; modules of the system are replaced as consumable items.

Could further collaboration with SawStop lead to a cost effective solution that could be integrated with the Bladestop detection system required for handling meat?

The cost of replacing a sheared blade is not considered an issue as in meat processing factories blades are typically replaced every day or two anyway.

This approach may enable a system with lower parts cost to be developed. This is because such a system could potentially comprise of modules with consumable parts above and below the table and a modified version of the current Bladestop controller; the existing mechanical frame, trigger mechanism and hydraulic system may not be required. There could be an income stream from sale of consumables. There would be a significant cost to undertake such a development.

4.6.2 Other Concepts

Other concepts identified but considered not viable due to adding to the cost of the current system and their likely lack of effectiveness are listed below:

- Moving the blade back and away from the operator. Either move just the blade from below and above the table or pivot a large part of the bandsaw.
- Push the operator away from the blade – could be by pushing the table back.
    - If the above are done at the speed the operator is approaching then the injury is limited.

- Vision inspection or thermal imagery. Not practicable as hands could be under meat, thus going undetected.

Factors that could influence whether or not to pursue potential improvements or alterative concepts include:

- What injuries and operator approach speeds occur in the industry.
- The desired level of protection.
- The potential performance enhancement from improvements or alternative concepts.
- The cost of Bladestop, potential improvements or alternative concepts.
- Maintenance and training costs – total cost of ownership.
- Time to market – so that the benefits of the system can be realised.
- Staged feature release schedule.

4.7 Cost

Bladestop cost refers to the supply of a new ‘Thompson Meat Machinery’ bandsaw fitted with the Bladestop system; it includes the cost of the new bandsaw.

Care is needed in reviewing costs from machines against MLA’s nominal target cost range of $40,000 to $60,000. Invetech understands this cost target is the buy price for customers.

Whilst the current MAR cost per machine is estimated at $82,450, this includes $9,900 per machine for refurbishment and warranty in the first year; thus the basic build cost could be $72,550.

A review of parts and labour costs and the cost structure to build a defined number of replication machines may help to ensure any development costs are appropriately identified and not confused/included with component costs. As an example, the cost of the controller printed circuit board loaded with components may include non-recurring development costs and not be based on a batch of 20.

Project management, administration, profit, marketing and reseller mark-up costs etc need to be identified and included in cost estimates. Any past unfunded or future development work may also impact costs and need to be understood and declared. Costs to be amortised need to be identified and a strategy/timeframe agreed. Reseller mark-up costs may significantly increase the final cost and we understand are not included in current estimates. A transparent approach is required to ensure all costs are understood.

It would not be unusual for machine development work and machine replication to be done using different cost structures i.e. labour rates, component mark-up costs, contingencies etc. For some components and assemblies outsourcing, including overseas, may be practical and offer cost advantages. Often as a design is finalised suppliers can be approached for more definite quotations for know quantities; reducing unknowns and the need for contingencies.

Whilst a detailed cost review is not part of this assignment, Invetech has done at MLA’s specific request, a preliminary high level review of the direct costs to make Bladestop machines. These estimates draw on data provided by MAR and Invetech’s experience and costing methods. Such a review should not be used for making business or commercial decisions as it is basically an indicative ‘back of the envelope’ estimate done without a thorough knowledge of what is involved,

without seeking any quotations, without understanding MAR's project cost structure, and without discussion with MAR.
Key points are listed below.

- The ballpark estimate assumes ordering parts for and building 20 machines in one batch.
- This ballpark estimate is limited to the 'cost of goods' i.e. cost of parts and labour to make a machine.
- No refurbishment, service or warranty costs are included. The original MAR estimate includes a $9,900 allowance for these.
- No indirect costs are included; however $10,000 was added as noted below for project administration, supervision and procurement).
- No development costs are included (past or future).
- No reseller margin is included.
- No marketing costs are included.
- Labour Costs reduced by $8,000.
    - Added $10,000 allowance for project administration, supervision and procurement.
    - Labour rates left unchanged at $110 and $120 per hour.
    - All labour times were reduced by approximately 50% as they appear generous for replication. Includes electrical fit out & wiring, mechanical fit out, installation, alignment, testing & training.
- Reduced costs for fabricated/machined component by $3,000. Costs estimated at $7,000 +20% = $8,400 versus $11,649.
- Reduced cost estimate of loaded control printed circuit board by $3,000. Anticipate cost at less than $1,000 versus $4,400.
- Savings likely to be possible when purchasing off the shelf items in quantities of 20 are not included in this review.

Based on the above method of estimation, the direct costs to make each machine may be in the vicinity of $60,000.

Invetech understands the MAR estimate for the same output is $72,550. This is derived from MAR's indicated a cost of $82,450 per machine including $9,900 allocated for refurbishment and warranty ($82,450 - $9,900 = $72,550).

Another indicative ballpark cost estimate for the same work and exclusions as noted above, based on Invetech's cost structure for replication work, is in the vicinity of $67,000.

Based on the above analysis, and depending on the level of out sourcing, cost of parts and cost structures, the direct costs per machine for a first batch of 20 machines, excluding refurbishment, warranty, indirect costs and other items noted above, may be in the range of **$50,000 to $75,000**. Final machine features could affect these estimates.

These estimates should not be confused with potential customer buying price as they do not include any indirect costs.

Invetech's indicative estimates should not be used as a basis for making business or commercial decisions. MAR is the only organisation currently in a position to provide thorough cost estimates for the Bladestop project.

4.8 Liability Issues

An organisation manufacturing and or selling the Bladestop system will need to understand any potential legal liability issues. The key driver in this area is selling a piece of equipment that can pose serious hazards to personnel. Whilst this is not the only piece of industrial equipment in this situation, significant attention in this area is advised.

Invetech believes a key issue is largely centred on what is the ‘lowest practicable level of risk reduction’ that can be achieved in relation to bandsaw hazards.

In general anyone manufacturing or altering a piece of industrial equipment becomes responsible for performing their own hazard identification and risk categorisation and ensuring the equipment is as safe as is practicable.

One method of Hazard Identification and Risk Assessment as per AS4024.1-2006 Safety of Machinery, and based on the anecdotal injury information mentioned by MLA and MAR would indicate bandsaws should ideally be treated as requiring Category 3 or 4 control systems. AS4024.1-2006 provides guidance when a specific standard does not apply to a machine. AS4024.1201-2006, section 6 – Strategy For Risk Reduction and 6.5 - Achievement Of Risk Reduction Objectives and in particular 6.5(c) “Have hazards been eliminated or risks from hazards been reduced to the lowest **practicable** level?” is of importance with respect to Bladestop. Care should be taken to ensure relevant standards are understood and not just limited parts. For bandsaws, relying on past procedures and precedence’s may not be an acceptable approach. MAR appear aware of these issues and the hierarchy approach to hazard minimisation and safety.

MAR has generated extensive risk and issue analysis documentation during the project. It would be wise to ensure the relevant versions of these documents are reviewed and updated as required.

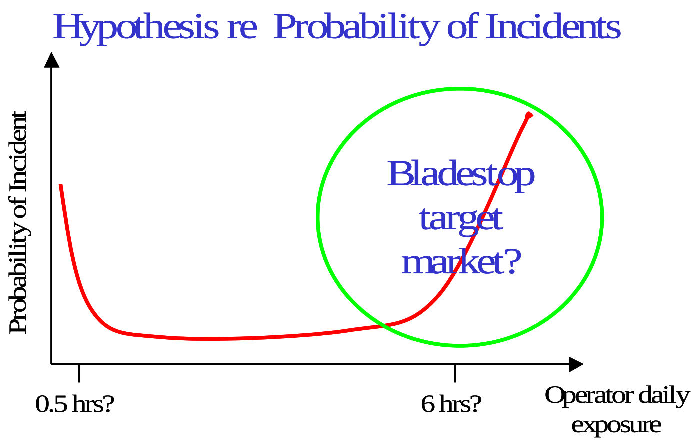
The User Requirements Specification should define a need to comply with and demonstrate compliance with relevant standards.

This report does not specifically address standards compliance issues.

5 Impact on Meat Processing Industry

A Bladestop type of device that achieves defined performance requirements at an acceptable price to the market has the potential to provide significant benefits to the meat processing industry. The challenge may be finding an appropriate balance between safety, functionality, ease of use and cost.

Key to the commercial viability is market data on injuries, cost of injuries and acceptable purchase price. With no data to go on, the hypothesis below is offered as to how the probability of an incident may be related to operator daily use of a bandsaw. It proposes that very little use and extensive daily use may have a higher incident rates than medium use per day.



If this hypothesis is correct, the return on investment (ROI) for meat processing factories may make the decision to purchase Bladestop more feasible.

The approach to date appears to have been a technology driven push to find a solution; now there is a need for market research to understand the needs of the industry. How many sectors exist from an incident perspective, how many machines and users in each sector, what features and costs do those sectors need and what may be possible to address those sectors?

Raising the awareness of the market about injury statistics and gaining acknowledgment of the total cost to a business of different types of injuries may be an important part of the successful deployment of a suitable Bladestop device. The potential impact on insurance premiums may be another benefit of Bladestop.

Meat process workers, their families and the broader community stand to benefit from an appropriate Bladestop type of machine.

The cost of development for Bladestop is beyond the means of individual businesses. By MLA taking on the project, the cost is shared and all stand to share in the potential benefits.

6 Recommended Next Steps

Invetech's key recommendations to assist plan a way forward are listed below. Additional information about these recommendations is provided in the body of this report.

- Undertake market research to understand the needs of the industry. Determine how many sectors exist from an incident perspective, how many machines and users in each sector, number and type of injuries in each sector, cost of injuries, what features and costs do those sectors need.
- Define the requirements for the system. (User Requirements Specification).
- Review and develop cost estimates for a set quantity of replication machines showing the cost structure and all contributing costs, and amortisation assumptions.
- Ensure there is adequate performance data on blade stopping time, distance and cut depth to demonstrate requirements are consistently achieved under workshop and production conditions. A test rig may be warranted to enable consistent testing.
- Evaluate if the system meets requirements.
- Explore if collaboration with SawStop can lead to a more cost effective solution that could be integrated with the Bladestop electronic detection system.
- Review Bladestop system:
  - Level of mechanical shock the system experiences.
  - Brake design. Can bouncing be reduced and performance improved?
  - Use of single trigger coil, time interval between and level of its testing.
  - Potential hazards to personnel when covers opened.
  - Basic bandsaw motor safety circuit.
  - Consider gloves with conductive middle or inner layer to reduce response time.
- Review if improvements or changes are warranted.
- Explore if a SawStop type consumable cartridge concept could be economically retrofitted to a range of bandsaws.
- Plan the way forward.

Other items are mentioned in the main table in this document.