

University of Wales Trinity Saint David
School of Engineering
BEng Mechanical and Manufacturing Engineering



Joel Lang
2014802

New Product Introduction (NPI) In a Steel
Door Factory

2023
Word count: 13222

'This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.'

J.Lang

18/5/23

Contents

Contents	3
Table of Figures	4
Table of Tables	5
Project team.....	6
1 Abstract	7
2 Aims and Objectives	9
2.1 Aim 1 – Manufacture 8 EI Doors Per Day	9
2.2 Aim 2 – Determine the Cost of Manufacturing an EI Door	9
2.3 Aim 3 – Achieve Employee Buy In	9
3 Timing Plan.....	10
4 Literature Review	12
4.1 System Throughput.....	12
4.1.1 Overall Equipment Effectiveness (OEE).....	12
4.1.2 Plan Do Check Act.....	13
4.1.3 The Six Big Losses	13
4.1.4 Value Stream Mapping (VSM)	14
4.1.5 Muda	15
4.1.6 Standard Operating Procedures.....	15
4.1.7 Statistical Process Control	16
4.1.8 Kaizen.....	16
4.2 Costing	16
4.2.1 Market Based Costing.....	17
4.2.2 Direct Costing	17
4.2.3 Absorption Costing	17
4.2.4 Activity Based Costing (ABC).....	18
4.2.5 Break Even Analysis	19
4.3 Change Management	19
4.3.1 Likert Scale	19
4.3.2 Kotter’s 8 Steps	21
4.3.3 McKinsey’s 7S	22
4.3.4 ADKAR	23
4.3.5 Lewin’s freeze/unfreeze model	23
5 Methodology	24
5.1 System Throughput.....	24
5.1.1 Areas of consideration	24
5.2 Waterjet	24

5.2.1	Plan	25
5.2.2	Do.....	35
5.2.3	Check	38
5.2.4	Act	39
5.3	Bonding	41
5.3.1	Plan	41
5.3.2	Do.....	46
5.3.3	Check	50
5.3.4	Act	51
5.4	Costing	52
5.4.1	Waterjet ABC costing.....	53
5.4.2	Bonding ABC Costing	54
5.4.3	Other Costs	55
5.4.4	Total Product Costing	55
5.4.5	Break Even Analysis.....	56
5.5	Change Management	57
5.5.1	Create Awareness	57
5.5.2	Desire for Change.....	59
5.5.3	Provide the Tools for Change	59
5.5.4	Recognition and Reward.....	61
5.5.5	Measuring Buy-In.....	62
5.5.6	Results.....	63
6	Discussion and Conclusion	65
7	Recommendation for Further Work	66
8	Appendix A	68
9	Works Cited	71

Table of Figures

Figure 1	EI exploded (Eurobond Doors Ltd, 2022)	7
Figure 2	EI internal (Eurobond Doors Ltd, 2022)	7
Figure 3	EI door (Eurobond Doors Ltd, 2022).....	7
Figure 4	EI door process flow. Created by Joel Lang using Word	8
Figure 5	Overall equipment effectiveness. Created by Joel Lang in Word. Information adapted from (Jaquin, Rozak, & Hardi Purba, 2020).	12

Figure 6 Likert scale, Created by Joel Lang using Word, Information adapted from (Awang, Mamat, & Afthanorhan, 2016)	20
Figure 7 Waterjet	25
Figure 8 Waterjet parts. Created by Joel Lang using Radan, parts used from (Eurobond Doors Ltd, 2022)	26
Figure 9 Waterjet initial process flow. Created by Joel Lang in LucidChart.....	28
Figure 10 NCR/ECR procedure. Created by Joel Lang using Powerpoint	29
Figure 11 Cycle time by material. Created by Joel Lang using Excel	32
Figure 12 Calcium Silicate by activity. Created by Joel Lang using Excel.....	33
Figure 13 Engineering change requests (Eurobond Doors Ltd, 2023)	34
Figure 14 Calcium Silicate exploded. Created by Joel Lang using Solidworks. Part files from (Eurobond Doors Ltd, 2022)	35
Figure 15 Calcium Silicate assembled Created by Joel Lang using Solidworks. Part files from (Eurobond Doors Ltd, 2022)	35
Figure 16 Calcium silicate cut length. Created by Joel Lang using Radan, Part files from (Eurobond Doors Ltd, 2022)	36
Figure 17 Forklift travel path. Created by Joel Lang using Solidworks.....	37
Figure 18 Bonding station	41
Figure 19 Bonding current state, Created by Joel Lang using LucidChart, information adapted from (Hindawi, 2017)	43
Figure 20 ECR's bonding (Eurobond Doors Ltd, 2023).....	45
Figure 21 Cores trolley.....	46
Figure 22 Bonding SOP (Eurobond doors Ltd, 2023)	47
Figure 23 EBD quarterly newsletter (Eurobond doors , 2022)	58
Figure 24 EI SOP 1 (Eurobond doors Ltd, 2023)	60
Figure 25 EI SOP 2 (Eurobond doors Ltd, 2023)	60
Figure 26 EI SOP 3 (Eurobond Doors Ltd, 2022)	60
Figure 27 Pulse survey 4-6 Created by Joel Lang using SurveyMonkey	62
Figure 28 Pulse survey 1-3. Created by Joel Lang using SurveyMonkey	62
Figure 29 Average engagement score. Created by Joel Lang using Excel.....	63

Table of Tables

Table 1 Project timing plan.....	10
Table 2 Kotter's 8 steps (Kotter, 2012)	21
Table 3 McKinsey's 7S (Waterman, Peters, & Phillips, 1980).....	22
Table 4 ADKAR (Hiatt, 2006)	23
Table 5 Lewins Freeze/unfreeze model (Smith, 2010)	23

Table 6 Waterjet required tasks	27
Table 7 Initial time study of waterjet production.....	31
Table 8 Waterjet snag list.....	33
Table 9 Waterjet timings after improvements	40
Table 10 Bonding OEE	42
Table 11 payback for investment	48
Table 12 Auto rivet gun FMEA (Goleansixsigma, 2023)	49
Table 13 Risk matrix (Ouyang, 2022).....	49
Table 14 Bonding OEE with improvements	50
Table 15 Waterjet ABC costing	53
Table 16 Bonding ABC costing	54
Table 17 Other costs.....	55
Table 18 Total product cost.....	55
Table 19 Break even analysis	56
Table 20 Pulse survey data.....	64

Project team

Name	Job title	Project role
Joel Lang	Manufacturing Engineer	Project Lead
Huw Williams	Development Engineer	Product Development and Design Support
Jacob Hanson	Engineering Manager	Manufacturing Support

1 Abstract

Eurobond Doors Ltd is a steel door manufacturer based in Cardiff, South Wales. The company specialises in large steel doors with high fire ratings, such as FD120 (2 hours of resistance) and FD240 (4 hours of resistance). A typical application for these doors is in data centres, whereby the contents of the room are both large and valuable.

European standards for data centres and other commercial settings require the doors to be an EI (integrity and insulation) standard. An EI standard means that a door can withstand deflection to prevent the spread of fire (integrity), and must also prevent heat transfer (insulation) so that any combustible material near the door does not ignite, and the area the door is situated in can be used as a safe escape route. (CEN-CENELEC, 2014)

In order to expand into the European market, Eurobond Doors has developed an EI door with a full range of furniture offerings. Gaining full certification in the process.



Figure 3 EI door (Eurobond Doors Ltd, 2022)

Figure 2 EI internal (Eurobond Doors Ltd, 2022)

Figure 1 EI exploded (Eurobond Doors Ltd, 2022)

The nature of the EI fire standard means that the door comprises specialist material to prevent heat transfer whilst maintaining integrity. Figure 1 details these materials, which are; composite sandwich panel containing rock wool and gypsum plasterboard that makes up the bulk of the core and Calcium silicate that is placed along the edges to form a subframe.

These materials are new to production and require new working methods to process them into parts for the doors. A new waterjet cutter has been purchased for manufacturing the EI door.

Furthermore, new components and features are included in the design that complicate production and add new variables to each process. Figure 4 details the process flow of an EI door and notes how much change is required at each stage.

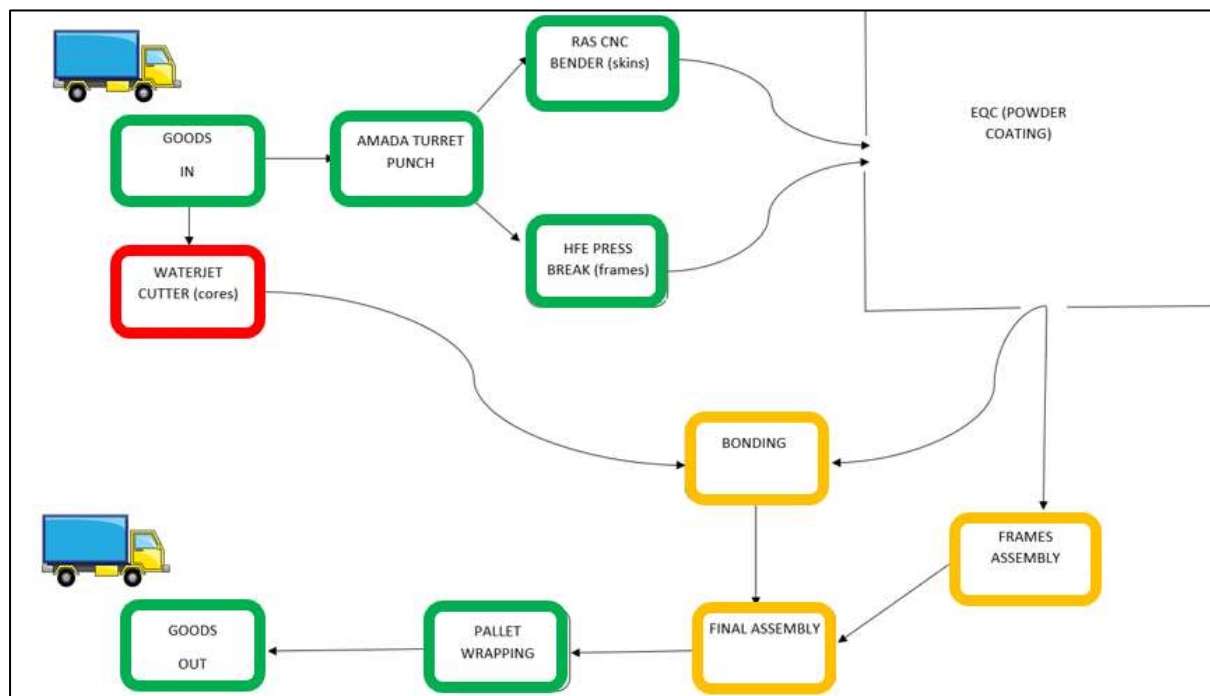
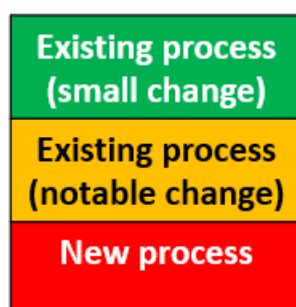


Figure 4 EI door process flow. Created by Joel Lang using Word



Production of the new door before this project consisted of prototype manufacture for testing purposes. This has been done in one-off/ prototype levels of the production scale. Therefore, to produce these doors on the anticipated scale, the prototyping processes need to be scaled up to batch production levels.

The first order of 200 doors began production in February 2023.

2 Aims and Objectives

2.1 Aim 1 – Manufacture 8 EI Doors Per Day

- Each process was assessed individually to determine if the capacity for 8 doors per day is achieved
- 1 day = 9.5 hours of working time
- Data from time studies were analysed at the conclusion of the project

2.2 Aim 2 – Determine the Cost of Manufacturing an EI Door

- Analysis was undertaken on the conclusion of the first order to determine the average cost per door
- The Bill of Materials (BOM) were analysed.
- Time studies were conducted.
- Other important factors, such as sales and transport costs, were also factored in

2.3 Aim 3 – Achieve Employee Buy In

- Questionnaires were conducted to collect information from employees periodically and at the conclusion of project
- Key metrics were assessed, e.g., feedback, happiness, relationships, personal growth
- Change in employee engagement over time was considered.

3 Timing Plan

Table 1 Project timing plan

	Week commencing																	
Task	28/11/2022	05/12/2022	12/12/2022	19/12/2022	26/12/2022	02/01/2023	09/01/2023	16/01/2023	23/01/2023	30/01/2023	06/02/2023	13/02/2023	20/02/2023	27/02/2023	06/03/2023	13/03/2023	20/03/2023	27/03/2023
batch trial run					Factory Shutdown													End of project
project review																		
address ECR's																		
operator survey																		
manufacture first order																		
data review																		
costing of door																		
survey analysis																		

Table 1 describes the timing plan for this project; the project begins with a batch trial run in preparation for the first order. This allows for a project review in week 2 that provides an opportunity to analyse data gathered in the batch run and address any issues with the first batch production.

The following weeks are an opportunity to address these issues and conduct an initial employee survey to determine the base level of employee engagement with the project.

There is a planned shutdown in week 5, after which the manufacture of the first order commences. This order will be manufactured incrementally. Allowing for periodic project reviews and opportunities to address potential issues that may arise.

On conclusion of the first order, a final project review is undertaken to assess what has been learned from this order so that improvement plans can be implemented.

In the final weeks of the project, a period of data collection and review is allocated to assess whether the aims of the project have been met or determine what further work is required.

4 Literature Review

4.1 System Throughput

When considering Aim 1, the metric that requires consideration is system throughput. *System throughput* can be defined as the total time taken to process a product. A collection of processes can be used to determine the overall system throughput of a factory. Alternatively, individual processes can be considered. (Hopp & Spearman, 2011)

4.1.1 Overall Equipment Effectiveness (OEE)

While system throughput provides valuable data, it does not allow an understanding of how efficient or inefficient production is and therefore does not allow areas for improvement to be identified. A more helpful way to quantify production throughput is overall equipment effectiveness (OEE). (Hanson, 2001)

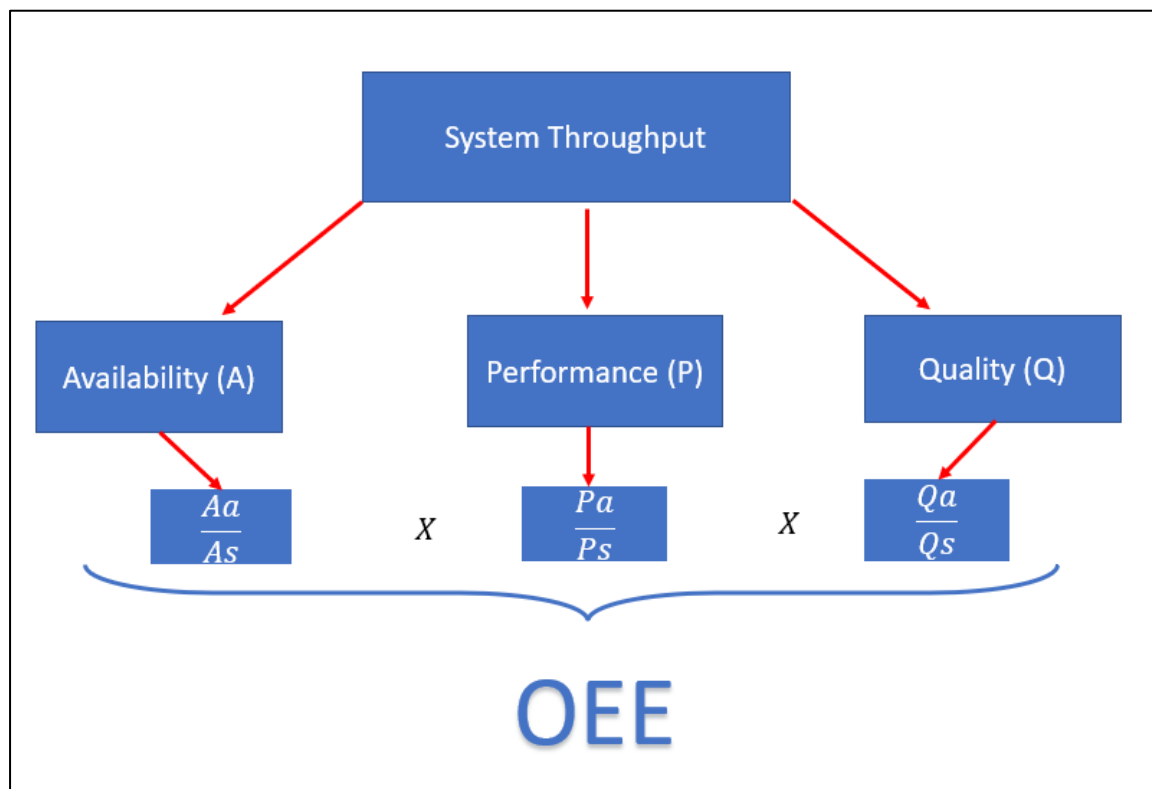


Figure 5 Overall equipment effectiveness. Created by Joel Lang in Word. Information adapted from (Jaqin, Rozak, & Hardi Purba, 2020).

Figure 5 details how system throughput can be broken down into three separate categories, Availability (A) which refers to how often the machine is available; including breakdowns, shift handovers and tool changes. Performance (P) which refers to actual processing time,

including machining time and setup time. Quality (Q) refers to the number of defects produced, resulting in the part needing to be remade and reprocessed. (Hanson, 2001)

The actual time taken for each of these factors is divided by the scheduled time for each factor. When multiplied, it gives a single value for OEE, which provides insight into how efficiently the process is running. (Hanson, 2001)

4.1.2 Plan Do Check Act

One approach to improving OEE is a Plan-Do-Check-Act cycle (PDCA) which involves

- Plan – identify an area for improvement and implement plans to address it.
- Do – implement the change that was devised in the plan stage.
- Check – analyse the results of this action and determine what has been learned.
- Act – make further plans based on what has been learned. Adopt or abandon the changes.

(Gidey, Jilcha, Beshah, & Kitaw, 2014), (Patel & Deshpande, 2017)

100% is the maximum OEE value, meaning the process has zero waste. However, this is not a realistic target to aim for. A highly automated environment may seek to achieve an OEE of 85-90%, whereas an environment that is more reliant on manual labour may seek to achieve an OEE of 70-80% (Basak, Baumer, Holweg, Hague, & Tuck, 2022)

When considering an OEE value that is lower than desired, it is helpful to look at the individual values (A, P, Q) so that they can be individually assessed to identify the root cause of waste. (Singh, Khamba, & Singh, 2021)

4.1.3 The Six Big Losses

There are six categories of waste that are now “becoming the real cause of focus to attain world-class manufacturing standards in association with strategic tools such as OEE. (Singh, Khamba, & Singh, 2021) “These elements of waste are often called “the six big losses.” Which fall under availability, performance, and quality and are as follows; (Singh, Khamba, & Singh, 2021)

Availability (A)

- Equipment downtime: downtime attributed to breakdowns and the time taken to get the equipment back to running. This also includes maintenance activities.
- Setup time: time lost due to setting up equipment before and between production batches and when changing to a different product.

Performance (P)

- Slow speed: equipment operating at speed lower than its capable of; this can depend on the material being used.
- Mid-operation stops: lost time due to the need for operator intervention; this may be workpiece jamming or requiring alignment, or the machine may require unblocking.

Quality (Q)

- Defects: any defective parts that require reworking or remaking. Therefore, requiring reprocessing
- Reduced Yield: rejected parts because of quality problems, leading to less product being produced overall

Using this framework allows waste sources to be identified efficiently, as once the factor requiring improvement has been identified, the wastes associated with that factor can be focussed on, and a PDCA cycle can be implemented to improve the value associated with the waste source; this will, in turn, improve the value it is associated with (A, P, Q) which will result in an improved OEE (Jaquin, Rozak, & Hardi Purba, 2020)

The PDCA framework may not be sufficient in the cases of complex problems that do not carry a clear cause-and-effect relationship. (Gidey, Jilcha, Beshah, & Kitaw, 2014)

While OEE is a valuable tool, it does have some limitations; the value can be affected by the level of competency carried by the operator, furthermore, it does not provide a framework for identifying the root cause of inefficiencies within the process; it may be necessary to supplement with other tools in order to do so. (Basak, Baumer, Holweg, Hague, & Tuck, 2022)

4.1.4 Value Stream Mapping (VSM)

When identifying areas for improvement, tasks within the process can be separated into two categories via value stream mapping (VSM). (Rother & Harris, 2013)

- Value adding tasks
- Non-value adding tasks

This can be achieved by mapping the process from start to finish, including how the material flows from when it enters a process to when it leaves, how people interact with the process and lastly, how information, such as engineering drawings, is used in the process. (George, Maxey, Rowlands, & Price, 2004)

The process map can be analysed in order to identify non value adding tasks, these tasks are things like, collecting and storing material, emptying skips, waiting for equipment and material etc. these tasks do not add value to the process and are a source of waste that should be reduced or removed from the process. (Bicheno & Holweg, 2016)

The remaining steps are value-adding steps that should be further analysed to assess their efficiency so that they can also be improved. (Bicheno & Holweg, 2016)

Lastly, a future state map that includes the eliminations/reductions of the non-value-adding tasks and the improvements of the value-adding tasks can be made. This allows the optimal process flow to be visualised and serves as a guide for ongoing improvements. (George, Maxey, Rowlands, & Price, 2004)

While there are many benefits to VSM, it can be very time-consuming, depending on the complexity of the process. Furthermore, including processes in their entirety may be challenging, especially when there are added complexities such as shift handovers. (Shou & Wang, 2017)

4.1.5 Muda

In lean manufacturing, the concept of “Muda” was first used in Toyota’s factory, which pioneered the field. This term translates to waste and is used to identify wasteful activities in the production process. (Rother & Shook, 2003)

While this concept helps identify non-value-adding tasks, it is also used to minimise waste within value-adding tasks. (Rother & Shook, 2003)

Waste within value-adding tasks can be considered “overprocessing,” which can be attributed to various factors such as using a more expensive raw material than is required, conducting quality checks more often or more thoroughly than required and performing steps within a process that is not fully understood. (Rother & Shook, 2003)

Along with VSM, there are several tools used within the Lean and six sigma guidelines that seek to eliminate or reduce these sources of waste.

4.1.6 Standard Operating Procedures

Clear working instructions such as Standard operating procedures (SOPs) can be developed so that the process can be well understood, eliminating waiting within value-adding tasks. SOPs can also improve efficiency by outlining the most streamlined working methods, thereby minimising the deviation from these guidelines. (Sutton, 2015)

The waste within quality checks can also be reduced by using clear guidelines such as SOPs to ensure unnecessary checks are not being done, reducing the cycle time. Furthermore, process improvement concepts such as VSM and Muda can be applied to the quality processes to maximise efficiency. (Rother & Shook, 2003)

4.1.7 Statistical Process Control

Statistical process control (SPC) is collecting, analysing, and monitoring key metrics within the production process, such as time. The time for individual tasks can be formatted using techniques such as Pareto analysis to identify tasks that experience variance. These tasks can then be further analysed so that the sources of variance are identified so that they can be controlled, reducing average cycle time. (Bheda, 2021)

In addition, these activities can be monitored over time to ensure that the controls put in place continue to work over time. Moreover, ongoing monitoring allows any new variances in the process to be identified and addressed. (Bheda, 2021)

SPC is beneficial for improving efficiency and reducing defects and, therefore, waste, thus resulting in cost savings. (Bheda, 2021)

Extensive and accurate data is required to use SPC effectively; therefore, it is inappropriate for use in new or young processes as data models must be developed over time to create control measures.

4.1.8 Kaizen

This term refers to a “Japanese philosophy that promotes continuous improvement due to continuous effort and employee involvement. (Palange & Dhatrik, 2021)” This, in essence, means that efforts given towards analysing and improving processes should continue indefinitely. (Palange & Dhatrik, 2021)

4.2 Costing

Costing a new product is essential for a business to set a sale price to generate a profit. Furthermore, costing a product will help a business understand where its product sits in the landscape amongst competitor products.

Associating monetary values with products can help justify business decisions such as research, development, and investment.

Lastly, understanding the costs involved with manufacturing can present an opportunity to identify high-cost areas of production to improve them, thus improving the profit margins and increasing manufacturing efficiency. (Jaya, Pathairage, & Sutrisana, 2010)

4.2.1 Market Based Costing

One method of costing a product for retail is to cost it based on market research. The price can be set according to the price set by competitors that already sell similar products. This allows businesses to competitively cost their product and ensure sales. However, using this method solely does not allow a business to understand the costs of producing the product. Therefore, the profit margins are not understood, and there is an element of uncertainty as to how the product/business is performing. (Hare, et al., 2000)

4.2.2 Direct Costing

Direct costing is a costing strategy that seeks to account for all the direct costs associated with producing a product, such as the material used in the product and the labour cost for manufacturing. (Bunea-Bontas, 2013)

This strategy enables a monetary value to be associated with producing a product but fails to consider indirect costs. These costs can be electricity bills or maintenance costs that contribute to the business' outgoings at the end of the year.

Failure to account for these costs can result in the product being under-priced, reducing profit margins.

4.2.3 Absorption Costing

An alternative costing strategy is absorption costing, whereby indirect costs are also accounted for in addition to the direct costs associated with a product. This allows a more accurate understanding of the cost of manufacturing and allows the product to be priced appropriately. (Marsh, 2012)

Factors such as machine purchase costs, maintenance and utility bills are distributed over the total quantity of products to reflect a cost per unit. For example, if the electricity bill for January is £1000 and the factory produces 1000 units, then a cost of £1 is added to the cost of each unit. (Wood, 2012)

This method is valuable for a company that can easily underestimate the actual cost associated with production; however, depending on the complexity of the product or business, this costing method can become very complex in itself, meaning that accurately conducting absorption costing can be time-consuming. (Wood, 2012)

4.2.4 Activity Based Costing (ABC)

Activity based costing (ABC) is a costing strategy that seeks to account for all costs associated with a product, both direct and indirect, much like absorption costing.

However, whereas absorption costing calculates the total indirect cost and divides this equally between all products produced, ABC seeks to understand to what degree each indirect cost can be attributed to a product. This is done by analysing each activity within the production process and proportionally distributing the indirect costs according to this analysis. (Marsh, 2012)

For example, if a factory has an electricity cost of £10,000 and produces two products, 'A' and 'B'. the factory manufactures 2000 units of each product; however, product A requires twice as much electricity to manufacture as product B; therefore, the indirect cost for product A would be double that of B, under ABC costing. (Hansen, Mowen, & Heitger, 2021)

Under absorption costing

$$\frac{\text{total cost}}{\text{total units}} = \frac{10000}{4000} = \text{£2.50 per unit}$$

For both A and B

Under Activity based costing

$$\text{cost for A} = \frac{\text{total cost} \times \% \text{ of usage}}{\text{number of units}} = \frac{10000 \times 0.6666}{2000} = \text{£3.33 per unit}$$

$$\text{cost for B} = \frac{\text{total cost} \times \% \text{ of usage}}{\text{number of units}} = \frac{10000 \times 0.3333}{2000} = \text{£1.67 per unit}$$

(Hansen, Mowen, & Heitger, 2021)

This method provides a more detailed and more accurate costing model. It can be instrumental in costing a new product, as fully understanding its associated costs is essential in appropriately pricing the product.

This method may also allow sources of waste to be identified within the process when abnormalities in costing are identified, which can lead to cost savings and increased system throughput. (Hofmann & Bosshard, 2017)

This method is complex, however, and can be a time-consuming task. The level of required accuracy should be considered before deciding whether it is appropriate. (Namazi, 2016)

4.2.5 Break Even Analysis

Once the product has been costed and priced for sale accordingly, a break-even analysis can be undertaken.

This is the practice of accounting for all the direct and indirect costs associated with producing a product and determining how many units need to be sold to break even. I.e., the point at which the business is neither making a profit nor a loss on a particular product. (Sinambela, Darmawan, Gardi, & Malaihollo, 2022)

Costs associated with research and development, such as testing costs and equipment procurement, should be considered.

One approach to break-even analysis is to calculate the break-even point at which the R&D costs have been recuperated, independent of other indirect costs. This is useful for analysing the payback for R&D investment and can justify future R&D expenditure. (Chukhray, Mrykhina, & Izonin, 2022)

4.3 Change Management

When change occurs within any organisation, the natural response from the workforce is to resist the change. This may be because employees “lack the experience and motivation to recognize the urgency of change. (Bateh, Castaneda, & Farah, 2013)”. The change may also provide uncertainty for the employees and may contribute to feelings of concern regarding job security. (Bateh, Castaneda, & Farah, 2013)

Achieving employee buy-in means that the population of employees is not only accepting of a system or change but actively supporting it.

Contributing factors can be, involving the employees in decision-making, asking for feedback throughout the development process and taking the feedback into consideration. Clear and frequent communication can also contribute to achieving buy-in as this ensures that the employees understand the reasons for the change, the benefits and necessity of the change and what impact this change will have on the employee's life at the business.

However, measuring buy-in can be difficult, as the feelings and emotions contributing to buy-in are qualitative data. When compared against a desired outcome, a level of subjectivity is required.

4.3.1 Likert Scale

Attempting to quantify the qualitative data is a helpful approach to measuring it. For this, surveys can be conducted that ask different questions but require the employee to answer the question on a scale of 1-10. This way, the answers can be formatted as quantitative data

and assessed across the population, as opposed to descriptive answers that are open to interpretation and are difficult to assess over the population of employees. (Joshi, Kale, Chandel, & Pal, 2015)

Key metrics should be measured using appropriate questions.

- Feedback – “You are satisfied with the feedback you receive.”
- Happiness – “You are happy at work.”
- Relationships – “You feel like you can approach your manager for help and that they will care about your concerns.”
- Personal growth – “You feel challenged sufficiently at work.”

(Van De Poll, 2021)

Each of these example questions can be asked with an accompanying scale, the Likert scale;

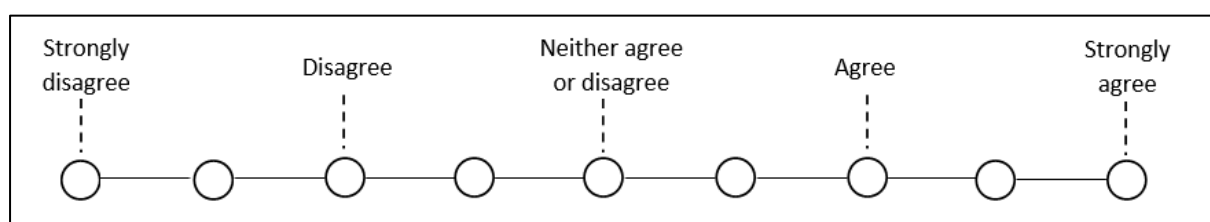


Figure 6 Likert scale, Created by Joel Lang using Word, Information adapted from (Awang, Mamat, & Afthanorhan, 2016)

When considering a significant change within a business, managing the change is essential if buy-in is to be achieved.

4.3.2 Kotter's 8 Steps

There are several established models for managing change. One such model is John Kotter's 8-step change model.

Table 2 Kotter's 8 steps (Kotter, 2012)

1	Create a sense of urgency	Evaluating the business's position in the market and identifying the necessity of the change, considering the possible outcomes for the business if the change is not implemented
2	Form a powerful coalition	Creating a team with enough influence to drive the change
3	Create a vision for change	Create a clear picture of how the business will look once the change has been implemented
4	Communicating the vision	Ensuring the vision for the change is communicated and well understood by all stakeholders
5	Empower others to act on the vision	Remove resistance to the change by creating a clear plan that encourages support for the change
6	Planning for and creating short term wins	Planning for recognising milestones in the early stages of the changes and celebrating them. Recognising stakeholders for their involvement in achieving the milestones
7	Consolidating gains and producing more change	Build upon the milestones and sustain the momentum generated.
8	Anchor new approaches in the organisation's culture	Ensure that the behavioural changes achieved through the change are kept and "anchored" within the business culture

This method provides a comprehensive approach to tackling change by providing clear steps on managing the change whilst ensuring sufficient support for the change within the organisation.

This strategy acknowledges the requirement for leadership when managing change and provides insight into how leading change should be approached so that stakeholders bear confidence in the leadership team. (Salman & Broten, 2017)

However, this model can be complex and may not be the appropriate strategy for all types of change. Furthermore, it does not address, in detail, how employees interact with the change and how best to encourage them throughout the process, which may affect the outcome of aim 3 (achieve employee buy-in) (Pollak & Pollack, 2015)

4.3.3 McKinsey's 7S

An alternative strategy to approaching change management is McKinsey's 7S model, which attempts to address the different factors that influence the success of a change but also highlights that all factors are linked to one another and must be addressed harmoniously to maximise the chance of successful change. (Channon & Caldart, 2015)

Table 3 McKinsey's 7S (Waterman, Peters, & Phillips, 1980)

Systems	The working methods used within the business
Structure	The chain of command, how teams interact with one another
Style	The management methods used
Strategy	The business plan for hitting targets
Shared values	The core beliefs on which the business culture is built around
Staff	The experience and skills held by the employees
Skills	The required skills for achieving the business' aims and objectives

This model provides a valuable framework when undergoing change, ensuring that essential factors contributing to successful change management are addressed. (Singh A. , 2013)

Unlike Kotter's 8-step model, this model provides more of an overview of each topic rather than a step-by-step guide on implementing change, which could be considered a limitation in cases of complex change or incompetent management.

It addresses the employees as a factor that can benefit achieving buy-in. However, it does not provide a detailed framework on how employees can be involved in change and driven by it, resulting in buy-in, much like Kotter's 8 steps.

4.3.4 ADKAR

A strategy that fills in the gaps of these models is the ADKAR change model, whereby individuals are at the focus of each step in the process.

Table 4 ADKAR (Hiatt, 2006)

Awareness	Making employees aware of the change, the reasons and necessity of it, the benefits for them and the business
Desire	Improving the desire for change within the employees by helping them understand how it aligns with their personal growth
Knowledge	Provide training for employees to ensure they are skilled and capable of implementing the change
Ability	Providing the appropriate resources for employees to accomplish the change (equipment, support)
Reinforcement	Acknowledging employee efforts and contributions and providing helpful feedback that enables further growth

This method explicitly addresses how to manage employees throughout the change, therefore, is a valuable strategy in the pursuit of employee buy-in.

However, it has its limitations and gaps as it fails to address other areas of change management that are also important considerations, such as strong leadership and the impact that organisational culture can have on change. (Shaikh, 2020)

4.3.5 Lewin's freeze/unfreeze model

An alternative change method that provides a simple framework for enacting change is Kurt Lewin's freeze/unfreeze model, which divides the change process into three distinct steps.

Table 5 Lewins Freeze/unfreeze model (Smith, 2010)

Unfreeze	A need for change has been identified, and the first steps in initiating change begin. This can include creating awareness and a sense of urgency for the change. As well as addressing the natural resistance to change.
Change	Enact the change, introduce the new processes or philosophies that the change is centred around, addressing employee behaviours and feelings towards the change throughout the process.
Freeze	Ensure the new processes or philosophies are withheld over a long period by integrating them into the company values and culture.

This model is a simplified overview of the change process. However, it can provide a valuable framework as the steps of change and the priorities within each step are very clear. However, this method does not address the necessity of leadership throughout the change process, so it should be used in conjunction with other methods.

5 Methodology

5.1 System Throughput

5.1.1 Areas of consideration

When considering system throughput, two main areas were chosen for the focus of this project.

5.1.1.1 Process 1 – Waterjet

The Waterjet cutter is a new machinery explicitly bought to produce EI doors. This product requires specialist materials such as Gypsum Plasterboard and Calcium silicate to be cut into intricate shapes, so the waterjet was procured for this purpose.

Since this equipment was brand new, entirely new working methods were required to be developed and refined to achieve an acceptable system throughput.

5.1.1.2 Process 2 – Bonding

Amongst the category of “existing process- significant change,” the bonding process was the area that required the most attention due to the added complexity of the EI door during this process. While frames assembly and final assembly are significant changes, the new elements of these processes can be easily substituted into existing working methods. This is not possible for bonding as the change is far more significant.

Therefore, the existing working methods must be modified to account for this

5.2 Waterjet

Since the waterjet cutter was a brand-new process with no production data, calculating OEE is not possible initially. Instead, a more appropriate approach to understanding and improving the system throughput of this process was to use process flow diagrams to first define the process. Then following a PDCA cycle, the process could be evaluated, areas for improvement could be identified, and plans to improve could be enacted.

Once the process was defined, small production runs can begin with the view to refining the process through ECR/NCR system. Through this system, inefficiencies in the process were defined and recorded as non-conformance reports (NCRs). The NCRs were then discussed

through a project review so that plans could be implemented to make improvements. The improvements were recorded on the Engineering change request (ECR) register.

Although OEE was not being used in this instance, the six big wastes associated with OEE could be considered to identify sources of waste within the process with the view to reducing or removing them.



Figure 7 Waterjet

5.2.1 Plan

When mapping a new process, a series of steps were be taken.

1. Define the process;

What is the required result of the process? Consider what inputs are required, such as raw materials and labour, the primary activities involved in the process, and the result of the process, i.e., the finished product or part. (Rahani & al-Ashraf, 2012)

In the case of the waterjet, the process is required to produce core parts for the door, which can be considered as two categories of parts. These are composite sandwich panel parts

that make up the bulk of the core and Calcium silicate pieces that make up the “sub-frame” within the door.

This process requires an input of each of these materials in sheet form, the waterjet cuts the required shape into the sheet, with the assistance of an operator for set up and offloading, And the resulting shape is the output of the process.

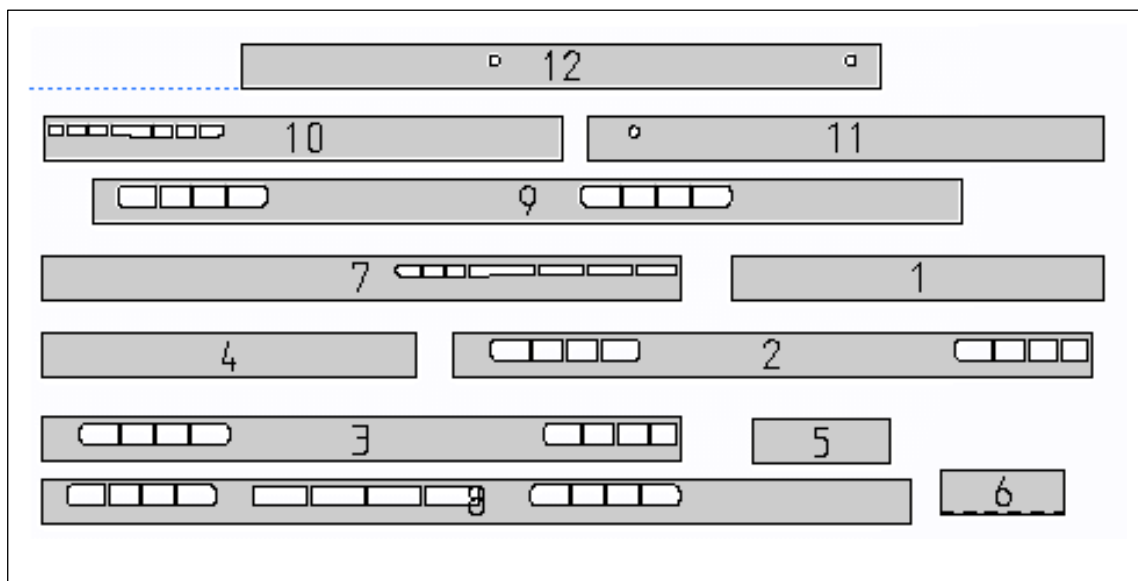


Figure 8 Waterjet parts. Created by Joel Lang using Radan, parts used from (Eurobond Doors Ltd, 2022)

2. Identify the steps involved in the process;

Identify the steps that contribute to each activity. Spend time using/observing the equipment in use and hold conversations with operators so that the process is wholly understood. (Rahani & al-Ashraf, 2012)

For this, early prototype production was observed to develop a list of activities contributing to the process. The steps taken by the operator are based partly on equipment training and partly on a trial-and-error basis when using the waterjet to produce miscellaneous parts for training purposes. A list of all the activities was recorded.

The tasks were split into two categories. 1. Regular tasks, these tasks are required to complete any given production run, although they may not occur in equal frequencies from run to run. 2. Irregular tasks, these tasks are not required in every production run, and there may be many runs before these tasks are required.

Table 6 Waterjet required tasks

Regular tasks	Irregular tasks
Retrieve material pallet	Unblocking cutting head
Load material onto bed	Adjusting water level
Load program	Filling up garnet hopper
Define material properties	
Turn on water	
Set light guard	
Set axis of cutting head	
Start program	
Cutting	
Turn off water (if done)	
Marking parts	
Removing and storing parts	
Removing waste	
Removing excess material	

3. Create a process flow

Sequence the identified steps according to the order they are required to occur.

The list of regular activities was formatted chronologically so that the following process flow could be created.

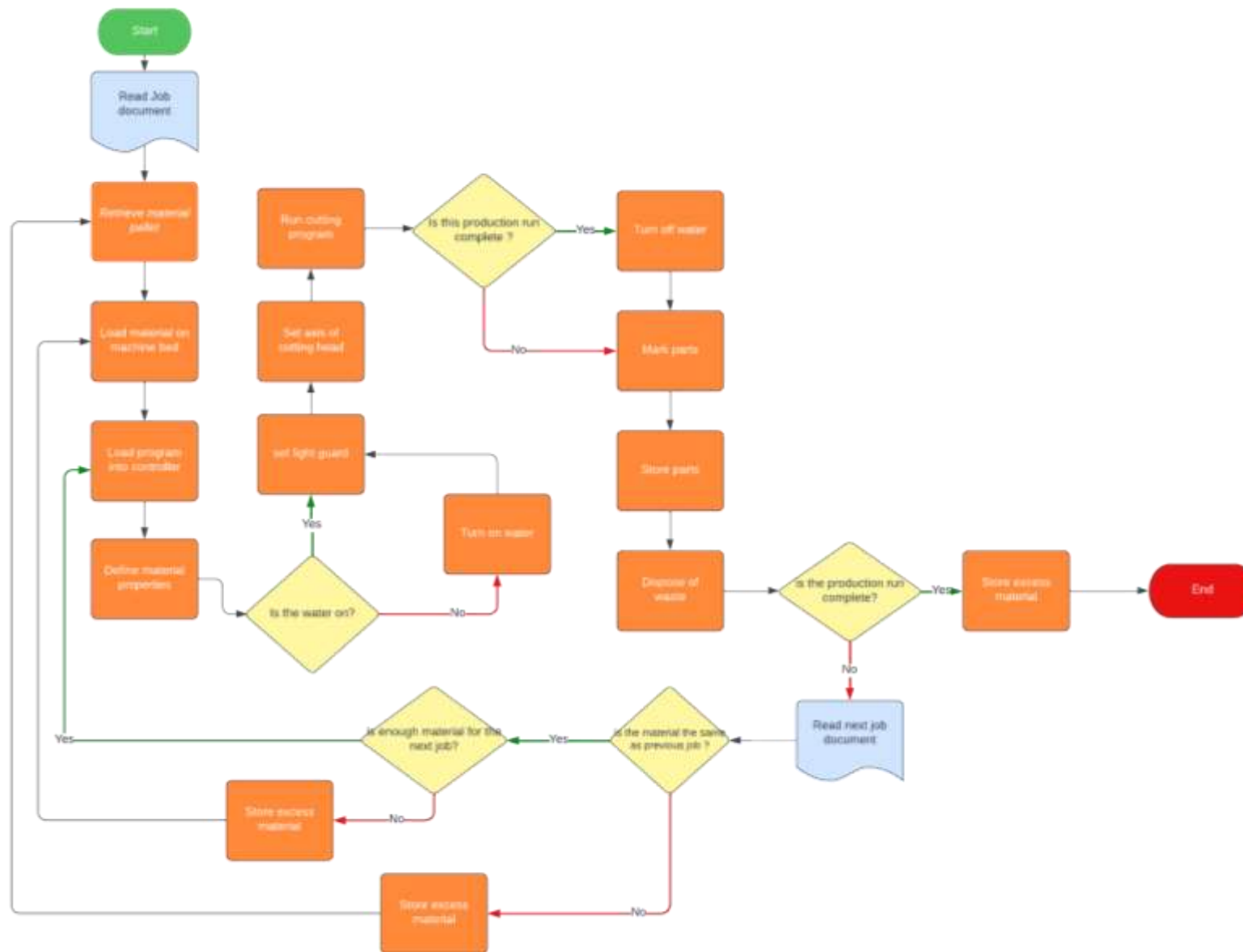


Figure 9 Waterjet initial process flow. Created by Joel Lang in LucidChart.

This initial process flow provides a visual representation of the process and a precise working method for which the operator can strive through prototyping and early production runs. It is presumed that this process flow is not perfect; therefore, it is essential to communicate clearly that this is not a Standard operating procedure and only a guide on approaching early manufacturing.

Using this guide, early prototyping can be monitored through time studies to assess the cycle time of each step so that a base level of system throughput could be understood.

Furthermore, time studies allow for waste within the process to be identified so that improvements could be made to the wasteful steps, with the view to reducing cycle time.

In addition, the process workflow can be further monitored to understand the accuracy of the workflow in Figure 9. Any deviations or additional steps could be accounted for, and the process flow chart could be amended.

5.2.1.1 NCR/ECR procedure

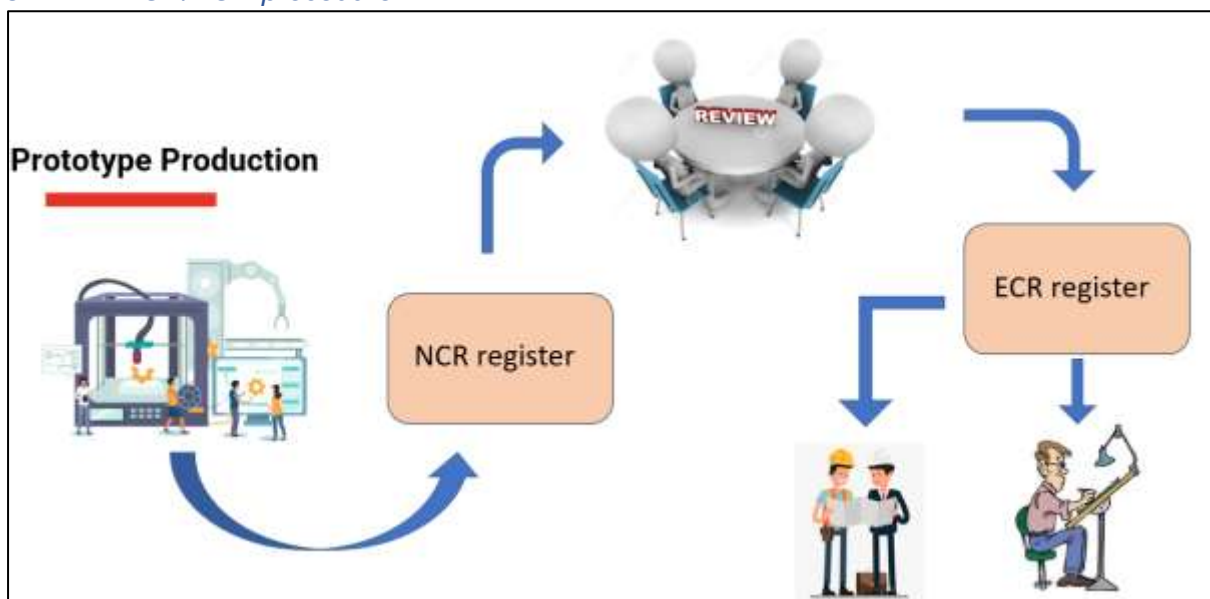


Figure 10 NCR/ECR procedure. Created by Joel Lang using Powerpoint

Figure 10 details how to prototype production was observed so that any issues or snags were recorded in the SharePoint system in the form of Non-conformance reports (NCRs). e.g., “The dimensions of the part are out of tolerance.” The NCR list is discussed during project reviews, and a solution is proposed as an engineering change request (ECR). The ECR is then assigned to the relevant department, either manufacturing or development, depending on the nature of the issue. This is also recorded in SharePoint, along with details of the required change and its priority.

This procedure was an important stage in the plan section of a PDCA cycle as it provides a system to reduce or eliminate the occurrence of defects and inefficiencies within the process so that system throughput improves.

5.2.1.2 time study of waterjet production

The time study monitored the entire production process for the waterjet cutter. Four distinct materials require processing for each door.

- Calcium Silicate
- Plasterboard (15mm)
- Plasterboard (12.5mm)
- Composite Sandwich Panel

In production runs with more than one door, the components made from each material are processed in batches. Moreover, once a reasonable sample of data is collected, the data is analysed to conclude the average time per material per door.

When recording the cycle time of different activities, there are three categories that any given activity can fall within. These are;

Manual: tasks completed manually by the operator without assistance from automatic machinery. (E.g., loading material onto a machine bed)

Auto: tasks completed automatically by machinery. (E.g., cutting time)

Walk: tasks that involve the operator moving from place to place so that they can undertake the next step in the process. (E.g., retrieving material pallet, walking to turn the water on)

Separating events into these three categories allows the areas to be assessed individually when the data is analysed. So, if there is excessive walk time, specific measures can be taken to address this and reduce it.

Table 7 Initial time study of waterjet production

Activity	Calcium Silicate			Plasterboard 15mm			Plasterboard 12.5mm			Composite Sandwich Panel		
	manual	auto	walk	manual	auto	walk	manual	auto	walk	manual	auto	walk
Loading bed	33.25	0	2.5	25	0	2.5	65.75	0	0	0	0	0
Setting axis	13.25	0	5.25	13.5	0	3.75	11.75	0	2.5	27	0	0
Loading programme	12.5	0	1.25	4.5	0	1.25	7.5	0	0	35.75	0	0
Define material properties	27	0	0	24	0	0	22.3	0	0	19.8	0	0
Turn on water	0	0	28	0	0	18	0	0	32.3	0	0	16.7
Set light guard	3	0	0	3	0	0	3	0	0	3	0	0
Start program	0	15	0	0	15	0	0	15	0	0	15	0
Cutting	4.75	1307.25	2.5	5	295	2.5	6	294.75	2.5	15	197.25	0
Removing bed from machine	30.5	20.25	1.25	22	20	2.5	20.5	20	0	0	0	0
Marking parts	91.5	0	2	0	0	0	0	0	0	21.25	0	0
Removing waste	46.25	0	0	38.5	0	0	34.75	0	0	169.5	0	0
Storing parts	117	0	0	51.25	0	0	36.5	0	0	97.25	0	0
Unblocking head	35.75	0	0	0	0	0	0	0	0	0	0	0
Storing material pallet	37	0	187	19.5	0	198	24	0	176	19.8	0	232
Retrieving material pallet	20.5	0	214	18.75	0	145	20	0	187	20.1	0	214
total per category (s)	472.25	1342.5	443.75	225	330	373.5	252.05	329.75	400.3	428.45	212.25	462.7
total per material (s)	2258.5			928.5			982.1			1103.4		

Total per Door (s)	5272.50
Total per Door (hrs)	1.46
Doors per Day	6.49

5.2.1.3 Initial Time Study Analysis

Table 7 details the initial time study conducted during the production run of 8 EI doors; average times for all tasks have been taken. The results represent the time to manufacture the core materials for 1 EI door. The study results show that the mean time to manufacture 1 EI door was 1.46 hours. Therefore, in its current state, this process can process 6.49 doors per 9.5-hour shift. This is 1.51 doors short of the 8-door-per-day target (Aim 1).

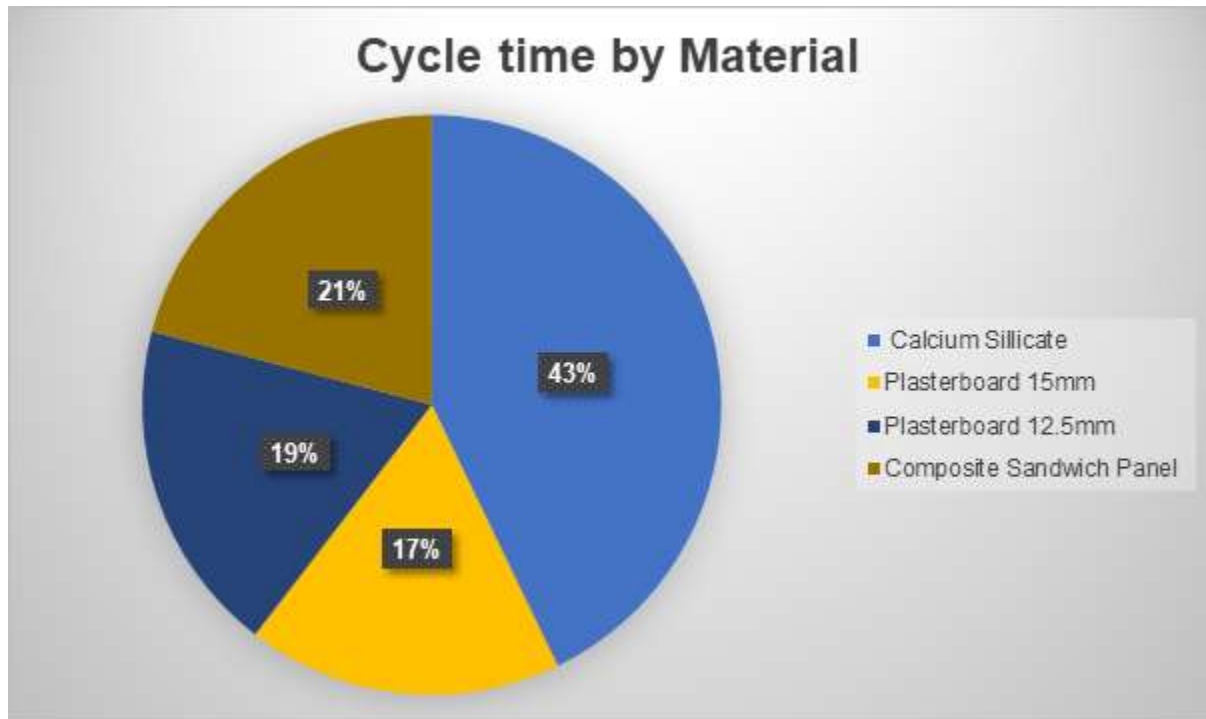


Figure 11 Cycle time by material. Created by Joel Lang using Excel

Figure 11 details how the cycle time was broken down by material. It shows that Calcium Silicate is responsible for 43% of the total cycle time. This is more than double that of the second largest contributor (composite sandwich panel at 21%).

Figure 12 explores how the different activities contribute to the total cycle time for Calcium Silicate. It details how 95% of the cycle time was attributed to cutting time. The second and third most significant contributors are retrieving and storing material pallets. The times required for these are significant in comparison to other activities. Furthermore, these activities are present for each material and significantly contribute to cycle time.

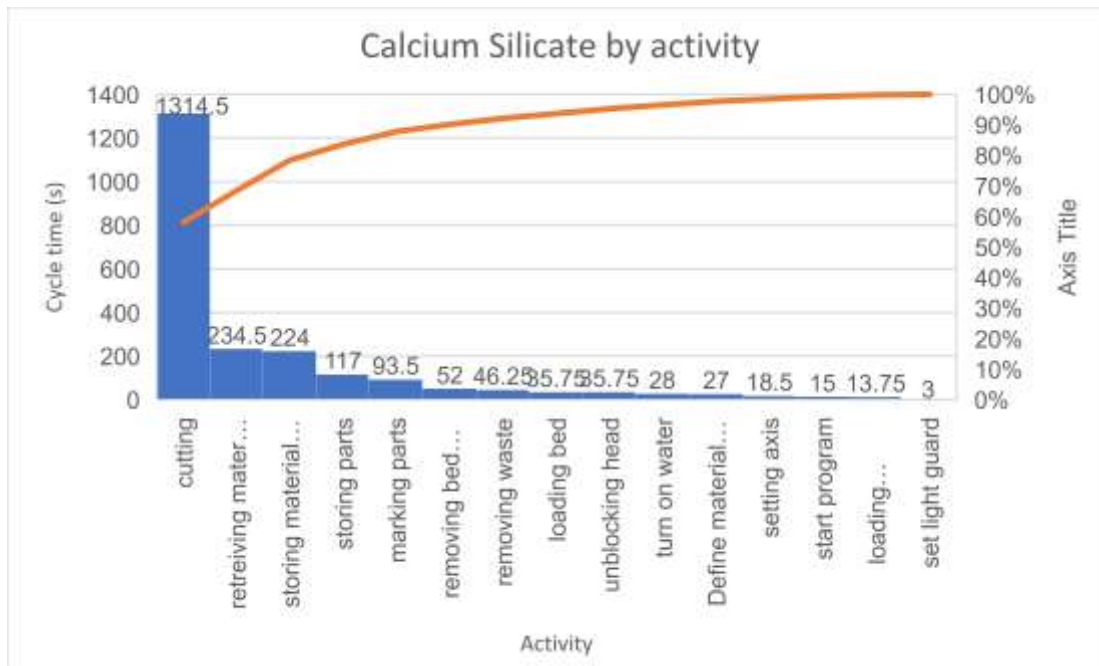


Figure 12 Calcium Silicate by activity. Created by Joel Lang using Excel

5.2.1.4 Snag list

In addition to the initial time studies and analysis, a “snag list” was recorded throughout the prototyping phase, “snags” can be defined as issues and discrepancies that prevent the process from operating at maximum efficiency.

Table 8 Waterjet snag list

Snag	Title	Description
1	Cutting order is inefficient	The software provided with the machine outputs an inefficient cutting order with large amounts of traversing. It is difficult and time-consuming to optimise manually.
2	Large walk to waste skip	The waste skip is located far away from the machine. The operator must make multiple trips to dispose of waste every production run.
3	Waste sheet material is often bulky	The operator must manually cut waste material into manageable sizes so that they can dispose of it
4	Material storage is far away	The material being stored in external warehouse results in considerable walk time to store material pallets and collect new ones

Using a snag list can provide context for analysing time studies during design reviews so that opportunities for improvement could be identified and implemented.

5.2.1.5 Engineering change requests (ECR's)

Engineering Change Request ☆										
ID ↓	Title ↓	Created By ↓	Requested By ↓	Assigned To ↓	Issue Status ↓	Priority ↓	Description ↓	Scope ↓	BRE Approved ... ↓	Due Date ↓
136	procure and install internal racking	Joel Lang	Joel Lang	Joel Lang	Active	Normal	Internal racking is required for the waterjet. 4 shelves are required to accommodate the different materials.	Production	NO	01/02/2023
135	Manufacture fixtures for waterjet to accom...	Joel Lang	Joel Lang	Joel Lang	Active	High	manufacture fixture that holds calcium silicate blocks, with a firm gap in-between blocks, so that the position of the pre-made blocks is consistent.	Production	NO	01/02/2023
134	Program Calcium silicate parts to only cut e...	Joel Lang	Joel Lang	Anthony Coombes	Active	High	remove cut lines for lengths that no longer need to be cut, program parts so that they are positioned relative to the fixtures that are to manufactured for the waterjet bed	Design	NO	01/02/2023
133	Source Calcium Silicate in pre-assembled bl...	Joel Lang	Joel Lang	Huw Williams	Active	High	buy calcium silicate in pre-assembled 60mm blocks so that cutting time can be reduced and assembly process can be improved	Production	NO	01/02/2023
ID ↓	Title ↓	Created By ↓	Requested By ↓	Assigned To ↓	Issue Status ↓	Priority ↓	Description ↓	Scope ↓	BRE Approved ... ↓	Due Date ↓
142	acquire radan license for waterjet	Joel Lang	Joel Lang	Joel Lang	Active	Normal	acquire radan license for the waterjet so that current production and B production can be integrated, develop optimised cutting order settings.	Production	NO	10/04/2023
141	Procure movable skips	Joel Lang	Joel Lang	Joel Lang	Active	Normal	procure new fleet of movable skips so that skips can be placed wherever convenient	Production	NO	20/04/2023

Figure 13 Engineering change requests (Eurobond Doors Ltd, 2023)

Figure 13 is the ECR register that is kept to describe the jobs that are required as a result of the project review. Each job has been assigned to the relevant stakeholder, with an accompanying description that provides details of the requirements. The priority and due date of the tasks are included so that the correct amount of attention can be given to the job.

By keeping these change requests in the SharePoint, they can be accessed by all stakeholders so that the progress of each task is clear and any required collaboration can be managed.

5.2.2 Do

A project review was held following the initial time studies and analysis of prototype production. It involved the development and manufacturing teams in discussing the issues identified and proposing solutions that seek to improve the cycle time and ease of manufacturing.

The proposed solutions to the NCRs and additional improvements were recorded as ECRs in the company SharePoint.

5.2.2.1 ECR - 133/134/135

One prominent topic of discussion was the excessive cutting time, particularly when cutting Calcium silicate. This is an example of slow speed which is one of the 6 big waste sources. (Sowmya & Chetan, 2016)

The parts are cut from a 20mm thick sheet. They are part-marked and stored before being assembled into 60mm blocks by screwing three identical parts together.

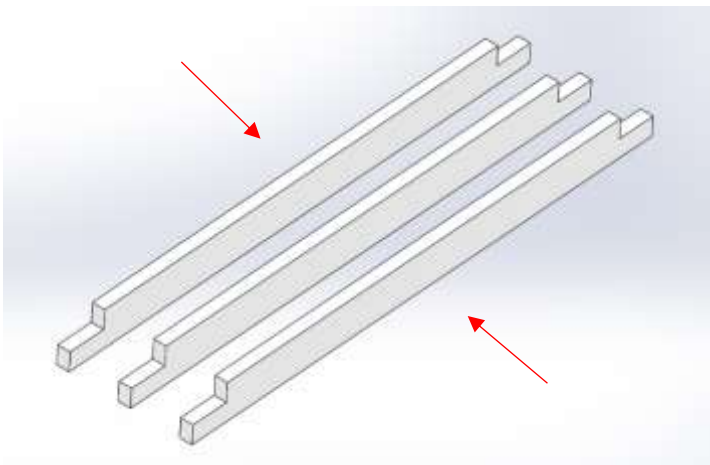


Figure 14 Calcium Silicate exploded. Created by Joel Lang using Solidworks. Part files from (Eurobond Doors Ltd, 2022)

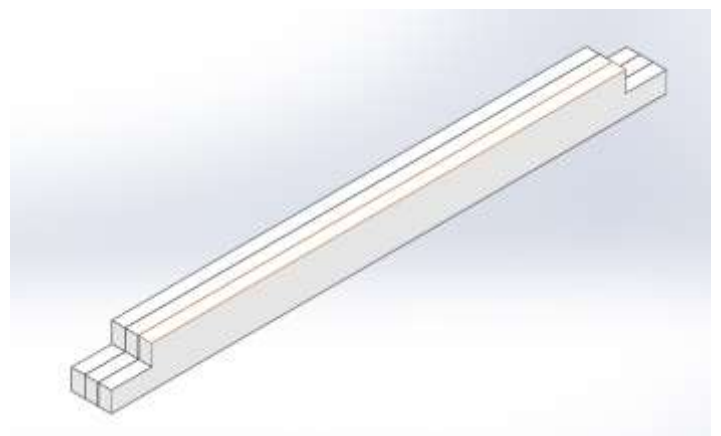


Figure 15 Calcium Silicate assembled Created by Joel Lang using Solidworks. Part files from (Eurobond Doors Ltd, 2022)

The first clear source of waste was that each of these three identical parts had been cut individually from a sheet; the waterjet cutter can cut material of up to 150mm in thickness; therefore, to reduce cycle time, it was proposed that three sheets could be stacked and cut simultaneously. Thereby reducing the cut length by 66%.

However, this change was not presumed to achieve a 66% time saving, as increasing the thickness of the material means that the cutting head must move at a slower pace to achieve a cut of the same quality.

Secondly, it was pointed out that every calcium silicate part has the same depth and width of 60x60mm. The difference from part to part is the length and the features dictated by the door's specification.

It was proposed that the material could be bought in strips that are 60x60mm in depth and width, leaving the waterjet to cut only the length and features into the part. Therefore, generating significant reductions in cutting time.

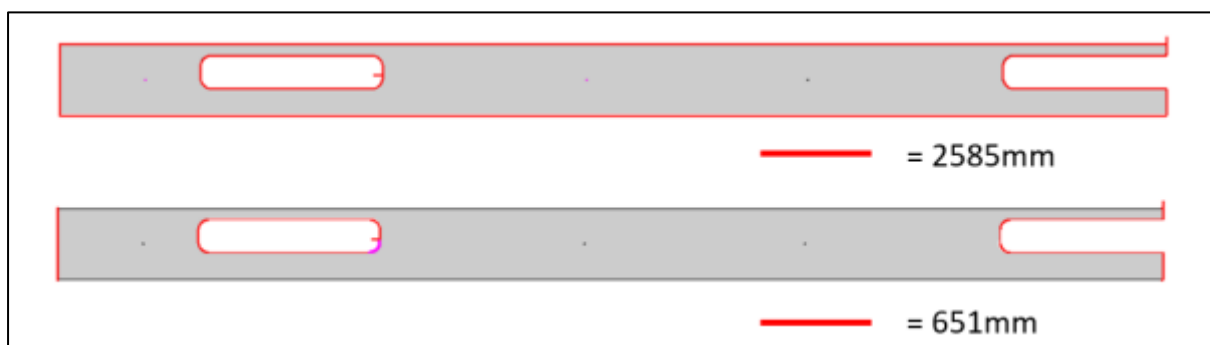


Figure 16 Calcium silicate cut length. Created by Joel Lang using Radan, Part files from (Eurobond Doors Ltd, 2022)

Figure 16 is an example of a typical Calcium Silicate part. The red lines represent the cut lines. By removing the need to cut the width of the piece and only cutting the length and features, the cut length is reduced from 2585mm to 651mm, which accounts for a 74.8% reduction in total cutting length

A fixture needed to be designed, manufactured, and fitted to the waterjet bed to accommodate the blocks. So that the Calcium Silicate could be placed in a consistent location and cutting programs could be generated using these known locations.

Whilst this was expected to reduce cutting time, a more extensive set-up time was expected as each block must be manually loaded into the fixture.

Moreover, this method removed the need to assemble the calcium silicate pieces into blocks, therefore removing an activity from the production process and reducing the overall cycle time for each door.

5.2.2.2 ECR - 136

Another clear opportunity for improvement was the significant time taken to store and retrieve material pallets which is an example of a mid-operation stop. (Sowmya & Chetan, 2016)

Figure 17 is a factory map highlighting the travel route the operator needs to take to retrieve and store material pallets from the waterjet to the storage warehouse.

A simple solution to reduce this was to install material racking adjacent to the waterjet so that it is not necessary to travel these distances regularly. Instead, stock can be kept within a short range of the machine, and the extensive travel distance is only required once a material pallet has run out and requires restocking, reducing the extent of the mid-operation stop. Thus, reducing cycle time. (Sowmya & Chetan, 2016)

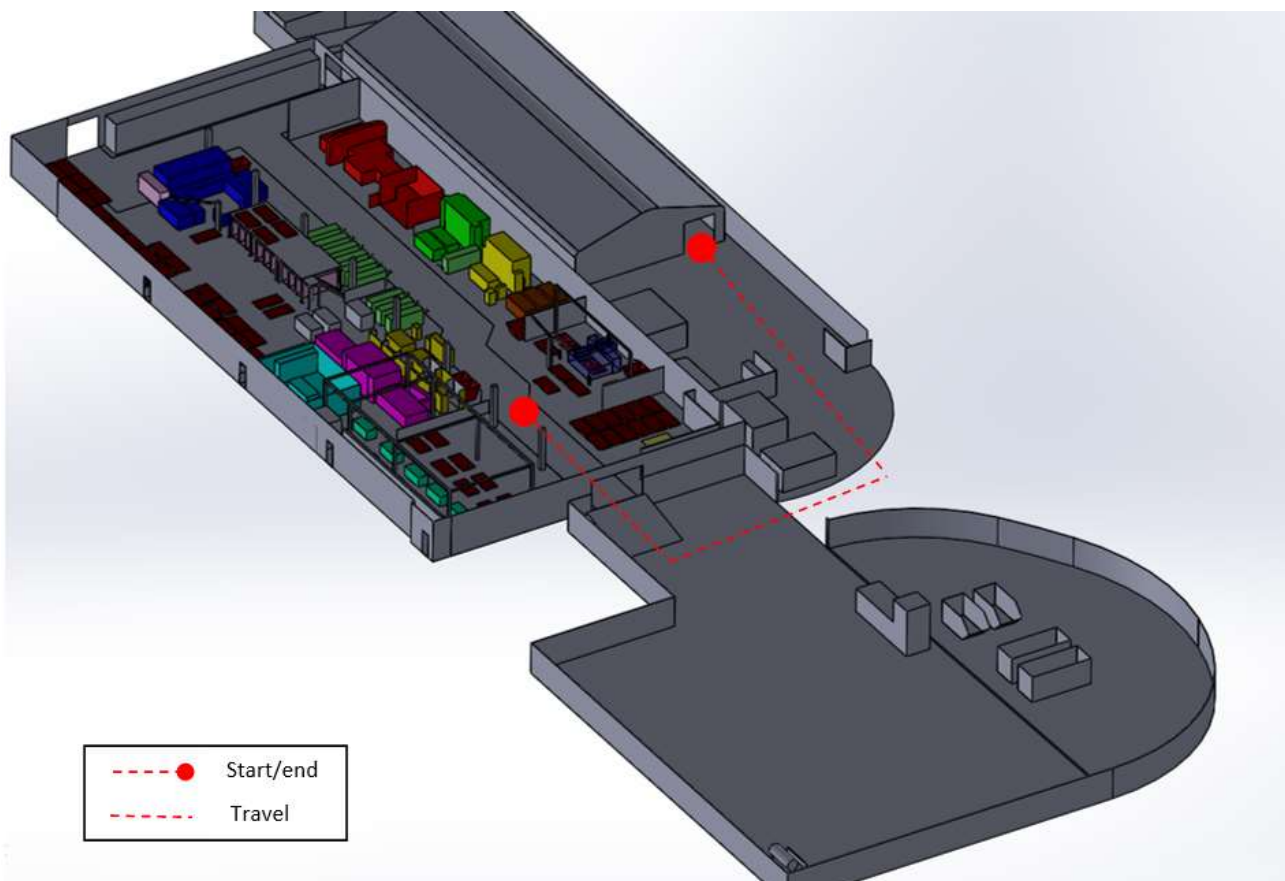


Figure 17 Forklift travel path. Created by Joel Lang using Solidworks

5.2.2.3 ECR 141

This ECR addresses snag 2 from Table 8, the excessive walk distance for waste disposal. It was proposed that new waste skips with wheels fitted to them be procured. This would allow them to be moved to a convenient location with ease. In contrast, the current waste skips could only be moved by a forklift. Therefore, limiting the areas they could be placed. Furthermore, they could only be moved by a certified forklift driver, limiting the skips' availability.

This a further step in minimising mid-operations stops. (Sowmya & Chetan, 2016)

5.2.2.4 ECR 142

Snag 1 identified that a big contributor to waste due to slow speed was the inefficient cutting order outputted by the machine's software. To address this, it was proposed that the software be upgraded to Radan. Radan is a CAD/CAM software that Eurobond doors currently use for other areas of production so adding the waterjet to this software would allow the waterjet to be seamlessly integrated into the businesses processes. Moreover, Radan is far more sophisticated than the native waterjet software. Allowing more control over the cutting order and the ability to automatically cut waste material into more manageable sizes for the convenience of the operator when removing waste. Thus, reducing the extent of the mid operation stop in this step and addressing snag 3. (Sowmya & Chetan, 2016)

5.2.3 Check

Having implemented the changes using the plan-do stages of a PDCA cycle, further time studies could be conducted in the next prototyping phase to assess the improvement in cycle time and determine what has been learned. The most recent time studies will produce a new value for system throughput. This value can be evaluated to see if Aim 1 has been met (produce 8 EI doors per day).

Table 9 details the revised cycle times for this process.

In the case of Calcium Silicate cutting time, the cycle time improved from **1307.25** seconds to **1035 seconds** per door, which equates to a 21% reduction. There was, however, an increase in cycle time relating to loading the machine bed with the Calcium Silicate and storing the parts post-cutting. This was expected due to the added complexity of using the manufactured fixtures to accommodate the cutting of the Calcium silicate in strip form.

Additionally, vast improvements were realised from the procurement of internal racking that places the material pallets adjacent to the waterjet so that material can be stored or retrieved without needing to travel to the external warehouse. The mean time for these tasks was reduced from 194.1 seconds to 49.2 seconds, equating to a 75.7% reduction. This task is required 8 times per door, which is a significant improvement.

With these improvements, the capacity per door has improved from 6.49 doors to 8.6 doors per day. This is an increase of 2.11 doors on average and exceeds the target of 8 doors per day as per Aim 1 of this project.

5.2.4 Act

The changes implemented in this cycle provide clear improvements to cycle time. Therefore, they can now be adopted into the process. The process flow chart can be modified to accommodate the changes so that the new revision of the process is defined. This enables further work to be planned to ensure continuous improvement. (Gidey, Jilcha, Beshah, & Kitaw, 2014)

Table 9 Waterjet timings after improvements

Activity	Calcium Silicate			Plasterboard 15mm			Plasterboard 12.5mm			Composite Sandwich Panel		
	manual	auto	walk	manual	auto	walk	manual	auto	walk	manual	auto	walk
Loading bed	93.2	0	2.5	25	0	2.5	65.75	0	0	0	0	0
Setting axis	13.25	0	5.25	13.5	0	3.75	11.75	0	2.5	27	0	0
Loading programme	12.5	0	1.25	4.5	0	1.25	7.5	0	0	35.75	0	0
Define material properties	27	0	0	24	0	0	22.3	0	0	19.8	0	0
Turn on water	0	0	28	0	0	18	0	0	32.3	0	0	16.7
Set light guard	3	0	0	3	0	0	3	0	0	3	0	0
Start program	0	15	0	0	15	0	0	15	0	0	15	0
Cutting	4.75	1035	2.5	5	295	2.5	6	294.75	2.5	15	197.25	0
Removing bed from machine	30.5	20.25	1.25	22	20	2.5	20.5	20	0	0	0	0
Marking parts	91.5	0	2	0	0	0	0	0	0	21.25	0	0
Removing waste	46.25	0	0	38.5	0	0	34.75	0	0	169.5	0	0
Storing parts	192	0	0	51.25	0	0	36.5	0	0	97.25	0	0
Unblocking head	35.75	0	0	0	0	0	0	0	0	0	0	0
Storing material pallet	37	0	45	19.5	0	46	24	0	48.6	19.8	0	49.8
Retrieving material pallet	20.5	0	47.3	18.75	0	49.8	20	0	50.1	20.1	0	56.7
Total per Category (s)	607.2	1070.25	135.05	225	330	126.3	252.05	329.75	136	428.45	212.25	123.2
Total per Material (s)	1812.5			681.3			717.8			763.9		

Total per Door (s)	3975.50
Total per Door (hrs)	1.10
Doors per Day	8.60

5.3 Bonding



Figure 18 Bonding station

5.3.1 Plan

The second major area of production that required consideration was the bonding process. This is an existing process within the business; however, significant changes were required to accommodate the production of EI doors. Moreover, this process regularly causes a bottleneck when production hits capacity. Therefore, taking a proactive approach to limiting future bottlenecks is valuable.

Through previous studies, extensive data existed for this process. Therefore, it was an ideal candidate for evaluating overall equipment effectiveness (OEE). This will allow a benchmark to be provided regarding how efficiently the process was currently operating. (Basak, Baumann, Holweg, Hague, & Tuck, 2022)

The OEE score and the individual scores for availability, performance and quality could be used in conjunction with the six major wastes to identify opportunities for improvement. (Sowmya & Chetan, 2016)

5.3.1.1 OEE of bonding

Table 10 Bonding OEE

OEE Score	47%
Availability	84%
<i>Operating Time (hours)</i>	8
<i>Planned Production Time (Hours)</i>	9.5
Performance	58%
<i>Pieces Produced</i>	11.1
<i>Ideal Speed (products per hour)</i>	2
<i>Operating Time (hours)</i>	9.5
Quality	95%
<i>Acceptable Pieces</i>	10.6
<i>Total Pieces</i>	11.1

Table 10 breaks down the OEE calculation, this data was based on historical data of the process, and an average has been taken so that the values used are mean.

The overall OEE was calculated to be 47% which is far lower than a typical target for a process like this, which is 70-80% since this process is heavily dependent on manual labour. (Basak, Baumers, Holweg, Hague, & Tuck, 2022)

When considering the individual values, the root cause of the low OEE value is performance-based, as performance has a score of only 58%, which, compared to the availability and Quality, is significantly lower.

Knowing this, the six big wastes could be considered to identify the opportunities for improvement. The two sources of waste relating to performance are 1) slow speed and 2) mid-operation stops. (Sowmya & Chetan, 2016)

With this information, it was now appropriate to use a value stream map (VSM) to define the steps within the process and identify the steps contributing to waste. (Chaple & Narkhede, 2017)

5.3.1.2 Value stream map (Bonding)

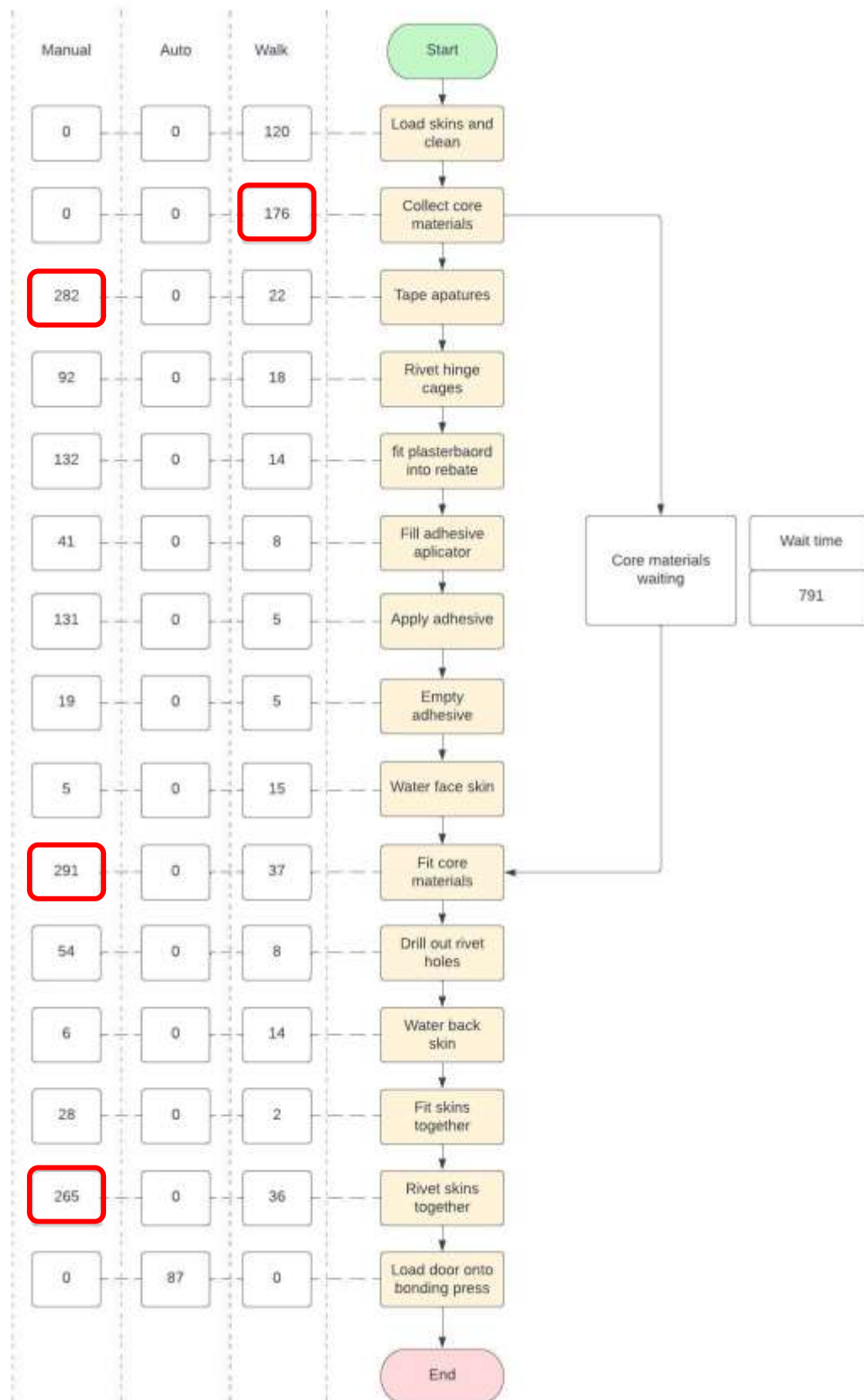


Figure 19 Bonding current state, Created by Joel Lang using LucidChart, information adapted from (Hindawi, 2017)

Figure 19 is a current state map of the bonding conditions with accompanying timings of each process step broken down into three categories: manual, auto or walk. Using these three categories makes it easier to identify the root causes of excessive cycle time.

Some notable steps are

- collect core materials – 176 walk time
This contributes to mid-operation stops as there is excessive time to collect all core materials, a task that does not add value to the process.
- Tape apertures – 282 manual time
This is a labour-intensive task whereby the operators must cut the tape and cover any holes in the sheet metal so the bonding glue does not seep through and damage the bonding press. This task contributes to slow speed.
- Fit core materials – 291 manual time
This task has the highest complexity in the process, contributing significantly to slow speed. Throughout prototype development, the order in which this task has been completed has evolved to become more efficient, but this is not yet standardised, which leads to a longer cycle time.
- Rivet skins together – 265 manual time
Due to the high volume of rivets required to rivet the skins together, this step contributes to slow speed.

From analysing the most significant contributors to the low-performance score, it is clear that the primary issue and therefore focus for improvement is waste due to slow speed. There are also opportunities to improve mid-operation stops. By addressing these areas via project review, a significant improvement should be made concerning performance, which should, in turn, improve the overall OEE. (Sowmya & Chetan, 2016)

Engineering Change Request ☆							
ID ↓ ▾	Title ▾	Created By ▾	Requested By ▾	Assigned To ▾	Issue Status ▾	Priority ▾	Description ▾
140	🔖 Procure automatic rivet gun	Joel Lang	Joel Lang	Joel Lang	Active	Low	Research and procure alternative rivet guns that improve cycle time
139	🔖 develop SOP's for EI bonding procedure	Joel Lang	Joel Lang	Joel Lang	Active	High	develop clear working instructions for EI bonding procedure, including sufficient detail so that documents can be used as a training manual.
138	🔖 Procure pre-cut fire tape	Joel Lang	Joel Lang	Joel Lang	Active	Normal	procure pre cut fire tape of different sizes to accommodate apertures in skin at bonding stage
137	🔖 Design and manufacture material handling ...	Joel Lang	Joel Lang	Joel Lang	Active	High	mobile storage trolleys are required for to handle composite cores and Calcium Silicate, each item needs to be accessible at any given time

Figure 20 ECR's bonding (Eurobond Doors Ltd, 2023)

5.3.2 Do

From the project review, the ECR's in Figure 20 were recorded. They each seek to improve on the waste sources identified via the current state process map in Figure 19.

5.3.2.1 ECR - 137

This ECR tackles the excessive walk time attributed to collecting the core materials.

Excessive walk time is an example of a mid-operation stop as this step adds no value to the process. It was proposed that mobile material storage solutions be manufactured so that core materials could be stored and transported; this means that core materials are located close to the bonding station, and the specific parts required for the job are easily identifiable and easily accessible. This should generate considerable time saving for this issue. (Singh, Khamba, & Singh, 2021)



Figure 21 Cores trolley

Figure 21 is an example of a material handling solution as a result of this ECR; in this example, the core pieces are loaded from the side, and the trolley is wheeled from the waterjet station, where they are cut, to the bonding station where they are assembled into the door. The benefit of being mobile is that the cores are adjacent to the workstation, so the walk time to collect them is minimised. Furthermore, the side loading feature allows access to any core piece whereas, previously, the core materials would be stacked onto a pallet. This occasionally results in the required core piece being buried underneath other jobs, so to access the required piece, the operators would need to move all core pieces that are on top of it, further adding to cycle time.

5.3.2.2 ECR - 138

When analysing the excessive manual time attributed to “taping apertures,” it was found that most of the time was used cutting the tape to the required size for each aperture. This activity is an example of slow speed, a waste source affecting performance. It was proposed that tape could be bought in pre-cut shapes and sizes so that the operators only needed to apply and not manually cut the tape themselves. (Sowmya & Chetan, 2016)

5.3.2.3 ECR - 139

ECR 139 aims to combat the slow speed waste associated with fitting the core materials. The step would benefit greatly from creating a standardised operating procedure (SOP) that the operators could be trained on, and it could serve as a training manual for future reference. This removes any uncertainty regarding this task which allows each step to be performed in the correct sequence without any mid-operation stops that occur when assembly does not occur in the correct order. (Sowmya & Chetan, 2016)

eurobond doors	El Door Bonding	Ref	SOP-281
		Issue Date	08-02-2023
		Revision	01
		Page	Page 8 of 15

12. ✓ Fit bottom panel in line with hinge packers. Ensure it sits flush against the packer. ✓ Fill the gaps with pre-cut plasterboard packers: between two main panels, and around them. ✓ Ensure plasterboard packers are fit around vision panel/louvre gap.



Figure 22 Bonding SOP (Eurobond doors ltd, 2023)

Figure 22 is a section of the SOP developed due to ECR 139. It details clear instructions as to how to approach this step of bonding. All operators undertook sufficient training on this SOP and signed documentation to clarify their understanding of the process. This will remove any confusion and likely improve the cycle time. Moreover, this SOP will be easily accessible for the operators should they be uncertain. (Mor, 2019)

5.3.2.4 ECR - 140

The current rivet guns require operators to load each rivet into the rivet gun before riveting manually. Resulting in a slow speed operation. Therefore, a feasibility study should be conducted into procuring auto-loading rivet guns that may speed up this process. (Jaqin, Rozak, & Hardi Purba, 2020)

5.3.2.5 Feasibility Study

After contacting our rivet gun supplier, a demonstration was arranged of an automatic rivet gun that auto loads rivets, the cost to purchase were quoted as £7,499. With two rivet guns being required, the total investment is **£14,998**.

The supplier informed us that these guns were Chinese machines that had yet to be sold in the UK. Therefore, concerns were raised about the serviceability of these guns since they were far more complex than the current guns in use, and the level of support we would receive from the manufacturer was still being determined.

Since this was a notable investment, conducting a thorough feasibility study was appropriate.

Table 11 payback for investment

time saving per rivet (s)	rivets per door	time saving per door (s)	capacity gained per day (units)	Additional profit generated per day* (£)	estimated pay back (days)
7	22	154	0.58	696	21.55

* Estimate based on target profit margin

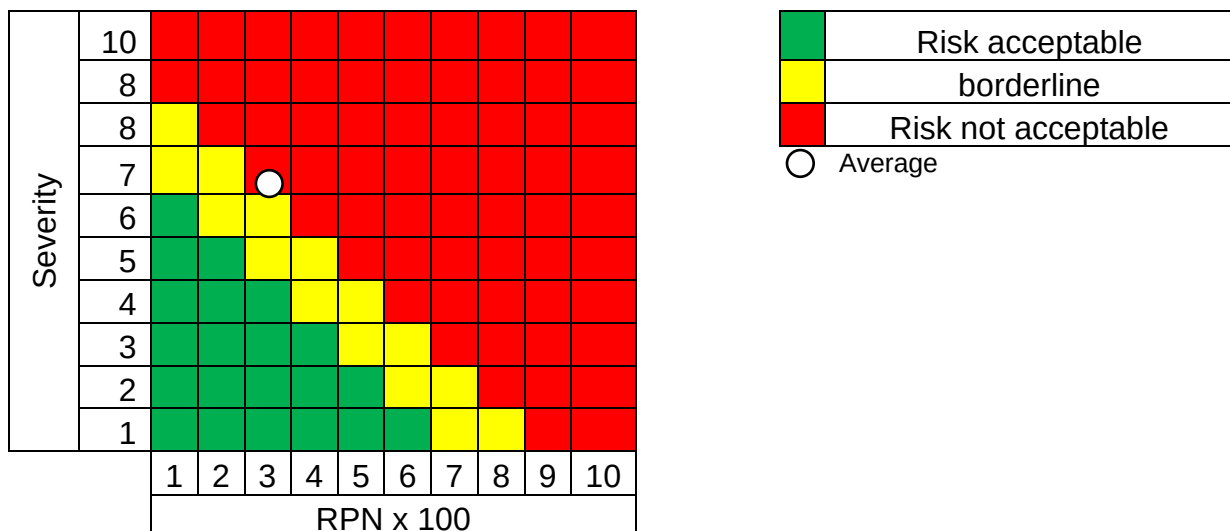
Since this was a notable investment, conducting a thorough feasibility study was appropriate.

Table 11 determines that the estimated payback for the investment is 21.55 days. This is a brief payback period which supports the case for purchasing. Before deciding, it was essential to understand the potential problems arising from using this equipment. For this, a Failure modes effect analysis (FMEA) was conducted. (Stamatis, 2003)

Table 12 Auto rivet gun FMEA (Goleansixsigma, 2023)

Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 10)	Potential Causes	OCCURRENCE (1 - 10)	Current Controls	DETECTION (1 - 10)	RPN
What is the process step, change or feature under investigation?	In what ways could the step, change or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step, change or feature to go wrong? (How could it occur?)		What controls exist that either prevent or detect the failure?		
Riveting	Rivets not holding	Door integrity compromised	10	poor quality rivets	7	inspect rivets	8	560
	rivets breaking during operation	increased cycle time	3	poor quality rivets	8	inspect rivets	8	192
	rivet not delivered	increase cycle time	4	air pressure not sufficient	8	preventative maintenance	4	128
Maintenance	mechanical breakdown	increase cycle time	7	poor quality parts	6	none - unknown quality	9	378
	electrical breakdown	increase cycle time	7	poor quality parts	6	none - unknown quality	9	378
	sensor breakdown	increase cycle time	7	poor quality parts	6	none - unknown quality	9	378

Table 13 Risk matrix (Ouyang, 2022)



Legend for scales found in appendix A

Table 12 explores the potential failures that could occur from purchasing automatic rivet guns. It also quantifies the risk factor associated with the potential failures by considering the severity, the occurrence rate and the effectiveness of control measures that aim to prevent each risk.

The study found that the average risk priority number (RPN) was 336, and the average severity was 6.1. when this average value was considered against a risk matrix in Table 13 the study concluded that risk was not acceptable. This is due mainly to the unknown levels of reliability of the machine and the support that would be received in the case of a breakdown. (Stamatis, 2003)

Therefore, it was not recommended to proceed with this investment. Instead, further research into reliability and support was required. Additionally, more research into alternative products was necessary.

5.3.3 Check

Table 14 Bonding OEE with improvements

OEE Score	66%
Availability	89%
<i>Operating Time (hours)</i>	8.5
<i>Planned Production Time (Hours)</i>	9.5
Performance	77%
<i>Pieces Produced</i>	14.7
<i>Ideal Speed (products per hour)</i>	2
<i>Operating Time (hours)</i>	9.5
Quality	96%
<i>Acceptable Pieces</i>	14.1
<i>Total Pieces</i>	14.7

Table 14 is the OEE score of the bonding process calculated after the **Do** section improvements were implemented. The overall OEE score now stands at 66%, significantly improving the initial score of 47%. However, this is still short of the industry target for processes that heavily rely on manual input, which is 70—80%. (Singh, Khamba, & Singh, 2021)

After addressing the wastes associated with performance, the score has improved significantly from 58% to 77%. However, this is still the lowest score out of the three factors. Further investigations and improvement plans using Plan-Do-Check-Act may be necessary to improve this score and achieve the 70-80% target.

5.3.4 Act

ECR 137, ECR 138 and ECR 139 all proved to be positive changes to the process that aided in improving the OEE score of the process. Therefore, these changes were adopted into the process. The SOPs for this procedure could now be amended to include the new systems, thus anchoring the new working methods so that they could be considered in further improvement cycles. (Rozak, Jaqin, & Purba, 2020)

ECR 140 proved not feasible at this time, so this change was abandoned pending further investigation. (Rozak, Jaqin, & Purba, 2020)

5.4 Costing

The most comprehensive method of costing considered in the literature review is Activity-based costing (ABC). This method provides the most accurate costing model as it attempts to consider the specific resources used in producing this product. This will be essential when costing the new product as definitive costs can be attributed to the product. (Namazi, 2016)

Other costing methods, such as absorption costing, use a simplified strategy whereby the overall costs of the factory are evenly distributed among the output of products to give a mean value; however, this method does not allow a distinction between different products to be made. For example, the EI door may require two times the amount of energy to produce compared to a standard steel door, but this method would assign a standard energy cost to all products. Whereas in the case of activity-based costing, the energy cost associated with EI door production would be proportional to its usage. (Bunea-Bontas, 2013)

Using ABC allows for the most accurate estimate of the production cost for an EI door, allowing for a profit margin to be understood when the cost is compared to the sale price.

ABC costing is a complex costing strategy that requires significant data to complete accurately; since this is a new product, sufficient data only exists for some processes. The processes that have been the subject of this report were good candidates for ABC costing due to the detailed time studies that have been undertaken. However, sufficient data does not exist for other processes. Therefore, ABC costing could be completed for the waterjet and bonding, but the remaining processes needed to use an alternative strategy to estimate cost. Absorption costing can be used so that direct and indirect costs can be attributed to all processes and, therefore, the total cost of the door. (Jaya, Pathairage, & Sutrisana, 2010)

Further to this point, understanding the profit margin allowed for a break-even analysis to be undertaken, providing a clear understanding regarding the point at which investments have been recovered and any further sales generate profit for the business.

5.4.1 Waterjet ABC costing

Table 15 Waterjet ABC costing

cost drivers		cost per unit	units used per door	cost per door	Details
machine running cost	water	£1.933 (m ³)	0.17	£0.329	water used per door * unit cost
	electricity	£0.334 (KwH)	1.104	£7.375	20KW per hour * cost per unit * hours used
	garnet	£0.60 (Kg)	33.22	£19.932	garnet used per door * cost per unit
waterjet other	maintenance	£1.845 (hr)	1.104	£2.037	(maintenance per year/hours run time)* hours per door
	depreciation	£7.38 (hr)	1.104	£8.148	(depreciation per year / annual run time)*hours per door
fork truck	fuel	£1.41 (hr)	0.159	£0.224	Cost to fuel fork truck per hour * hours used per door
	maintenance	£0.79 (hr)	0.159	£0.126	(annual maintenance / annual hours used)* hours used per door
	depreciation	£0.844 (hr)	0.159	£0.134	(annual depreciation/total hours)*hours used per door
resources	labour	£12.50 (hr)	1.104	£13.800	unit cost * units used
material	Calcium Silicate	£68.40 (block)	4	£273.600	unit cost * units used
	Plasterboard (12.5)	£12.34 (sheet)	0.5	£6.170	unit cost * units used
	Plasterboard (15)	£16.89 (sheet)	0.5	£8.445	unit cost * units used
	Composite panel	£120 (sheet)	1	£120.000	unit cost * units used
			total	£460.319	

5.4.2 Bonding ABC Costing

Table 16 Bonding ABC costing

cost drivers		cost per unit	units used per door	cost per door	Details
machine running cost	water	£1.933 (m ³)	0.005	£0.010	water used per door * unit cost
	electricity	£0.334 (KwH)	0.566	£3.781	20KW per hour * cost per unit * hours used
	acetone	£4.99 (ltr)	0.34	£1.697	garnet used per door * cost per unit
Bonding other	maintenance	£2.10 (Hr)	0.566	£1.189	(maintenance per year/hours run time)* hours per door
	depreciation	£5.80 (Hr)	0.566	£3.283	(depreciation per year / annual run time)*hours per door
resources	labour	£25 (hr)	0.566	£14.150	unit cost * units used
material	Adhesive	£18 (ltr)	0.2	£3.600	unit cost * units used
	hinge blocks	£4 (qty 1)	4	£16.000	unit cost * units used
	Alu honeycomb	£33.3 (sheet)	2	£66.600	unit cost * units used
	fire tape	£60 (roll)	0.2	£12.000	unit cost * units used
			total	£122.309	

5.4.3 Other Costs

Table 17 Other costs

	Annual cost	EI doors per year	% of total doors	cost per EI door
Sales	£150,000.00	1664	30.00%	£27.04
Marketing	£20,000.00	1664		£12.02
Internal admin	£60,000.00	1664	30.00%	£10.82
Haulage				£250.00
Installation				£110.00
Utilities	£144,000	1664	30.00%	£25.96

total	£435.84
-------	---------

5.4.4 Total Product Costing

Table 18 Total product cost

process	labour	materials	outsource cost	cost
goods in	£1.875	£0.000		
Waterjet				£460.319
Amada turret punch	£4.375	£386.000		
RAS CNC panel bender	£4.250	£0.000		
HFE press break	£4.875	£0.000		
Powder coating			£120.000	
Bonding				£122.309
Frames assembly	£11.125	£48.000		
Final assembly	£14.000	£456.250		
Pallet wrapping	£0.625	£3.400		
Goods out	£0.625	£0.000		
other costs				£435.84

total	£2,073.868
-------	------------

5.4.5 Break Even Analysis

Table 19 Break even analysis

testing	indicative (fire)	£80,000.00
	certification (fire)	£280,000.00
	certification (smoke)	£10,000.00
	certification (hinge)	£8,500.00
prototyping	labour	£2,500.00
	materials	£34,000.00
	resources	£6,000.00
	utilities	£576.00
	consultation	£16,500.00
	design team	£80,000.00
	manufacturing team	£20,000.00
total		£538,076.00
cost to produce door		£2,073.870
sale price of door		£3,500.00
profit per door		£1,426.13
doors to break even		377.30
days to break even		47.16

Table 19 concludes the costing section of this project, determining that the overall R&D cost was estimated to total £538k. Given the target sale price of £3,500 and the cost to manufacture an EI door (£2,073.87) as determined by tables 14,15,16&17. The expected profit generated per door is £1,426.13.

Therefore, the project is expected to break even after the delivery of 377.3 doors, which is estimated to take 47.16 business days, based on the projected sale volumes and manufacturing capabilities of the business.

5.5 Change Management

Depending on the primary focus of the change management, different models may suit. In this case, the primary purpose of utilising change management methods was to achieve employee buy-in. Therefore, utilising change management methods where the employees are the primary or significant focus made the most sense. Kotter's 8 steps and ADKAR are models that do this. Therefore, the change management strategy was implemented with these in mind. This is not to say that elements from other models are irrelevant and were not utilised, as it was beneficial to take inspiration from Lewin's freeze/unfreeze model and McKinsey's 7 steps.

5.5.1 Create Awareness

In the ADKAR change management model, the first step is to create awareness of the change so that employees understand the necessity of the change, its benefits, and what it means for the business and their working lives. In addition, Kotter's 8 steps begin by creating a sense of urgency; therefore, a logical starting point was to create awareness/urgency surrounding the project. It was decided that launching an awareness campaign for the project would be highly beneficial in installing employee awareness.

Eurobond Doors releases a quarterly newsletter updating employees with critical business information and social events. (Hiatt, 2006) (Kotter, 2012)

is an excerpt from the quarterly newsletter that was distributed amongst staff in the business. This was an opportunity to provide some background information about the requirements of the new product and the benefits it will bring. Therefore, creating a sense of awareness for the project. This was also an opportunity to include some key stats, such as "annual growth in excess of 50%", so that the impact of the change can be quantified. (Hiatt, 2006) (Kotter, 2012)



<<<

The current overall economic outlook is uncertain with high inflation, rising interest rates and high energy costs. This creates challenges both on a business level as well as for many of us individually.

Our decision some time ago to put our focus and priorities towards the data-centre market shows now to be the right one. Demand for many products is slowing down but demand for data continues to grow and there are no signals that the activity level in the construction of data centres is slowing down.

The data-centre market is very demanding when it comes to product quality and service and requires a highly bespoke, high value product. We have shown to be a reliable partner and we have achieved a big market share in this market segment in the UK.

Over the last 2 years we have heavily invested in the development of an EI (integrity and insulation) door range. All testing has been completed successfully and this will open a massive growth opportunity for us in the European data-centre market. We have signed the first order for delivery in March 2023. It is critical for the future of our business to make sure this first order will be a success. We have to secure to deliver on time with the top quality we are known for and with the required support to satisfy the end customer.

A successful introduction of the EI door range will be transformational for our business and allow for annual growth in excess of 50%

The focus on the data-centre market at the same time creates multiple challenges. The projects are getting bigger and it is a pure bespoke and project based business. Managing our manufacturing

Figure 23 EBD quarterly newsletter (Eurobond doors , 2022)

5.5.2 Desire for Change

In addition to the newsletter, the project team decided that it would be beneficial to involve operators throughout the development process of the door by including them in prototype assemblies and having open discussions about the project so that they became familiar with the project and any concerns can be listened to and addressed throughout prototype production. Furthermore, involving the operators allows frequent communication and an understanding of how this project will further their development and improve the business's profitability, which will, in turn, benefit the operators.

By doing this, the vision for change is being communicated, and others are being empowered to act upon the vision, which are critical steps in Kotter's 8 steps for change. (Kotter, 2012)

This step also addresses the Desire stage of ADKAR, as this provided an opportunity for communication with employees so that they could understand how this project aligns with their personal growth. Additionally, the Knowledge stage of ADKAR is put into motion as the operators begin their training on an informal basis. (Hiatt, 2006)

5.5.3 Provide the Tools for Change

In addition to Knowledge (Provide training for employees to ensure they are skilled and capable of implementing the change), the next step is Ability (Provide the appropriate resources for employees to accomplish the change). These steps are related, and work that covers both aspects can be done. (Hiatt, 2006)

To address these steps, standardised operating procedures were written in all areas of EI door production to serve as a formal training manual for the operators to read and have available to them should they require it for support. In addition to this, the project team committed to supporting operators through prototype production. As early production commenced, the support team slowly phased out their presence so that operators started to take ownership of the project and feel more confident manufacturing an EI door. (Mor, 2019)

- ✓ Turn frame around and place pre-cut plasterboard alongside Fold 3.
- ✓ Layer rockwool on Fold 2. Trim rockwool if necessary.



Figure 24 EI SOP 1 (Eurobond doors ltd, 2023)

- ✓ Take steel lockbox part with holes for furniture fitting.
- ✓ Fit one 12.5mm plasterboard on the bottom, then rockwool, then another 12.5mm plasterboard
- ✓ Slot both steel parts together.
- ✓ Door Loop only – the tag for conduit will be attached to the steel part.



Figure 25 EI SOP 2 (Eurobond doors ltd, 2023)

5. HEAT RESISTANT TAPE

- ✓ Cover all apertures where adhesive will be applied with Heat resistant tape P/N – PAC 310605 (both blades).

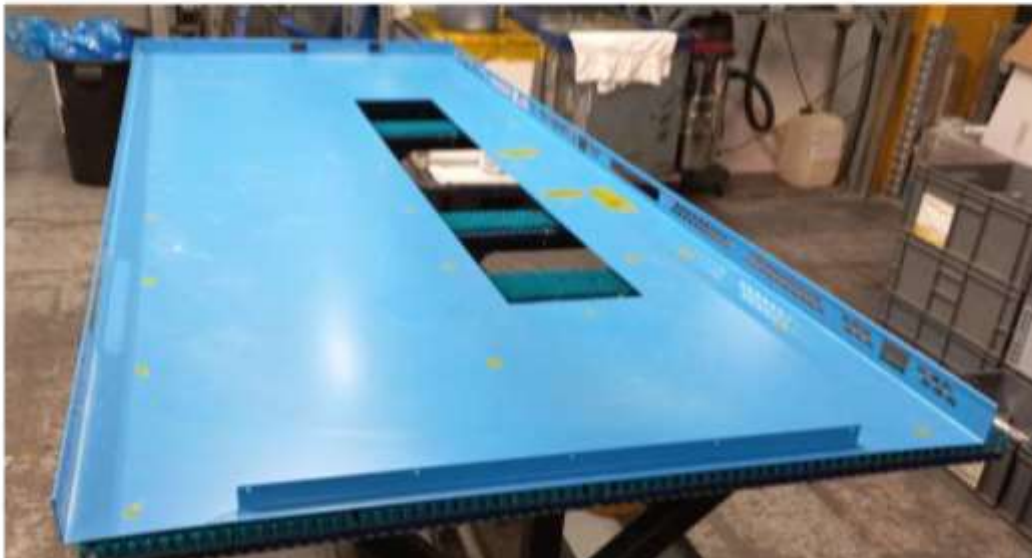


Figure 26 EI SOP 3 (Eurobond Doors Ltd, 2022)

Figure 24, Figure 25 and Figure 26 are examples of the SOPs developed for operator training. These documents provide the knowledge and resources that the operator requires per the ADKAR model. These documents will also improve the system throughput by reducing mid-operation stops, optimising workflow and reducing defects, as evidenced by the methodology in section 5. (Mor, 2019)

Moreover, these documents will serve as a permanent resource for future reference and training of future operators. Therefore, futureproofing the processes, should key stakeholders leave the business. (Mor, 2019)

5.5.4 Recognition and Reward

The final stage of ADKAR, Reinforcement (Acknowledging employee efforts and contributions, providing helpful feedback that enabled further growth), was addressed by highlighting employee efforts in the monthly spotlight award, which recognises employee contributions and rewards them. (Hiatt, 2006)

“Good afternoon,

*I am pleased to announce that **Carl Reddish – Production Operator** was selected as **December’s ‘Spotlight Award Winner’**. Carl selected a scratch card containing the ‘£30.00 Love to Shop Vouchers’.*

Carl’s recognition includes the following: -

- *His continued positive impact on shopfloor morale, along with his consistent effort to achieve good quality work is faultless.*
- *He makes everyone’s day brighter.*
- *He has enthusiastically supported the EI door project and offered valuable feedback.*

(Eurobond doors , 2022)

This form of open recognition and reward further encourages the employee that is being recognised. It also reinforced the benefits of positive engagement with the project amongst the workforce and encouraged them to follow suit.

This form of recognition also ties in with Kotter’s 6th step (Planning to recognise milestones in the early stages of the changes and celebrating them. Recognising stakeholders for their involvement in achieving the milestones) (Kotter, 2012)

These steps are slightly different to acknowledging ongoing efforts. Therefore, significant milestones in the NPI process were defined so that they could be recognised and contributors could be acknowledged. They were as follows;

- First batch of prototypes (assisted)
- First batch of prototypes (unassisted)
- First batch from order book (unassisted)

Each of these milestones will be publicly addressed in the company newsletter whilst naming those who contributed to the success of each step.

5.5.5 Measuring Buy-In

To assess whether aim 3 of the project, “achieve employee buy-in”, has been met, pulse surveys were conducted periodically throughout the project to quantify the resistance to the change. The change in attitude could be monitored throughout the project, which will allow an understanding of what elements of the change management strategy were effective so that these elements could be focused on going forward. (Awang, Mamat, & Afthanorhan, 2016)

El door development feedback	
1. You are excited by the El door project	4. How has the project effected your levels of happiness at work?
☐ Strongly agree	☐ Very positive
☐ Agree	☐ Positive
☐ Neither agree nor disagree	☐ Neutral
☐ Disagree	☐ Negative
☐ Strongly disagree	☐ Very negative
2. You feel like the project is challenging you	5. Your feedback regarding the project is valued and useful
☐ Strongly agree	☐ Strongly agree
☐ Agree	☐ Agree
☐ Neither agree nor disagree	☐ Neither agree nor disagree
☐ Disagree	☐ Disagree
☐ Strongly disagree	☐ Strongly disagree
3. You are happy at work	6. you are satisfied with the level of feedback you receive
☐ Strongly agree	☐ Strongly agree
☐ Agree	☐ Agree
☐ Neither agree nor disagree	☐ Neither agree nor disagree
☐ Disagree	☐ Disagree
☐ Strongly disagree	☐ Strongly disagree

Figure 28 Pulse survey 1-3. Created by Joel Lang using SurveyMonkey

Figure 27 Pulse survey 4-6 Created by Joel Lang using SurveyMonkey

Figure 27 & Figure 28 are screenshots of the pulse survey periodically distributed amongst stakeholders. The survey was kept the same in each instance so that changes in attitude could be monitored.

The survey addresses the critical metrics associated with buy-in, such as Feedback, Happiness, Relationships and Personal growth.

5.5.6 Results

To quantify the feedback from the pulse surveys, the answers were scored from -2 (most negative) to +2 (most positive) and average values were taken for each employee, each survey, as well as overall averages for all employees to give a single value, the “engagement score”.

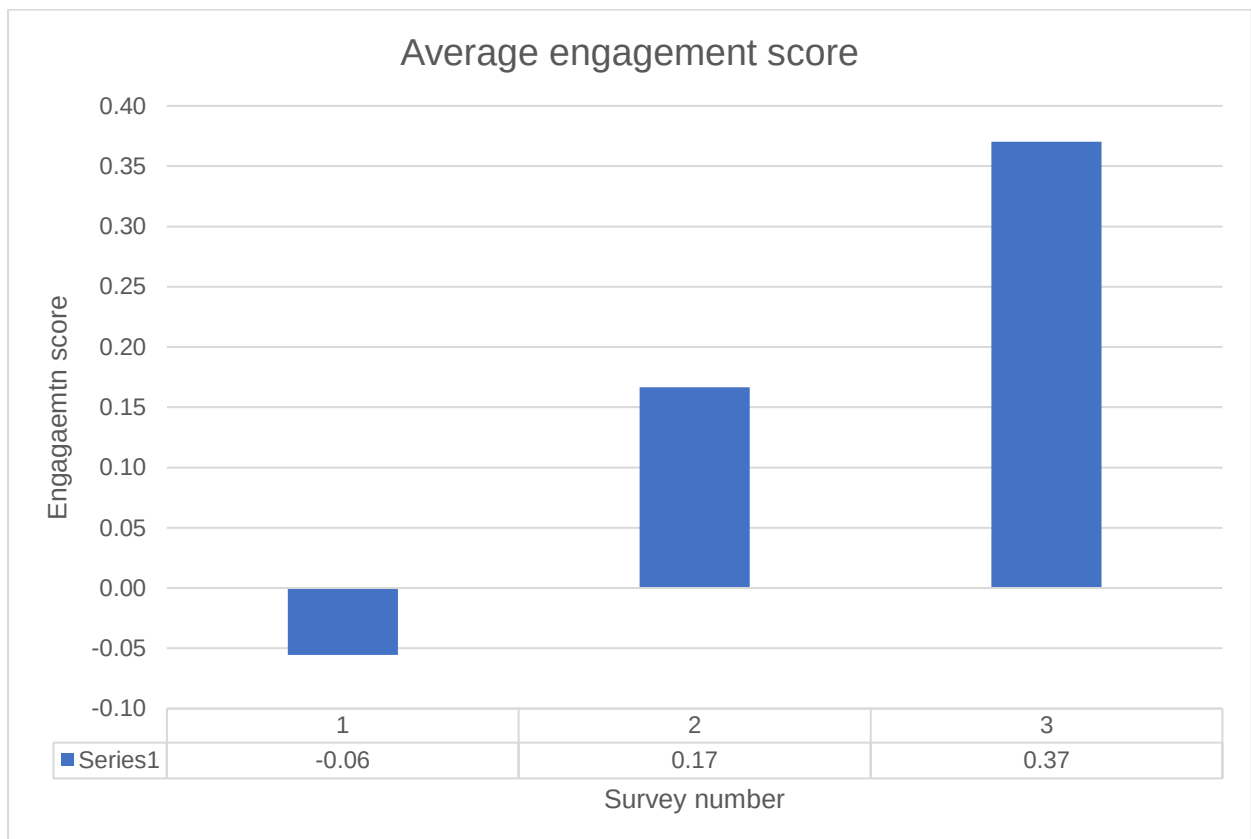


Figure 29 Average engagement score. Created by Joel Lang using Excel

Figure 29 is the overall average engagement score recorded at each survey point during the project. Initially, the project resulted in a slightly negative engagement score as the project met natural resistance; this is to be expected of a significant change within the business. However, as the project progressed with a proactive attitude to change management, the engagement score trended towards positive, with Survey 2 and Survey 3 scoring an average of 0.17 and 0.37, respectively.

Table 20 Pulse survey data

Operator		Survey 1 1/11/22							Survey 2 7/1/23							Survey 3 15/3/23						
First	Last	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	averag e	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	averag e	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	averag e
Carl	Reddish	-2	1	0	-1	1	0	-0.17	0	2	0	0	1	1	0.67	1	2	1	2	2	2	1.67
Barrie	Davies	1	1	-1	0	-1	0	0.00	0	1	-1	0	0	0	0.00	0	2	-1	0	1	1	0.50
Ben	Harris	1	0	1	0	0	-1	0.17	1	1	1	0	0	0	0.50	1	1	1	0	1	0	0.67
Blake	Matthew	-2	2	1	-1	1	1	0.33	-2	1	1	1	1	1	0.50	-1	1	1	1	1	0	0.50
Callum	Feneck	0	1	-1	0	1	0	0.17	1	1	0	1	0	0	0.50	1	2	1	1	0	0	0.83
Chay	Williams	-1	1	-2	-1	-2	0	-0.83	-1	2	-2	0	-1	-1	-0.50	0	1	-2	-1	0	0	-0.33
Christoph	Williams	-1	2	0	0	0	0	0.17	-1	2	0	1	0	0	0.33	-1	1	0	1	0	0	0.17
Daniel	Hawkins	-2	1	-1	0	1	1	0.00	-1	1	0	1	0	1	0.33	0	2	0	1	-1	-1	0.17
David	Griffiths	-2	0	0	0	0	0	-0.33	-2	0	0	-1	-1	-1	-0.83	-2	0	-1	0	-1	-1	-0.83
								-0.06							0.17							0.37

Table 20 shows the survey results per employee throughout the project. Notably, operator Carl Reddish significantly increased their engagement score from -0.17 initially to 1.67 in the final survey of the project. This can be attributed to the active engagement put forth by Karl, the feedback and consideration that was returned to him, as well as the recognition and reward via the monthly spotlight award.

Although the overall average improved, many operators showed a negligible change over time, with some individuals' scores trending negatively. Further investigation is required to understand why this is happening in order to make further improvements in employee engagement.

6 Discussion and Conclusion

New product introduction is a challenging prospect that can be managed using various tools and techniques. In the case of the Waterjet, where there were no existing working procedures, utilising process flow maps was an ideal starting place so that the process had an initial starting point that allowed other tools to be used to identify and enact improvement.

Furthermore, using time studies to gather process data was essential in carrying out the Plan-Do-Check-Act cycle that was used in order to improve cycle time and achieve the first aim of the project, “manufacture 8 EI doors per day.”

Conversely, the bonding process was a well-established process that had extensive data that allowed for tools that require such data to be used, such as OEE. Once OEE was determined, the Six big wastes could be considered to identify sources of waste with the view to removing or reducing them so that this process could also achieve the target of 8 doors per day and reduce the probability of becoming a bottleneck in the process.

When considering the cost to manufacture an EI door, various costing strategies were reviewed; each method had varying levels of depth and accuracy. The most comprehensive method was activity-based costing. However, this method requires significant data to use accurately. Therefore, it could only be used for the waterjet and bonding processes since significant data existed due to this project.

A more simplified strategy, absorption costing, had to be used for the remaining processes. While this is considered less accurate and less comprehensive than ABC costing, this method allowed a costing estimate to be attributed to each process. That included both direct and indirect costs.

Lastly, this project posed a significant change to the day-to-day operations of Eurobond doors. Therefore, it was decided that change management had to be a primary consideration of the project to ensure that the change was implemented successfully and stayed successful for a prolonged period.

To achieve this, a range of change management models and methods were considered, with Kotter’s 8 steps and ADKAR ultimately being closely followed throughout the process as these methods had a particular focus on the employees affected by the change, which was the focus of aim 3 of the project “achieve employee buy-in”.

Following these methods, an awareness campaign was conducted along with other tools, such as developing SOPs so the employees had the resources to take ownership of the change.

The level of engagement was improved throughout the project by utilising these techniques.

Since there is no definitive way to assess whether buy-in has been achieved, the data must be analysed to determine the trends in employee engagement. Furthermore, personal experiences with employee engagement must be considered.

The results of the change management strategies showed that employee engagement increased over time. Therefore, the levels of buy-in were also increasing. Providing evidence that aim 3 of the project (achieve employee buy-in) has been achieved.

Moreover, informal discussions with the employees have become more positive over time. Early sentiments of resistance have been replaced with an inquisitive and optimistic attitude to the project. (E.g., “How much do we sell these doors for?” “How many doors are we going to sell?”). Further validating the levels of employee buy-in.

7 Recommendation for Further Work

Although significant headway has been made in improving the processes in this report, this was only one cycle of PDCA. In lean manufacturing, Kaizen refers to the commitment to continuous improvement. Therefore, to continue to optimise, the PDCA cycle can be repeated over time to improve efficiency further and reduce cycle time.

Once significant data has been gathered for the waterjet, OOE can be evaluated, and the six big wastes can then be considered with the view to eliminating/minimising them in the same way that the bonding process was analysed in this report.

Over time, bottlenecks are likely to arise in other areas of production that still need to be considered. Therefore, all processes should be monitored going forward to identify these bottlenecks so that the tools used to improve the waterjet and bonding can be used elsewhere.

Moreover, as significant data is developed, it would be beneficial to utilise statistical process control models in various production areas to ensure variations in quality and cycle time are easily identified. (Bheda, 2021)

When costing the product, Activity Based costing was only possible in some aspects of production due to the lack of data. It is recommended that as sufficient data is gathered as part of the indefinite continuous improvement, activity-based costing is utilised to provide a more thorough and accurate cost to manufacture, which will, in turn, provide a more accurate profit margin so that the product can be priced for sale appropriately.

The final step of Kotter's 8 steps talks about anchoring the new approaches into the organisation's culture, Lewin's freeze/unfreeze model concludes with a similar sentiment. Therefore, to ensure the change is successful and remains successful over time, it is essential to address this step. (Kotter, 2012)

One way to address this is to continuously acknowledge the efforts put forth by staff to support and maintain the implementation of this project. This can be done via the monthly spotlight award and quarterly newsletter. (Kotter, 2012)

Furthermore, as the production of the new product grows and scales, future production milestones can be anticipated so that they can be celebrated, and the input from staff that contributed to the milestones can be acknowledged and celebrated. (Kotter, 2012)

This will contribute to the ongoing pursuit of employee buy-in as employee engagement score will improve over time.

8 Appendix A

Occurrence Scale

Probability of Failure	Time Period	Per Item Failure Rates	Ranking
Very High: Failure is almost inevitable	More than once per day	≥ 1 in 2	10
	Once every 3-4 days	1 in 3	9
High: Generally associated with processes similar to previous processes that have often failed	Once every week	1 in 8	8
	Once every month	1 in 20	7
Moderate: Generally associated with processes similar to previous processes which have experienced occasional failures, but not in major proportions	Once every 3 months	1 in 80	6
	Once every 6 months	1 in 400	5
	Once a year	1 in 800	4
Low: Isolated failures associated with similar processes	Once every 1 - 3 years	1 in 1,500	3
Very Low: Only isolated failures associated with almost identical processes	Once every 3 - 6 years	1 in 3,000	2
Remote: Failure is unlikely. No failures associated with almost identical processes	Once Every 7+ Years	1 in 6000	1

(Goleansixsigma, 2023)

Detection Scale		
Detection	Criteria: Likelihood the existence of a defect will be detected by process controls before next or subsequent process, -OR- before exposure to a client	Ranking
Almost Impossible	No known controls available to detect failure mode	10
Very Remote	Very remote likelihood current controls will detect failure mode	9
Remote	Remote likelihood current controls will detect failure mode	8
Very Low	Very low likelihood current controls will detect failure mode	7
Low	Low likelihood current controls will detect failure mode	6
Moderate	Moderate likelihood current controls will detect failure mode	5
Moderately High	Moderately high likelihood current controls will detect failure mode	4
High	High likelihood current controls will detect failure mode	3
Very High	Very high likelihood current controls will detect failure mode	2
Almost Certain	Current controls almost certain to detect the failure mode. Reliable detection controls are known with similar processes.	1

(Goleansixsigma, 2023)

Severity Scale		
Effect	Criteria: Severity of Effect	Ranking
Hazardous - Without Warning	May expose client to loss, harm or major disruption - failure will occur without warning	10
Hazardous - With Warning	May expose client to loss, harm or major disruption - failure will occur with warning	9
Very High	Major disruption of service involving client interaction, resulting in either associate re-work or inconvenience to client	8
High	Minor disruption of service involving client interaction and resulting in either associate re-work or inconvenience to clients	7
Moderate	Major disruption of service not involving client interaction and resulting in either associate re-work or inconvenience to clients	6
Low	Minor disruption of service not involving client interaction and resulting in either associate re-work or inconvenience to clients	5
Very Low	Minor disruption of service involving client interaction that does not result in either associate re-work or inconvenience to clients	4
Minor	Minor disruption of service not involving client interaction and does not result in either associate re-work or inconvenience to clients	3
Very Minor	No disruption of service noticed by the client in any capacity and does not result in either associate re-work or inconvenience to clients	2
None	No Effect	1

(Goleansixsigma, 2023)

9 Works Cited

- Awang, Z., Mamat, M., & Afthanorhan, A. (2016). the likert scale analysis parametric based structural equation modeling (SEM). *Computational methods in social sciences*, 14-20.
- Basak, S., Baumer, M., Holweg, M., Hague, R., & Tuck, C. (2022). Reducing production losses in additive manufacturing using overall equipment effectiveness. *Additive Manufacturing*.
- Bateh, J., Castaneda, M. E., & Farah, J. E. (2013). Employee Resistance To Organizational Change. *International Journal of Management & Information Systems*, 113-116.
- Bheda, R. (2021). Lean quality management. In P. Jana, & M. Twiwari, *Lean Tools in Apparel Manufacturing* (pp. 311-329). Amsterdam : Elsevier .
- Bicheno, J., & Holweg, M. (2016). *The lean toolbox*. Buckingham: PRODUCTION AND INVENTORY CONTROL, SYSTEMS AND INDUSTRIAL ENGINEERING (PICSIE) BOOKS.
- Bunea-Bontas, C. A. (2013). THE COST OF PRODUCTION UNDER DIRECT COSTING AND ABSORPTION. *Economy series*.
- CEN-CENELEC. (2014, October 31). EN 16034:2014. *Pedestrian doorsets, industrial, commercial, garage doors and openable windows - Product standard, performance characteristics - Fire resisting and/or smoke control characteristics*. Brussels, Belgium : CEN-CENELEC.
- Channon, D. F., & Caldart, A. A. (2015). McKinsey's 7S model . *Wiley encyclopedia of management* , 1-1.
- Chaple, P. A., & Narkhede, E. B. (2017). *Value stream mapping in discrete manufacturing: a case study* . Mumbai: Department of production and industrial engineering .
- Chukhray, N., Mrykhina, O., & Izonin, I. (2022). Holistic Approach to R&D Products' Evaluation for. *Journal of open innovation: technology, market and complexity*, p.9.
- Eurobond doors . (2022, December 3). December 2022 quarterly news letter. Cardiff, United Kingdom : Eurobond doors Ltd.
- Eurobond Doors Ltd. (2022, December 12). Design team site. *EI door rev14*. Cardiff, United Kingdom: Eurobond doors .
- Eurobond Doors Ltd. (2023, April 27). Engineering change request . *EBD Quality management system* . Cardiff, RCT.
- Eurobond doors Ltd. (2023, February 8). SOP-281 EI Door bonding. *EI door bonding* . Cardiff, United Kingdom: Eurobond doors Ltd .
- George, M., Maxey , J., Rowlands, D., & Price, M. (2004). *The lean six sigma pocket toolbox*. McGraw Hill Professional .
- Gidey, E., Jilcha, K., Beshah, B., & Kitaw, D. (2014). The Plan-Do-Check-Act Cycle of Value Addition. *Industrial Engineering & Management*.
- Goleansixsigma. (2023, June 13). *Failure modes & effects analysis* . Retrieved from goleansixsigma: <https://goleansixsigma.com/failure-modes-effects-analysis-fmea/#1589317797331-dec53299-fbe6>

- Hansen, D. R., Mowen, M. M., & Heitger, D. L. (2021). *Cost management*. Boston: Cengage Learning.
- Hanson, C. R. (2001). *overall equipment effectiveness: a powerful production/ maintenance tool for increased profits* . New York: Industrial press, Inc.
- Hare, D., Dickson, J., McDade, P., Morrison, D., Priestley, D., & Wilson, G. (2000). A Market-Based Approach to Pricing With-Profits Guarantees. *British Actuarial Journal*, 143-213.
- Hiatt, J. (2006). *ADKAR: A Model for Change in Business, Government, and Our Community*. Loveland: Prosci Learning Center Publications .
- Hindawi. (2017). Value Stream Mapping of Rope Manufacturing: A Case Study. *International Journal of Manufacturing Engineering*.
- Hofmann, E., & Bosshard, J. (2017). Supply chain management and. *Physical distributon &logistics management* , 712-731.
- Hopp, J. W., & Spearman, L. M. (2011). *Factory physics* . Illinois: Waveland Press.
- Jaquin, C., Rozak, A., & Hardi Purba, H. (2020). Case Study in Increasing Overall Equipment Effectiveness on Progressive Press Machine Using Plan-do-check-act Cycle. *International Journal of Engineering* , 2245-2251.
- Jaya, N. M., Pathairage, C. P., & Sutrisana, M. (2010, May). A critical review on application of activity-based costing in the construction industry. *W055 - Special Track 18th CIB World Building Congress*. Salford, United Kingdom.
- Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert Scale: Explored and Explain. *British Journal of Applied Science & Technology* , 396-403.
- Kotter, J. (2012). *Leading change* . Massachusetts: Harvard Business Review Press.
- Marsh, C. (2012). *Financial management for non-finincial managers*. London: Kogan Page .
- Mor, R. S. (2019). Productivity gains through standardization of work in a manufcaturing company . *Journal of manufacturing technology management* , 899-919.
- Namazi, M. (2016). Time-driven activity-based costing: Theory, applications. *Iranian Journal of Management Studies*, 457-482.
- Ouyang, L. (2022). *Multiple perspectives on analysing risk factors in FMEA*. Amsterdam: Elsevier.
- Palange, A., & Dhatrak, P. (2021). Lean manufacturing a vital tool to enhance productivity in manufacturing. *Materials Today: Proceedings* (pp. 729-736). Amsterdam: Elsevier.
- Patel, P. M., & Deshpande, V. A. (2017). Application Of Plan-Do-Check-Act Cycle For. *International Journal for Research in Applied Science & Engineering*, 192-201.
- Pollak, J., & Pollack, R. (2015). Using Kotter's Eight Stage Process to Manage. *Systemic Practice and Action Research* , 51-66.
- Rahani, A. R., & al-Ashraf, M. (2012). Production Flow Analysis through Value Stream Mapping: A Lean Manufacturing Process Case Study. *Procedia Engineering*, 1727-1734.

- Rother, M., & Harris, R. (2013). *Creating Continuous Flow: An Action Guide for Managers, Engineers, and Production Associates*. Boston: Lean enterprise institute.
- Rother, M., & Shook, J. (2003). *Learning to see; value- stream mapping to create value and elimiate muda*. Cambridge : the lean enterprise institute, Inc.
- Rozak, A., Jaqin, C., & Purba, H. (2020). *Case Study in Increasing Overall Equipment Effectiveness on Progressive Press Machine Using Plan-do-check-act Cycle*. Jakarta: International Journal of engineering.
- Salman, Y., & Broten, N. (2017). *An Analysis of John P. Kotter's Leading Change*. London: Macat Library.
- Shaikh, A. (2020). Understanding change: A critical review of literature . *Annals of Contemporary Developments in Management & HR*, 40-44.
- Shou, W., & Wang, J. (2017). A cross-sector review on the use of value stream mapping. *International Journal of Production Research* , 3906-3928.
- Sinambela, E. A., Darmawan, D., Gardi, B., & Malaihollo, F. J. (2022). Cost Control through Break Even Point Analysis. *International Journal of Service Science, Management, Engineering, and Technology*, 1-3.
- Singh, A. (2013). A Study of Role of McKinsey's 7S Framework in Achieving Organizational Excellence. *Organization Development Journal* , 39-50.
- Singh, S., Khamba, J. S., & Singh, D. (2021). Analyzing the Role of Six Big Losses in OEE to Enhance the Performance: Literature Review and Directions. *Advances in Industrial and Production Engineering* (pp. 411-421). Singapore: Springer.
- Smith, J. (2010). Managing Organizational Change: Applying Lewin's Freeze/Unfreeze Model. *Journal of Organizational Behavior*, 145-162.
- Sowmya, K., & Chetan, N. (2016). A review on effective utalization of resources using overall equipment effectiveness by reducing six big losses. *int J Sci Res Eng Technol*, 2394-4099.
- Stamatis, D. H. (2003). *Failure mode and effect analysis: FMEA from theory to execution*. June: Quality press.
- Sutton, I. (2015). Operating procedures . In I. Sutton, *Process risk and reliablility management* (pp. 272-369). Houston: imprint Gulf Professional Publishing.
- Van De Poll, J. (2021). An Alternative to the Likert Scale When Polling Employees. *The International Journal Of Business & Management* , 9(5).
- Waterman, R. H., Peters, T. J., & Phillips, J. R. (1980). Structure is not organization. *Business horixzons* , 14-26.
- Wood, F. (2012). *Business Acounting 2*. Hoboken: Pearson Prentice Hall.