Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Study on Offal Sortation and Transportation Systems

2021-1278 Study on Offal Sortation and Transportation Systems

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AMPC and NIRAS acknowledges the Traditional Owners of the land on which we work and settle on. We pay our respects to Indigenous Elders of the past, present and emerging and extend the respect to all Aboriginal and Torres Strait Islanders people.

Contents

1.0 Executive Summary

Current practices of offal handling within the red meat industry in Australia, vary in technology and methodology from site to site whereas other sectors of the red meat processing, such as carcass deboning and carton handling, have the benefit of a variety of commercialised solutions.

NIRAS have at the request of the Australian Meat Processor Corporation (AMPC) conducted an investigation and research into the optimisation of offal sortation and transportation systems, through investigations and consultations with existing red meat processing sites. While the sample studies are limited, there are similarities that can be extrapolated from the investigated sites.

The dominant findings from the investigations of the sites include:

- Employment of one operator handling both red and green offal, with major risk of contamination of red offal;
- Restricted spatial availability to undertake sortation;
- Accessibility of offal chutes;
- Pacing of operators sorting of offal, and
- Staff shortages with retention time generally being < 3 months,

NIRAS evaluated the common issues based on these findings and formed outlined solutions. The most significant issues faced when formulating solutions are the restriction of space and limited return on Investment. Most sites investigated employed 1-2 individuals to sort offal. Labour savings and spaces are designed to just fit in the standard offal handling system, limiting more complex alternative solutions.

In conclusion NIRAS has prepared solutions with consideration of

- Footprint and spatial allowance for brownfield sites,
- Technical feasibility,
- Labour and capital savings,
- Existing practices,
- Reliance of other solutions, and
- Requirement for rework on existing systems for brownfield sites.

These solutions, while they can operate independently, can be used in conjunction to complement each other, these include:

- Changing the method of handling condemned and healthy offal, and
- Separating the offal into 2 separate lines being red and green offal.

While these solutions only require relatively simple additions and changes, the benefits that accrue are justifiable with the potential savings and restrictions, benefitting the red meat industry with using a cost-effective overhaul of the current system. In further pursuit of this study, the testing of the recommended solution can be carried out by conducting trials within a selected red meat brownfield site with existing installation of the current standard offal handling system and compare the operating costs and technical benefits of both.

2.0 Introduction

The offal sortation and transportation systems of most red meat facilities have remained unchanged for the majority of the time since the introduction of the viscera conveying systems, commonly seen in most red meat facilities in Australia. This traditional transportation system carries both red and green offal in a single line of conveyor, both of which are segmented into their own batches to minimize cross-contamination, where operators are required to manually pick and sort each offal part and place them into appropriate chutes.

Given the numerous types of offal to be sorted and the desire for sites to increase their throughputs, this system can manifest as a bottleneck to a site's growth.

The focus of the Study on Offal Sortation and Transportation Systems has been undertaken to determine methods to replace or improve on the current offal sortation procedures and alleviate the common issues faced by the red meat industry by exploring technical and methodical solutions with account for the challenges and restrictions of its implementation with the current nature of the offal handling process.

The project is divided into 5 different sets of tasks. These are:

1. Conduct initial research to provide more insights on commercialised, documented, or experimental solutions;
2. Conduct physical site studies of two red meat sites to gather data and understand common issues faced within the industry;
3. Evaluate findings found in site investigations;
4. Formulate potential solutions that can be adapted within the industry to improve on current practices, and
5. Evaluate solutions and provide recommendations based on assessments.

Upon completion of these assessment, appropriate solutions have be identified according to current economic and technological limitations, and future opportunities of developing and implementing.

3.0 Project Objectives

The objectives of the Study of Offal Sortation and Transportation Systems project are:

- Educate AMPC, processors, and providers of possible use-cases of findings and concepts applicable for offal sortation and transportation.
- Ascertain the readiness level of the red meat industry to adopt and leverage solutions.
- Document possible solution use cases that can be applied readily or require further specialised study on to be implemented effectively in the future.
- Develop concept solutions for the industry.

4.0 Methodology

4.1 Stage 1 – Initial Research

During the initial research conducted in investigating existing applications of offal sortation, most practices were found to consist of manual operations of sorting offal into viscera conveyors. There was little conception or discussion in regard to automation of this process and the studies that were found were conceptual and experimental, suggesting the immaturity of the technology and its application. Due to the limited availability of resources, this resulted in:

- Limited variety of solutions that can be implemented within the Australian red meat industry, and
- Limited proof of feasibility of proposed technology.

Despite the barriers, further investigations were conducted to assess the feasibility of some of the experimental solutions.

4.2 Stage 2 – Site Studies and Data Gathering

Red meat processing sites were approached and interviewed to gather initial data and initiate discussions and feedback with site owners and managers.

In this step, RFIs were exchanged to understand the level of operations, issues, and throughputs.. Important to keep note of other unrecorded issues during on-site investigations.

On-site investigations were conducted to capture and validate the information provided while also revealing some apparent biases present in the information provided by site participants. The offal handling area was inspected, taking into account of the equipment, labour workflow, and recording any deviations from the standard method of offal handling.

While there were some impacts due to COVID-19 and restrictions, some on-site investigations were still possible.

Due to the limited sample sites, it would be normally difficult to foresee similarities for other sites. Additional sites were interviewed to ascertain their issues and concerns. No physical inspection was made of these supplemental sites.

Data recorded was primarily qualitative as practices on the sites tend to not be quantifiable and purely descriptive, such as issues of operations, health, safety, and quality concerns.

4.3 Data Evaluation

The data collected, while qualitative, can have a degree of measurability that can be used to determine the frequency and level of impact. This can be used to gauge the severity of issues found in workplaces (Refer to Appendix 2).

The severity of issues are determined by 4 aspects. These are:

- Operational concerns;
- Safety concerns;
- Product quality concerns, and
- Commonality of issue.

4.4 Formulation of Solutions

With limited data on the initial investigations into current practices, experimental, and concepted solutions for offal sortation and transportation, an initial solution was to assess the implementation of a vision grading system and automated offal sortation system. Prior to the start of this project, AMPC had already conducted an experimental project on offal grading through a visual system with AgResearch Ltd. to determine its feasibility (AgResearch Ltd., 2018). The project concluded with a high level of feasibility purely within the scope of vision grading of vulnerable surfaces, but with some issues that required addressing.

Given the limitations of the vision system with identifying covered surfaces, particularly the underside of the offal, a method to allow the vision system to inspect the opposite side of the offal would be required. An active and a passive inversion method were considered, with each having their respective positive and negative aspects.

While the solutions above alleviate workload required for manual grading, offal products would still be required to be sorted. A robot sortation system that could handle each specific offal was considered, however, due to the complexity and lack of available space on all current viscera tables, this would require significant research and development and experimentation programs before it can be feasibly utilised under a commercial setting. Currently, available literature for robotic offal handling is limited to conceptual studies only (Stommel, et al., 2014).

As the system to automate offal of this level is currently in its conceptual and experimental phase, viable alternatives have been considered, particularly one with simplistic approach that does not require significant capital investment.

NIRAS have undertaken further research globally, including a current site in Scandinavia which has implemented a vacuum transfer system.

Other options that do not involve in a complete overhaul of the offal handling process were also considered.

Upon inspecting the current practices for beef and small stock sites for offal handling, viscera conveying tables are commonly used with little-to-no variation of the practice. The common practices with utilising the viscera conveyors are:

1. Transporting both red and green offal on a conveyor, and
2. Discarding rejected offal at the end of the conveyor.

NIRAS had identified these points with the possibility of implementing alternative procedures that can alleviate workloads. These are:

1. Separate product line for red and green offal, and
2. Inverting the handling process of rejected and acceptable offal.

4.5 Evaluation of Solutions

Solutions are evaluated based on 2 major grading systems and 1 conclusive grading evaluation. These are based on:

- Solution Effectivity,
- Solution Feasibility, and
- Solution Grading Evaluation.

In addition to this, there are 2 major factors of variation in grading the solutions, producing 4 different scenarios. This can be viewed as:

	Standalone Solutions	Consolidated Solutions
Greenfield Site	Scenario Green-Standalone	Scenario Green-Consolidated
Brownfield Site	Scenario Brown-Standalone	Scenario Brown-Consolidated

4.5.1 Solution Effectivity

The schedule of issues was used to grade the potential solutions to determine commonality of issues that a solution may address. These provide a measurable value to understand the effectivity of a solution. Adding to this, the issue is valued by the 4 aspects as discussed in 4.3 Data Evaluation. The calculation of the solution's effectivity value can be found in Appendix 2 and 3.

4.5.2 Solution Feasibility

Solution Feasibility gauges a number of different factors. These include:

- Spatial feasibility – How much space is required and if the space taken would intrude an operator's personal space.
- Technical feasibility and complexity – Technical challenges in implementing concepts contrasted with the efficacy of the results.
- Labour elimination or relief – Measure of if any labour is eliminated or reduction in workload.
- Rework or replacement on current system – Gauges the work required to replace existing systems of a typical brownfield plant.
- Capital cost – How much capital investment required to implement the solution.
- Existing practices – Coverage of information of whether the solution has been commercialised or tested,
- Reliance on other solutions.

Each factor is allocated with capped (maximum) points, depending on its impact of decision. These are allocated as seen in Table 9.5.1 in Appendix 5.

4.5.3 Scenario Variability

The assessments are affected by factors of:

- Whether the solutions are intended for a greenfield or brownfield site, and
- If the solutions can be seen as individual, somewhat independent solutions that can be used to complement the other solutions or viewed as a collection of solutions working as a complete system.

Greenfield vs Brownfield Site

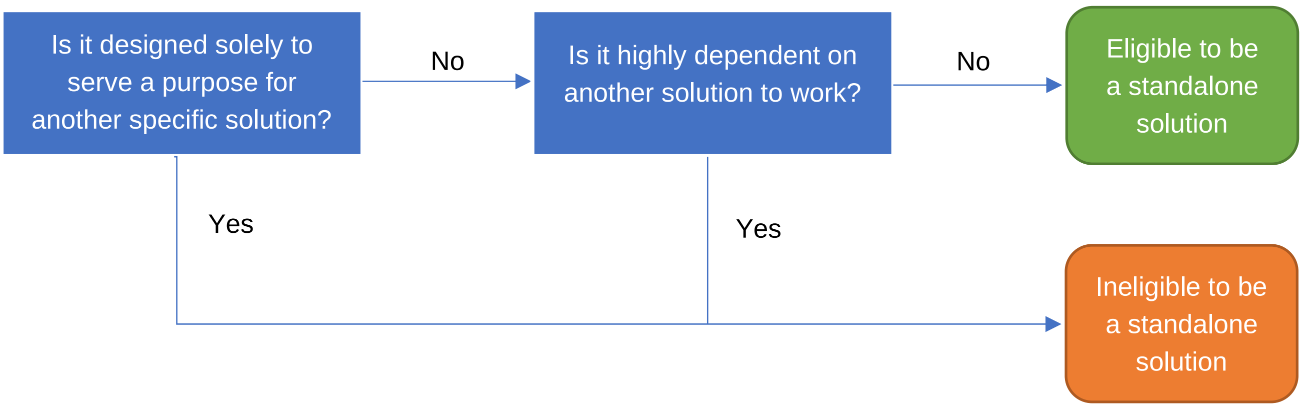
Differences in the scenario between a greenfield and brownfield site:

Differences	Greenfield Site	Brownfield Site
Issue Lack of Space	While space saving and efficiency is always encourage, it is not as crucial of an issue as a brownfield site and space utilisation can always be adjusted in the planning and design phase.	Plays a definitive factor whether a solution can fit in the working area. Would the solution promote spatial savings, better working space, or fit within the area?
Issue Accessibility of Offal Chutes/Collection Point	Offal chute points are not fixed and can be adjusted in the planning and design phase.	Offal chutes of existing sites are fixed and will require funding to modify the access points.
Feasibility Factor Spatial Feasibility	Appropriate space utilisation is always encouraged, but not an area of major concerns as layout can always be amended.	Assesses if the solution can fit in well with the limitations of the allocated space.
Feasibility Factor Rework/Replacement on Current System	No existing equipment to deal with.	Brownfield sites with offal facilities have fully equipped systems to handle offal. Replacement of this system must be taken into consideration.

Standalone vs Consolidated Solution

Standalone solutions can be described as semi-independent solutions and can be used under multiple applications to support/improve on the weaknesses of other solutions. Standalone solutions can also be considered as a consolidated solution due to their independency.

Differences in the scenario between a standalone and consolidated solution:



5.0 Project Outcomes

5.1 Observations and Grading of Issues

Through the summation and evaluation of data collected from the sites, NIRAS was able to draw some similarities of results that may imply industry-level concerns and those that may seem site-specific but may also imply that other sites may share, based on external observations with NIRAS clients' outside the body of this study.

The sites studied commonly:

- Agreed that there is a lack of space for workers and the offal sortation system;
- Have staff shortages and short staff retention time (generally within 3 months);
- Do not experience significant loss of time as conveyor runs regardless of manning availability to a reject chute;
- Reduce the level of offal collection if staff shortages occur,
- Near-identical workflow and level of technology despite having differences in level of automation for other processes;
- Frequent staff rotations (1 hour per rotation), and
- Have about 5-10% of offal rejected.

Other issues that are not commonly shared but are additional causes of concern include:

- Strain injuries from repetitive manual handling;
- Same worker handling both red and green offal; potentially contaminating red offal products,
- Access to offal chutes are not within comfortable reach for operators, requiring them to twist, rotate and "throw" products, and
- Pacing issues with the speed of products, especially with plants seeking to increase their carcass throughput rate.

By weighing the grade of issues using an assessment criteria (as discussed in 4.3 Data Evaluation), the evaluation resulted in:

AMPC Best Practice Guide - Schedule of Issues for Brownfield Sites							
Issue							
Details		Relevancy of Concerns				Commonality and Severity	
Priority	Issue	Operational Concern Value	Safety Concern Value	Product Quality Concern Value	Number of sites with issue	Priority Value	Severity Rank
1	Heavy product handling	4	6	2	1	12	High
2	Staff shortage/retention	6	0	0	2	9	High
3	Lack of space	3	3	0	2	9	High
4	Accessibility of Offal Chutes/Collection Point	4	2	3	1	9	High
5	Handling of Both Red & Green Offal	0	0	4	1	4	High
6	High-pace of handling	3	3	0	1	6	Medium
7	Overlap of offal during handling	0	0	3	2	4.5	Medium
8	Frequent staff rotation	3	0	0	2	4.5	Medium

Table 1 Schedule of issues to evaluate the severity of factors of concern.

The main concerns of the assessment being:

1. Occupational health and safety with frequent handling heavy products;
2. Staff shortages and short staff retention;
3. Lack of space;
4. Accessibility of offal collection points, and
5. Cross contamination concerns with operators handling both red and green offal.

5.2 Solutions

Through the period of the project from the identification of concepts and observation of operations, NIRAS has considered the following solutions:

- **Hook-chain red offal conveying** – Instead of placing red offal on conveyor pans, the offal is suspended on an overhead hook to allow for workers to inspect off the offal and the offal to be dropped from the chain into a chute removing the need to carry them over to chutes, this could be implemented without the need to alter or remove the existing offal conveyor pans to accommodate for the hook system;

- **Alternative reject handling** – The current practice of handling acceptable and rejected offal is that acceptable offal is manually selected and physically directed into chutes whereas rejected offal is kept on the conveyor and automatically deposited to a reject chute. Reject offal accounts for 5-10% of the total processed offal. If this handling process was reversed, the need for specialized manning of offal sortation can be removed and can therefore be undertaken by a single inspector;
- **Vision systems for offal detection** – Allows differentiation between offal types and defects. While this may open the door for automation specifically on offal inspection, the current technology challenges include the ability to thoroughly inspect the offal parts and the false-positives associated with vision scanning;
- **Offal Inverting: U-bend chute** – This would normally be used in conjunction with solutions involving inspection, such as the vision systems. Instead of manually inverting the offal for inspection, the offal can be inserted into a u-bend and allow the momentum to invert the offal, however, this would require the u-bend chut to be washed subsequently;
- **Offal-Inverting: Mechanical Pan Rotator** – Similar to the point above, offal on pan can be rotated with enclosures to invert the offal, however, this would require double the washing, which may double its utility costs;
- **Vacuum transfer suction tube** – Hose-like tubes can be handled and directed by workers to be automatically collected without the need for workers to manually handle and carry offal;
- **Robotic offal handling** – Robotic intervention may eliminate the need for workers and allow the automation of offal collection through methods such as pick & place, vacuum transfer.. This can also be explored further as a separation system for offal.
- **Automated Chute Sorting System –** Chute system with 2 channels and a motorized mechanism that diverts products to specific channels. This can be used to separate red and green offal into 2 separate channels in a single entry point.
- **Passive Chute Sorting System –** Similar in principle to the automated chute sorting system with different mechanism. Chute system with 2 channels and a passive mechanism that diverts products to specific channels using the product's own weight. This can be used to separate red and green offal into 2 separate channels in a single entry point.

5.3 Solution Grading Results

Each solution is first graded on 2 different assessments:

- The number of issues, each with its severity values based on the priority value in Table 2, that it can achieve to solve, and
- The feasibility of each solution.

Results from both assessments are consolidated into one to quantify the grading.

The bulk of the solution discussion will go in details with the scenario of brownfield site as most data are derived from investigating brownfield sites. Discussions between standalone and consolidated solutions may intertwine in this bulk depending on the context.

The differences between the results of the scenarios of brownfield vs greenfield sites and standalone vs consolidated solutions are discussed separately to evaluate the significance and similarities.

5.3.1 Solution Feasibility Results

The feasibility assessment of the solutions (as discussed in 4.5.2 Solution Feasibility) resulted in:

AMPC Best Practice Guide - Solution Feasibility and Evaluation for Brownfield Sites											
Solution Details				Feasibility Factors							
Priority	Solution Heading	Issue	Description	Spatial Feasibility	Technical Feasibility & Complexity	Labour Elimination	Rework or Replacement on Current System	Capital Cost	Existing Practices	Reliance on Other Solutions	Feasibility Value
1	Revamped Offal Handling	Alternate Reject Handling	Inversion of handling of reject and acceptable offal. As 5-10% of offal are normally rejected, this can be handled manually, substantially reducing the amount of work needed.	4	4	4	3	4	2	2	23
2	Revamped Offal Handling	Hook-Chain Red Offal Conveying	Red offal pluck are hanged onto hook-chain conveyors to separate handling with green offal.	3	3	4	4	3	3	2	22
3	Chute System	Automated Chute Sorting System	Chute system with 2 channels and a mechanism that diverts products to specific channels. This can be used to separate rejected and healthy offal into 2 separate channels in a single entry point.	4	3	3	3	3	0	1	17
4	Chute System	Passive Chute Sorting System	Similar in principle to the automated chute sorting system with different mechanism and limited use. Chute system with 2 channels and a passive mechanism that diverts products to specific channels using the product's own weight. This can be used to separate red and green offal into 2 separate channels in a single entry point.	4	3	3	3	3	0	1	17
5	Vacuum Transfer	Vacuum Transfer Suction Tube	Hose-like tubes can be handled and directed by workers to be automatically collected without the need for workers to manually handle and carry offal.	2	3	2	1	2	2	2	14
6	Vision Robotic Automation	Vision System - Camera	Used to automatically inspect for diseases, and offal identification.	2	1	4	2	2	1	1	13
7	Vision Robotic Automation	Offal Inverting - U-Bend	Used in conjunction with vision system. Offal on pans are sent via a u-bend chute to flip the offal to allow the vision system to scan the opposite.	1	2	4	1	2	0	0	10
8	Vision Robotic Automation	Offal-Inverting - Mechanical Pan Rotator	Used in conjunction with vision system. Offal are placed on pans that can rotate in order to flip the offal to allow the vision system to scan the opposite side.	1	1	4	2	1	0	0	9
9	Vision Robotic Automation	Robotic Offal Handling	Used in conjunction with vision system. Ability to automatically pick and place offal parts into chutes.	1	1	4	1	0	0.5	0	7.5

Table 3 Assessment of solutions tabulated against several feasibility factors.

The four highest rated solutions are:

- Alternate reject handling
- Hook-chain red offal conveying
- Automated chute-sorting system
- Passive chute-sorting system

Other solutions faired around half the points of each of the two highest points, with the lowest being the robotic offal handling.

5.3.2 Solution-Issue Effectivity Results

An assessment of issue coverage and weighing (as discussed in 4.5.1 Solution Effectivity) resulted in 4 separate scenarios within the context of brownfield vs greenfield sites and standalone vs consolidated solutions.

The common themes for these solutions are:

- Alternative reject handling, hook-chain red offal conveying, and automated and passive chute sorting system with the highest ranking values with respect to greenfield and brownfield sites.

- Revamped offal handling (consisting of both alternate reject handling and hook-chain red offal conveying) is regarded as better options for both greenfield and brownfield scenario.

5.3.3 Scenario Variations

Resulting favourability of each solutions (As seen in Appendix 3 and 5) are roughly similar for the 4 cases. It can be seen than the grading for the revamped offal handling solutions remain mostly unchanged for greenfield and brownfield sites due to them having relatively high factors for with factors of footprint and equipment replacement.

It is also seen for vision robotic automation solutions that the scoring faired better in greenfield than in brownfield sites due to the lower grading for footprint and equipment replacement, but still faired poorly on the grading, which is highly contributed to the required capital investment, technical complexity, R&D/commercialisation status, handling of red and green offal types, and rate and load of products.

5.4 Budget Costings

Costings will vary with the evolvement of technology and volatility of material and component pricing. Detailed design will need to be conducted with manufacturers for appropriate costings.

	Approximate Costing	Details of Inclusions	Exclusions
Vision System Automation RGB & HIS Camera X-Ray Grader Robotic System	780,000 to 900,000 AUD	• 1 set of RGB camera • 1 set of NIR HIS camera • 1 set of x-ray scanning system • 1 set of robotic grader • 1 set of light and housing box • Software license deployment	• **Offal inverter** • Programming • Conveyor rework • Installation & commissioning

Revamped Offal Handling
Red Offal Hook Chain Conveyor
Alternate Reject Handling
	75,000 to 100,000 AUD (Brownfield and Greenfield)	• Chain conveyor and offal hooks
		  ◦ Est. 5,000 AUD/m
		  ◦ Est. 10 to 15m typical length
		• Material cost
		• Rework on offal chute (Brownfield)
		• Installation (Greenfield)
			• Automation potential
			• Hook washing

Automatic Chute Sorting System	17,500 AUD	• Material cost • Motor • Fabrication cost • Electrical works	• Fabrication design • Switching mechanism • Installation & commissioning
Passive Chute Sorting System	10,000 AUD	• Material cost • Fabrication cost	• Fabrication design • Installation & commissioning

6.0 Discussion

6.1 Priority of Issues

As described, the four most prioritised issue are evaluated to be:

1. Occupational health and safety with frequent handling heavy products;
2. Staff shortages and short staff retention;
3. Lack of space;
4. Accessibility of offal collection points;
5. Cross contamination concerns with operators handling both red and green offal.

Occupational Health and Safety

Operators are seen handling heavy offal parts (such as paunch) that may pose potential strain injuries, especially when handled at high rates. By reducing the frequency of lifting and/or alleviating the need to handle heavy offal parts, risk of injuries can be minimized.

Staff Shortages

Staff shortages have been an ongoing issue within the red meat industry, and with the current implications of COVID-19, is constraining operations to an even greater extent. Regional sites, particularly those with smaller population density, are affected the most. Several sites, including those outside of the sample pool, strongly expressed the difficulty in resourcing for labour. While there are government initiatives that have been set to alleviate this issue, such as the Pacific Labour Scheme, there are underlying expenses and responsibilities associated, which may lead to higher operational costs and a solution that is not sustainable long term.

Lack of Space

While issues with lack of space may not necessarily affect current operations on a high-level basis, it can have implications on future plans and operators' performance and comfort in the long term.

Future plans for expansion and increased production will require improvements for facilities, which will prompt necessary equipment, research, and/or manpower to cope. Smaller sites suffer from the need to "squeeze" operations to fit minimum footprint and the allocated space for offal handling is of no exception. This creates huge challenges to adding additional equipment, especially those that would result in a design overhaul of the operation.

Smaller sites have confined transverse spaces and work area for operators. An observed site was seen collecting gall bladders into bucket containers, which further restricts workable area. Some sites only allocate working areas barely adequate for 2-persons, creating a claustrophobic environment to work in and can create safety issues, especially around operators cutting offal plucks with knives.

Spatial feasibility will be one of the main critical factors for implementing solutions.

Accessibility of Offal Collection Points

An operator was observed to work in a restrictive working area when sorting for offal. The operator was positioned inconveniently where some offal chutes were outside their comfortable reaches. Due to the distance between a specific chute and the operator, this resulted in the operator needing to throw the product at a distance to keep up with the pacing of the offal line. On rare occasions, products could be stuck when thrown or fall on the floor. This can impact the product quality, operational performance, and operator's safety.

Due to the limited sample sites, the level of frequency of this issue happening in small to medium plants cannot be accurately gauged and will need further investigation.

Handling of Both Red and Green Offal

An operator was observed to have handled both red and green offal without any sanitisation practices in between each batch of handling. While the viscera conveyor offers separation between the two offal groups, the method of handling negates the hygienic purpose of the separation.

This incorrect double handling of offal may be due in part to:

- Inadequate working area to occupy 2 operators, and
- Slow rate of production to justify employing 2 operators handling similar tasks.

Further investigation will be needed to address the commonality of this practice.

6.2 Operational Culture

Common Technology and Operations

One of the common points observed on sites are the similar technology and workflow used (as seen in Appendix 1). The methodology of offal handling for lamb and beef abattoirs share similar concept and technology. This is normally done by:

- Removing green and red offal plucks from carcass and placing them in designated pans of a conveyor,
- Cutting and trimming acceptable offal plucks into individual offal parts,
- Inspecting for offal defects and mark condemned offal,
- Picking and placing every specific offal part into a designated chute, and
- Rejected offal left on conveyor to be delivered to a reject chute.

Whereas in the pork industry, green and red offal are separated into 2 different conveyors. Green offal are left on conveyor pans whereas red offal are hung on hooks.

This near-identical process can be due to manufacturers adapting the same concept as a standard form to transport offal. As manufacturers tend to be the "market leaders" for specific technologies, most clients can become heavily reliant on just a select few manufacturers to be safe with their choices. Due to this standardisation, it has become a commonplace for most red meat sites, particularly for beef and sheep abattoirs, as it is the “default recommended” method.

The standard practice for offal handling would require a change in philosophy of operations. There are things that can be handled differently, such as direct handling of rejects. Instead of operators handling 90-95% of healthy offal, operators should instead handle the 5-10% of rejected offal, significantly lowering the workload.

Assessment of Industry Readiness

Many site owners looking to improve operations primarily focus on their primary processing capacity, with finished goods handling capacity being their second focus. Processes improvements for by-product are not normally held within the same regard of importance as the former operations due to profitability of types of products per kg vs the investment required. In retrospect, bottlenecks in all operations must be considered as this will also help to remediate logistical complications for the whole operation.

Common Technology and Operations discusses about the normalisation and lack of evolvement of offal handling systems. Most sites maintain the same level of technology. When the topic regarding improvements of offal handling is brought up, site managers and owners agree with the notion, despite the lack of discussion within the field of by-products processing.

The main barrier of industry readiness would primarily be the capability of improvements within brownfield sites, especially when considering major overhaul of operations. Taking into account of the perspective of site owners, the biggest barriers are the cost of the solutions and its return of investment. This will progressively be less of a concern as technology improve and cost lessens, making the technology financially accessible for more plants to acquire.

Moving forward, consideration for by-products process lines must be accounted for and options should be established.

Specialisation and Technological/Methodical Awareness

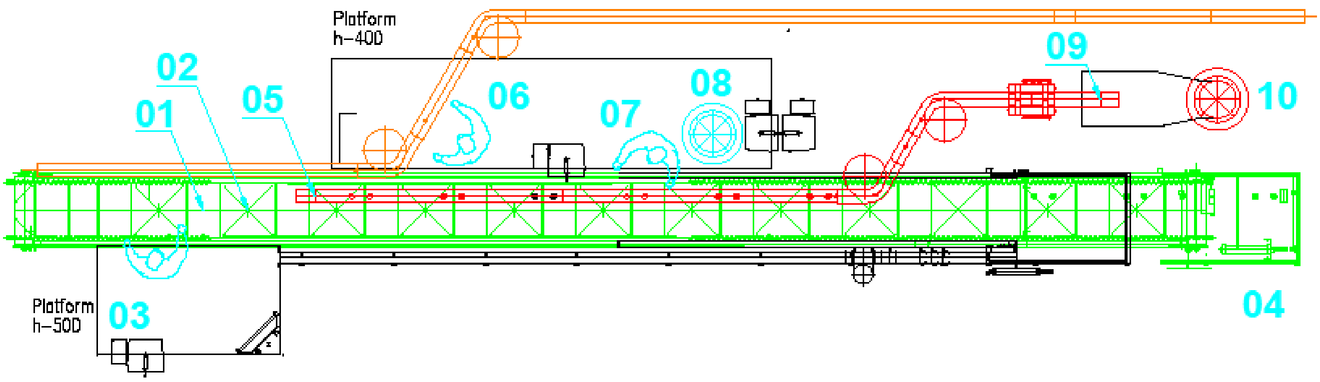
Differences of expertise and technologies of specific industry also play a key-role in adaptability of sites. Most of the site managers that NIRAS had discussions with previously tend to work within their space of expertise. While this is inherently a good thing for specialisation, it can also be a barrier to knowledge outside of their space. A specific equipment that a typical pork abattoir use may not be commonly implemented, but possible for a lamb abattoir.

6.3 Solution

6.3.1 Preferred Solution

The evaluation of the solutions are largely in favour of the Alternative Reject Handling and Hook-Chain Red Offal Conveying with respect to be feasibility and effectivity. With simpler mechanical changes, it avoids the complexities derived from automation and can be adapted for small-to-medium sized plants.

Due to the higher feasibility ranking and the possibility of complementing the alternative reject handling and hook-chain red offal conveying together, NIRAS has conceptualised on the combination of these two solutions. The combined solution will require some level of overhaul of the current industry practices but does not require current equipment to be dismantled, but with the exception of rearranging and redirecting the flow of offal products.



LEGEND	
(green)	GREEN OFFAL LINE
(red)	RED OFFAL LINE
(orange)	CARCASS LINE

OFFAL SORTATION COMPONENTS	
ID	DESCRIPTION
01	Intestine Pan
02	Paunch Pan
03	Green Offal Removal
04	Green Offal Chute
05	180° Vertical Hook In
06	Red Offal Removal
07	Green & Red Offal Inspection and Rejection
08	Offal Reject Chute
09	180° Vertical Hook Out
10	Red Offal Chute

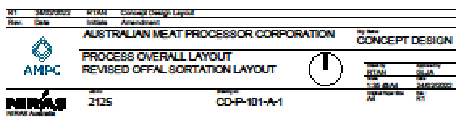


Figure 1 Layout concept of solutions involving alternative reject handling and hook-chain red offal conveying.

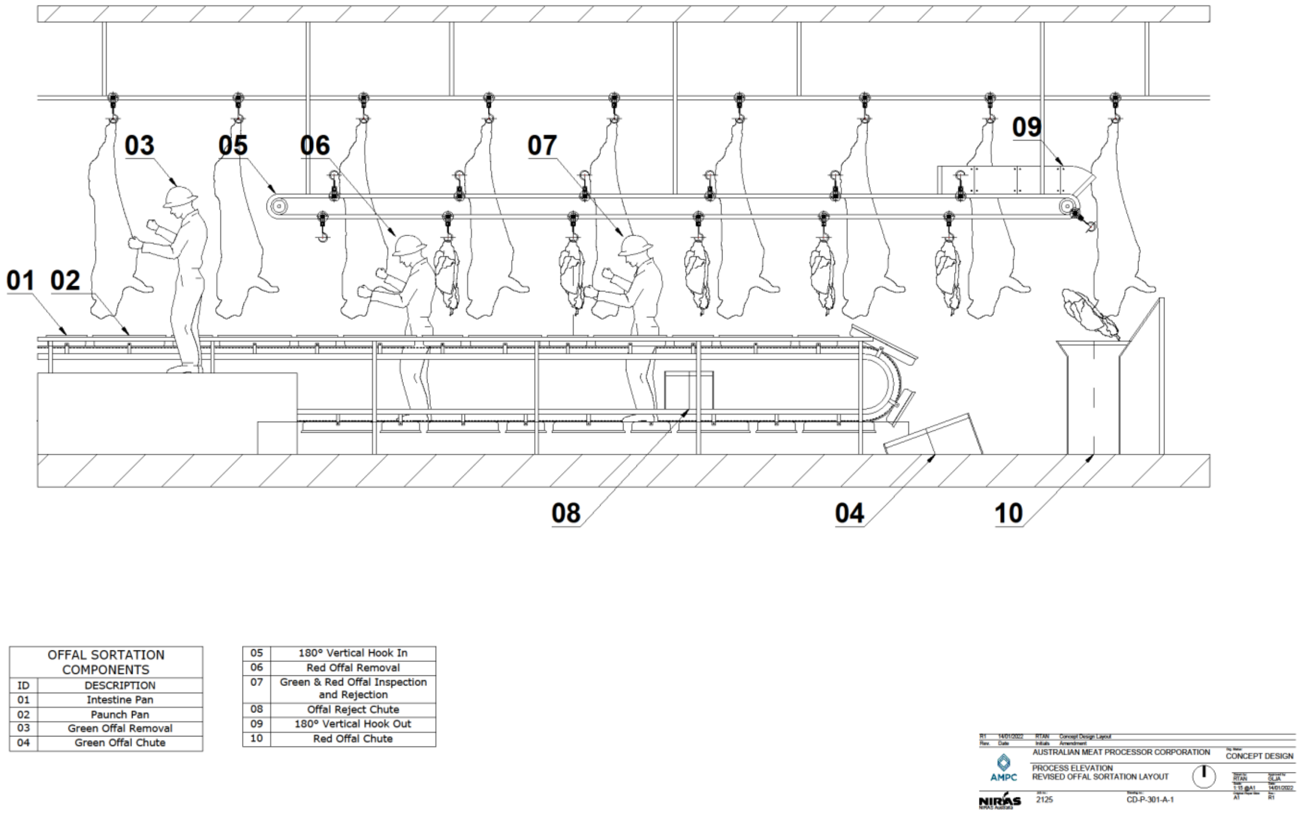


Figure 2 Side view of the solutions involving alternative reject handling and hook-chain red offal conveying.

The solution will separate both the red and green offal into 2 lines. The solution can utilise the industry's current offal conveying system with minor modifications. Green offal will be carried on the standard viscera conveyor whereas red offal plucks will be hanged on a hook-chain conveyor.

With the availability of the pan that would normally carry the red offal plucks, this can be utilised to separate intestines (01) and paunch (02). An operator would remove the green offal off a carcass and arrange them accordingly (03).

Healthy green offal will be transported to the end of the line instead of transporting condemned offal (04). Given that 5-10% of offal are rejected, there will be a substantial decrease in manual handling of condemned offal rather than healthy ones.

Red offal will remain within the carcass until an operator removes the red offal pluck and hang it on a separate hook-chain conveyor (06). An inspector will evaluate the red offal plucks for diseases (07). If the inspector identifies an offal pluck to be condemned, the inspector will manually take off the pluck and deposit it into a reject chute (08). Acceptable offal will be carried on until the end of the conveyor where the hook will rotate at the end (09) and drop the offal pluck into a chute (10).

There is a crucial design consideration to be taken when designing this concept, especially for the pan conveyors. As acceptable offal are deposited at the end of the conveyors, there will likely be leftover fluid and pieces of the rejected offal that is left when an operator removes them. Contaminated pans will discard the residue into the vicinity of the offal chute. One solution to counteract this issue is to install an automated lid that will close when a rejected pan approaches the chute.

6.3.2 Alternative Preferred Addons

These options can operate independently depending on the use-case and serve as great complement to existing and concepted systems.

6.3.2.1 Chute Sorting System

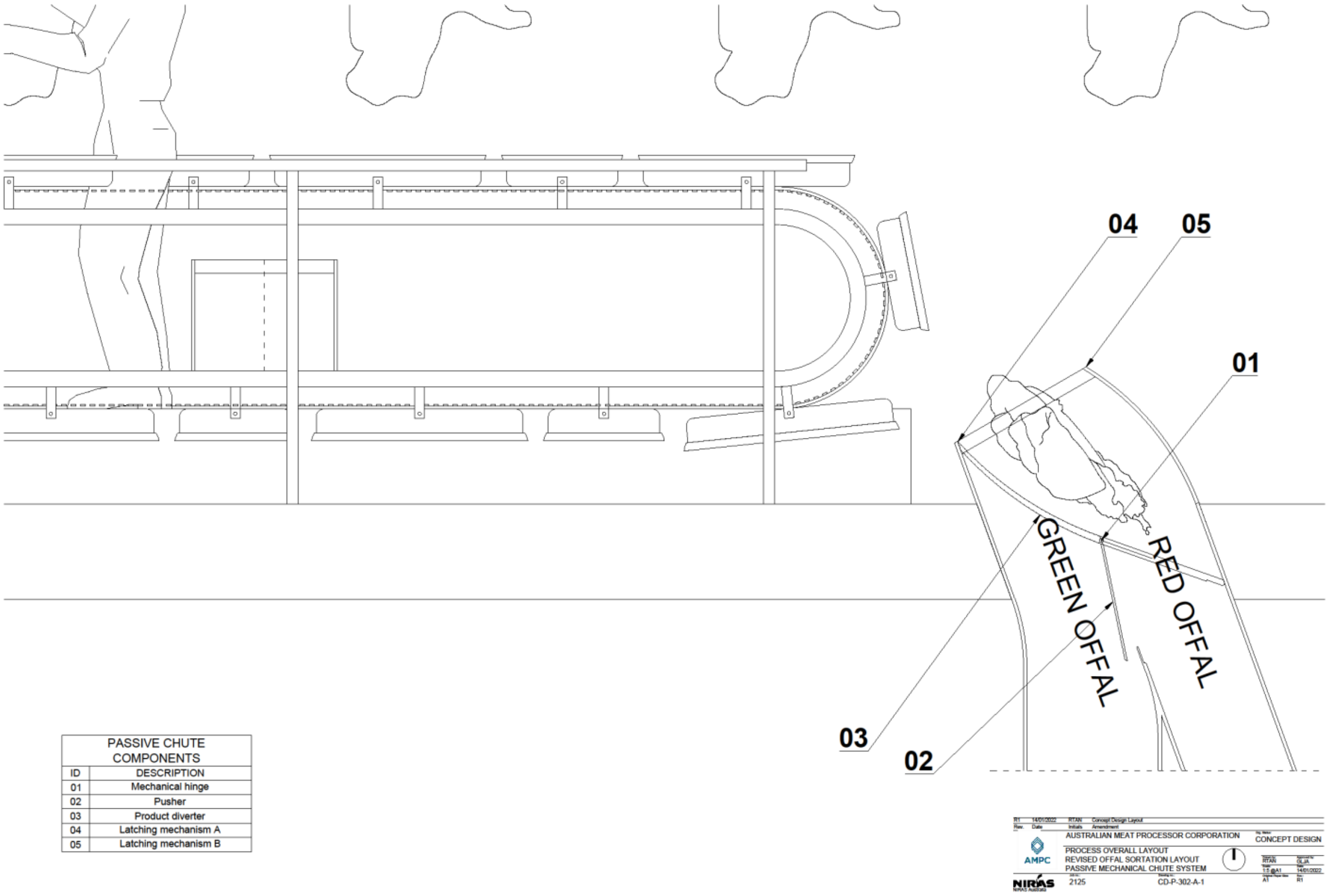


Figure 3 Concept for passive chute sortation system to handle diversion of red and green offal. State A.

The chute system share some similar aspects to the automated chute system but is operationally different and specific. As most offal conveyors alternate between red and green offal pans, the passive chute utilises this alternation to divert between channels. The system relies on the weight and force of impact of dropped offal to trigger the switch of the diverter. The chute operates in two states; red offal channel (State A) and green offal channel (State B).

State A - When the chute is in the state to take in red offal, the plate diverter (03) will lock itself in position A with the use of latching/locking mechanism (04). The mechanism should be strong enough to hold the weight of the diverter but weak enough to release when there is an opposite torque is acted on the hinge (01) caused by the weight of the offal. As the plate diverter is released, it will swing to the opposite side of the mouth of the chute and locks itself on a different latching mechanism, transitioning to State B.

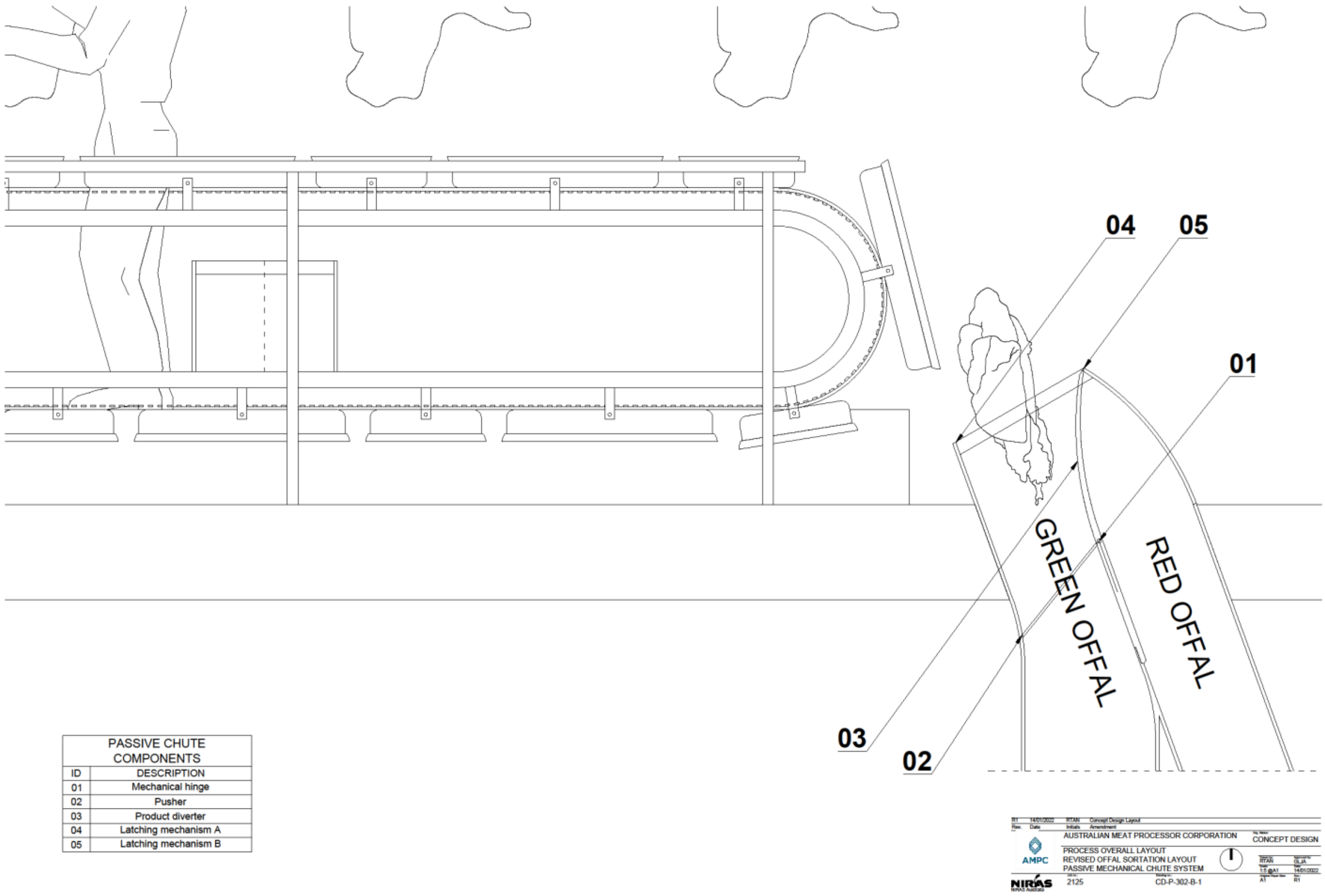


Figure 4 Concept for passive chute sortation system to handle diversion of red and green offal. State B.

State B - When the chute is in the state to take in green offal, there is a second plate specifically as a switching trigger for the green offal to push (02). The plate diverter (03) will lock itself in position B with the use of a similar latching/locking mechanism (05). Once a batch of green offal goes through the chute, it will push itself through the plate (02) and causes the plates to rotate back from (05) to (04), transitioning back to State A.

Given that the system heavily relies on the weight of the offal and the locking mechanisms, there must be design considerations to the wear and tear of the locking mechanisms. Dampers are highly recommended to minimize this effect.

An automated chute system with utilising motorized hinge to divert the products can also be used in this situation to provide better reliance with automation. This could be done in sync with the offal conveyor, or for better assurance, a laser/light detection system to determine when an offal had passed through.

A design consideration to this would be ensuring that surfaces between the two channels must not be shared across to avoid cross contamination. Each channel can have their respective walls to avoid this. Reject channel should be the lowest channel to ensure that any potential fluid that drip down will not end up into another channel.

6.3.3 Vision System Automation

The vision system has the potential of providing the benefits of complete automation and higher labour reduction at a commercial setting. However, this concept is still at its infancy. Currently, the vision system had undergone substantial progress with the research and development project conducted by AgResearch (2018). The trials have proven its with determining red offal types and diseases however, the testing is only limited to the capability of grading red offal on surface level. The vision system will require additional equipment to assist and make use of the vision system, such as a compact and effective mechanism that would allow visual captures of all sides of the offal and the use of robotic actuations to perform actions automatically.

Currently, designing an independent system around the vision system pose some challenges, especially with maximizing its automation potential with the current technology. Further trials and research will need to be conducted to take the system into a commercial scale.

6.3.3.1 Challenges

The challenges presented below are considerations to be undertaken where applicable when designing a vision system and its supplementary equipment.

General Challenges

Due to strict health and quality concerns with handling contaminated products in the red meat industry, the efficacy required to identify diseases is substantial and leaves minimal room for margin of error, especially at the rate of a typical medium-sized plant.

Currently, robotic and automation equipment generally have high capital investment. Costings are highly dependent on payload, complexity, and sensor requirements. However, findings have shown that the general cost for industrial robots has been in a progressive decline overtime and is expected to follow this trend in the future (ARK, 2019).

There are also challenges with the accompanying technologies that rely on or are required for an autonomous vision system.

Vision System

- A black-box room would be required to provide appropriate lighting for capturing the offal. While this is technically feasible and have been done with other products, it may require a considerable amount of space.
- Most plants predominantly use stainless-steel-built offal conveyors. Vision systems generally do not operate correctly when scanning tissues with steel in the background. The material of the conveyor pans will need to be adapted to polypropylene or similar.
- In other observed sites that NIRAS have been involved with (outside of the scope of this study) that utilises both vision and robotic handling systems, the vision detection system are dependent on controlled environment and parameters. For example, in a poultry plant that utilises delta robots to pack products into trays, products must not be too close to each other. Otherwise, the vision system will be unable to distinguish the products and treat them as rejects. In the scenario of offal handling, products are clustered together and may impose some challenges to perform. The study conducted by AgResearch (2018) has done a trial with classifiyingred offal according to the observed spectrum (without shape characteristics) with an efficacy of 81%. While this is high, commercial settings would require the efficacy to be a lot higher.

Offal Inversion Mechanism

- Irregular-shaped objects may be challenging to be completely flipped when considering the flatness of surfaces for each of the offal, thus may be challenging to guarantee its effectivity.
- Timing of inversion is constrained to the small pan (if offal conveyors are kept to the original design).
  - Given the short width of the small pan, the time the conveyor takes to lapse through the distance leaves a small window of time to operate
  - This is a factor that requires more consideration of the intended scanning system is to be placed on the inversion region
- Depending on the setup of the inversion system, 2 sets of vision system may be required; one pre-inversion and another post-inversion, unless the device allows the accommodation of a single set.
- The equipment will require washing as it is handling potentially diseased, unidentified offal.
- The system may consume twice to thrice the amount of utilities required for washing (washing protocols for the inversion equipment, and the offal conveyors before and after the equipment, unless an all-in-one system is considered)
- If a standalone inversion equipment is implemented:
  - Implementing this will require major modification to the current conveyor system to accommodate the equipment

Robotic Offal Handling

- Require an additional vision system to identify offal positions in real time
- Offal, being irregular-shaped and lubricous due to being covered with bodily fluid, can be challenging to grasp with robotic actuators.
- Depending on the type of robot chosen, there will be trade-offs in size, capital, picking rate, and payload. For most pick and place robots, picking rates are normally inversely proportional to payload. With the variation in weights and number of offal parts to be sorted per pan, multiple robots may be required to handle the amount of offal. Handling of heavier offal parts such as paunch would require alternative methodology.
- If larger robots are considered, guarding surrounding the robots would be required, which is a spatial consideration for smaller plants.

Total automation of vision system has the potential for commercial utilisation in the future as the technology becomes better and more trials are conducted. As of currently, there are other alternative methods to make use of it with the current feasibility.

6.3.3.2 Alternative Application

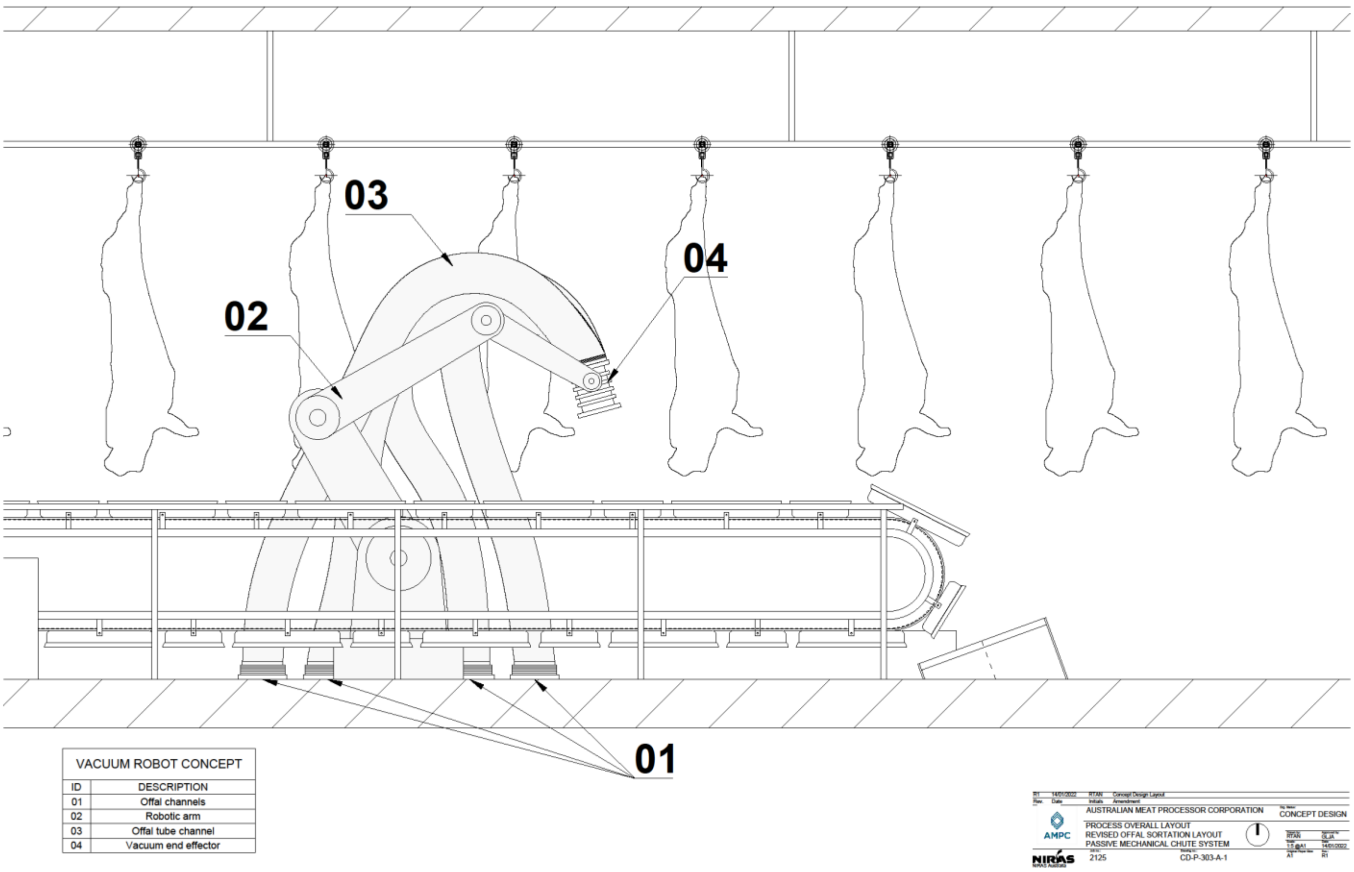
Simple Vision System

Alternatively, the vision detection process can be configured differently by tailoring it for simpler utility. It can be used as a supplemental tool for identifying of diseased offal with the aid of manual inspection. Inspectors can mark diseased offal with a dye of strong contrast of colour and have the vision system electronically mark and record it in a logistic system as instructions for other automated equipment.

This can be used as a directive mechanism for handling rejects, however the argument against this would be that inspectors can simply utilise a trigger mechanism to indicate rejected product, depending on its versatility regarding where, when, and how the trigger mechanism is designed.

Vacuum Robotic End Effector

Paired with the vision system, robotic equipment can be utilised to automate most of the process for offal handling. Instead of using traditional robotic grippers to displace offal products into specific chutes, vacuum transfer modules can be equipped at the robot's end effector to selectively capture each offal. The robot can also be equipped with several different channels to one end effector with the ability to switch between each channel for lesser associated costing and payload on the end effector. This can be accomplished with a switching mechanism that blocks other channels that is built on the end effector. Alternatively, depending on the feasibility, multiple robots can also be utilised for coping with better rates and segregation of products.



This is applicable to some offal parts small enough (normally red offal) to be handled. Larger offal such as paunch would require alternative method of transportation.

6.3.3.3 Growth Potential and Opportunities

Despite current limitations, vision systems are continuously advancing with better options and methodology with lower associated costs.

Cloud Computing

With use of cloud computing systems, complex vision processing can be achieved at much faster rates, allowing for more streamlined offal grading as the methodology develops overtime. Whilst the algorithm used by AgResearch

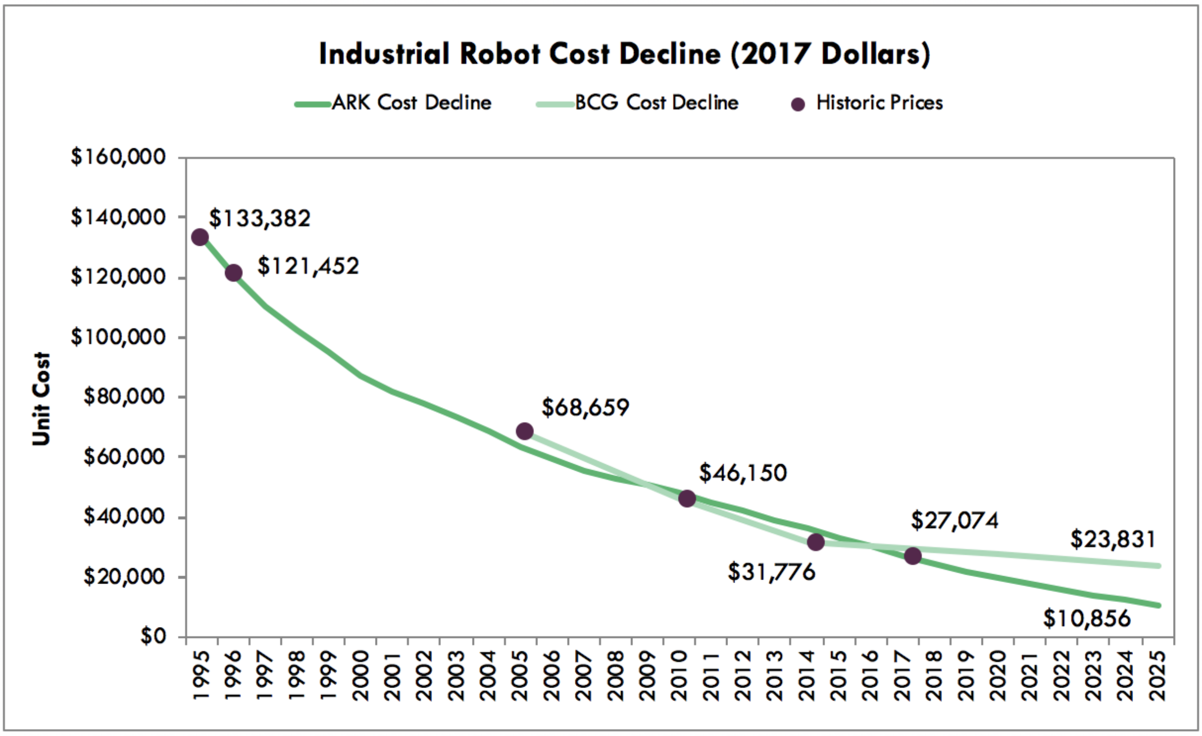
(2018, p. 21) processes a dataset in less than 1 second, additional grading methodology and algorithm may require more processing time, especially with integration of machine learning.

Alternative Vision System Setup

The trial conducted by AgResearch (2018) does not include the use of machine learning, however there is another study that investigated identification of red porcine offal using several types of algorithms, such as Conditional Random Field (CRF), Auto-Context (AC), Weighted Atlas AC (WAAC), and supplementary combination with Integral Context (IC). This provided with relatively fruitful performance on most of them, attaining around 82-85% quadratic scores, except for CRF. (McKenna, et al., 2018, pp. 294-296). The photographic datasets were captured as red offal hanging on hook chains without requiring a black-box. This method has the potential of integrating with the recommended solution without the spatial constraints of requiring a black-box and potentially a complex rotation mechanism. However, as McKenna's, et al.'s study focuses solely on segmentation methods of red offal, further investigations would be required to validate with other functions.

Decline in Cost of Robotics

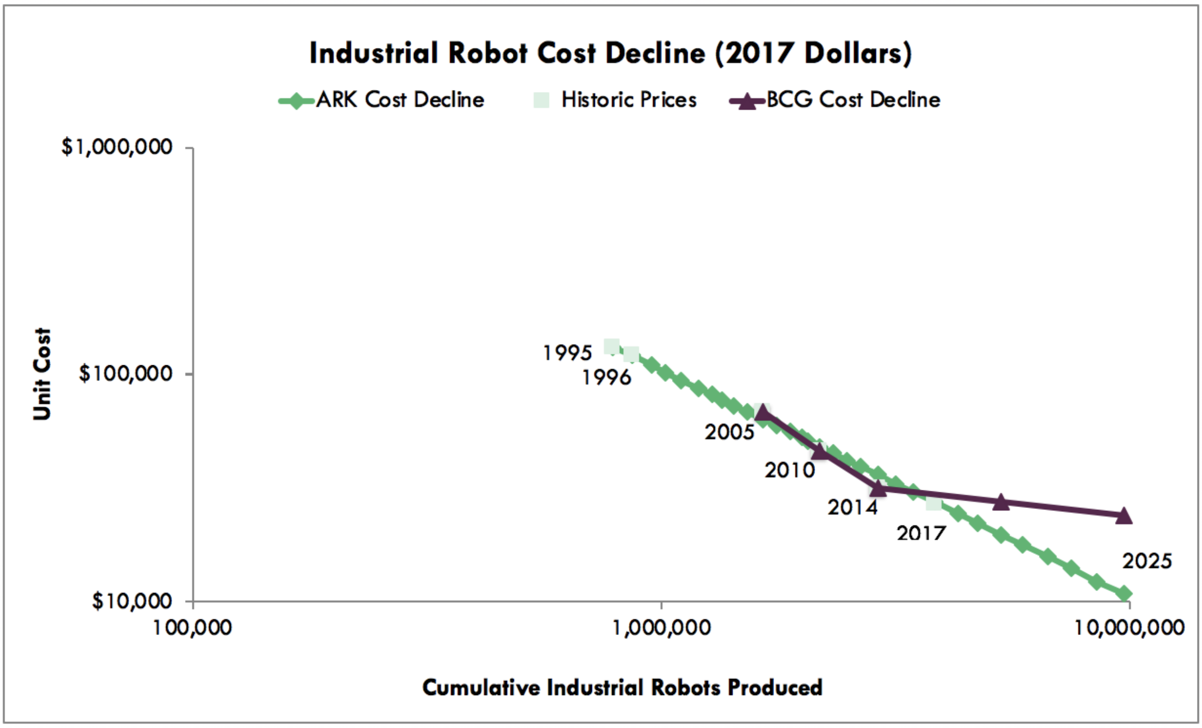
As observed in ARK's research (2019), costings for the average industrial robot has been declining by roughly 50% per decade.



Source: ARK Investment Management LLC, 2019 | ark-invest.com; Data from: United Nations Economic Commission for Europe; International Federation of Robotics; Sirkin, Hal, et al. "How Robots Will Redefine Competitiveness." BCG, 23 Sept. 2015, https://arkinv.st/2VLo0Jt.

Figure 3 Trend of the average cost of an industrial robot based on historic prices and ARK's and Boston Consulting Group's estimation (ARK, 2019).

The research had also shown the trend and forecast of the decrease in industrial robotic cost with respect of Wright's Law, which in the context of this case, is the relatively fixed percentage of decline in the cost of industrial robots for every cumulative number of units produced.



Source: ARK Investment Management LLC, 2019 | ark-invest.com; Data from: United Nations Economic Commission for Europe; International Federation of Robotics; Sirkin, Hal, et al. "How Robots Will Redefine Competitiveness." BCG, 23 Sept. 2015, https://arkinv.st/2VLo0Jt.

Figure 4 Trend and prediction of the average cost of an industrial robot with respect to Wright's Law (ARK, 2019).

As robotic components become more financially accessible, this opens up the possibility of allowing diversified research & development implementation that may be suitable with more niche operations, such as offal sortation, and in turn, making the technology financially feasible for site owners to acquire in future advancements.

7.0 Recommendations and Conclusions

7.1 Next Steps

In order to refine this project, it is recommended that a suitable site be identified to participate in carrying out experimental tests of concepts. If trials prove to be successful, the concept could be implemented in commercial settings.

With the support of AMPC to take this project into the next steps, NIRAS has had discussions with ALC (Australian Lamb Colac) with the opportunity of potentially conducting trials on the implementation of the recommended solution. ALC has agreed to participate in trials of proposed concepts.

In the next steps, NIRAS will develop and refine the recommended concepts with third party manufacturers and conduct trials within ALC's offal sortation facility. The steps to be undertaken are:

- Modifying the current operation of ALC's offal sortation facility to suit the recommended solution,
- Introducing hook-chain conveying for red offal,
- Modifying existing and installing new offal channels to accommodate the changes,

- Training of staffs to operate the recommended solution,
- Commencing and studying the trials conducted, and
- Report observation and results from the trial.

Further discussions and agreements with the parties are to be conducted at the conclusion of this phase.

7.2 Conclusion

Based on the evaluation of the findings and solutions, the feasibility of automating the offal handling process is not yet equipped for a commercial setting, with the main factors being the lack of space, the current experimental and conceptual phase of the system with respect to the technical complexity, and the associated cost. While the feasibility and recommendation does not currently justify the solution, this is not in any shape of form to discredit this concept of automation, rather it should be seen as a potential opportunity to further investigate the issues and develop the concept further when the level of available technology and study can be justified.

Alternatively, reconfiguring of current practices and operational culture can be done to alleviate current workload. By handling reject products, which composes of 5-10% of total offal production, this would free up the capacity of operators significantly and may allow meaningful reduction in labour.

Moving forward, the reliance on single-specific methodology of handling would arguably be more healthy to see a shift to a diversity of methods and innovation.

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9.0 Appendices

9.1 Appendix 1 – Site Investigation

Image 9.1.1: Offal Sortation Facility (Site #1)

Image 9.1.2: Offal Sortation Facility (Site #2)

9.2 Appendix 2 – Issue Analysis

Issue Details				Relevancy of Concerns			Commonality and Severity				Solutions						
Priority	Issue Heading	Issue	Description	Operational Concern Value	Safety Concern Value	Product Quality Concern Valu	Number of sites with issue	Priority Value	Severity Rank	Reason of Ranking	Vision System - Camera	Offal Inverting - U-Bend	Offal-Inverting - Mechanical Pan Rotatc	Robotic Offal Handling	Revised Reject Handling	Hook-Chain Red Offal Conveying	Vacuum Transfer Suction Tub
1	Spatial Issues	Lack of space	Offal handling stations are fitted with just enough space. This may hinder room for improvement for expansion/upgrade to offal stations	4	3	0	2	14	High	Insufficient area utilisation can result in injuries, inefficient practices, and lesser room for improvements.					x	x	
2	Labour Replenishment & Management	Staff shortage/retention	Huge issues with finding staff to work for offal handling	6	0	0	2	12	High	Significant management issue regarding labour shortages.	x	x	x	x	x		
3	Spatial Issues	Accessibility of Offal Chutes/Collection Point	Drop-off points for offal are too far away for workers, resulting in them throwing the offal into chutes, drop-off points, etc. May damage products or cause product to be stuck	4	2	3	1	9	High	Inappropriate practices may result in injuries and lower quality & rate of production.	x	x	x	x	x	x	x
4	Cross Contamination	Workers Handling Both Red & Green Offal	Some sites are seen to have 1 worker handling both red and green offal for sortation. This can be a health hazard to consumer of red offal.	0	0	4	1	4	High	Quality and health concerns as this is done consecutively throughout the operation.	x	x	x	x	x	x	x
5	Cross Contamination	Overlap of offal during handling	Offal handled by some workers may cross-contaminate on other offal pans (offal being dragged and touching other pans, offal fluid dripping to other pan). Can be an issue for rejected offal.	0	0	3	2	6	Medium	Some quality and health concerns and happens occasionally.						x	x
6	Labour Replenishment & Management	Frequent staff rotation	Staff rotated to handle offal every 1h	3	0	0	2	6	Medium	Some management issue regarding labour shortages.	x	x	x	x			
7	Labour Fatigue & Safety	High-pace of handling for workers	Normally 1-2 workers are stationed to handle multiple sortation of specific offals and can be a fast paced environment with the number of offal that need to be sorted.	3	3	0	1	6	Medium	No associated safety risk, but may result in perfectly healthy offals to be rejected.					x	x	x
8	Labour Fatigue & Safety	Physical strain from manual handling	Workers expected to lift heavy offal products, causing fatigue	2	2	0	1	4	Low	No reported injuries, however, fatigue is still an issue.	x	x	x	x	x	x	x

Table 9.2.1: Schedule of issues to evaluate the severity of factors of concern and the solution's applicability to each issue.

Severity of Issue Guideline				
Severity Rank	**Factors of Severity**			
Severity Rank	Operational Concern Value	Safety Concern Value	Product Quality Concern Value	Priority Value
High	**EQUAL** to or **MORE** than 4	**EQUAL** to or **MORE** than 4	**EQUAL** to or **MORE** than 4	**EQUAL** to or **MORE** than 12
Medium	**LESS** than 4 or **MORE** than 2	**LESS** than 4 or **MORE** than 2	**LESS** than 4 or **MORE** than 2	**LESS** than 12 or **MORE** than 5
Low	**EQUAL** to or **MORE** than 2	**EQUAL** to or **MORE** than 2	**EQUAL** to or **MORE** than 2	**EQUAL** to or **LESS** than 5
Note: The guideline ranking operates on OR logical operator. E.g., Issue #1 can be ranked with HIGH severity if its Safety Concern Value is 6 while its Priority Value is 9.				

Table 9.2.2: Guideline on ranking the issue priority.

9.3 Appendix 3 – Solution Effectivity Grading

Solution-Issue Effectivity Grading for Brownfield Sites										
Details		Standalone Complementary Solutions								
		Vision Robotic Automation				Revamped Offal Handling		Single Alternatives/Additions		
Severity Rank	Issue Details	Vision System - Camera	Offal Inverting - U-Bend	Offal-Inverting - Mechanical Pan Rotator	Robotic Offal Handling	Alternate Reject Handling	Hook-Chain Red Offal Conveying	Vacuum Transfer Suction Tube	Automated Chute Sorting System	Passive Chute Sorting System
High	Heavy product handling	0.00	N/A	N/A	N/A	9.50	11.75	7.25	11.75	11.75
High	Staff shortage/retention	7.25	N/A	N/A	N/A	7.25	8.94	3.88	8.94	8.94
High	Lack of space	3.88	N/A	N/A	N/A	8.94	7.25	3.88	8.94	8.94
High	Accessibility of Offal Chutes/Collection Point	0.00	N/A	N/A	N/A	8.94	8.94	3.88	8.94	8.94
High	Handling of Both Red & Green Offal	0.00	N/A	N/A	N/A	4.25	4.25	3.50	3.50	3.50
Medium	High-pace of handling	2.98	N/A	N/A	N/A	3.80	4.63	3.39	4.63	4.63
Medium	Overlap of offal during handling	0.00	N/A	N/A	N/A	2.36	3.59	3.59	3.59	2.36
Medium	Frequent staff rotation	3.59	N/A	N/A	N/A	2.36	2.36	0.00	2.98	2.98
	Standardised Effectivity Value	0.65	#N/A	#N/A	#N/A	1.74	1.89	1.07	1.95	1.90

Table 9.3.1: Weighted grading of solutions to determine the effectivity based on number and severity of issues that a solution covers (Scenario Brown-Standalone)

Solution-Issue Effectivity Grading for Brownfield Sites							
Details		Consolidated System Solutions					
		Vision Robotic Automation				Revamped Offal Handling	
Severity Rank	Issue Details	Vision System - Camera	Offal Inverting - U-Bend	Offal-Inverting - Mechanical Pan Rotator	Robotic Offal Handling	Alternate Reject Handling	Hook-Chain Red Offal Conveying
High	Heavy product handling	3.88				9.50	
High	Staff shortage/retention	8.94				7.25	
High	Lack of space	0.00				8.09	
High	Accessibility of Offal Chutes/Collection Point	7.25				8.94	
High	Handling of Both Red & Green Offal	2.00				4.25	
Medium	High-pace of handling	2.15				4.63	
Medium	Overlap of offal during handling	2.36				2.98	
Medium	Frequent staff rotation	3.59				2.36	
	Standardised Effectivity Value	1.10				1.76	

Table 9.3.2: Weighted grading of solutions to determine the effectivity based on number and severity of issues that a solution covers (Scenario Brown-Consolidated)

Solution-Issue Effectivity Grading for Greenfield Sites										
Details		Standalone Complementary Solutions								
		Vision Robotic Automation				Revamped Offal Handling		Single Alternatives/Additions		
Severity Rank	Issue Details	Vision System - Camera	Offal Inverting - U-Bend	Offal-Inverting - Mechanical Pan Rotator	Robotic Offal Handling	Alternate Reject Handling	Hook-Chain Red Offal Conveying	Vacuum Transfer Suction Tube	Automated Chute Sorting System	Passive Chute Sorting System
High	Heavy product handling	0.00	N/A	N/A	N/A	9.50	11.75	7.25	11.75	11.75
High	Staff shortage/retention	7.25	N/A	N/A	N/A	7.25	8.94	3.88	8.94	8.94
High	Handling of Both Red & Green Offal	0.00	N/A	N/A	N/A	4.25	4.25	3.50	3.50	3.50
Medium	High-pace of handling	2.98	N/A	N/A	N/A	3.80	4.63	3.39	4.63	4.63
Medium	Overlap of offal during handling	0.00	N/A	N/A	N/A	2.36	3.59	3.59	3.59	2.36
Medium	Frequent staff rotation	3.59	N/A	N/A	N/A	2.36	2.36	0.00	2.98	2.98
	Standardised Effectivity Value	0.75	#N/A	#N/A	#N/A	1.61	1.93	1.18	1.93	1.86

Table 9.3.3: Weighted grading of solutions to determine the effectivity based on number and severity of issues that a solution covers (Scenario Green-Standalone)

Solution-Issue Effectivity Grading for Greenfield Sites							
Details		Consolidated System Solutions					
		Vision Robotic Automation				Revamped Offal Handling	
Severity Rank	Issue Details	Vision System - Camera	Offal Inverting - U-Bend	Offal-Inverting - Mechanical Pan Rotator	Robotic Offal Handling	Alternate Reject Handling	Hook-Chain Red Offal Conveying
High	Heavy product handling	3.88				9.50	
High	Staff shortage/retention	8.94				7.25	
High	Handling of Both Red & Green Offal	2.00				4.25	
Medium	High-pace of handling	2.15				4.63	
Medium	Overlap of offal during handling	2.36				2.98	
Medium	Frequent staff rotation	3.59				2.36	
	Standardised Effectivity Value	1.25				1.68	

Table 9.3.4: Weighted grading of solutions to determine the effectivity based on number and severity of issues that a solution covers (Scenario Green-Consolidated)

9.4 Appendix 4 – Solution Effectivity Grading

The Effectivity value is calculated by:

$$\sum_{i=1}^{n} SR_i \times \frac{x_i}{x_{max}} \times SA_i \times K_s + K_c$$

Where:

n	=	Total number of issues
i	=	Focus of issue
SR_i	=	Issue's severity rank
x_i	=	Issue's priority value
x_{max}	=	Highest achievable severity value of an issue
SA_i	=	Solution's level of applicability on issue
K_s	=	Weighted coefficient of severity
K_c	=	Weighted coefficient of a standard issue

SR_i provides a weighted value depending on whether the issue is classed as high, medium or low severity. This is done to balance variables that depend on simply the priority value whilst taking into account of the severity of specific department of concerns, such as Issue #4 in Table 9.2.1 in Appendix 2.

K_s weighs the Effectivity value in a way depending on the severity of each individual issue whereas K_c weighs towards how many issues that a solution covers. This is done to balance out points based on severity versus number of issues.

9.5 Appendix 5 – Solution Effectivity Grading

AMPC Best Practice Guide - Solution Feasibility and Evaluation for Brownfield Sites											
Solution Details				Feasibility Factors							
Priority	Solution Heading	Issue	Description	Spatial Feasibility	Technical Feasibility & Complexity	Labour Elimination	Rework or Replacement on Current System	Capital Cost	Existing Practices	Reliance on Other Solutions	Feasbility Value
1	Revamped Offal Handling	Alternate Reject Handling	Inversion of handling of reject and acceptable offal. As 5-10% of offal are normally rejected, this can be handled manually, substantially reducing the amount of work needed.	4	4	4	3	4	2	2	23
2	Revamped Offal Handling	Hook-Chain Red Offal Conveying	Red offal pluck are hanged onto hook-chain conveyors to separate handling with green offal.	3	3	4	4	3	3	2	22
3	Chute System	Automated Chute Sorting System	Chute system with 2 channels and a mechanism that diverts products to specific channels. This can be used to separate rejected and healthy offal into 2 separate channels in a single entry point.	4	3	3	3	3	0	1	17
4	Chute System	Passive Chute Sorting System	Similar in principle to the automated chute sorting system with different mechanism and limited use. Chute system with 2 channels and a passive mechanism that diverts products to specific channels using the product's own weight. This can be used to separate red and green offal into 2 separate channels in a single entry point.	4	3	3	3	3	0	1	17
5	Vacuum Transfer	Vacuum Transfer Suction Tube	Hose-like tubes can be handled and directed by workers to be automatically collected without the need for workers to manually handle and carry offal.	2	3	2	1	2	2	2	14
6	Vision Robotic Automation	Vision System - Camera	Used to automatically inspect for diseases, and offal identification.	2	1	4	2	2	1	1	13
7	Vision Robotic Automation	Offal Inverting - U-Bend	Used in conjunction with vision system. Offal on pans are sent via a u-bend chute to flip the offal to allow the vision system to scan the opposite.	1	2	4	1	2	0	0	10
8	Vision Robotic Automation	Offal-Inverting - Mechanical Pan Rotator	Used in conjunction with vision system. Offal are placed on pans that can rotate in order to flip the offal to allow the vision system to scan the opposite side.	1	1	4	2	1	0	0	9
9	Vision Robotic Automation	Robotic Offal Handling	Used in conjunction with vision system. Ability to automatically pick and place offal parts into chutes.	1	1	4	1	0	0.5	0	7.5

Table 9.5.1: Assessment of the feasibility of the solutions accounting of several feasibility factors against issue grading.

Factor	Points	Evaluation
Spatial Feasibility	0	Spatially unable to be implemented.
	1	Very difficult in integrating solution. Will intrude operation and little possibility to work around.
	2	Difficult in integrating solution. Some workaround needed.
	3	Some work needed to integrate solution with small issues.
	4	Feasible to integrate solution. Very little to no issues to work around.
Technical Feasibility	0	Technically unable to be implemented.
	1	Very difficult in integrating solution. Will intrude operation and little possibility to work around.

	2	Difficult in integrating solution. Some workaround needed.
	3	Some work needed to integrate solution with small issues.
	4	Feasible to integrate solution. Very little to no issues to work around.
Labour Elimination	0	Does not eliminate labour nor does it reduce workload.
	1	Does not eliminate labour but has some reduction of workload.
	2	Eliminates some of the required labour.
	3	Eliminates a lot of the required labour.
	4	Eliminates most/all the required labour.
Rework/Replacement on Current System	0	Total replacement of current system.
	1	Major rework on current system (dismantling and reinstallation of <50% of current equipment).
	2	Moderate rework required on current system.
	3	Minor rework on current system (replacement of smaller parts/systems).
	4	No rework required on current system.
Capital Cost	0	No savings or exceeds more than the current practice.
	1	Long payback period.
	2	Medium payback period.
	3	Feasible payback period.
	4	Fast payback period.
Existing Practices	0	No documented concept.
	1	Concept exist but only documented as a research study.
	2	Few case studies can be found with actual operations.
	3	Industry standard for this industry or commonly used in other industry but suitable for this application.
Reliance on Other Solutions	0	Complete/heavy dependence on other solutions to work.
	2	Can operate independently.

Table 9.5.2: Feasibility factor grading reasoning for specific solutions.

9.6 Appendix 6 – Solution Grading Evaluation

AMPC Best Practice Guide - Solution Feasibility and Evaluation for Brownfield Sites								
Solution Details					Grading Evaluation			
					Standalone Solution		*Consolidated Solution	
Priority	Solution Heading	Issue	Description	Feasbility Value	Solution Effectivity on Issues (SA)	Grading (SA)	Solution Effectivity on Issues (CS)	Grading (CS)
1	Revamped Offal Handling	Alternate Reject Handling	Inversion of handling of reject and acceptable offal. As 5-10% of offal are normally rejected, this can be handled manually, substantially reducing the amount of work needed.	23	1.74	79.8	1.76	80.8
2	Revamped Offal Handling	Hook-Chain Red Offal Conveying	Red offal pluck are hanged onto hook-chain conveyors to separate handling with green offal.	22	1.89	83.3	1.76	77.3
3	Chute System	Automated Chute Sorting System	Chute system with 2 channels and a mechanism that diverts products to specific channels. This can be used to separate rejected and healthy offal into 2 separate channels in a single entry point.	17	1.95	66.3	1.95	66.3
4	Chute System	Passive Chute Sorting System	Similar in principle to the automated chute sorting system with different mechanism and limited use. Chute system with 2 channels and a passive mechanism that diverts products to specific channels using the product's own weight. This can be used to separate red and green offal into 2 separate channels in a single entry point.	17	1.90	64.8	1.90	64.8
5	Vacuum Transfer	Vacuum Transfer Suction Tube	Hose-like tubes can be handled and directed by workers to be automatically collected without the need for workers to manually handle and carry offal.	14	1.07	30.1	1.07	30.1
6	Vision Robotic Automation	Vision System - Camera	Used to automatically inspect for diseases, and offal identification.	13	0.65	16.8	1.10	28.7
7	Vision Robotic Automation	Offal Inverting - U-Bend	Used in conjunction with vision system. Offal on pans are sent via a u-bend chute to flip the offal to allow the vision system to scan the opposite.	10	#N/A	#N/A	1.10	22.1
8	Vision Robotic Automation	Offal-Inverting - Mechanical Pan Rotator	Used in conjunction with vision system. Offal are placed on pans that can rotate in order to flip the offal to allow the vision system to scan the opposite side.	9	#N/A	#N/A	1.10	19.9
9	Vision Robotic Automation	Robotic Offal Handling	Used in conjunction with vision system. Ability to automatically pick and place offal parts into chutes.	7.5	#N/A	#N/A	1.10	16.6

Table 9.6.1: Grading by consolidating results between feasibility value and solution effectivity (graded as 0-100) for brownfield sites.

AMPC Best Practice Guide - Solution Feasibility and Evaluation for Greenfield Sites								
Solution Details					Grading Evaluation			
					Standalone Solution		*Consolidated Solution	
Priority	Solution Heading	Issue	Description	Feasibility Value	Solution Effectivity on Issues (SA	Grading (SA)	Solution Effectivity on Issues (CS	Grading (CS)
1	Revamped Offal Handling	Alternate Reject Handling	Inversion of handling of reject and acceptable offal. As 5-10% of offal are normally rejected, this can be handled manually, substantially reducing the amount of work needed.	16	1.61	75.6	1.7	79.3
2	Revamped Offal Handling	Hook-Chain Red Offal Conveying	Red offal pluck are hanged onto hook-chain conveyors to separate handling with green offal.	15	1.93	85.3	1.68	74.3
3	Chute System	Automated Chute Sorting System	Chute system with 2 channels and a mechanism that diverts products to specific channels. This can be used to separate rejected and healthy offal into 2 separate channels in a single entry point.	10	1.93	56.6	1.93	56.6
4	Chute System	Passive Chute Sorting System	Similar in principle to the automated chute sorting system with different mechanism and limited use. Chute system with 2 channels and a passive mechanism that diverts products to specific channels using the product's own weight. This can be used to separate red and green offal into 2 separate channels in a single entry point.	10	1.86	54.7	1.86	54.7
5	Vacuum Transfer	Vacuum Transfer Suction Tube	Hose-like tubes can be handled and directed by workers to be automatically collected without the need for workers to manually handle and carry offal.	11	1.18	38.0	1.18	38.0
6	Vision Robotic Automation	Vision System - Camera	Used to automatically inspect for diseases, and offal identification.	9	0.75	19.9	1.25	33.0
7	Vision Robotic Automation	Offal Inverting - U-Bend	Used in conjunction with vision system. Offal on pans are sent via a u-bend chute to flip the offal to allow the vision system to scan the opposite.	8	#N/A	#N/A	1.25	29.3
8	Vision Robotic Automation	Offal-Inverting - Mechanical Pan Rotator	Used in conjunction with vision system. Offal are placed on pans that can rotate in order to flip the offal to allow the vision system to scan the opposite side.	6	#N/A	#N/A	1.25	22.0
9	Vision Robotic Automation	Robotic Offal Handling	Used in conjunction with vision system. Ability to automatically pick and place offal parts into chutes.	5.5	#N/A	#N/A	1.25	20.2

Table 9.6.2: Grading by consolidating results between feasibility value and solution effectivity (graded as 0-100) for greenfield sites.