# FINAL REPORT

# Demonstrating & Trialing Of An Internet-Of-Things Solution For Real-Time Computation And Delivery Of Plant KPIs

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| **PROJECT CODE:** | 2017-1003 |
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| **DATE SUBMITTED:** | November 2018 |
| **DATE PUBLISHED:** | May 2018 |
| **PUBLISHED BY:** | AMPC |

The Australian Meat Processor Corporation acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

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## TABLE OF CONTENTS

**ACKNOWLEDGEMENTS**

We acknowledge the support provided by Australian Meat Processing Corporation, their members, stakeholders and partners including red meat processors (RMP).

# 1.0 EXECUTIVE SUMMARY

This project considered opportunities for introducing Industrial Internet of Things (IIoT) solutions to the Australian red meat processing industry aiming to improving meat processing worker and plant productivity. Based on the outcomes of an industry consultation that was conducted in this project, the project developed an IIoT wearable technology system for achieving the following in real-time: (1) identifying workers regardless of location (e.g. at different workstations and/or moving around a plant), (2) recognition of different worker activities (i.e., productive, blade alignment and idle) with correlations to knife sharpness, and (3) pathway to monitor and optimize throughput per worker per hour KPIs. A trial of the IIoT system was conducted in a meat processing plant and demonstrated its effectiveness in assessing and improving in-plant productivity.

The key outcomes and findings of the project are summarized as follows:

- An IIoT system (combining a variety of sensors integrated in a wearable IIoT device, wireless sensor gateways, low power and Wi-Fi networks, and cloud-based data analysis software) for computing worker identities and KPIs that are critical in assessing and improving meat processing worker and plant productivity.
- Documentation and video evidence of the trial and the resulting operational effectiveness of this IIoT system in-plant.
- Indications from a cost-benefit analysis of payback in as little as 0.4 years (which can be reduced further where plants have suitable IT infrastructure in place that can be utilized).
- No negative impact on the plant operations, worker safety, or loss of productivity.
- Proof that this and other IIoT solutions can lead to novel approaches for significantly improving plant productivity.

The benefits for the industry are:

- Improved efficiency and profitability of the Australian red meat industry.
- Increased plant throughput per FTE per time unit.
- Real-time in-plant efficiency data (e.g., enabling immediate determine if sections of the workforce are unutilized or under-utilized).
- Platform for more effective, automated and efficient worker training.
- Improved floor supervisor effectiveness

## 2.0 INTRODUCTION

This final report presents the outcomes of the R&D project, titled "Demonstrating and Trialling of an Internet of Things Solution for Real-Time Computation and Delivery of Plant KPIs" (Project No: 2017-1003). The objective of this project was to develop and trail an Industrial Internet of Things (IIoT) solution for the Australian red meat processing industry. The project conducted a consultation with the Australian meat processing industry that identified major opportunities for introducing IIoT solutions for real-time computing of knife sharpness and plant yield KPIs. This consultation outcome led to the development and trial of an IIoT solutions for real-time KPI computation of knife sharpness that was conducted at the plant of an industry partner. This report provides an overview of this solution and the outcomes of its trial during several normal production shifts. This report also summarizes the outcomes of a cost benefit analysis that show that deployment of this (and potential others) IIoT solution in the red meat processing plants will help increase plant productivity while presenting insignificant financial and operational risks. For example, our cost benefit analysis estimated a payback period of approximately 0.4 years when considering a variety of throughput efficiency gains that could be achieved.

## 3.0 PROJECT OBJECTIVES

The main objectives of this project are:

- // In conjunction with AMPC and industry partners, further understand the KPIs and other drivers that govern the critical production process in meat processing.
- // Design an IIoT solution that addresses a major industry opportunity in the area of fine-grained computation and visualization of plant KPI's.
- // Develop and demonstrate this IoT solution in plants of one or more industry partners (this may involve integration with plant machinery, personnel, and existing IT solutions used by the industry).
- // Demonstrate this solution to the industry to illustrate related IoT benefits and gain stakeholder support.

The development and demonstration of an IoT solution for the Australian red meat processing industry specifically aims to assist the industry in exploring viable solutions through research and development in support of AMPC's main objectives by exploring technologies that has the potential to:

- // Improve the efficiency and profitability of the Australian red meat industry.
- // Improve product quality.
- // Improve equipment efficiency and integration between equipment and the internet.
- // Provide enhanced data collection, analytics, traceability, and decision making.
- // Improve operator efficiency, wellbeing and longevity.

# 4.0 METHODOLOGY

The project methodology tightly followed a demand and delivery model of the industry that became evident from consultations with the industry in previous projects. This methodology is compatible with some recent trends in the red meat processing industry and the IT technologies being used or trialled. From our consultations, it is evident that the major drivers for the meat processing business are cost and quality. Cost and quality KPIs originate from major customers and they are mapped to corresponding meat processing plant operations and supply chain operations.
Some of the major opportunities for improving plant productivity in all aspects of operational/plant process, include:

- KPI-based assessment of production processes, e.g., by automatically computing and visualising fine grained KPIs, providing personalized KPI visualisations to both the plant management and personnel within the appropriate scope of their responsibilities.
- Efficiently managing plant resources, e.g., by electronically tagging all meat products, automating meat product inventory, providing robotic transportation of meat products to/from chillers as needed to fill up a customer order, and optimization of all these.
- Automating some manual tasks, e.g., by assessing product quality faster and more reliable with specialized camera systems, or by automating complex meat cutting tasks by using imaging data to create meat cutting plans that are executed by robotic cutting machines.
- Training personnel more efficiently by electronically monitoring and mentoring personnel while they are working in the production line and performing specialized meat processing tasks.

A survey consisting of questionnaires to gather processor information as well as general interests in IoT solutions and future involvement was conducted by the AMPC on behalf of Swinburne University and All Energy Pty Ltd. This survey, in part, provides insight into the perception of IoT adoption in the industry and whether businesses are interested in IoT solutions, including willingness in further discussions and potential trial participation. The questions in the survey (Please refer to Milestone 1 report for survey questions, related discussion and outcomes) were framed to present various IoT applications and solutions that address the aforementioned opportunities to the processors and to determine which of those options hold the highest ratings amongst the respondents.

The result of this consultation during the initial stage of the was to develop and trial an IIoT solution for the following option that was include in the consultation survey: “Real-time fine grained KPI monitoring to support decision making and in turn deliver productivity improvements and reduction in costs.”

## 5.0 PROJECT OUTCOMES

### 5.1 SUMMARY OF IOT SOLUTIONS FOR REAL-TIME KPI MONITORING

Based on a consultation with three industry partners that responded to a survey and follow up plant visits we developed two IoT solutions that involved the real-time computation and visualization of the following KPIs:

- // (First pass) yield per individual worker
- // Knife sharpness per worker

Unlike any existing KPIs and corresponding IT solutions currently used in existing meat processing plants, the IoT solutions we developed for computing these KPIs provide:

- // Improved assessment of the performance of individual workers. Existing yield and knife sharpness KPIs that are currently employed by the industry, only assess the performance of one or more production shifts. The IoT-based solutions for computing yield and knife sharpness KPIs we developed in this project, permit monitoring and assess the performance of individual workers both within any specific shift and across multiple shifts.
- // IoT-driven KPI computation and delivery is performed in real-time and in the form of KPI visualizations displayed instantaneously in the smart phones or tablets of the floor supervisors and other plant managers (existing KPI computation currently takes days or weeks to produce).

Such fine-grained KPIs allow the identification and correction of the root problems that affect the productivity of specific shifts or that of an entire plant by allowing drill down to the KPI components for each specific worker. Real-time KPI delivery allows corrective actions to be performed immediately. For a detailed description of the identified opportunities and corresponding IIoT solutions design, please refer to Milestone reports 3, 5 and 6.

#### 5.1.1 IIOT SOLUTION FOR REAL-TIME IDENTIFICATION OF PLANT WORKER

The fundamental challenge in computing the related KPIs for yield and knife sharpness of each worker is to be able to identify and associate workers and workstation autonomously with minimal intrusion to the working conditions. The IIoT solution for identifying workers and their corresponding workstation involves the following:

1. A worker carries a tiny Bluetooth low energy or RFID sensor (called transmitter).
2. Each workstation has a Bluetooth low energy and/or RFID proximity sensor (called receiver).
3. The *IoT worker identification solution* keeps track of workers and their associations with corresponding workstations by tracking the real-time handshakes between transmitters and receivers.

#### 5.1.2 IIOT SOLUTION FOR REAL-TIME COMPUTATION OF YIELD PER WORKER

Computation and visualisation in real-time the output (throughput and potentially yield) of each plant worker is very important and has significant impact on product quality, productivity and costs. For example, consider the case where quality of the meat product (e.g. primal cut) during cutting operation varies over a particular shift (e.g. deviation in prime cuts may result in high value meat sold at lower prices or result in product being sold as trim.). Currently, the KPIs used to measure yield employed by the industry is very coarse (% of output weigh from input weight in a shift). This KPI does not provide for timely detection of yield variation due to primal cut quality.

This IIoT solution provides the means to compute fine-grained KPIs i.e. yield/throughput per worker by using a combination of IoT devices such as smart IoT weighing scales, mobile smart phones, and waterproof computers. Our IIoT solution assumes a table-based deboning process that is based on a conveyor belt transporting carcass parts through the cutting room. Workers in the cutting room occupy specific workstations in the line of the conveyer belt and have a specific task in the deboning process i.e. produce a wide range of cuts. The incoming meat is weighed on the IoT weighing scale when the worker picks it up for cutting. The deboned meat is then re-weighted on the IoT weighing scale. An IIoT application running in the cloud uses the captured weight data to instantaneously compute fine-grained KPI's i.e. yield, output and quality per specific worker. The IIoT application monitors yield per worker in real-time and raise alerts in case of a deviation (e.g. issues with product quality).

### 5.1.3 IIOT SOLUTION FOR REAL-TIME COMPUTATION OF KNIFE SHARPNESS / OPERATOR EFFICIENCY PARAMETER

The IIoT solution for knife sharpness / operator efficiency uses an IIoT solution for worker identification, a waterproof computer and remote plant servers (or cloud) to compute the KPI, and a tablet or phone to visualise the KPI. In addition, this solution employs an accelerometer that is worn at the cutting hand of each worker to measure the speed and direction of cutting movements and recognise knife bluntness indicators (increased and/or multiple cutting movements as opposed to single and/or lower cutting movements; hacking and sawing).

The design of this solution assumes that workers are stationed at a workstation (generally a table). In addition, these solutions assume that workers wear a waterproof IoT accelerometer in the wrist of their cutting hand that is used to capture workers' hand movements to compute knife acceleration (G-force via accelerometer) and rotational speed (degrees per second via gyroscope) and movement angle.

A key step in the design of this IIoT solution is the collection of ground truth. Ground truth is a term used in data analytics to refer to data collected while observing a specific situation, i.e., in this case capturing data from one or more workers that wear accelerometers while using either a sharp or a blunt knife (but not both) and performing various cutting actions. During the project, it was determined that using a blunt knife is not efficient for operations, hence the Ground truth could be the highest efficiency possible (e.g. when such ground truth data underpins the ability of this IoT solution to assess each worker's knife sharpness). A desktop/mobile application was developed to alert floor supervisors when a deviation from ground truth is detected. When such a deviation is observed a suggestion to the operator and/or supervisor for resharpening or retraining on proper knife sharpening technique can be made.

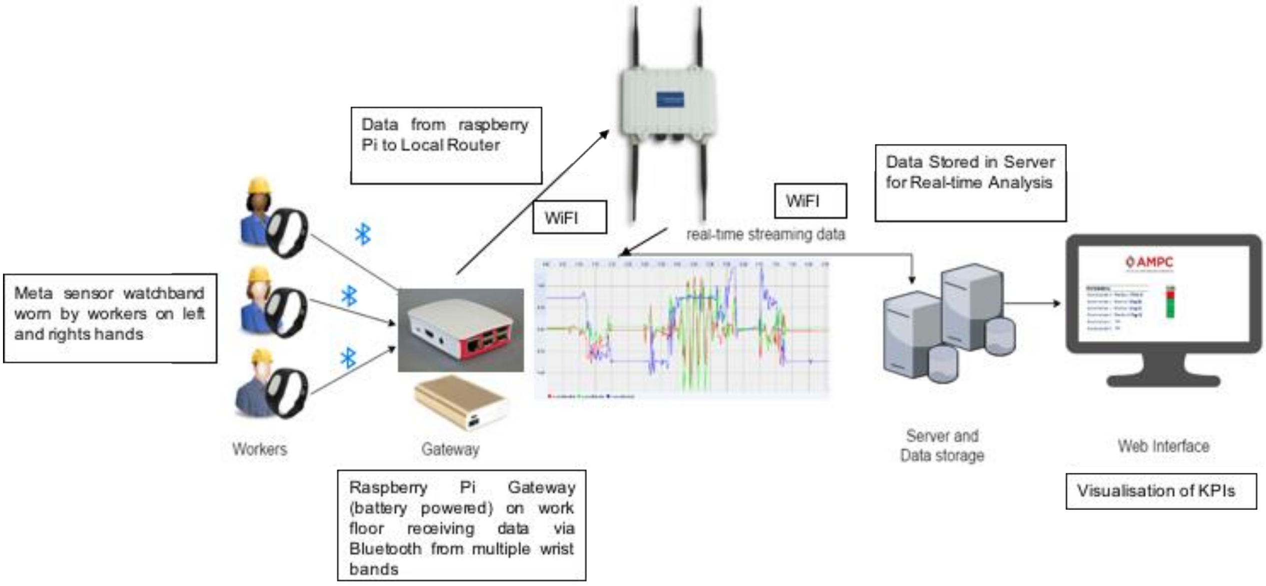
## 5.2 IN-PLANT TRIAL FOR REAL-TIME COMPUTATION OF KNIFE SHARPNESS PER WORKER KPI

A trial of the IIoT solutions (as described in section 4.2 and 4.3) was planned in the plant of two industry partners. However, due to several operational issues, the IIoT solution for real-time computation of yield per worker could not be conducted.

Hence, in this section we provide a summary of the in-plant trial conducted for the IIoT solution developed for the knife sharpness per worker KPI (as described in Sections 4.3). The trials were conducted at a selected AMPC industry partner plant. The solution also incorporates the IIoT solution for plant worker identification (as described in Section 5.1). The IIoT (software) solution was developed in-house by Swinburne University of Technology (SUT). While this solution is general purpose and can be deployed and used in any plant, some components were further tailored to fit the environment of this trial conducted at the partner plant.

### 5.2.1 SYSTEM ARCHITECTURE

Figure 1 presents the architecture of the trialled solution for real-time computation of knife sharpness per worker KPI. The knife sharpness KPI is computed from accelerometer data collected from the MetaWear wearable (watch-looking) sensor. Plant workers wore these sensors in both hands. This IoT solution assesses the workers' cutting movements and determines if a significant cutting movement deviation from the ground truth is occurring. Accelerometer data from multiple workers are collected by a data collection application installed on an IoT gateway. The gateway device, a raspberry pi, is powered by a battery pack and is sealed in a plastic case that makes it waterproof. A waterproof Wi-Fi router is used to collect the data from the raspberry pi and transfer such data to the server (a waterproof computer) for further storage and analysis. An application deployed on this server uses the accelerometer data to computer the knife sharpness per worker KPI. The IIoT solution trialled was developed using commercial off the shelf technology (COTS) where by significantly reducing the cost

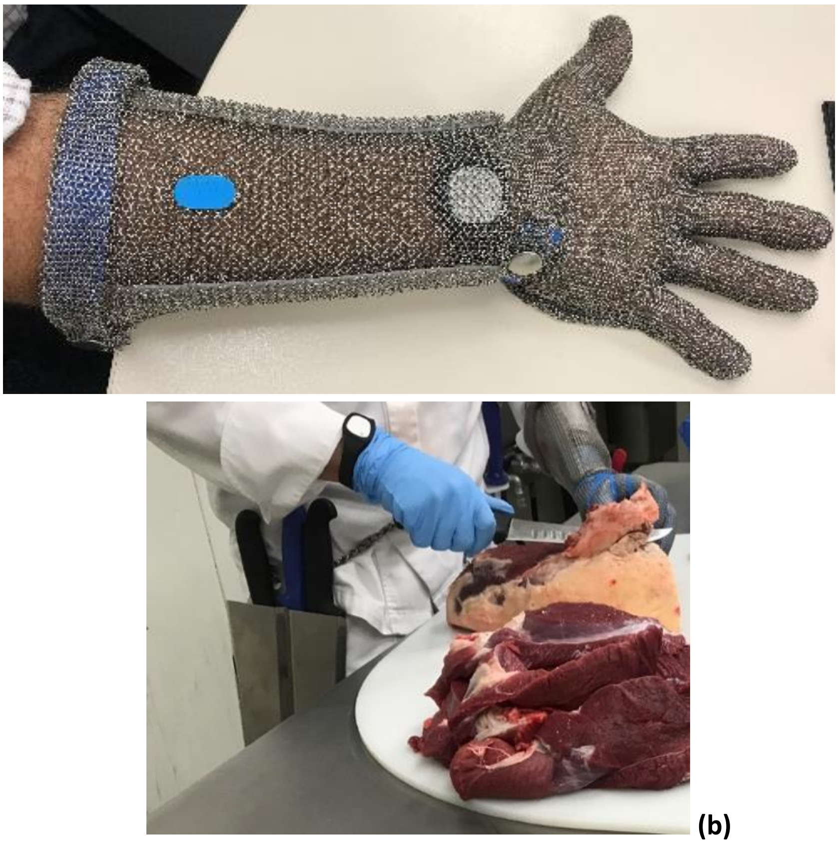



of the IoT hardware. Please refer to Milestone report 3 for detailed hardware used for the trial.

*Figure 1 Architecture of deployed/trialled IIoT solution*

### 5.2.2 IN-PLANT TRIAL AT AMPC INDUSTRY PARTNER

Figures 2 provide a photo of a pre-trial conducted to prepare for a longer 2 days trail. The image shows a worker wearing the Meta Sensor (watch-looking) IoT sensor and performing a cut. The worker performed this operation using a combination of both blunt and sharp knives. Please refer to Milestone reports 5 & 6 for a detailed description of in-plant trial results. Following the pre-trial, a 2 day in-plant trial was conducted. Figure 3 present the images captured during the 2 day in-plant trial.



**(a)**

**(b)**

*Figure 2: (a) IIoT Meta sensor (Watch Device) worn under protective mesh glove (b) Images from Pre-trial conducted at AMPC Industry Partner Plant*

*(a) : Meta sensor (Watch Device) used for the Trial*

*(b) Worker wearing the watch during Trial*

*(c) IoT gateway devices (raspberry pi) used in the trial*

*(d) IIoT Solution deployed in the plant*

*(e) Real time data capture during trial, located within the plant's observation room.*

*(f) Workers with MetaWear sensor watchbands in action for Day 1 (above) and Day 2 (below) _ captured by GoPro video camera.*

*Figure 3: Images from 2 day trial conducted at AMPC Industry Partner Plant*

## 6.0 DISCUSSION

This section presents a summary of the results of the in-plant trial and the corresponding cost benefit analysis conducted using the data captured from the trial. Please refer to Milestone report 7 for a detailed description of the in-plant trial findings and cost benefit analysis. The following were the main outcomes from the two-day trial of this IIoT solution:

- The trial proved the feasibility of the proposed IIoT solution.
- No safety issues were identified (most likely due to the use of waterproof equipment in developing the IoT solution).
- The battery pack connected to the Raspberry Pi worked reliably and demonstrated the ability to last for a few days before re-charging.
- Most importantly, the IIoT solution for knife sharpness per worker KPI was positively accepted by the workers and supervisors with worker reporting no interference or loss of productivity to their regular work activities due to the installation/deployment of the IoT sensors (watches) and gateways.
- During the pre-trial we were able to establish a significant difference between using a sharp and blunt knife (as evidenced by the ANNOVA analysis presented Milestone report 7)

### 6.1 SUMMARY OF IN-PLANT TRIALS

The IIoT solution focused on detecting four main activity categories in order to compute the throughput efficiency per worker KPI metric. Below is a description of the activity categories:

**Productive movement**: A productive activity from the perspective of a knife sharpness KPI was considered to be any cutting/slicing activity performed using a sharp knife. Since an objective quantitative value for a sharp knife was not available, we used the data after a knife alignment to be a presentation of a productive activity using a sharp knife. This category may include any of the following activities the worker may be performing namely cutting, defatting pulling with non-cutting hand, retrieving product from conveyor; distance of stretch, returning product to conveyor, product to trim and product to render.

**Unproductive movement**: The unproductive movement was considered to be any activity that involved the use of a non-sharp knife or an activity that closely matched the characteristics of a non-sharp knife. This may include activities such as orientating (spinning / rotating) product for repositioning, inverting (flipping) product for repositioning, cleaning, dropped meat and using a blunt knife.

**Idle:** The idle time mainly included the following activities namely waiting for product, communication with supervisor, communication with co-workers. The idle time was when the operator was not using the knife (i.e. the knife was mostly static).

**Aligning**: This activity included the blade correcting operation that operators performed from time to time on the floor.

Figure 4 is an indicative sample of activity performed by one worker. Time spent idle, productive, and aligning a knife was assigned a value of 0, 1, and 2 respectively in the developed model. Active states (i.e. the worker being productive) are the rectangles of height 1, and are analogous to pieces of meat worked upon. Based on a 53 minute segment of data obtained for Worker 1 and Worker 2 on day 1, the IIoT solution (using less than 10% of the captured data as ground truth) produced 92.21% accuracy. The verification of the outcomes were conducted by comparing the results of the model with the video recorded during the in-plant trial. Table 1 and the pie chart in Figure 5 presents a breakdown of time spent on each activity by Worker 1 and Worker 2.

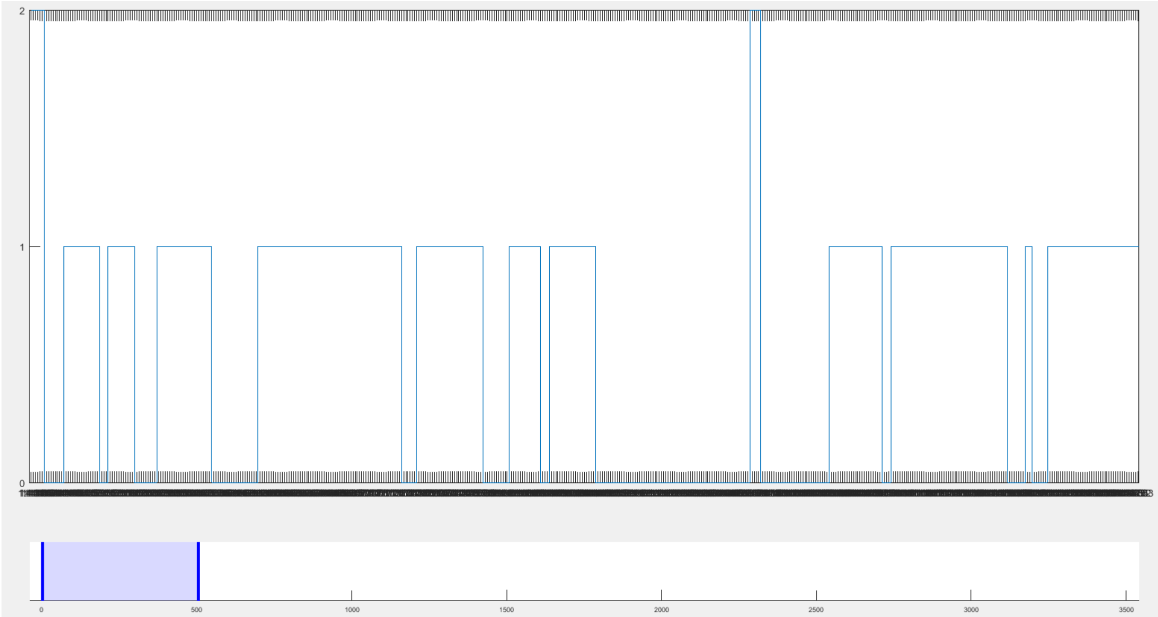


*Figure 4: Representation of Time Spent Idle, Productive, and Aligning as 0, 1, and 2 Respectively.*

*Table 1: Percentage Breakdown of Activities, W1 and W2*

| | Worker 1 (Experienced) | Worker 2 (Inexperienced) |
|---|---|---|
| **Idle Time** | **36%** | **8%** |
| **Productive Time** | **63%** | **91%** |
| **Alignment Time** | **1%** | **1%** |
| **Active States** | **49** | **30** |

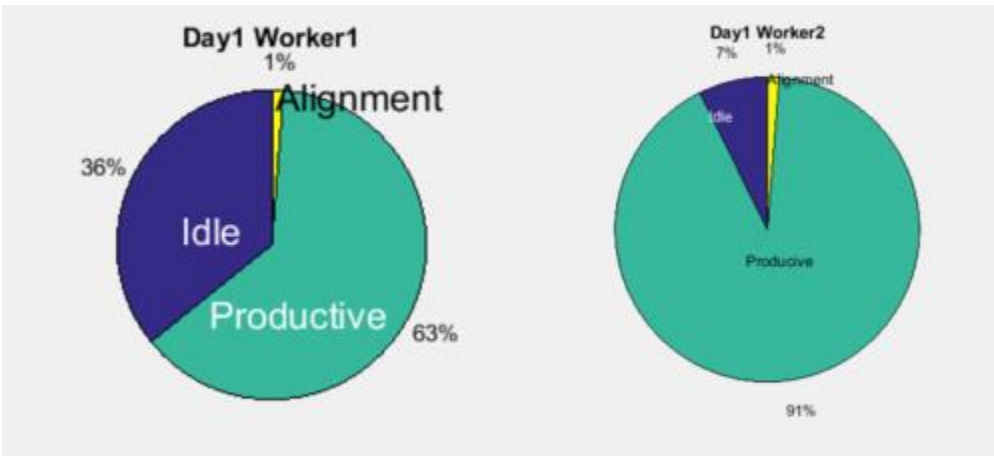



*Figure 5: Pie Graph of Percentage Time Breakdown for W1 and W2*

It can be observed from the results, although worker 1 (from here denoted as W1) spent significantly more time being idle than W2, the active states were nevertheless considerably more. This means that the inexperienced worker W2 was spending a good deal more time on each piece of meat than W1. This throughput was factored into the cost benefit analysis (CBA).

## 6.2 COST BENEFIT ANALYSIS (CBA)

With the analysed data produced by the developed IIoT solution obtained from the 2 day in-plant trial, it was considered how to translate this to an economic benefit (please note, a detailed description of the CBA is available in Milestone report 7 with a summary provided in the appendix). The highest benefit item that could be computed from the developed IIoT solution for computing real-time knife sharpness KPI per worker was improved throughput translating to reduced time per unit of product output, and reduced injuries.

- Reduced injury
  - Estimated as reduced knife movements with a blunt knife. Calculated by observed reduced knife movements (66%) by fraction of unsatisfactorily sharp knives found by AMPC/MLA/MINTRAC[1] (52%)
- Reduced time/increased throughput
  - Estimated as the difference in productive speed between an average worker and an experienced worker (24%). Represented as less time to complete the shift

The estimated costs and benefits analysis is summarised in the following tables. To allow easy application of OHS statistics and other metrics, the CBA was calculated on a per worker basis. When deployed over a full production floor, there will be a slight economy of scale translating to a lower cost per worker. Also note the largely hypothetical nature of the predicted benefits; a full deployment would need to occur with rigorous data collection and comparison over a range of parameters in order to verify these estimations.

*Table 2: Estimated Cost of IIoT Equipment per Worker*

| | |
|---|---|
| **Equipment Purchase Cost** | $24,096 |
| **Installation Cost** | $0 |
| **Number of Deployed Units (Workers)** | 2 |
| **Cost per Worker** | $12,048<br>[Note: equipment only costs as low as $160 per worker where existing infrastructure is suitable and can be utilized] |

It is noted that the above cost is based on a small number of deployments. After complete development / build-out, the equipment cost could be reduced further. It is estimated that for 40 workers, deployment per worker is closer to $6,760 per worker. For very large deployment, costs trend towards $160 per worker (assuming one (1) Metawear watch device and one (1) raspberry pi per worker) plus $3000 for a waterproof PC and router. The PC and router is a one time investment. The

[1] MINTRAC, AMPC, MLA, 2009. Sharpness of workers' knives: a case study of thirteen Australian abattoirs

use of existing infrastructure (e.g. an existing WIFI and computing server) would further reduce deployment costs. Most of the software is open source hence software costs are minimal to negligible. The next phase of the project will consider in greater detail the cost of a commercial device and solution development.

*Table 3: Estimated Costs per Worker*

| Costs | Rate | Unit | Number of Units | Cost per Annum |
|---|---|---|---|---|
| Maintenance and Repair | 5% | Cap Ex | $12,048 | $602.4 |
| Parasitic Load (0.1 kW) | 0.16 | $/kWh | 380 | $60.80 |
| | | | Subtotal | $663.2 |

*Table 4: Estimated Benefit per Worker*

| Benefits | Current Metric | Unit | Improvement | New Metric | Rate | Benefit per Annum |
|---|---|---|---|---|---|---|
| Reduced LTIs | | /Worker / Annum | 35% | | | $6,608 |
| Throughput per unit time improvement via enhanced productivity | | Hours | 24% | | | $22,848 |
| | | | | | Subtotal | $29,456 |

With a net increased revenue of $29,456 for improved productivity, a simple payback period of 0.4 years is estimated from this trial. However, this period does not include an allowance for systems development and integration, commissioning, and on-going (data) analytics and support. Below, we provide an estimate for developing, deploying and maintaining the IIoT solution for real-time knife sharpens per worker KPI. The payback cost of just developing a commercial solution is estimated at 0.2 years.

| Item | Number of Units | Approximate Cost / Unit | Subtotal |
|---|---|---|---|
| Equipment Procuring | 40 | 160 | $6,400 |
| IIoT Commercial Software Development | 2000 | 100 | $200,000 |
| Ongoing Software Support | 800 | 80 | $64,000 |
| | | Total | $270,400 |
| | | **Total/Worker** | $6,760 |

The sensitivity of the payback period for the IIoT solution that has been developed and trialled in this project is presented in Figure 6.

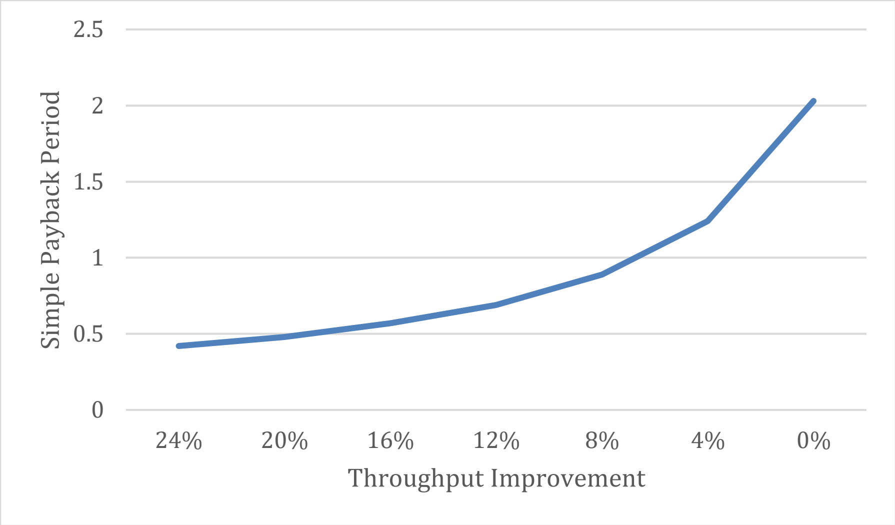



*Figure 6: Impact of throughput improvement percentage on simple payback period.*

In section 7.1 we provide potential commercialisation pathways that could be explored to reduce the total cost of ownership of this IIoT solution.

## 6.3 COMMERCIALISATION PATHWAYS

The pathways we have identified for commercial development and deployment of the proposed IIoT solution include:

- Joint venture between a single Red Meat Processing company and a tech developer. “The Telstra” model: where Telstra need a product, they either buy a small company or invest in a new company. Value is immediately created in the new company due to the take over or a large and ready first customer for the new company model.
- Co-investment via multiple Red Meat Processing companies in the platform technology / tech developer with profit sharing.
- Direct procurement by the Red Meat Processing (i.e. purchase of a full system developed SUT).

The main source of revenue for any new company is expected to be from the ongoing data analytics, as mathematical analysis / correlation / drilling down to optimize the system requires specialized software which a company could buy outright or could be “leased” where the tech developer provides a cloud based analytics service with associated updates as required.

The advantage of a Red Meat Processing investing in a new company or SME is that part of the funding could be obtained from the federal (e.g., Accelerated Commercialisation) or a state government entity (e.g. Advance Queensland, Business Victoria) which could be leveraged with other funding such as AMPC or CRC-P funding, as well as making potential use of R&D tax concessions.

## 7.0 CONCLUSIONS/RECOMMENDATIONS

This milestone reported the outcomes of the AMPC project, titled "Demonstrating and Trialling of an Internet of Things Solution for Real-Time Computation and Delivery of Plant KPIs" (Project No: 2017-1003)", which has been conducted by Swinburne University of Technology and All Energy Pty Ltd. The project is a pioneering effort in introducing and trialling an Industrial Internet of Things (IIoT) solution for the red meat processing industry. More specifically, the project developed and trialled an IIoT solution for real-time computation of knife sharpness KPIs per worker using commercial off the shelf sensors, low-power networking and cloud computing resources integrated via open source software. This approach achieved fast (under 4 months) development and implementation of a pilot solution for knife sharpness KPI that has successfully being trialled at AMPC industry partner plant. This trial and its follow-up cost benefit analysis showed that deployment of this (and potential others) IIoT solution in the red meat processing plants will help increase plant productivity while presenting insignificant financial (e.g., an estimated 0.4 years of payback period) and operational risks (e.g., no negative impact in production throughput or risk of increased injuries).

This project has established that IIoT solutions are feasible and economically viable for introduction in an Australian red meat processing plants. This is illustrated by the following outcomes that have been achieved during the trial of the real-time knife sharpness KPIs solution in normal production shifts:

// Considerable benefits in reducing the time per unit throughput that will pay off for this solution in as little as 0.4 years. The payback period is less reduced in plants where suitable IT infrastructure already exists.

// The trial had no negative impact on the plant operations or the production shifts involved.

// No impact on health and safety.

// Plant workers reported no interference or loss of productivity from the IoT devices they wear during the trial. The IIoT solution was well received by plant worker and supervisors.

// More importantly, the IIoT solution trial has produced quantitative data in real-time that clearly indicate that less experienced workers devote significant effort/time during the boning operation than experienced workers (in some cases almost 50% more). This can lead to novel approaches for improving plant productivity.

# 8.0 APPENDICES

## 8.1 APPENDIX 1: LIST OF OTHER POTENTIAL BENEFITS

Below is a list of other potential benefits that could be released via the IIoT solution developed in this project.

- Reduced injury
  - Estimated as reduced knife movements with a blunt knife. Could be calculated by observed reduced knife movements (66%) by fraction of unsatisfactorily sharp knives found by AMPC/MLA/MINTRAC2 (52%)
- Improvement in yield
  - Could not be inferred from data without weighing of pieces before and after. This would have interrupted the normal working speed.
- Reduced time/increased throughput
  - Estimated as the difference in productive speed between an average worker and an experienced worker (24%). Represented as less time to complete the shift.
- Reduced supervisor movements
  - Unable to be inferred from data gathering architecture so omitted from CBA. Relatively small expected benefit.
- Real-time anomaly correction
  - Benefit represented in reduced claims and rework; automated increase / improvement in product availability to idle operators.
- Reduced claims and rework
  - unable to be retrieved from records so omitted from CBA.
- Reduced training hours
  - Unable to be inferred from data, relatively small expected benefit.

Further trials, data collection and associated analytics could differentiate operator activities into 5 broad categories with distinct sub-activities as follows:

- Productive movement
  - Cutting
  - Defatting (pulling with non-cutting hand)
  - Retrieving product from conveyor; distance of stretch
  - Returning product to conveyor

[2] MINTRAC, AMPC, MLA, 2009. Sharpness of workers' knives: a case study of thirteen Australian abattoirs

- / Product to trim
- / Product to render

// Un-productive movement / source of inefficiency:

- / Orientating (spinning / rotating) product for repositioning
- / Inverting (flipping) product for repositioning
- / Cleaning during a time when productive movement could occur
- / Dropped meat

// Idle:

- / Waiting for product
- / Away from station
  - / Communication with supervisor
  - / Communication with co-workers
  - / Cleaning

// Aligning - Blade correcting

// Stretching. Note: stretching periods and timing could be optimized.

**HYPOTHETICAL Future Goal:**

The following figure provides a H**YPOTHICAL** time split into 17 different activities that may be able to be achieved with a sufficient amount of data and analysis system training based on the actual Productive (shaded blue, orange and purple), Idle (shaded green), and Alignment (shaded red data) data for an experienced worker.