

# ACMA6013

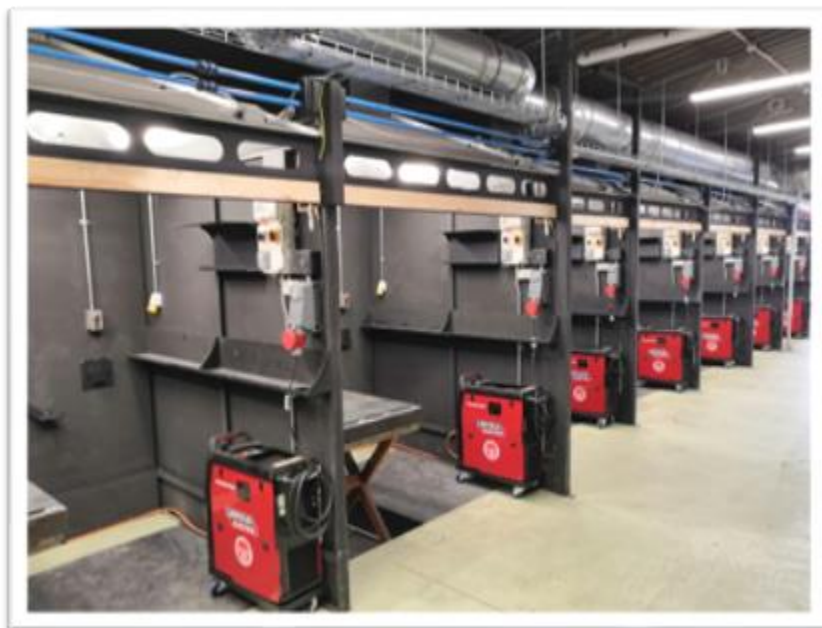
## Independent Project

Improving the efficiency of a working practice Using  
Six Sigma Methods



**Prifysgol Cymru**  
Y Drindod Dewi Sant  
**University of Wales**  
Trinity Saint David

# BISLEY



Morgan Baker

2111367

2023-2024

## Declarations

### ***Declaration/Statements page***

#### DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

Signed:        Morgan Baker        Date:        17/05/2024

#### STATEMENT 1

This work is the result of my own investigations, except where otherwise stated. Where correction services have been used, the extent and nature of the correction is clearly marked in a footnote(s).

Other sources are acknowledged by footnotes giving explicit references. A bibliography is appended.

Signed:        Morgan Baker        Date:        17/05/2024

#### STATEMENT 2

I hereby give consent for my work, if accepted, to be available for photocopying and for inter-library loan, and for the title and summary to be made available to outside organisations.

Signed:        Morgan Baker        Date:        17/05/2024

## Abstract

This report depicted a summation of a project with a goal to improve the effectiveness and efficiency of a working practice to reduce costs of both direct and indirect and increase productivity through means of six sigma methods and techniques. The current manufacturing process involved daily tasks that negatively affected the costs and product output, which were highlighted and used to form a plan of action to remove or reduce the issues associated with the current procedure. A finalised solution was assessed to see potential improvement highlighted through extensive data statistics and graphical illustrations. Furthermore, elements such as maintainability and sustainability were considered prior to finalising a solution to ensure the longevity of the improvements. These results were further compared with actual data recorded after the improvements had been implemented to prove or validate the work undertaken and how the new production process. Also, a plan to maintain these benefits through methods of control.

## Table of Contents

|                                                |    |
|------------------------------------------------|----|
| Declarations .....                             | 2  |
| Abstract.....                                  | 3  |
| Table of Contents.....                         | 4  |
| List of Figures .....                          | 6  |
| List of Tables .....                           | 6  |
| 1. Introduction .....                          | 7  |
| 1.1 Motivation .....                           | 7  |
| 1.2 Company Background .....                   | 7  |
| 1.3 Aims of the project .....                  | 7  |
| 1.4 Contribution to knowledge .....            | 8  |
| 1.5 Organisation of Thesis .....               | 8  |
| 2. Background Research .....                   | 10 |
| 2.1 Timescales and provisional work plan ..... | 10 |
| 2.1.1 Gantt Chart .....                        | 10 |
| 2.3 Project Charter.....                       | 11 |
| 2.4 Literacy Review .....                      | 12 |
| 2.5 Chapter Conclusions .....                  | 15 |
| 3. Define .....                                | 16 |
| 3.1. Problem Statement.....                    | 16 |
| 3.2. Current Operating Procedure .....         | 16 |
| 3.3. Areas Critical to Quality .....           | 17 |
| 3.3.1. Costs to Operate Equipment .....        | 17 |
| 3.3.2. Time Being Wasted .....                 | 17 |
| 3.3.3. Lifespan of Equipment .....             | 17 |
| 4. Measure .....                               | 18 |
| 4.1 Determine Types of Data .....              | 18 |
| 4.2 Plan for Data Collection .....             | 18 |
| 4.2.1 Data Collection.....                     | 19 |
| 4.3 Identify Variations in Measuring .....     | 21 |
| 4.3.1 Time to Produce Components .....         | 22 |
| 4.3.2 Electricity Costs.....                   | 22 |
| 4.3.3 Time to Operate Control Panel.....       | 22 |
| 5. Analysis .....                              | 23 |
| 5.1 Process Analysis .....                     | 23 |
| 5.2 Review Analysis.....                       | 24 |

|                                                 |    |
|-------------------------------------------------|----|
| 5.2.1 Time to Manufacture Components .....      | 24 |
| 5.2.2 Consumption of Electricity .....          | 24 |
| 5.2.3 Time spent to operate Control Panel ..... | 25 |
| 5.3 Graphical Analysis .....                    | 26 |
| 5.3.1 Graphical Analysis Conclusions.....       | 28 |
| 6. Improve & Control .....                      | 30 |
| 6.1 Generate Improvement .....                  | 30 |
| 6.2 FMEA.....                                   | 31 |
| 6.2.1 Costings.....                             | 33 |
| 6.3 Process Map.....                            | 33 |
| 6.4 Piolet Prospal .....                        | 35 |
| 6.5 Validate Improvements .....                 | 37 |
| 6.6 Methods of Control.....                     | 38 |
| 7. Conclusion.....                              | 39 |
| 8. References .....                             | 40 |

## List of Figures

Figure 1- Project Gantt Chart

Figure 2- Process Map for Manufacturing Process

Figure 3- Ishikawa Diagram (Fish Bone Diagram)

Figure 4- Time Taken to Produce Components in One Hour

Figure 5- Cost to Run Extractor Unattended Throughout One Week

Figure 6- Percentage of Productivity During the Average Working Shift

Figure 7- Process Map for Implementing Improvement and Testing

Figure 8- Wiring Diagram of New Control Panel

Figure 9- Testing Panel

Figure 10- Components Wired in Panel

Figure 11- Mounted New Control Panel

Figure 12- Welding Bay with New Control Panel

Figure 13- Life Span of AC motors

## List of Tables

Table 1- Meet the Team

Table 2- Data Collection Plan

Table 3- Time Spent Operating Control panel

Table 4- Costs Implications on Wasted Time

Table 5- Time to Manufacture 1 component

Table 6- Time/Productivity Data Sheet

Table 7- Financial Data Sheet

Table 8- 5 Why's

Table 9- Benefits Calculator

Table 10- FMEA

Table 11- Costs for Components

Table 12- Return of Investment

# 1. Introduction

## 1.1 Motivation

In any production or manufacturing environment it is vital that your equipment synergise to allow the products to be produced efficiently and effectively. Other benefits include maximising the throughput of product. It is also vital that the operations or working procedures are examined and analysed to prove beneficial to the manufacturer. There are several methods to improve a process which include reduce waste, reduce costs both direct and indirect, increase product output, decrease consumables used to manufacture, decrease required servicing or improving reliability. These improvements can be organised through a project using six sigma elements to provide a precise, measured and greatly beneficial implementation.

## 1.2 Company Background

Bisley are well known for their quality designs and products in office storage equipment e.g. Lockers and filing cabinets and have been doing it successfully for the last 80 years. From their office storage equipment and have now developed a new form of product that incorporates wood and fits a more modern office style. Around 50 designs from office products or industrial toolboxes to personal storage systems including the award-winning class multi draw cabinet which has been around since 1958.

## 1.3 Aims of the project

My project idea is to improve the working practice for the manufacturing of steel components involving the operation a welding bay extraction system. The aim is to carry out investigation into multiple solutions including restoring an electrical panel or the relocation of the controls for extraction etc. Of which all advantages and disadvantages of the solutions will be highlighted and explained before a final solution is decided.

Damage has been caused accidentally by heavy lifting equipment such as forklifts and pump trucks, therefore most ancillaries for example the lamps and push buttons have been damaged or rendered useless. Also, the panel used to operate the extraction systems is not in a desirable location compared with the welding bay causing the operator to have to waste time walking to and from the control panel before and after welding/grinding activities. Which could be utilised for production operations.

Therefore, there is good reasons for investment to develop an improvement, and cause for the opportunity to research, plan and implement a solution to improve reduce the time/ money wasted during current operational procedure. The new process itself should consider certain factors such as direct and indirect costs, workload/downtime maintainability and should follow relevant health and safety legislation.

Throughout this project, you will see evidence of six sigma techniques to help define, measure, and analyse DMAIC (Define, Measure, Analyse, Improve and Control)) aspects that should improve the outcome of the project and will develop an understand of the gains/benefits of the implementation made towards improving this process. Some of the tools and techniques seen in this report will include Gantt charts, graphical illustrations,

diagrams, and process maps. As stated in Lenka Girmanova's article Application of Six Sigma Using DMAIC Methodology in the Process of Product Quality Control in Metallurgical Operation, The Six Sigma DMAIC can be considered a guide for problem solving and product or process improvement. The majority of companies start to implement Six Sigma using the DMAIC methodology.

#### 1.4 Contribution to knowledge

There have been a few contributions made through drafting this report which are named in this section, these have contributed knowledge from the format and structure to some of the content and details. These contributions can be seen below:

- Using the six sigma define, measure, analyse, improve and control (DMAIC) method to improve a process or work operation.
- How lean manufacturing works in maintenance engineering role within a metal working manufacturing plant.
- Cost effective analysis, direct and indirect costs.
- Optimisation of a welding process

#### 1.5 Organisation of Thesis

- Chapter 2 background research: this section involves the initial searching and ideas of a project such as concepts as timescales and a project charter. A workplan can be seen in a Gantt chart which will highlight when sections of work have been started and when completed. The charter will discuss the responsibilities, the problem statement, risks, and assumptions. Finally, this chapter contains a literacy review of various relevant journals and articles influencing ideas such as the report structure and lean manufacturing.
- Chapter 3 Define: this chapter includes the definition of the project along with the reasons for this being chosen. The current operational procedure and the problems associated with it, including the precise area critical to quality that will be the areas intended for improvement.
- Chapter 4 Measure: in this section will be a plan for how and what data will be collected. A summary of the data collected in numerical and graphical forms. Also, critically identifying possible variations or anomalies found within the data, an explanation for such anomalies and how they affect the results.
- Chapter 5 Analyse: this chapter will assess the operating procedure and use the data acquired in the measure chapter to discuss the drawbacks of the process and what factors are being directly affected such as any direct or indirect costs. Also, the importance of lean manufacturing will be discussed through the time wasted during the original operating process.
- Chapter 6 Improve & Control: In this chapter will describe the implementation of the improvement in detail, then explain why this improvement has been selected through using various diagrams such as FMEA, costings and process maps. Furthermore, how the new method of work can be upheld therefore to maintain the improvement to provide long-term benefits.

- Chapter 7 Conclusion: This concluding chapter will conclude the report, a summary of the findings throughout all chapters, whether the project has been a success, what can be expected from the improvement in the future.

## 2. Background Research

In most cases of automation ensuring that a production line is efficient requires the product throughput to match the demand. The production line in question does not match this automation philosophy.

### 2.1 Timescales and provisional work plan

This project has already been given a green light and go ahead prior to drafting this report. The idea for this project was discussed before the new academic year began in September 2023 but work towards the project did not occur until after the date above.

Due to the nature of this project, the deadline of June 2024 was given. This included all practical and relevant theory work involved such as finalising a solution, implementation, and time to evaluate the results for comparison.

#### 2.1.1 Gantt Chart

The project scope can be categorised by each of the following stages you will find in this report, a Gantt Chart as seen below will also be used to assist with time keeping throughout to assure that deadlines are met and completed.

As James M. Wilson says in his article Gantt Charts: A Centenary Appreciation, the proliferation of microcomputer-based project management packages has led to a revival in the use of Gantt charts. This popularity underscores their usefulness as a management tool.

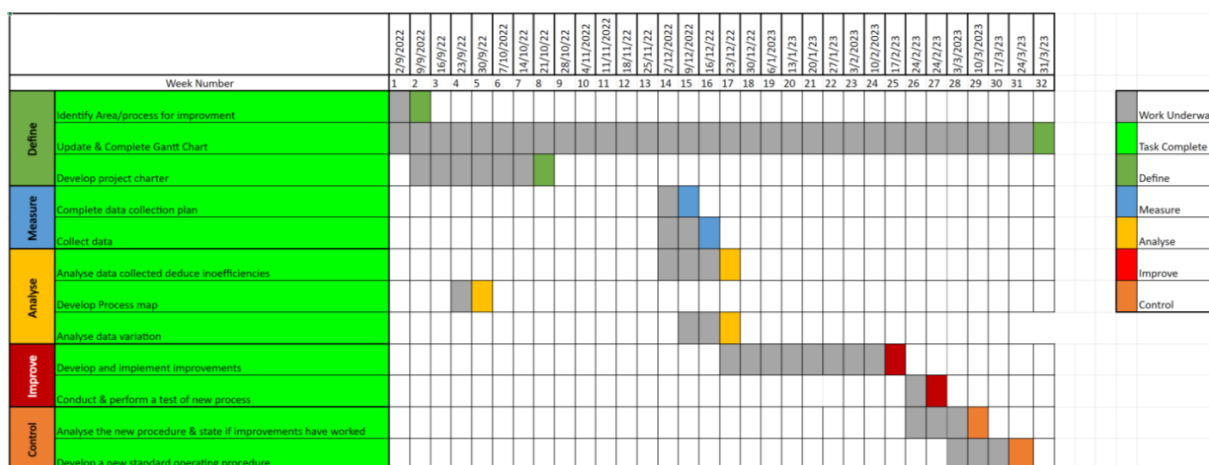


Figure 1- Project Gantt Chart

Unfortunately, a Gantt chart does not explicitly cope with complexity, ambiguity, uncertainty and change (Joana Geraldi) however if the project is unlikely to have any major setbacks or delays.

## 2.3 Project Charter

### **Problem Statement & Area for opportunity**

Welding bay extraction system left operating unattended/while manufacturing process is not taking place during a normal working day. Identify problems regarding current working practices, find exactly where and how time is being wasted to operate control panel/electricity being used to keep motor running. Implement a new working practice, and train operates to use the new procedure to prevent wasted time and money, this should provide evidence of ROI (return of investment) after improvement have been made to the manufacturing process.

### **Business Needs & Justification**

On average the operator over 5 minutes of his normal working shift walking to and from the control panel to operate the extraction. This time could be redirected towards manufacturing components and prevents the equipment from being left running unattended. This will grant the business certain benefits such as increasing the output of components manufactured and boost the efficiency of the process, reducing the amount of indirect costs for the business in terms of electricity, and potentially reducing the life span of equipment resulting in less long term down time for maintenance to take place.

### **Risks & Problems**

Risks include creating downtime to implement changes to the process taking longer than expected due to both ability of maintenance staff or, issues with the supply of components necessary to make the improvements such as the new control panel within the welding bay or the retrieving the contactors/relays required for the specification of the panel.

### **Assumptions**

The first assumption is that the operator is leaving the equipment running to due to the lack of indication caused by the damage on control panel itself. Of which lamps that indicate operating status of the panel are not working therefore he is unaware if the equipment requires to be switched off. Or secondly and more likely the operator is saving time not walking to and from the control panel when going for breaks to complete working activities. Depending on these assumptions we could a gain in productivity or a reduction in costs being spent on keeping the equipment running.

| Internal Project Team |                |
|-----------------------|----------------|
| Name                  | Role           |
| Morgan Baker          | Champion       |
| Steffan Richards      | Manager        |
| Carl Tucker           | Parts/Supplier |
| Dave Davis            | Operator       |
| Tudor Jones           | Quality        |

Table 1- Meet the Team

## 2.4 Literacy Review

In this chapter will be discussing up to date published journals and engineering papers/studies that I believe are relevant to my project. The relevance will be key to analyse to suggest methods of improvements that I can use for my project, and to help avoid mistakes when discussing certain factors. As put by Jeffrey W. Knopf, put briefly, a literature review summarizes and evaluates a body of writings about a specific topic.

To perform this, I will be discussing the papers abstract to gain an introductory understanding of what the paper entails and therefore I can determine its relevance towards my project. I will then be looking into the conclusion to help reinforce my knowledge and understanding of the paper's findings, self-evaluations, results, and summation. Following this I can then perform a critical analysis on the topics above and talk about why the papers are relevant and henceforth grant me the ability to develop my own project to a higher standard.

These papers/journals will include manufacturing processes such as the optimisation of welding bays and the methods of extraction for particulate matter. To manufacturing planning and research such as Lean manufacturing, six sigma, and cost-effective analyses.

In 2006, Richard Ernst PhD authored an article entitled 'Indirect Costs and Cost-Effectiveness Analysis. This article examines the methodological implications in terms of direct and indirect costs of health care interventions. Which will require the total indirect costs to be constrained while a computational procedure maintains a 'trade off' rate between losses of health benefits and reduction in indirect costs.

The premise of adding direct and indirect costs that can change systems of work to benefit both customer and company through corrections and adaptations in this case is stated as 'intrusively appealing, but also introduces complications into models of cost effective analysis.' certain benefits attained through such systems of work included the rate of which the every scenario can be analysed due to the computation algorithm. The systems can determine which method of treatment to give to a patient, which is most effective in terms of reducing the in-direct costs and giving the patient the optimum level of care necessary.

Despite the subject of the paper is improving systems of work involving health care the methodology can be used to significant effect within the manufacturing engineering sector. For example, there can often be many solutions to solve an engineering problem some

solutions might cost more but can get the job done in less time (more direct costs, but potentially less indirect costs). Some solutions can be the opposite where more time is taken but the less it can cost. It will be beneficial to find a median where the job is completed in a reasonable amount of time while maintaining a reasonable cost. The algorithm could potentially generate this solution automatically especially with recent computational advancements such as artificial intelligent thus saving time and resources discussing multiple solutions for problems.

In 2012 Jeron De Mast published an article examining the methodology of using six sigma to improve the quality of a production process. An article titled 'Analysis of the Six Sigma DMAIC Method from the Perspective of Problem Solving.' The abstract of which expresses the DMAIC approach (define, measure, analyse, improve, control) to problem solve. In other words, this paper critically compares the DMAIC method with insights from scientific theories in the field of problem-solving highlighting several types of problems which DMAIC method can be used effectively and while identifying inefficiencies with using this method.

Several conclusions have been found in this paper with using DMAIC method one of which is applicable to empirical problems and is well-structured for this, but not to ill-structured problems or messes of subjective problems for tasks of smaller scope. It is clear from the research in this paper that the DMAIC method requires a precise desired goal to achieve to be used effectively, and being well suited for extensive problem-solving tasks, diagnosis/research, and remedies/solutions.

This paper will match the format and structure of the following so is incredibly insightful and beneficial to have a good understanding of DMAIC methodology. The fact that it is especially useful for problems with large scope and to achieve a direct goal makes it perfect for the intended use of improving a system of work within a manufacturing process.

Also in 2012, Edwin Raja Dhas & Jenkins Hexley Dhas authored a paper titled 'A review on Optimising of Welding Process.' This paper describes a new way of thinking to change and improve the welding process to develop products at an economical price through investing in procuring new equipment and controlling the process variables. These variables include welding parameters such as welding speed, voltage, current, and time, all of which will need to be considered across all welding types for the process to be optimised.

The paper concludes by stating that the desire output of a welding process is given by the selection of appropriate parameters listed above. To find the most efficient and effective utilisation of the process can be achieved by conducting experiments which include a variety of materials and tests while changing the variables to find the best solution. These parameters can then be logged and used in a form of algorithm which can find the optimal solution for any condition.

The relevance of this paper may not seem obvious, but it can highlight benefits to the process once the welding bay is functional. By optimising the effectiveness of the process

can reduce indirect costs through time taken to produce components, the quality of the welding itself can see an improvement, also by reducing the time taken to produce parts can result in an increase of total parts produced in one shift, therefore a growth a productivity.

Recently in 2023 Suveg V Iyer authored a paper entitled 'Digitalisation: a tool for the successful long-term adoption of lean manufacturing.' This paper will discuss the digitalisation as a tool for the adoption of lean manufacturing through real time data acquisition using computational methods. The solution of which will incorporate a low cost-based method to acquire the data for the purpose of strategic decision making to then improve the effectiveness of a modular production line.

The real time data acquisition and its processing is highlighted as a key step to improving lean manufacturing in production equipment. But during the findings of the report; it is stated that it is equally as important to have a method of visualising the results and have it capable of communicating the results in an effective manner. The method of a digital interface will help interpret data with improved accuracy and quality.

The relevance of this paper is crucial for making my project a success as the importance of measuring and acquiring data both before and after the improvements are implemented cannot be underestimated. This means that to prove my project is worth investing in I must firstly provide sufficient data that convinces the investor that there is significant room for improvements to be made to the production line whereby both costs can be reduced, and productivity can be improved upon. Furthermore, the results of which will need to be analysed once the project is completed to see if the estimated data matches the data acquired after the improvements have been implemented.

Finally in 2017, Monika Smętkowska and Beata Mrugalska released a case study titled 'Using Six Sigma DMAIC to Improve the Quality of the Production Process.' This paper presents how to implement the DMAIC cycle as an element of continuous improvement in practice for the need to improve quality in the industrial sector. Both the application of DMAIC and problems within the organisation will be analysed. And finally, propositions for improvements which can then be implemented to increase the effectiveness of the working practice will be presented.

The conclusion of this paper shows that through the application of DMAIC the quality improvement used in Six Sigma concept, can increase the effectiveness of the appearing problems. While highlighting areas and methods for improvements such as trainings for employees, work standardisation and productive maintenance and after that. Also, that it is necessary to introduce continuous control on the efficiency of the processes performed to maintain the improvements.

The relevance from this paper is shown through the organisation, structure, and headings. The define, measure, analyse, improve, and control headings will all be relevant and seen

throughout my report as it is very practical and useful guide for an effective six sigma structured report.

## 2.5 Chapter Conclusions

This chapter has involved detailing an extensive literature review. The main findings are:

- There is potential to be gained from a change or implementation. A time and cost benefit.
- Who is responsible and for what roles they have in the project.
- What risks are there, whether delays will have a factor or controlling the new working process.
- To create a well round report that benefits a project it is best to use a DMAIC format.

### 3. Define

#### 3.1. Problem Statement

Currently experiencing issues within the production department whereby a welding bay extraction system is being used but left on unattended. An investigation is required to find out why this is happening, what are the current working practises in place, what effects it's having on the business in terms of costs, efficiency, downtime etc. whether improvements to the working practices can be made, or what can be implemented and put in place to prevent this issue from reoccurring.

Firstly, the working practice should be that the extractor is switched off when not in use. However, it appears that this is not always the case as is often left operating while unattended on multiple occasions throughout the day.

Secondly, we must know when exactly the extractor is being left running without an operator present and why this is the case. Whether it is negligence on the operator's behalf, or the controls for the extraction are in some way compromised.

Thirdly, what are the benefits that could be gained in terms of ROI (return of investment). Such as reducing electricity costs through reducing operating hours of the machinery and what results can be expected after implementing an improvement to the process already in place.

Lastly, to incorporate Lean principles to identify, locate and improve a process whereby non value adding activities are found and resolve them. Take the current normal working operation procedure and identify areas for improvement, propose a solution and carry it out, to improve the efficiency of the manufacturing process involved in the welding bay and reduce the wasted electricity from leaving the extraction motor running unattended.

#### 3.2. Current Operating Procedure

The current operational procedure typically requires the operator to dedicate approximately 90 seconds to activate the extraction motor before commencing their work. This time encompasses walking to and from the control panel, accounting for potential delays such as yielding to forklifts or other heavy lifting equipment like gantry cranes and pallet trucks. Following motor activation, the operator proceeds to weld the corners of the cabinet doors and tops, utilising either a spot welder or handheld MIG welder. Should any defects be identified in the cabinet components, a pneumatic grinder is employed to smooth the panel before painting. Throughout the operator's shift (from 6 am to 2:30 pm), this process continues uninterrupted, with only brief pauses of 15 minutes for breakfast and 30 minutes for dinner. During these breaks, the extraction system must be switched off while unattended. Adhering to this procedure, there remains an average surplus of over 5 minutes daily when the motor continues running unnecessarily, resulting in the operator needing to leave their workstation to access the control panel.

### 3.3. Areas Critical to Quality

The critical elements to focus on improving are varied from wasted electricity costs, wasted time, and potentially reducing the life span of equipment, an explanation of each is as follows:

#### 3.3.1. Costs to Operate Equipment

Calculating the expenses associated with the extraction process and assessing the proportion of wasted energy to sustain the fan during idle periods essential. For example, even if operational for just an hour daily, the costs incurred to uphold equipment functionality throughout a year could stretch into thousands. To accurately gauge the expenditure, precise data regarding the duration of time the equipment is operational while unattended, and the specifications of the motor must be obtained providing the energy consumption required for operational velocity. Additionally, awareness of the prevailing electricity tariffs imposed by the council, subjected to Bisley Office Equipment, is essential for a thorough evaluation.

#### 3.3.2. Time Being Wasted

Calculating the time spent operating the extraction control panel is crucial for multiple reasons. Firstly, it enables us to assess the financial resources allocated to sustaining extraction operations during periods of inactivity, therefore a clearer evaluation of potential returns on investment following process improvements. Secondly, by understanding the reasons behind this time wastage, we can streamline efforts towards implementing solutions aimed at preventing the extraction from being left running. Lastly, reassigning this wasted time towards product manufacturing offers an opportunity to enhance overall productivity within the process, effectively repurposing idle time to increase and improve operational output.

#### 3.3.3. Lifespan of Equipment

It is Important to account for the additional operational time of the equipment, as it puts continuous strain on its components, including the motor, fan bearings, ducting seals, and fan blades. Over time, these parts become less efficient due to the accumulation of dust and debris, necessitating increased maintenance costs. This could lead to downtime for repairs when components fail, potentially halting the manufacturing process and causing delays in product delivery. Such disruptions can result in dissatisfied customers and damage to our reputation.

## 4. Measure

### 4.1 Determine Types of Data

It will be important to track non-profitable activities, such as when the operator walks to use the control panel. The average time per shift will be calculated and used to illustrate the cumulative time over a week, month, and year.

Similarly, monitor the electricity expenses incurred while operating the panel, providing insights into the costs on a weekly, monthly, and yearly basis. This data will help pinpoint potential efficiency gains.

Both sets of data fall under the quantitative category, representing numerical values with measured units, rather than qualitative pass/fail indicators. Moreover, the recorded values for the project are continuous data, measured on a continuum basis, such as the time utilised during a day that could otherwise be used to manufacturing components.

### 4.2 Plan for Data Collection

|                                | Type of Data | Type of Measure | Freq.                           | Frequency | Illustration    |
|--------------------------------|--------------|-----------------|---------------------------------|-----------|-----------------|
| Time to manufacture 1Component | Discrete     | Attribute       | Once per component manufactured | 1 Hour    | Scatter         |
| Consumption of Electricity     | Continuous   | Variable        | Daily                           | 1 week    | Colum/bar Graph |
| Time to operate panel          | Continuous   | Variable        | Hourly                          | Daily     | Pie Chart       |

Table 2- Data Collection Plan

It is worth noting the difference between discrete and continuous data, discrete is data that can only be taken in a range of values and ‘can be counted and has a limited number of values. It usually comes in the form of whole numbers or integers.’ (Anas Al Masud) Whereas continuous data can be measured and can be theoretically an unlimited number of different values that are not fixed to a range.

#### 4.2.1 Data Collection

|             | Operating hours | Hours taken to operate panel |
|-------------|-----------------|------------------------------|
| Monday      | 7.9             | 0.1                          |
| Tuesday     | 7.92            | 0.08                         |
| Wednesday   | 7.95            | 0.05                         |
| Thursday    | 7.96            | 0.04                         |
| Friday      | 7.8             | 0.2                          |
| Total hours | 39.53           | 0.47                         |
| Average     | 7.906           | 0.094                        |

Table 3- Time Spent Operating Control panel

In table 3 the total and average amount of time that the operator spent using the control panel were measured for the duration of a normal working week. The hours taken to operate the panel are the non-value adding hours that will be used in table 6&7 to calculate the losses involved. In Derrik C. Darden journal about time wasters in the workplace sums up the issue of wasted time by saying ‘The individual worker is focusing on a task that is non-productive toward the goal, objective, or mission of the organization. The worker is being sidetracked from the essential task at hand.’

|           | Hours Wasted | £ per kWh Before May 2023 | £ per kWh After May 2023 |
|-----------|--------------|---------------------------|--------------------------|
| Monday    | 0.1          | £0.36                     | £0.49                    |
| Tuesday   | 0.08         | £0.29                     | £0.39                    |
| Wednesday | 0.05         | £0.18                     | £0.24                    |
| Thursday  | 0.04         | £0.14                     | £0.20                    |
| Friday    | 0.2          | £0.72                     | £0.98                    |
| Totals    | 0.47         | £1.69                     | £2.30                    |

Table 4- Costs Implications on Wasted Time

Table 4 shows the relationship between the amount of time wasted during a normal working week as seen also in table 3, and the cost implications associated with that the including both before and after May 2023. This should be used to breakdown the costs per day and deduce whether some days are more costly than others.

| Components produced                       | Time taken (seconds) | Total Time Taken (seconds) | Total Time Taken (minutes) |
|-------------------------------------------|----------------------|----------------------------|----------------------------|
| 1                                         | 150                  | 150                        | 2.50                       |
| 2                                         | 180                  | 330                        | 5.50                       |
| 3                                         | 146.4                | 476.4                      | 7.94                       |
| 4                                         | 153                  | 629.4                      | 10.49                      |
| 5                                         | 148.8                | 778.2                      | 12.97                      |
| 6                                         | 162                  | 940.2                      | 15.67                      |
| 7                                         | 157                  | 1097.2                     | 18.29                      |
| 8                                         | 164                  | 1261.2                     | 21.02                      |
| 9                                         | 175                  | 1436.2                     | 23.94                      |
| 10                                        | 225                  | 1661.2                     | 27.69                      |
| 11                                        | 180                  | 1841.2                     | 30.69                      |
| 12                                        | 166                  | 2007.2                     | 33.45                      |
| 13                                        | 157.2                | 2164.4                     | 36.07                      |
| 14                                        | 200                  | 2364.4                     | 39.41                      |
| 15                                        | 155.4                | 2519.8                     | 42.00                      |
| 16                                        | 156                  | 2675.8                     | 44.60                      |
| 17                                        | 159                  | 2834.8                     | 47.25                      |
| 18                                        | 148                  | 2982.8                     | 49.71                      |
| 19                                        | 169.8                | 3152.6                     | 52.54                      |
| 20                                        | 162                  | 3314.6                     | 55.24                      |
| 21                                        | 150                  | 3464.6                     | 57.74                      |
| 22                                        | 165                  | 3629.6                     | 60.49                      |
| Average Time Taken to Produce 1 Component |                      | 164.98 Seconds             |                            |

Table 5- Time to Manufacture 1 component

Table 5 measures the amount of time taken for the operator to complete or fully manufacture a single component. This was performed for 1 hour and 22 components were produced. The average time taken for 1 component will be used in table 6 to calculate the potential gain in components when compared to the time spent operating the control panel.

|                                         | Days  | Weeks | Months | Years  |
|-----------------------------------------|-------|-------|--------|--------|
| Operator Shift (Hours)                  | 8     | 40    | 160    | 1920   |
| Time Wasted by Operator (Hours)         | 0.09  | 0.44  | 1.75   | 21     |
| Time Wasted by Operator (Seconds)       | 315   | 1575  | 6300   | 75600  |
| Time to Manufacture Component (Seconds) | 165   | 825   | 3300   | 39600  |
| Number of Gained components             | 1.91  | 9.55  | 38.18  | 458.18 |
| Percentage of Increased Production      | 1.09% |       |        |        |

Table 6- Time/Productivity Data Sheet

- Operator shift: 6am-2.30pm, 8-hour shift plus 30 minutes for lunch.

- Time wasted by operator: the average amount of hours and seconds spent by the operator to use the control panel during the time periods seen in the columns.
- Time to manufacture component: this is the average amount of time that the operator takes to manufacture one component including inspection and reworks.
- Number of gained components: the number of potential components that could be produced if the time wasted by the operator was redirected towards manufacturing.
- Percentage of increased production: this provides a percentage of how much time is spent for the operator to use the control panel compared to their 8-hour shift. Therefore, can be depicted as potential for increased production or current percentage of wasted time during their shift.

|                                          | Hourly | Days  | Weeks | Months | Years   |
|------------------------------------------|--------|-------|-------|--------|---------|
| Running Time of Extractor Fan (Hours)    |        | 8     | 40    | 160    | 1920    |
| Wasted Running Time of Extractor (Hours) |        | 0.09  | 0.44  | 1.75   | 21      |
| Cost of Electricity Before May 2023      | £0.36  |       |       |        |         |
| Cost of Electricity After May 2023       | £0.49  |       |       |        |         |
| Cost to Run 10kW Motor                   | £4.90  |       |       |        |         |
| Wasted Electricity Cost                  |        | £0.44 | £2.20 | £8.82  | £114.40 |
| Operator Wage                            | £12.50 | £100  | £500  | £2000  | £24000  |
| Wasted Cost for Operator Wages           |        | £1.09 | £5.47 | £21.88 | £262.50 |
| Total Wasted Costs                       |        | £1.53 | £7.67 | £30.70 | £376.90 |

Table 7- Financial Data Sheet

- Running time of extractor fan: the amount of time the extractor is left running during a full shift including when left running unattended.
- Wasted running time of extractor fan: the amount of time whereby the extractor is running while unattended
- Cost of electricity: the hourly rate of electricity per kilowatt hour before and after May of 2023 where the price increased by £0.13.
- Cost to run 10kW motor: the hourly cost to upkeep a 10kilowatt motor at the price of £0.49 per kilowatt hour.
- Wasted electricity cost: the price to maintain operation of the 10kW motor during the wasted running time of the extractor.
- Operator wage: hourly rate of pay for the operator.
- Wasted cost for operator wage: cost to pay the operator their working wage during the wasted running time of the extractor.
- Total wasted cost: total wasted costs combining the wasted operator wage and time running the extractor.

#### 4.3 Identify Variations in Measuring

This section will highlight the potential variation found in the measurements found in the above tables and subsequent data collection. As seen, the results for electricity consumption, time taken to produce one component, and time spent operating control

panel can all be interpreted from the data. Below can be found an explanation for each set of data and whereby some variation may have occurred. Also, a plan to reduce the amount of variation to nullify anomalies or incorrect data.

It is important to understand how these anomalies can occur as the business is relying on myself and other members involved with the project to invest time, money, and resources with the goal of improving the efficiency of this process. Therefore, it is required that the results recorded will be accurate to the current manufacturing process, thus show the truest possible direct/indirect costs that could be gained through an improvement to the process, and if there are other benefits that can be gained from the implementation.

#### 4.3.1 Time to Produce Components

A noticeable difference can be seen in the data in table 6, the amount of time it takes to produce one component, specifically the column titled 'Time Taken (minutes)'. This is because welding processes often lead to slight variations in quality. Furthermore, the operator is responsible for inspecting the component before and after the welding activities to identify any defects or damage to the panel. Upon detecting defects or damage, the operator must use a pneumatic grinder to eliminate these imperfections or discard the panel if the component is unrepairable. Such cases can substantially affect the time required to produce a single panel. Hence, why it is crucial to gather a comprehensive dataset to calculate an average as this approach mitigates the influence of anomalies in the recorded results over a wide-ranging data.

#### 4.3.2 Electricity Costs

Variations regarding the electricity costs can occur in terms of measuring the consumption of the motor, this is caused by the time when the extractor is activated to when reaching its operational running speed. On start up, this will consume a greater quantity of energy than if the motor is operating at its normal RPM within the same amount of time. This extra energy consumption has not been considered in table 7 (financial data sheet) since the motor's startup time is brief. This is thanks to the minimal inertia needed to reach its operational speed with the fan's weight attached to it.

#### 4.3.3 Time to Operate Control Panel

Similarly, to the production time of one component found in section 4.3.1; The duration of time spent by the operator using the control varies, this is influenced by its location to the welding bay where extraction is needed. When the operator must walk away from the bay to toggle the extraction, it leads to time consumed by non-value adding tasks. This process is often disrupted by passing forklifts or other heavy lifting equipment like cranes. Consequently, measuring the total time spent operating the control panel for each shift throughout a regular workweek becomes essential. This data will enable me to calculate both the total and average time lost in terms of efficiency, pinpointing areas for process improvement to minimise indirect costs and non-value adding activities.

## 5. Analysis

### 5.1 Process Analysis

To gain an understanding of the inefficiencies throughout the manufacturing process, it is vital to know exactly what the process involves therefore in figure 2 found below is a simple yet effective process map flow chart to show what the operator carries out for each component. As described by J. Mike Jacka, a process map can be used 'to analyse and enhance their critical processes in order to deliver the highest level of service.'

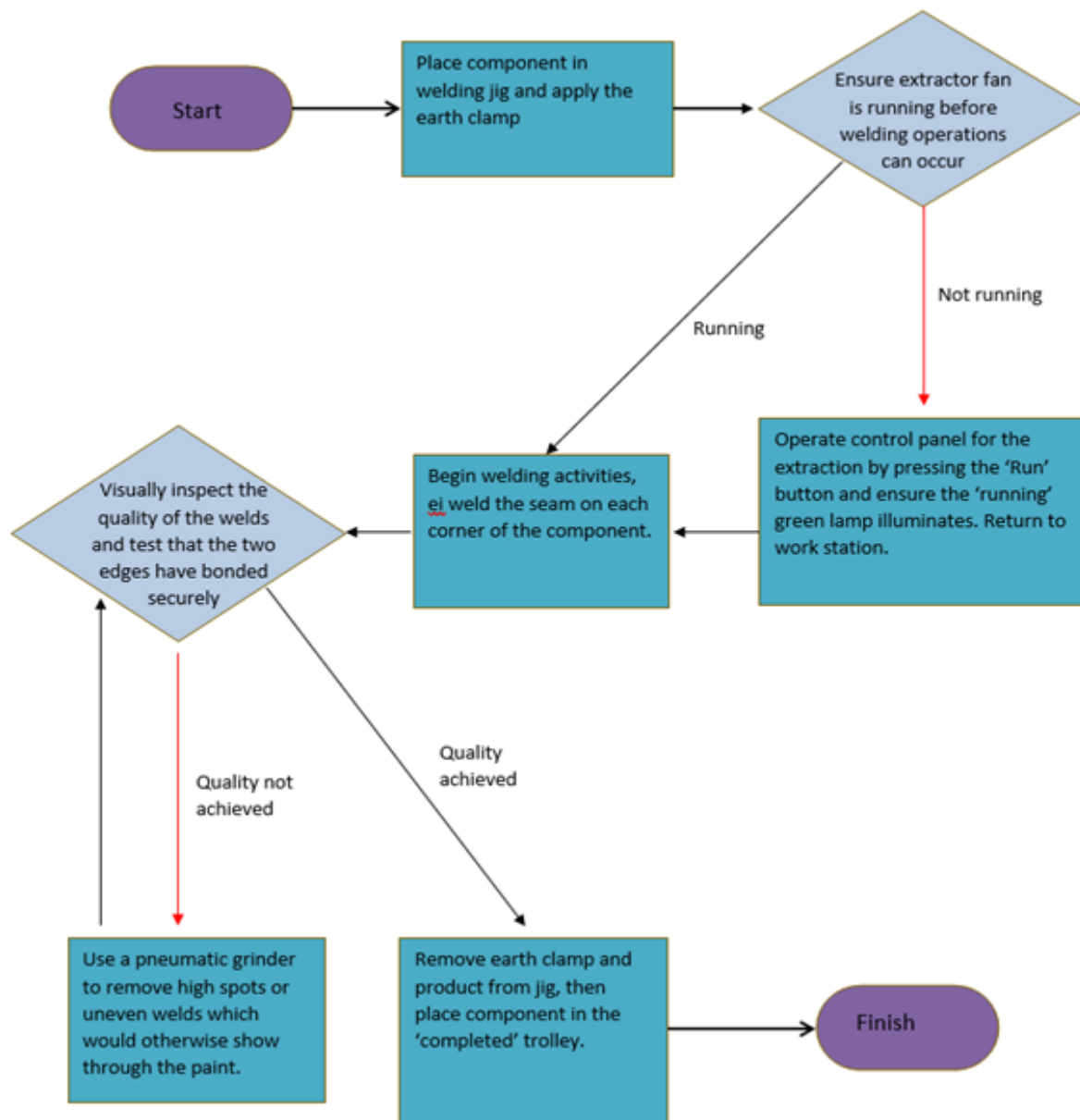


Figure 2- Process Map for Manufacturing Process

By taking a brief analysis of this process map, the goal is to take as much question out of the equation as possible, consequently to this will help 'speed up' the overall process and thus allow for improvements to the efficiency to be utilised for benefits such as increased productivity and reduced costs.

## 5.2 Review Analysis

In this chapter will be an in-depth analysis into each of the category that has the potential for improvements. Highlighted in the following sections (5.2.1-5.2.3) will be the inefficiencies within the current working practise, based on the data collection and tables 3-6. With assistance through using graphical analysis tools, an explanation of the inefficiencies is discussed in the following.

### 5.2.1 Time to Manufacture Components

To gain further insight into the manufacturing process of the components, an Ishikawa Diagram was created, commonly referred to as a fishbone diagram. This tool assists with visually representing the intricate factors involved with the process, therefore enabling a more precise analysis to identify potential areas for improvements. For instance, to shorten the production time of a component, potential solutions could involve offering additional welding training to operators or investing in higher-quality tools and raw materials. These paths represent feasible investments capable of enhancing overall efficiency. As put by Kam Cheong Wong 'It provides a structured and systematic approach to identify and collate potential causes for an effect.'

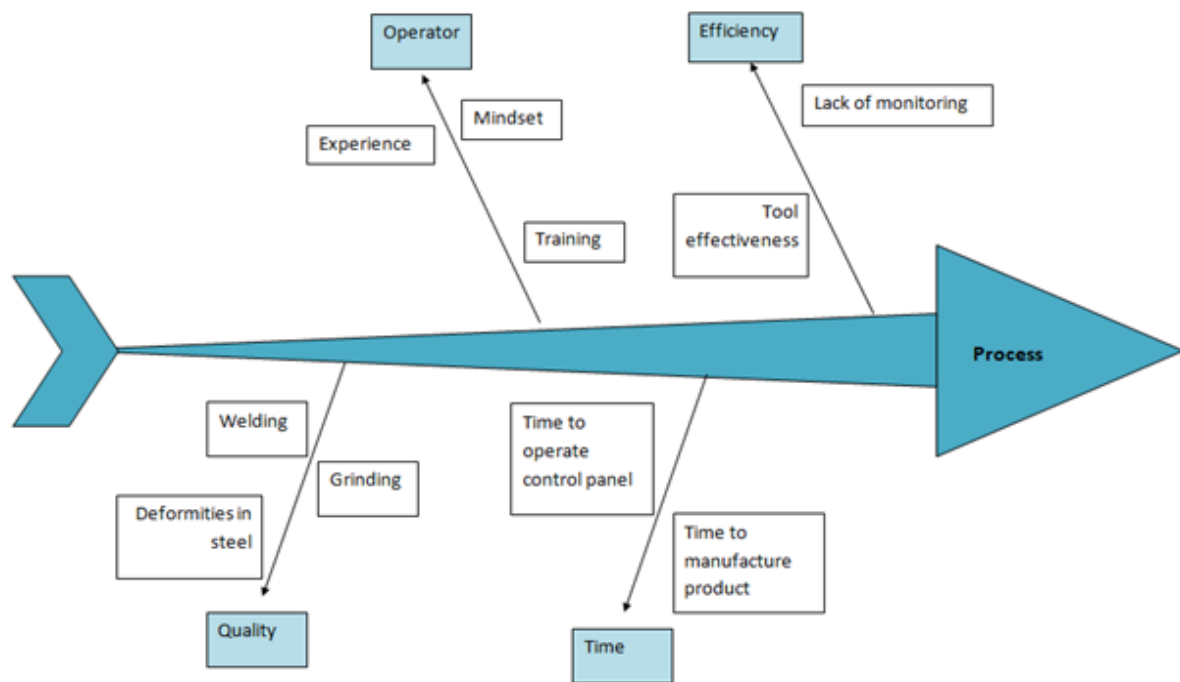


Figure 3- Ishikawa Diagram (Fish Bone Diagram)

### 5.2.2 Consumption of Electricity

The primary cause of inefficiency in this situation stems from the unnecessary consumption required to sustain extraction operations even when manufacturing is halted, such as during the operator's break. Although the standard procedure dictates the operator should deactivate the extraction before taking their breaks, however, currently it remains operational and unattended. Based on the data gathered, this results in a weekly

expenditure of £2.20, which may not seem significant on its own, but over the course of a year, it accumulates to £114.40, as seen in table 7.

### 5.2.3 Time spent to operate Control Panel

To analyse the amount of time wasted by the operator to use the control panel for the extraction required for the manufacturing process, and subsequently examine where this non-value adding activity is inherited, 5 Whys demonstration has been produced. Alan J Card quoted in his journal the problem with 5 whys, the pedagogical argument for '5 whys' is that it creates an 'aha moment' by revealing the hidden influence of a distant cause, which illustrates the importance of digging deeper into a causal pathway. This quick and easy learning experience can be a powerful lesson in systems safety and QI.

| Identified Problem |      | Excessive amounts of time being used for non-profiteering activities, offering increased costs and reduced production time.                                                                                                                                                           |
|--------------------|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.                 | Why? | The operator is required to use extraction for their working practices such as welding and grinding for personal safety and environmental legislation. They are also required to deactivate the system when on break using the control panel.                                         |
| 2.                 | Why? | Operator must leave their workstation to operate the control panel to deactivate the extraction fan. Which is occasionally being performed during working hours to allow the operator to maintain their allowance for of time for break, or not being performed at all.               |
| 3.                 | Why? | The location of the control panel is greater than 10m meters from the operator's workstation and on average this results in over 5 minutes per shift as a delay for the manufacturing process. To be precise according to table 6, 15 seconds or 5 minutes and 15 seconds on average. |
| 4.                 | Why? | The current control panel was installed prior to the welding bay for other purposes and therefore predates the welding bay and cannot be moved.                                                                                                                                       |
| 5.                 | Why? | The original and current control panel has other functions such as extraction for the building and fire extinguishing indicators.                                                                                                                                                     |
| Possible Solution  |      | A new control panel that allows foe operation from the operator's workstation without requiring them to leave, such as in the welding bay or designated working area.                                                                                                                 |

Table 8- 5 Why's

### 5.3 Graphical Analysis

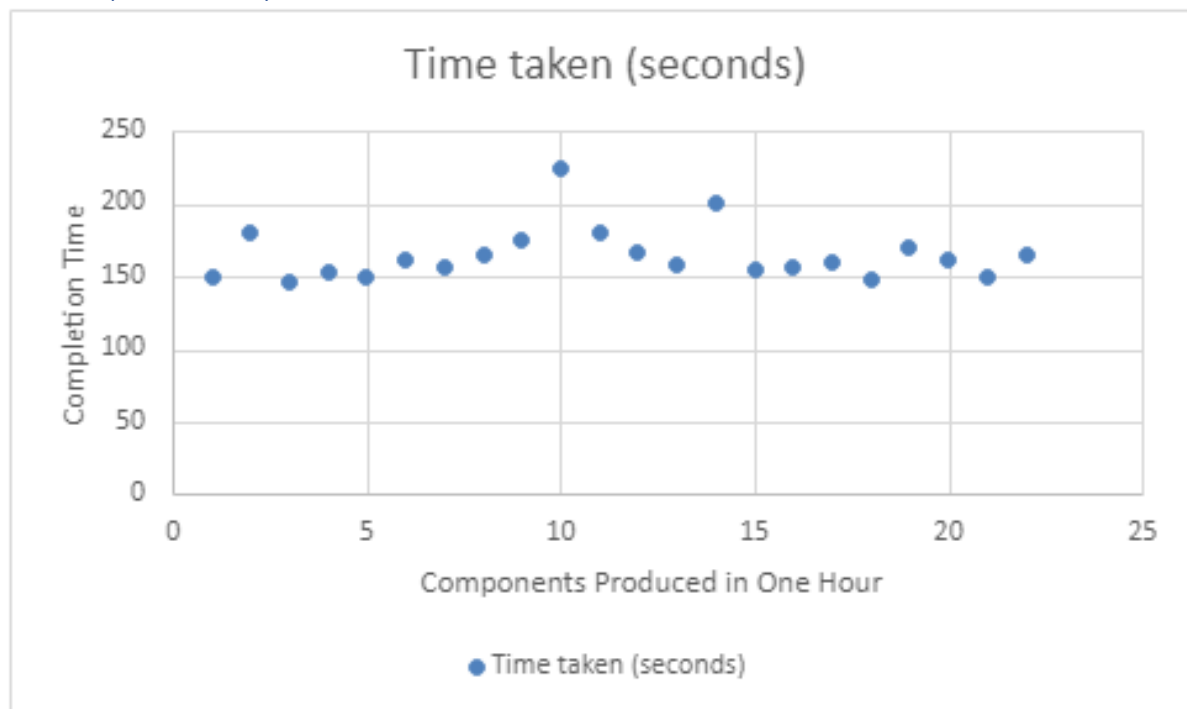


Figure 4- Time Taken to Produce Components in One Hour

Data based on table 5

Figure 4 is a scatter graph showing the observed range of outcomes when the operator produces a single component using the welding bay. This data will be crucial in assessing whether the time spent operating the control panel can be optimised to enhance the process efficiency by increasing the current component production. Yunhai Wang describes line and scatter graphs as 'usually considered to be the best choice for visualizing time series data, whereas sometimes also scatter plots are used for showing main trends.' The visible trend in figure 4 is almost a straight line, however due to parts 10 & 14 has stretched the average line to a slight curve.

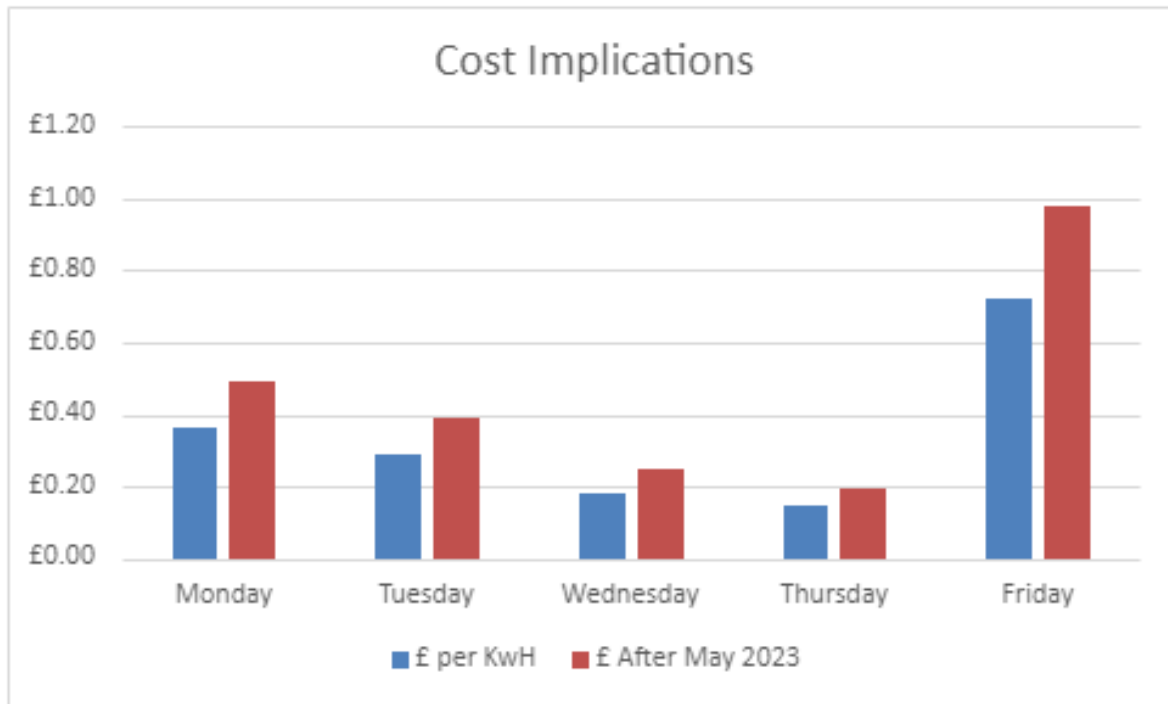


Figure 5- Cost to Run Extractor Unattended Throughout One Week

Based on data in table 4

Bar charts are one of the most common visualization types (Justin Talbot). Figure 5 illustrates the daily indirect expenses incurred during a typical working week when the motor for the extraction system is left running unattended. It also compares the electricity cost per kilowatt-hour (kWh) before and after May 2023.

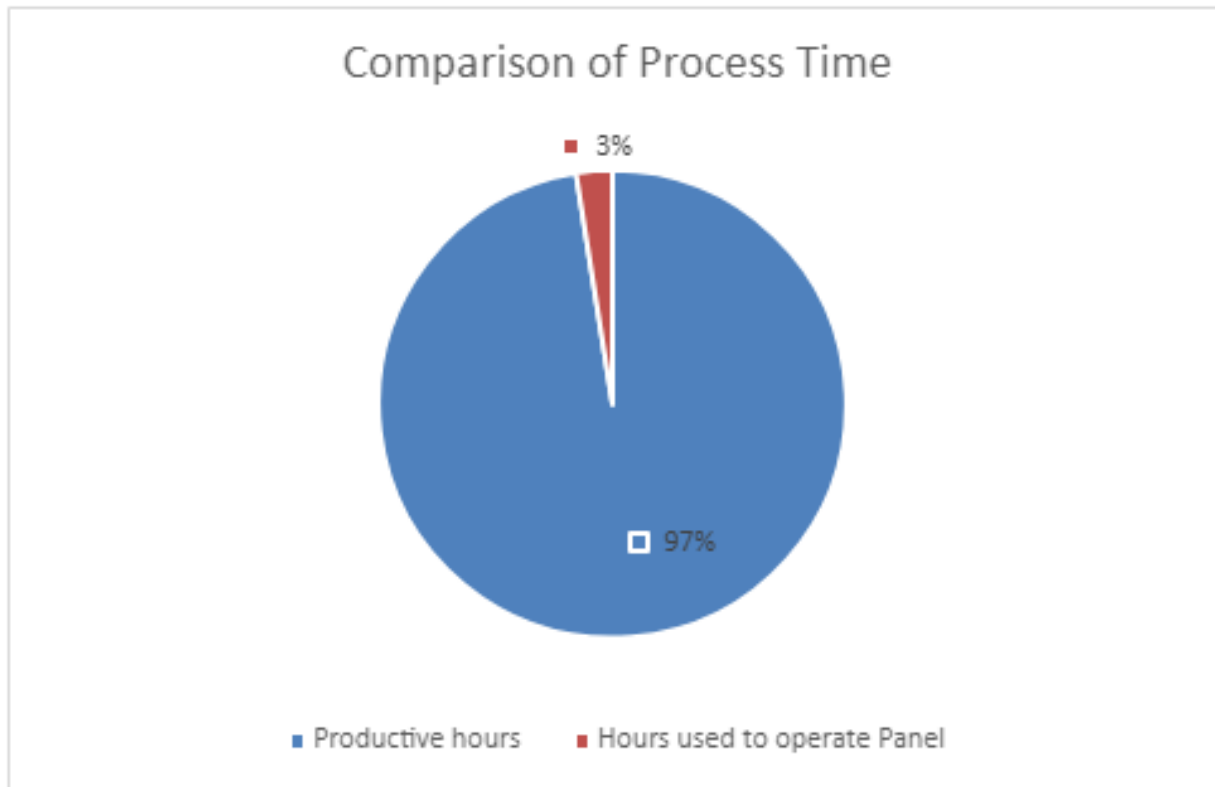


Figure 6- Percentage of Productivity During the Average Working Shift

Percentages based on data in table 3

The pie chart in figure 6 highlights the non-value-added time during a standard working shift. Notably, a small yet impactful portion of this time is attributed to the operator's activity in using the control panel. Pie charts are a useful tool for visualising a portion of difference between multiple sections or pieces of detail. Here is what Harri Siirtola said about pie charts in his report entitled 'The Cost of Pie Charts' The results show that the pie chart is slower and less accurate than the stacked bar chart, especially when the difference between the elements is small, but the participants find it slightly more pleasant to use.

#### 5.3.1 Graphical Analysis Conclusions

To demonstrate the potential in this project and to show the benefits of investment in the project, a thorough analysis is crucial. The following will entail an evaluation of all aspects, including examining graphical representations that illustrate inefficiencies based on collected data. The main advantage of using graphical illustrations is to assist with the perspective and perception of viewers regarding the values recorded during the data collection. A technique whereby it can enhance clarity and credibility, bolstering the conveyed information.

Firstly, the scatter graph in figure 4 provides a sample size of the components manufactured within 1 normal working hour. Based on the illustration you can deduce that 22 components were manufactured, meaning the average time to produce one component was 165 seconds or 2 minutes 45 seconds. This calculation is a result of the range of values observed of which 2 components took a noticeably greater amount of time. This is a result of the complex process whereby the operator needs to assess the quality of the component and

make improvements using a pneumatic grinder, re-check the quality again until the standards are met. This being part of the process they will perform for every component which can take an unspecified amount of time. Hence the importance of attaining a range of values to minimise the effects of these anomalies.

Secondly, the bar chart depicts the electricity consumption during a normal working week when the extractor is left unattended while allowing the viewer to make a comparison between the current price of electricity and the price after May 2023 caused by inflation. This is a considerable increase in costs which highlights the importance of minimising wasted resources. In this case both money through running equipment, and time due to the poor location of the control panel and the subsequent time wasted operating it. As you can see the average cost implication a day is £0.44 after May 2023 from table 7, which at face value does not seem too considerable but will equate to £114.40. This sum of indirect cost can be utilised for further investments in other areas such as marketing or design, as a result could boost the potential in business in terms of sales for example. Additionally, it is evident that the time required to operate the control panel decreases steadily throughout the week, suggesting a potential improvement in the operator's efficiency over time. This trend could be attributed to the operator gradually becoming more adept at their tasks. Essentially after a weekend break, there may be an adjustment period as the operator readjusts to their work routine. Moreover, notably increased time spent operating the control panel on Fridays may reflect a common phenomenon observed in various work environments where the staff is anticipating the weekend. In such instances, it is probable that the operator spends more time engaging in casual conversations with other operators while commuting to and from the control panel.

Lastly, the pie chart in figure 6 shows a comparison illustrating the contrast between the time the operator dedicates to manufacturing components during a shift and the time spent operating the control panel for extraction. Such a visualisation highlights the potential time savings achievable through an improvement to the process whereby the wasted time is utilised to increase and benefit the production process.

## 6. Improve & Control

### 6.1 Generate Improvement

The proposed design improvement is as follows, to engineer and construct a unique control panel that exclusively operates the extraction system and have the unit mounted within the welding bay compound. This will be within 'arm's reach' to prevent the operator's commute to and from the current control panel location. This also has the advantage of removing the various distractions the operator will encounter such as other members of staff or heavy lifting equipment such as fork trucks and cranes.

This improvement will enable the operator to immediately activate and deactivate the extraction system, eliminating the inefficiencies associated with operating the existing panel. As a result, the business can save £114 annually from May 2023 onwards as seen in table 7, provided the new panel is utilised this could also save maintenance on the system and improve the life span of the equipment due to a significant reduction in total running time of the equipment. Moreover, this solution also eliminates the average of over 315 seconds or 5 minutes 15 seconds spent per shift traveling to and from the current panel. This time savings grants the operator during each shift to perform value-added activities like increased manufacturing output. Considering that an operator typically spends 2 and a half minutes manufacturing a single component, this could potentially translate to more than 2 additional components produced per day. Both the potential savings and benefits can be seen in table 9 as follows.

|           | Operating Hours | Hours Wasted to Operate Panel | Products Gained |        |         |         |
|-----------|-----------------|-------------------------------|-----------------|--------|---------|---------|
|           |                 |                               | Daily           | Weekly | Monthly | Yearly  |
| Monday    | 7.9             | 0.1                           | 2.38            | 11.91  | 47.65   | 571.81  |
| Tuesday   | 7.92            | 0.08                          | 1.91            | 9.53   | 38.12   | 457.45  |
| Wednesday | 7.95            | 0.05                          | 1.19            | 5.96   | 23.83   | 285.90  |
| Thursday  | 7.96            | 0.04                          | 0.95            | 4.77   | 19.06   | 228.72  |
| Friday    | 7.8             | 0.2                           | 4.77            | 23.83  | 95.30   | 1143.61 |
| Average   | 7.906           | 0.09                          | 2.24            | 11.20  | 44.79   | 537.50  |

Table 9- Benefits Calculator

In table 9 can be seen the average amount of hours wasted by the operator using the control panel. These values were measured through a normal working week however it was important to include the average value to be used in the calculations thus removing the impact of anomalies. The time being wasted during the shift was compared to the time

taken to produce one component and calculate the subsequent increasing in productivity. For example, you can expect to see on average an extra 2 components per shift if the operator was not required to leave the welding bay to control the extraction system.

## 6.2 FMEA

To help reinforce the above solution and thus prove the project will be a success in improving the efficiency of the process; a Failure Mode Effect Analysis (FMEA) has been conducted as seen in table 10. This is a risk management tool to depict the severity and likelihood of process stages encountering a problem. FMEA is a systematic approach to identify and prioritise risks associated with the process failures, ensuring improved reliability, quality, and cost-effectiveness. The risk priority number (RPN) highlights the potential risk associated with each process step. Essentially it is crucial to dedicate extra care and time to managing the step with the highest priority number. As described by Robin E. McDermott in his book FMEA, are a systematic method of identifying and preventing product and process problems before they occur. FMEAs are focused on preventing defects, enhancing safety, and increasing customer satisfaction.

| Process Step                        | Possible Failure                                       | Possible Effects                                                                                                                                                              | Severity | Possible Cause                                                        | Likelihood | Controls                                                                                                                                                                          | Detection | RPN |
|-------------------------------------|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|-----------------------------------------------------------------------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-----|
| Mounting Board                      | Mounting board in incorrect position.                  | Mounting the board in the wrong position could become an obstruction to shop floor workers or have negative effects on the efficiency of the operators manufacturing process. | 10       | Bad planning or lack of communication with shop floor staff/ managers | 2          | Plan and discuss in depth a good place to mount the panel with staff on shop floor, once they are happy then check with the manager of the area to make sure they are happy also. | 6         | 120 |
| Wiring components                   | Components connected incorrectly, faulty wiring.       | Incorrect wiring could damage components and will result in time and money towards Replacements.                                                                              | 7        | Accidental mistake or misreading the diagram                          | 3          | Check wiring with diagram throughout or and have a senior staff member check work if unsure.                                                                                      | 5         | 105 |
| Ordering components and materials   | Ordering the incorrect component or size of material's | More money and time must be spent placing reordering the correct components                                                                                                   | 4        | Lack of research or poor knowledge of necessary components            | 3          | Research components and assess specification relevant to project design and function                                                                                              | 3         | 36  |
| Collecting components and materials | Incorrect component or material delivered              | Time spent on returning component and further time spent to send correct components                                                                                           | 7        | Supplier or distributor making a mistake                              | 1          | Research delivery company, check timing of delivery while chasing up parts if waiting on them to be delivered                                                                     | 2         | 14  |
| Creating Wiring Diagram             | Mistake made on schematic                              | A mistake would cause the incorrect operation of the panel which would be a setback                                                                                           | 6        | Knowledge of the subject or poor communication prior to drawing       | 2          | Check with another qualified electrician to make sure diagram is correct prior to connecting components.                                                                          | 1         | 12  |

Table 10- FMEA

### 6.2.1 Costings

To gauge the setup expenses for implementing the improvement solution, a compiled list detailing the costs of necessary components can be found below in table 11. This compilation will serve as the basis for calculating the return on investment, indicating the period required before witnessing the savings from the improvement to the process.

| Part/Component/Work            | Quantity | Price per Item | Cost    | Cumulative Costs |
|--------------------------------|----------|----------------|---------|------------------|
| Schneider 500x500 panel        | 1        | £114.00        | £114.00 | £114.00          |
| Finder relay                   | 1        | £17.96         | £17.96  | £131.96          |
| Schneider 2A MCB               | 1        | £22.83         | £22.83  | £154.79          |
| Power Supply                   | 1        | £41.33         | £41.33  | £196.12          |
| Isolator                       | 1        | £18.69         | £18.69  | £214.81          |
| timer                          | 1        | £24.42         | £24.42  | £239.23          |
| terminal screwdriver           | 2        | £3.45          | £6.90   | £246.13          |
| 2 gang plug sockets            | 1        | £18.95         | £18.95  | £265.08          |
| Schneider 16A MCB              | 1        | £17.02         | £17.02  | £282.10          |
| Connector Blocks               | 8        | £0.58          | £4.64   | £286.74          |
| 2-inch cable tray (3m lengths) | 4        | £8.46          | £33.84  | £320.58          |
| Total Cost of Components       |          |                |         | £320.58          |

Table 11- Costs for Components

The total Setup cost to implement the improvement as seen above is £320.58. Therefore, if £114.40 is upkeep every year on keeping the extraction system operating while unattended then a return of investment will be achieved 2.5 years. This is based on data seen in table 7 which incorporates the increase in electricity costs occurring May 2023. It is also important to raise awareness that the 2.5 years ROT is based purely on the cost implications due to wasted running costs. So, when the cost of the operators' wages is included the total wasted costs of £376.90 ensures a return of investment within the first year of this improved process. This further cost benefit is a result of the wages for the operator to perform value adding activities such as manufacturing more components as seen in table 6 in opposed to dedicating time to operate his control panel which will be reduced to negligible when the solution is fully implemented.

### 6.3 Process Map

To ensure the efficient execution of process improvements, a comprehensive plan for implementing the necessary changes is to be devised to realise the proposed solution. The steps involved are illustrated in the process map below in Figure 7, outlining the tasks required to transition from the old panel to the new one and adapt the controls accordingly.

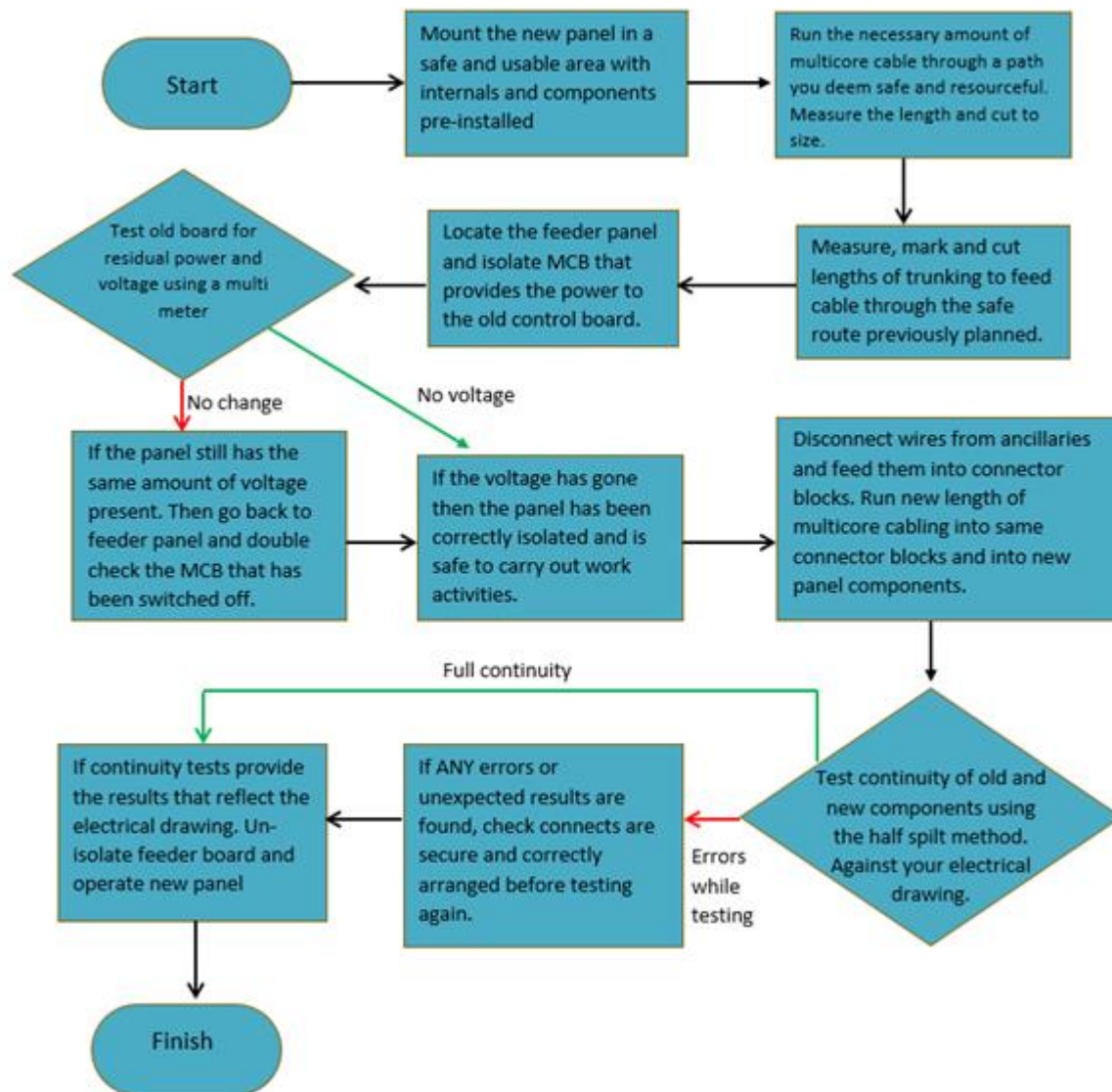
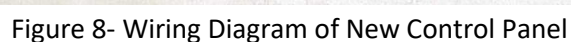


Figure 7- Process Map for Implementing Improvement and Testing

Flow charts such as figure 7 can be a useful tool for representing the steps in a given process to analyse and breakdown into its individual components. This technique is used widely across multiple fields and industries such as engineering, IT & computing, and various services. Due to their simple nature a flowchart is easy to create and interpret, As Kanis Charntaweekhun says ‘a novice often uses a flowchart as a tool to help him summarize the idea into all necessary steps of solution’.

The implementation of the proposed solution discussed in chapter 6.1 began with the gathering of tools and components needed to construct and produce project essentially the new control panel and ancillaries further required for the production for example power outlets. Coupled with ordering the necessary components found in the costing table 11 for the new control panel. With assurance from the manager, a wiring diagram to allow the panel to function and what it will resemble once wired up was created.





Connecting components correctly is essential to ensure the panel functions optimally. Upon receiving the main panel, structural elements like trunking and din rail were promptly mounted inside. These parts were pre-measured and cut, with any sharp edges smoothed out using a file to prevent cable chafing and potential shorts. Next, 20mm holes were drilled into the panel's front door using a hole saw to accommodate push buttons and lamps. Components were then mounted onto the rails, strategically spaced to facilitate neat and efficient wire connections.

Figure 9- Testing Panel

While referring to the wiring diagram, all components were connected using single core 1.5mm cable. Cables were routed from the lamps/push buttons to connector blocks to safeguard against disconnection when the door is opened or closed. After completing and successfully testing the wiring, the panel was affixed to the bay wall in the operator's preferred location. Prior to installation, the location was coordinated with the supervisor and confirmed for suitability and ease of use.

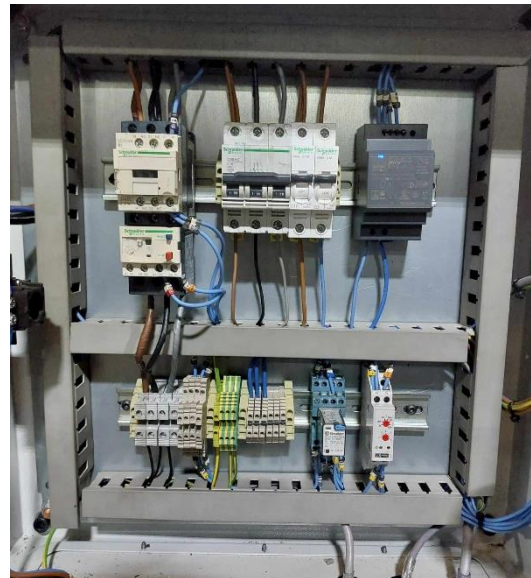


Figure 10- Components Wired in Panel

Between the distribution board and the panel, a 5-core 2.5mm armoured cable was installed. The 3-phase supply was then linked to the isolator, continuing through to the contactor and finally extending to the extractor fans situated in the factory's roof. This process necessitated the use of a cherry picker, onto which the required tools and equipment were loaded, granting access to the



motors located in the roof.

Figure 11- Mounted New Control Panel



Figure 12- Welding Bay with New Control Panel

## 6.5 Validate Improvements

To validate the improvements made to the process through the solution discussed in chapter 6.4. Evidence is required to show the implementation has been a worthwhile investment and therefore demonstrate that the project has been a success. It was briefly mentioned in 6.2.1 that it will take 2.5 years for the project to pay for itself and thus start to witness a return of investment. To expand on these points mentioned in chapter 6.2.1 it is important to account for both wasted costs of both the extraction system running while unattended, and the wasted cost inflicted by operator's wage on non-value adding activities, such as the operation of the control panel. To sum up and visualise a breakdown of these costs and time scales; refer to table 12 found below.

|                       | Daily | Weekly | Monthly | Annually | Setup Costs | Return of Investment |                |                |
|-----------------------|-------|--------|---------|----------|-------------|----------------------|----------------|----------------|
|                       |       |        |         |          |             | Year 1               | Year 2         | Year 3         |
| Wasted running cost   | £0.44 | £2.20  | £8.82   | £114.40  | £320.58     | -£206.18             | -£91.78        | £22.62         |
| Wasted operator wages | £1.09 | £5.47  | £21.88  | £262.50  | £320.58     | -£58.08              | £204.42        | 466.92         |
| Total                 | £1.53 | £7.67  | £30.70  | £376.90  | £320.58     | <b>£56.32</b>        | <b>£433.22</b> | <b>£810.12</b> |

Table 12- Return of Investment

The reduction in costs in terms of running costs and wage costs for the operator alone are not great enough to allow the business to gain a return of investment within the first year of the improvements being implemented. However, combined more than £50 as seen in table 12 has been returned in the first year, mostly due to the reduction in wasted operator wages through a better utilisation of their time at work. Other observations include a total

of over £800 by the end of the third year. Also, with regards to just the running costs of the equipment, it will take 3 years before a return will be seen.

Finally, it is important to note that the return of investment plan or estimate as seen in table 12 does not factor for unplanned maintenance or reactive maintenance, breakdowns or problems with the equipment. However, these examples will be incredibly rare and almost impossible to predict. As seen in figure 13 the lifespan of AC motors is great. Infact a 10kW motor is the equivalent to 13hp for reference. Therefore, we can expect a range of 10-15 years between replacements.

| HP Range | Average Motor Life (years) | Life Range (years) |
|----------|----------------------------|--------------------|
| <1       | 12                         | 10-15              |
| 1-5      | 17.1                       | 13-19              |
| 5.1-20   | 19.4                       | 16-20              |
| 21-50    | 21.8                       | 18-26              |
| 51-125   | 28.5                       | 24-33              |
| >125     | 29.3                       | 25-38              |

Figure 13- Life Spane of AC motors

Data collected from Regal Rexnord Webpage titled What is the Typical Life Expectancy of an AC motor.

## 6.6 Methods of Control

Certain systems are required to be implemented to ensure the adherence to the new method of work and to maintain the associated benefits. For example, the operator overseeing the welding bay and extractor system is solely tasked with ensuring that the equipment is shut down before departing their workstation. To assist with remembering and to promptly become aware and up to speed, the operator receives training on the new process and is guided through the new working procedure. Additionally, a printed guide detailing the procedure is affixed to the workstation to ensure that others who may use the welding bay such as, staff on alternate shifts, weekend attendees or when the regular operator is unavailable are aware of the revised operational procedure.

However, these measures may not suffice to consistently across all operators. Therefore, to ensure the extractor is deactivated when left unattended and to strengthen the adherence to the updated protocol, a timer module has been integrated into the new control panel. This module is programmed to deactivate the extractor if it remains active for an extended period. Specifically, it is configured to power down the motor after one hour of inactivity. This will reinforce the return of investment plan closely if the operator fails to follow the new working procedure.

Both above control measures should reliably and consistently negate the indirect costs associated with electricity usage and non-profiteering activities.

## 7. Conclusion

To prove and discuss whether this project can be deemed a success, it will be important to reflect on the points made in the Abstract. Firstly, the efficiency and effectiveness of a working practice has been improved through the reduction of non-profiteering activities and through utilising a relatively small budget to minimise the effect of direct and indirect costs. Secondly to study the manufacturing process to identify where and how the daily operator tasks cause negative effects on costs and production. As a result, these have been identified and documented through this report and rectified through the utilisation of a new method of working practice and new equipment. Thirdly, to finalise a solution with the goal of improving a method of working practice to behold greater production and reduced costs. Through thorough analysis of data and information collated in tables and graphical illustrations to highlight these areas for improvement. Furthermore, using this data, predictions have been drawn to assess the annual return of investment accounting for setup costs. Finally, the ideology of maintainability and sustainability of the solution has been secured through control methods to ensure the longevity of the improvements.

## 8. References

- Gitmanova, L. (2017). *Application of Six Sigma Using DMAIC Methodology in the Process of Product Quality Control in Metallurgical Operation*, Technical University of Kosice, Kosice, Slovak Republic
- Wilson, J. M. (2003). *Gantt Charts: A Centenary Appreciation*. Volume 149. Issue 2. Department of Business and Management, Glasgow University, University Avenue, Glasgow G12 8QQ, Scotland, UK
- Geraldi, J. (2012). *Gantt charts revisited: A critical analysis of its roots and implications to the management of projects today*. Bartlett Faculty of the Built Environment, University College London, London, UK)
- Knopf, J. W. (2006). *Doing a Literature Review*. PS: Political Science & Politics, Volume 39, Issue 1, Cambridge University
- Ernst, R. PhD. (2006). *Indirect Costs and Cost-Effectiveness Analysis*. Los Angeles, CA, USA, Volume 9. Number 4. VALUE IN HEALTH
- Mast, J. D. & Lokkerbol, J. (2012). *Analysis of the Six Sigma DMAIC Method from the Perspective of Problem Solving*. University of Amsterdam, Institute for Business and Industrial Statistics, Plantage Muidergracht 12, 1018TV Amsterdam, The Netherlands.
- Dhas, E. R. & Dhas, J. H. (2012). *A review on Optimising of Welding Process*. Noorul Islam Centre for Higher Education, Nagercoil 629180, India
- Iyer, S. V. (2023). *Digitalisation: a tool for the successful long-term adoption of lean manufacturing*. 30<sup>th</sup> CIRP Life Cycle Engineering Conference. Birla Institute of Technology and Science Pilani. Pilani Campus, India, 333031
- Smętkowska, M. & Mrugalska, B. (2017). *Using Six Sigma DMAIC to Improve the Quality of the Production Process*. 14<sup>th</sup> International Symposium in Management. Poznan University of Technology, Faculty of Engineering Management, Ul. Strzelecka 11, 60-965 Pozan, Poland
- Masud, A. A. *Discrete data vs continuous data: Main Differences*.  
<https://www.questionpro.com/blog/discrete-data-vs-continuous-data/#:~:text=Discrete%20data%20is%20information%20that,that%20falls%20inside%20a%20range.>
- Darden, D. C. (2015) *Time Wasting Activities within the Workplace Don't Be a part of Them*.  
[https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=2623378](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2623378)
- J. Mike, Jacka. (2012). *Business Process Mapping Workbook: Improving Customer Satisfaction*. <https://onlinelibrary.wiley.com/doi/book/10.1002/9781119198406>
- Wong, K. C. Woo, K. Z. Woo. K. H. (2016). *Quality Improvement in Behavioural Health: Ishikawa Diagram*. [https://link.springer.com/chapter/10.1007/978-3-319-26209-3\\_9](https://link.springer.com/chapter/10.1007/978-3-319-26209-3_9)
- Card, A. J. (2016). *The Problems with 5 Why's*. Volume 26, Issue 8, *BMJ Quality & Safety* 2017;26:671-677.

Wang, Y. (2017). *Line Graph or Scatter Plot? Automatic Selection of Methods for Visualizing Trends in Time Series*. Volume 24 Issue 2. IEEE Transactions on Visualization and Computer Graphics

Talbot, J. (2014) *Four Experiments on the Perception of Bar Charts*. IEEE Transactions on Visualization and Computer Graphics (Volume: 20, Issue: 12)

Siirtola, H. (2019) *The Cost of Pie Charts*. 23rd International Conference Information Visualisation (IV) Paris, France

McDermott, R. E. (2009) *FMEA*.

file:///C:/Users/Morgan/Downloads/10.1201\_b16656\_previewpdf%20(1).pdf

Charntaweekhun, K. (2006) *Visual Programming Using Flowchart*. International Symposium on Communications and Information Technologies, Bangkok, Thailand

Regal Rexnord. *What is the Typical Life Expectancy of an AC motor?*

<https://www.regalrexnord.com/regal-rexnord-insights/typical-life-expectancy-ac-motor>