# Manufacturing Process Standardization at Affordable Interior Systems

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# Abstract

The objective of our MQP was focused on defect reduction within the worksurfaces and casegoods department at AIS because of the high cost it brought to their operations. Affordable Interior Systems or “AIS” is a large furniture manufacturer in Massachusetts. For our project, we observed their existing processes to standardize AIS’ operations. To achieve this goal, we updated their data collection systems and implemented lean practices such as creating standard work and a visual management board. To combat AIS’ high turnover rate, we recommended changes to their existing redo reporting system and employee incentive programs. These improvements can help AIS reduce their defect cost by a substantial amount over a period of time. Our root cause analysis and recommendations will serve as a foundation to improve their operations.

# Acknowledgments

The AIS MQP team would like to thank our project advisor, Professor Walter Towner Ph.D., for his guidance and support during our project. We would also like to thank our sponsor, AIS Inc., for giving us the opportunity to partner with their company and their contribution to this project's overall success.

We want to extend our appreciation to all the employees at AIS. Specifically, we would like to thank Steve Savage (WPI '85), Jason Truscott (WPI '94), Fernando Perez (WPI '13), Keith LaBlanc, Larry Scangas, Jessica Plaza, and Gregg Roberts. These AIS supervisors, managers, and engineers provided insight into their processes and many resources for our project, making us feel part of the AIS community.

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# Introduction

## About the Sponsor

Affordable Interior Systems (AIS), a furniture manufacturer, is a significant brand in the office furniture industry for its sleek and effective products. They offer a variety of products built with care in the USA including panel systems, beam-based solutions, desks and benches, seating, storage, height-adjustable tables and conferencing, and work tool accessories. AIS is dedicated to upholding its ideals, recognizing corporate objectives, achieving product design awards, celebrating employee anniversaries, and supporting the community through charity endeavors. They have been awarded the OFDA Manufacturer of the Year award every year since 2010 for its product design, innovative production, and sustainability efforts. AIS has reached annual sales of over $220 million with much credit to the dedicated sales team spanning across North America. They currently have several facilities in the United States, but our team focused our work within the Leominster, Massachusetts location which specializes in manufacturing particle board furniture. The facility has a continuously expanding workforce with over 500 employees working on the production floor. AIS embraces diversity with many of the employees coming from Hispanic or Latin backgrounds and accommodating those with limited working proficiency in English. With the business continuing to expand, AIS continues to carry on great integrity within their business operations with an emphasis on lean manufacturing.[1] The production floor in Leominster can be seen below.

*Figure 1: Worksurfaces Department Manufacturing Floor*

[1] AIS. (n.d.). Retrieved February 6, 2023, from https://www.ais-inc.com/

# Background

## Worksurfaces and Casegoods Departments

The Leominster AIS facility, built in 2017, invests heavily in panel processing machinery to manufacture its own line of laminate casegoods and other wood-based items. Our team focused our observations and efforts on two departments: worksurfaces and casegoods. AIS offers worksurfaces suitable for office needs, produced in the worksurfaces department, and general casegoods for freestanding office furniture, produces in the casegoods department. These products each require an extensive production line that is almost entirely manual assembly; much of the process includes operators manning machinery and tools to assemble the final product. Both production lines have similar processes, including the materials used, with the only difference being the thickness of the boards. A particle board is made by bonding wood chips together with resin or another binding substance, and is the main material used in these two manufacturing departments. AIS mostly utilizes high pressure laminate and thermally fused laminate for the finishes of their final products depending on the desired thickness.[1]

## Standardization in Manufacturing

Standard work helps a manufacturing company to document their processes. It is a means of establishing precise procedures to complete a task in the safest, easiest, and most repeatable way. Standard work also helps to eliminate variability in the system and improve the throughput of individual workstations. It is an effective tool that can be utilized regardless of the level of automation in the manufacturing process.[2]

To be able to produce standard work, takt time, work sequence, and standard inventory must be known. Takt time is the rate at which the products are produced to meet customer demand. Work sequence is the order in which the manufacturing process steps must be completed. Standard inventory is the quantity of raw materials necessary to produce the final product.

[2] Watts, M. (2018, November 7). *Standard Work - isixsigma.com*. Isixsigma.Com. https://www.isixsigma.com/dictionary/standard-work/#:~:text=An%20overview%3A%20What%20is%20standard,and%20perform%20a%20process%20repeatedly.

Standard work is especially important in work environments where variability is present in the manufacturing process. Its implementation facilitates employees to follow a consistent set of steps to complete their work in the same fashion each time.

In standard work, sequential steps and trials are key. The standard work for a manufacturing process acts as a user manual for any employee looking to understand a system. It outlines how the system operates from raw material to finished product and is simple enough to understand from the perspective of a new employee. A variation of standard work utilized in our project is called a "must-do". A must-do is a shortened version of the standard work which includes only the necessary tasks to ensure a job is done correctly, reminding the employees which tasks they should be sure to not leave out.[3]

## Lean Manufacturing

Lean manufacturing is a process that uses a set of tools based on the lean thinking ideology that increases value and decreases waste. Lean thinking is a process that follows a five-step process designed to lead change in a work environment by using technical and soft skills. Step 1 is specifying the value of a product or service based on what the customer requires and developing a production goal. After creating a goal, step 2 identifies the value stream, or how to get from the customer to the end of the process using process engineering. Step 3 focuses on the flow of material and eliminating where the bottlenecks are present to increase productivity and efficiency. In step 4, lean thinking outlines a pull system structure to improve the time the product spends in the system and how quickly it reaches the customer. In a pull system, the customer dictates the rate of production, reducing the amount of inventory and stockpiled material. The final step, step 5, in lean thinking is "perfection," which integrates lean ideas into corporate culture so that every employee understands lean and can take part in it.[4]

Lean manufacturing concepts arose in the 20$^{th}$ century when large manufacturing facilities with expansive assembly line processes started to grow. Lean principles and ideas give organizations a competitive advantage because they eliminate waste and emphasize the

[3] Hatch, M. (2022, August 29). *Lean Visual Management Tools: 5 Types of Visual Controls - TXM*. TXM Lean Solutions. https://txm.com/5-types-of-visual-controls/

[4] Lynn, R. (2020, July 13). *What is Lean Manufacturing? | Planview*. Planview; Planview. https://www.planview.com/resources/guide/what-is-lean-manufacturing/

importance of efficiency and consistency. Founders Taiichi Ohno and Eiji Toyoda mastered lean initiatives by eliminating waste in the Toyota Production System (TPS), now recognized as the most well-known examples of lean methodology. It is important to note that the success of the TPS could not take place with just the lean tools that were implemented, but also the management principles used to develop the culture and adapt the lean philosophies. Some of these techniques include a good atmosphere in the workplace, setting objectives, proper motivation, and the development of employees.[5]

## Data Collection and Analysis

AIS collects data to determine the number of defects they are creating. Data collection is the process of accumulating information, and it comes in two different forms: quantitative and qualitative.[6] Quantitative data is purely numerical while qualitative is an observation of characteristics. Both data types are collected at AIS, and they are critical to process improvement in the manufacturing setting.

There are many formats in which data can be collected, however we are going to focus on two specific methods: user surveys and manual observation forms. A manual observation form is a data collection method where an operator can input data manually into drop down menus or text boxes to report on what they have observed; the data collected can be both quantitative and qualitative.[7] The forms can be physical or digital, but for this project we used only digital forms as they make data management easier. The importance of this method is that it allows for the firsthand account of an event to be recorded as quickly as possible without the need to implement automatic data collection with cameras or sensors. Having the firsthand account recorded in real-time allows for the flow of information to be more direct to the other departments within the company.

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[5] Sanders, A. (2016b). *Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing*.

[6] *Quantitative and qualitative data | Australian Bureau of Statistics*. (n.d.). Australian Bureau of Statistics. Retrieved February 7, 2023, from https://www.abs.gov.au/statistics/understanding-statistics/statistical-terms-and-concepts/quantitative-and-qualitative-data

[7] Cote, C. (2021, December 2). *7 Data Collection Methods in Business Analytics*. Business Insights Blog; Harvard Business School. https://online.hbs.edu/blog/post/data-collection-methods

The next method of data collection we used was user surveys. A user survey is a data collection method where a user is assessed about their personal experience in order to conduct research; the data collected is qualitative.[8] The user feedback data is used to help improve the user experience on new or existing implementations. This is useful for continuous improvement because it provides insight from the users on characteristics of the operations that cannot be analyzed with quantitative data.

[8] *How to use surveys for user experience research*. (n.d.). Https://www.Qualtrics.Com. Retrieved March 15, 2023, from https://www.qualtrics.com/experience-management/customer/user-survey/

## Objective & Project Goals

The objective of this MQP, as requested by AIS, is to reduce the level of scrap produced by the Worksurfaces department. We will use axiomatic design and multiple lean manufacturing tools to identify current challenges and areas at risk of producing scrap. The project will focus on the data monitoring system and the flow of information throughout the organization. We anticipate that our solutions will create a strong foundation for baseline data that will allow AIS to effectively measure and monitor their progress to draw accurate data and form real-time conclusions. Using axiomatic design, we will develop the following goals to achieve our main objective:

| | Project Goal | Description |
|---|---|---|
| **1** | Collect accurate scrap generation data. | Evaluate and improve the effectiveness of the current data monitoring system in showing the area and amount in which redos occur. We anticipate finding a solution that improves the usability and accessibility of the system. |
| **2** | Eliminate gaps in communication. | Observe team meetings and evaluate if the current structure is effective. Propose a standardized meeting structure that eliminates disconnection throughout the organization. |
| **3** | Make standard work accessible. | Evaluate current standard work and assess its clarity and accessibility. |

## Project Rationale

On a day-to-day basis, AIS needs to kit several orders, but the demand and current process causes waste of time and money. All the products in the worksurfaces department production line are made of particle boards which are not only costly to the manufacturer, but they are also difficult to recycle because of the glues present in the boards.[9] Another added cost is the laminate board on each side of the particle board. AIS has 253 different types of laminate boards available to choose from, and on average, the cost per square foot across each type of laminate and particle board is $1.15. While this may seem like a low number at first, due to the capacity of the manufacturing facility, this resulted in a total scrap cost of $2,221,611 from January 2019 to September 2022. With a scrap cost this high, AIS was looking for any way to reduce the amount of scrap created due to errors in the manufacturing process.

[9] Besserer, A., Troilo, S., & Girods, P. (2021). *Cascading Recycling of Wood Waste: A Review - PMC*. PubMed Central (PMC); National Library of Medicine.

# Methods

## Gantt Chart

For effective project management, our team utilized detailed time sheets that showed all work categorized or indexed against the appropriate work order to apply earned value to a project. A common tool for tracking both individual and group progress in completing the action steps is a Gantt Chart. A Gantt Chart is a visual timeline that aids in maintaining perspective on the workload and goals. The steps that must be taken to achieve the goal, the start and end dates, and the responsible party are the key elements.[10]

The Gantt Chart seen in Figure 2 was created with MS Excel and was set up in a tabular format with our defined goals and problem identification. Within each category, specific tasks were broken down with an illustration of a schedule to plan, coordinate, and track activities in our project within the 3-term timeline. Each term is roughly seven weeks, aligning with A, B, and C terms of the WPI undergraduate calendar.

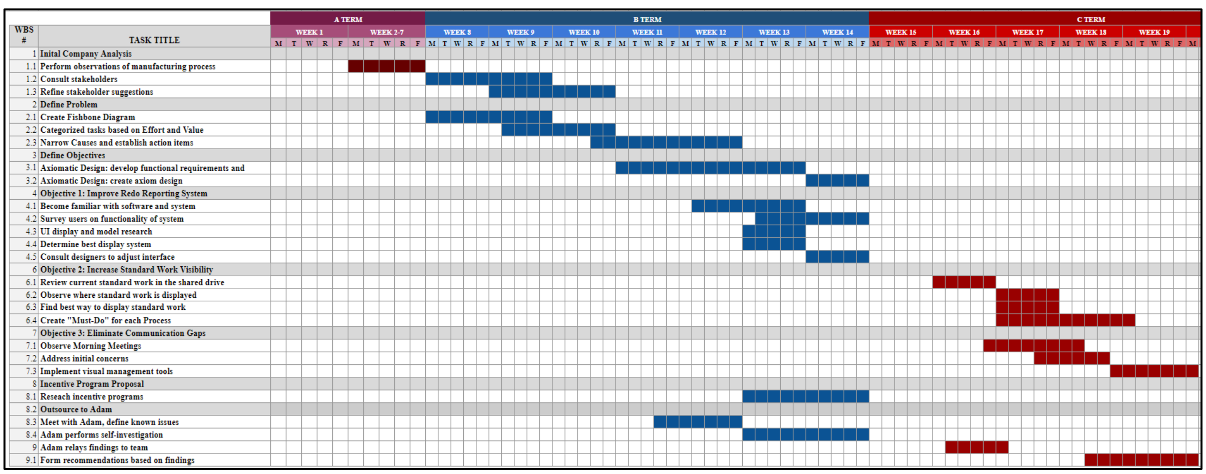


*Figure 2: Gantt Chart*

## Value Stream Mapping

We created a value stream map (VSM) to understand the details of the material processing steps and information flow within the worksurfaces department. A VSM is a lean manufacturing tool that displays the flow of inventory through each step until the product is

[10] Lofurno, M. (2002). The Gantt chart. *Compoundings*, *52*(6), 35. http://ezproxy.wpi.edu/login?url=https://www.proquest.com/trade-journals/gantt-chart/docview/222315419/se-2

delivered. It also displays the phases and events required for the product to reach the customer, such as product development, the supply chain, optimization, quality assurance and customer service. It is useful for visualization of the current process and identification of waste in and between processes. Additionally, it aids in understanding the entire process from the second the order is created to it being delivered to the customer. Typically, a VSM will involve a series of time observations, but we concluded that time studies were not necessary to achieve our objective.

To create the initial VSM we toured AIS's manufacturing facility and spoke with various engineers and supervisors to understand the connection between production, the supplier, the floor, support, and the customer. The engineers ensured that their assigned production lines were running safely and effectively and participated in design and maintenance projects. Supervisors made sure that the production line was operational and assisted in achieving short- and long-term goals through proper communication and organization of their staff. Supervisors and engineers communicated when there was an issue that affected the other and implemented a solution that resolved the issue.

The Value Stream Map shown in Appendix B2, represents the areas with a higher risk of producing scrap through "Quality Problem" stop signs. These stop signs take place at the kitting, router, and edge bander processes. The process begins when a customer sends their order to "Production Control," the person or team in charge of coordinating and planning the production operations shown in the value stream map. They electronically communicate the production schedule to the supplier who delivers the correct amount of product to the site. Receiving holds the inventory until it is delivered to processing, where it goes through six processing steps and then waits at shipping. The six steps shown in Figure 3, the process map below, are lamination, kitting, routing, edge banding, cleaning, and boxing, and the inventory sits between each step. After processing, the product is shipped to the customer and the process repeats. Below is the current state process map we developed after touring the worksurfaces department.

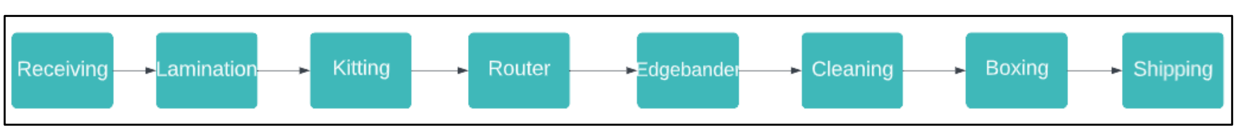


*Figure 3: Worksurfaces Department Process Map*

After initial touring and observation, each team member observed AIS operators at every process step and took notes of patterns and potential causes of redos. Our observations, along with further in-depth discussion with various AIS employees, allowed us to break each process from the VSM into detailed steps and gather more data on quality problems. We compiled our data and developed an initial summary of waste and risk.

## Axiomatic Design

For our project, we implemented axiomatic design to communicate our objectives and reduce the complexity of our project. Axiomatic design is a design theory method that breaks down a system or process into its measurable activities that are driven by requirements and identifies which activities affect which requirements. It requires a problem statement definition based on customer requirements and then the goals, or the functional requirements, are created to resolve the problem statement. The design parameters are the elements of the design solution that will solve the specified functional requirement. Once the solutions are created, they are analyzed and optimized with a matrix that ensures each design parameter only affects its corresponding functional requirement. Ultimately, axiomatic design was the best way for our team to break down our project and create objectives and goals.[11]

We identified that our customer, AIS, needed to decrease and quantify their defect rate, in addition to facilitating reporting and standardizing their process. Our Functional Requirements (FRs) and Design Parameters (DPs) can be seen below in Figure 4.

[11] Brown, C. A. (2023, January). An Introduction to Axiomatic Design. Mechanical Engineering Department Presentation. Worcester Polytechnic Institute; Worcester Polytechnic Institute. Retrieved from https://www.youtube.com/watch?v=WiimzxRJhWs.

FR0: Reduce scrap rate
FR1: Collect accurate scrap generation data
  FR1.1: Updating the reporting system UI
  FR1.2: Encourage employees to report defects on time
FR2: Regulate system
  FR2.1: Update standard work
  FR2.2: Increase standard work visibility
FR3: Improve communication between the hierarchy of employees

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DP0: Standard system to reduce scrap rate
DP1: New reporting system
  DP1.1: New UI layout to facilitate easy reporting
  DP1.2: Incentive program for on time defect reporting
DP2: Define processes with standard work
  DP2.1: Design must-dos
  DP2.2: Publish process standard work
DP3: Implement visual management tools to increase employee engagement in production and redo reporting

*Figure 4: FRs & DPs*

After determining the FRs and the DPs, we formed them into a matrix to test that each FR lined up with the DP because each FR required a DP to be completed. An ideal matrix should have each DP affecting only one FR. A triangular matrix, similar to our matrix in Figure 5, is also an effective result.[11] Our matrix below does not look triangular because the AIS defect system was too complex, resulting in overlapping FRs and DPs.

| | | New reporting system DP1 | New UI layout to facilitate easy reporting DP1.1 | Incentive program for on time defect reporting DP1.2 | Define processes with standard work DP2 | Design must-dos DP2.1 | Publish process standard work DP2.2 | Implement visual management tools to increa employee engagement in production and reporting DP3 |
|---|---|---|---|---|---|---|---|---|
| Collect accurate scrap generation data | FR1 | x | | | | | | |
| Updating the reporting system UI | FR1.1 | | x | | | | | |
| Encourage employees to report defects on time | FR1.2 | | | x | | | x | x |
| Regulate system | FR2 | | | | x | x | | |
| Update standard work | FR2.1 | x | | x | x | x | | |
| Increase standard work visibility | FR2.2 | x | x | | x | x | x | |
| communication between the hierarchy of employees | FR3 | | | | | x | | x |

*Figure 5: Axiomatic Design Matrix*

## Fishbone Diagram

Our team created a fishbone diagram, or an Ishikawa diagram, which is a lean manufacturing tool that visualizes a problem's causes and effects.[12] On the far right of the diagram, a main effect is written that describes the overall reason for investigating the problem. Fishbones, or categories of causes, form the rest of the fish's body to the left. Each cause category is broken down into individual causes that are independent of one another on the left side of the fishbone, and their individual effects on the right side of the fishbone. These individual causes and effects help to describe the complete picture of why the overall problem occurs.[13]

We created several fishbone diagrams using several different methods to value the causes of problems on the manufacturing floor. Our first draft of the fishbone diagram, as seen in Figure 6 below, was created with six weeks of observations. During these six weeks, we studied each individual step of the worksurfaces department production process, which we broke down in the value stream map, which can be seen in Appendix B1, and spoke with floor managers who explained their processes and issues they saw in their day-to-day work. After we combined our notes, we presented this first draft in Figure 6 to manufacturing managers, a quality control manager, a process & implementation manager, and a team lead from the manufacturing floor.

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[12] Botezatu, C., Condrea, I., Oroian, B., Hriţuc, A., Eţcu, M., & Slătineanu, L. (2019). Use of the Ishikawa diagram in the investigation of some industrial processes. IOP Conference Series: Materials Science and Engineering, 1, 012012. https://doi.org/10.1088/1757-899x/682/1/012012

[13] Clary, R., & Wandersee, J. (2010). Fishbone Diagrams: Organize Reading Content With a "Bare Bones" Strategy. Science Scope, 33(9), 31–37. http://www.jstor.org/stable/43184028

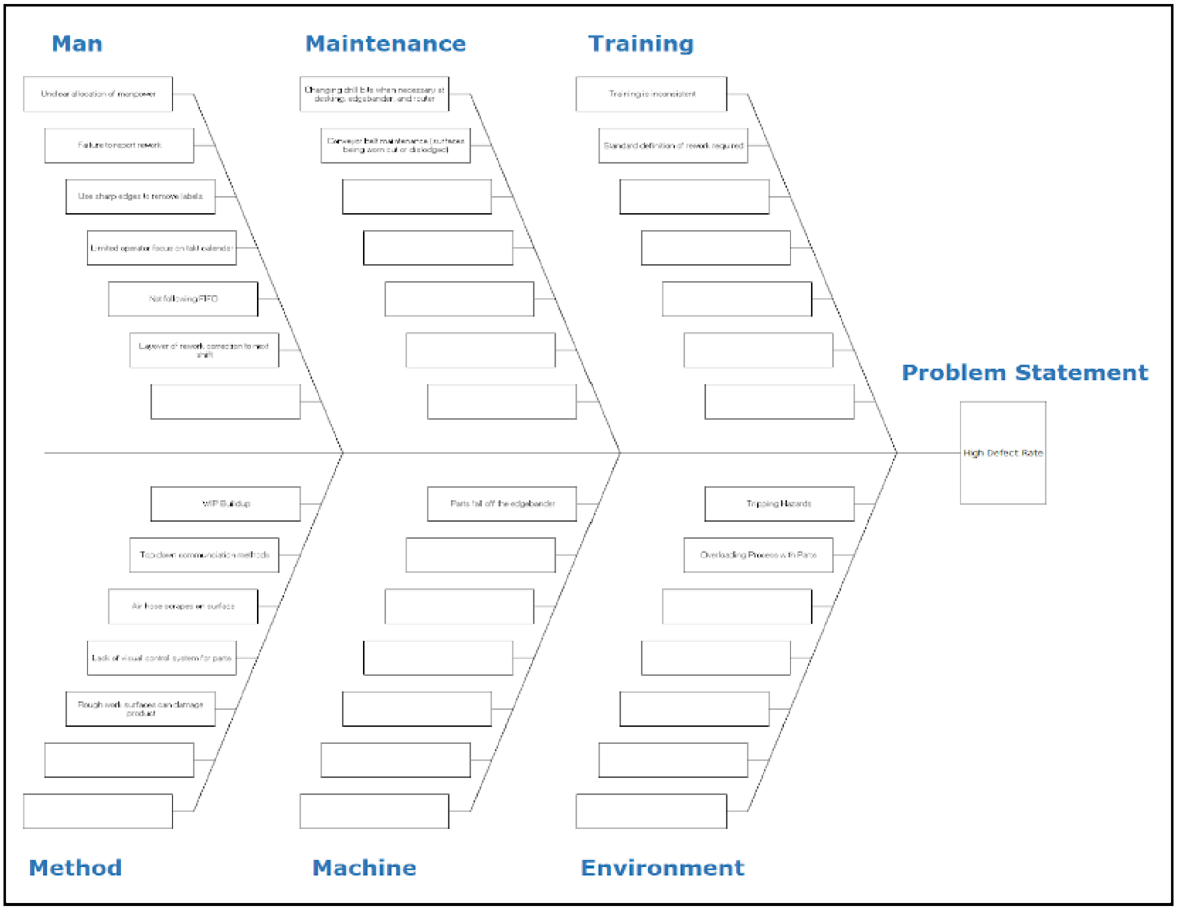


*Figure 6: Fishbone Diagram Draft 1*

After speaking with stakeholders, our team realized that our observations did not capture the full scope of problems within the AIS' operations. As recommended by a value stream manufacturing manager from the meeting, we scheduled a meeting with the stakeholders involved in the process. The meeting attendees were as follows: a pack leader, a worksurfaces department supervisor, a team lead in desking, a maintenance operator, a router operator, a team lead for quality, a value stream manager, a chief operating officer, a QC manager, two manufacturing managers, and a process & implementation manager.

The meeting began with identifying the problem statement: high defect rates on the floor. From there, we began the process of determining the main causes of the problem statement, which will be used as the categories in the fishbone diagram. The stakeholders used their knowledge of areas in the process where they most commonly see errors and defects occur. With our combined observations of defects, the root causes were found to be environment, process, material, training, machine, maintenance, and standard work. After deciding the main causes, the next question was "why do these causes occur?" to find out the "why," everybody was asked to write down any issues they observed on sticky notes. These sticky notes were organized into their respective categories, as seen in Figure 7.

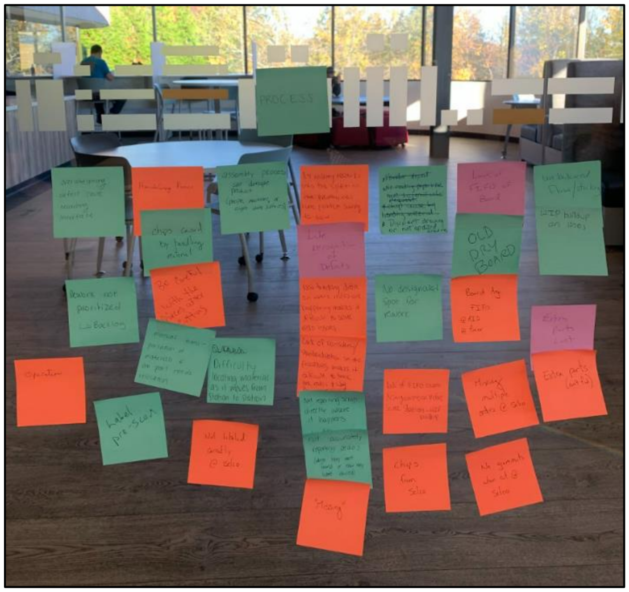

*Figure 7: Identifying Root Causes*

We were able to recognize all the causes and effects through our team's observations and the stakeholder meeting. From here, our team needed to assign value to these elements to determine a route for our project. We created a final fishbone diagram which can be seen in Appendix D3.

## Analytical Hierarchy Process

Once a set of causes and effects was identified through the Fishbone diagram, our group was tasked with determining which issues were most valuable for us to investigate during our MQP. We decided that this would be done using the Analytical Hierarchy Process (AHP), a process by which alternatives are compared using specific criteria to determine the best choice.[14,15]

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[14] Goodwin, P., & Wright, G. (2014). *Decision Analysis for Management Judgment*. *Wiley.com* (5th ed.). Wiley. Retrieved February 24, 2023, from https://www.wiley.com/en-us/Decision+Analysis+for+Management+Judgment%2C+5th+Edition-p-9781118740736.

[15] Saaty, T.L. (1988). *What is the Analytic Hierarchy Process?*. In: Mitra, G., Greenberg, H.J., Lootsma, F.A., Rijkaert, M.J., Zimmermann, H.J. (eds) Mathematical Models for Decision Support. NATO ASI Series, vol 48. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-83555-1_5

The presence of defects at AIS were analyzed through an AHP. At its core, the AHP is used to determine which problems are most pressing as calculated by our instincts. AHP is most valuable when used to break down problems requiring a significant amount of intuition.[15] Our MQP team decided to interpret our observed issues under the criteria of both "effort", being the amount of manpower and time required to achieve the desired end-goal, and "value", being the predicted overall benefit fixing the problem in question would have toward our main issue of defects in the worksurfaces department.

Effort and value were rated on a scale from 1-5; 1 indicating the most difficult or least valuable, and 5 indicating the least difficult or most valuable. Our team sat down and deliberated what each cause and effect would present as challenges in our work. To visualize our interpretation of each observed cause and effect, the score for both effort and value of each line was added. This highest "score", being the sum of the effort and value scores, was used to determine which causes would be simple to solve, which we referred to as "low-hanging fruit". Problems considered low-hanging fruit, such as wrong materials being applied to the product, the use of sharp tools to remove labels, and the frequency at which tools were replaced, were deemed to have high reward for low effort. This is due to their straight-forward solutions leading to direct improvement of the defect problem present on the worksurfaces department manufacturing floor.

The less desirable scores were also chosen as they provided us with challenges to overcome. Some of those chosen tasks included fixing the lack of first-in-first-out (FIFO), unbalanced flow of materials in the system, and standardizing the orientation of parts in the system. Though these causes were interpreted to have significant impact on the overall issue at hand, their resolutions are more difficult to achieve, giving them a lower score.

As a result of performing the AHP, our team determined which tasks would be most reasonable for us to accomplish within our project timeline. The issues we sought to resolve were defined as the following:

1. Tooling issues (planned to outsource to a Mechanical Engineer)
2. Boards fall into space inside edgebander
3. Improper and untimely scrap entry
4. Total Productive Maintenance is ignored
5. Process of orienting board is inconsistent

6. Wrong edgeband applied
7. Use of sharp edges to remove labels

Our MQP team found that the Analytical Hierarchy Process was an effective method for deciding which issues that are present at AIS to prioritize and resolve. Our AHP can be seen in Appendix E. To clearly grasp which issues would be most realistic for us to tackle within the scope of our project work, we were able to discover both low-hanging fruit and more challenging tasks by grading each cause and effect based on effort and value.

# UI Research & UI models

## Redo System

In the AIS manufacturing site, any visible defects on the product are categorized as "redos". The term "redo" is used instead of defect because any time one of them is found on the product, the product is then sent back through the manufacturing process to try and fix the defect.

When a defect is noticed by one of the machine operators, they go to the production line lead and notify them of the defect found. After being notified of the defect, the line lead locates any computer in their department to fill out a digital form which requires information such as part number and the reason for the report. See Figure 8 for the redo reporting interface. The information in the report then populates a spreadsheet containing all the data for the various reported redos over a period.

There are many ways in which the product or raw material can be damaged during the manufacturing process. Through our fishbone diagram and AHP analyses, we were able to identify 55 potential causes for defects. The standardization of the total manufacturing process is important because of the 55 causes present at one time. Standardization allows for the same process to be replicated with each unit, which then minimizes the risk of variation in the cause of defects.

A key step in standardizing the total manufacturing process is collecting accurate data to pinpoint stress points in the process. To do so, we found that one area which could be improved was the redo reporting system user interface. The reporting system at the time contained two drop down menus and two entry boxes. The drop down menus were for the "Reason" and the "Employee." "Reason" refers to the reason why a defect exists on the product, and "Employee" is the name of the line lead which filled out the form. The two entry boxes are “Redo Quantity” and “Notes.” The redo quantity is kept at one every time because each unit needs to have its own redo reporting form filled out. The notes category allows for the user to enter in any other notes that cannot be specified through other questions in the form.

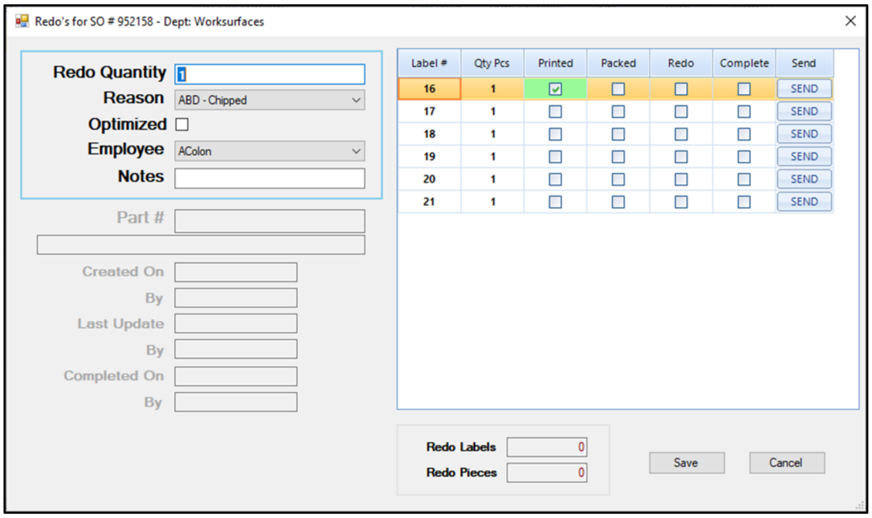


*Figure 8: Current Redo Reporting Interface*

To improve the current user interface for the redo reporting system, we researched a variety of academic papers related to user interface design. One of the key takeaways to improve the overall design of the program was to simplify it, “interface complexity significantly affects the operator’s visual search strategy.”[16] In the current “Reason” category, 78 choices were available to choose from. This level of complexity in a drop down menu, due to the number of elements on the screen, suggests that the visual search time for a user’s correct “reason” is much longer than what is feasible. This number is so high because both the location of the observed defect in the manufacturing process and the defect type itself are paired together. The 78 available choices to the user results in confusion and encourages line leads to type out the redo reason manually in the “notes” textbox instead of choosing an appropriate reason from the drop down menu.

Another stress point was the “employee” drop down menu. Unlike the “reason” drop down menu, the “employee” drop down menu is a stress point to the engineers who analyze the data. The employee who fills out the form should be the same one that observed the defect

[16] Wu, L., Zhu, Z., & Li, B. (2015, September 26). *Influence of information overload on operator’s user experience of human–machine interface in LED manufacturing systems*. Springer-Verlag London.

because they can provide the best information regarding it. When utilizing the data from the defect reporting system, it is imperative that the engineers collect all the information regarding what caused each defect so that they may conduct a full investigation.

While conducting our research into different user design and interface papers, we realized that the language in which the interface is displayed poses difficulties for the Spanish speaking employees. When posed with a completely different language than their native one, the complexity of the interface drastically increases. “This frequently causes the users to completely abandon further interactivity with the website because they are unable to easily select the language they understand.”[17] For the user to be able to input accurate information into the redo reporting system, they must first be able to understand what is being asked of them. The current form complicates the data collection process from the employees who are natively Spanish speakers.

## Daily Production Meetings: Observation & Research

Daily production meetings are crucial in the manufacturing industry because they help maintain a strong company culture by communicating goals and breaking down strengths and weaknesses of the previous day’s work. With our project, we anticipate closing communication gaps by improving AIS daily production meetings to fix upward and downward communication throughout the organization.

During our observations, we viewed the worksurfaces department daily production meetings and the casegoods department daily production meetings, which occur right after the employees return from break. By witnessing the meetings of two different production lines, we were able to form comparisons between the two.

Due to the noise created by the production lines around the worksurfaces department, the supervisor stood on a stool to deliver the meeting. However, even when standing next to her, it was difficult to understand what she was saying. We observed several employees having side conversations or using their phones during the meeting, potentially due to being unable to hear

[17] Miraz, M., Excell, P., & Ali, M. (2014, December 20). *User interface (UI) design issues for multilingual users: a case study*. Springer-Verlag Berlin Heidelberg.

their supervisor. During the 8-minute worksurface's meeting, the first 3 minutes was presented in Spanish and the remaining 5 minutes was in English.

We compared this meeting to casegoods department daily production meeting, which was conducted by the casegoods department supervisor. This meeting took place in a quieter section of the production floor, and the employees seemed more engaged throughout the meeting. The meeting began with several simple stretches which reduce the risk of injury. Afterwards, the group moved on to a discussion of the production goals for the day, led by the floor's management. In contrast to the worksurfaces department meeting, the casegoods department supervisor alternated statements in English and Spanish which kept the meeting as one cohesive meeting, rather than splitting it into two. The casegoods department meeting was approximately 6 minutes, with a minute for stretching, and the supervisor noted that he keeps his meeting shorter to maintain his employee's attention.

The casegoods and workssurfaces department meetings also vary in how quantitative data is presented. In the worksurfaces department, the number of parts created and the number of defects from the day before are presented every day. In the casegoods department, the supervisor feels that presenting data every day is overwhelming for the employees, so he stated that he discusses numbers every few days. Both supervisors have access to whiteboards but do not use them during their morning meetings.

Our goal for observing both meetings was to recognize their strengths and weaknesses and work towards creating an ideal structure for the worksurfaces department production meeting.

## Visual Management at AIS

The purpose of visual management is to provide a snapshot of operations by increasing information visibility to employees.[18] After an initial discussion with the worksurfaces department supervisor, we decided to design a visual management board to display data reflecting daily production, quality, and safety. We designed a dashboard that would effectively communicate information about the workplace and focus specifically on performance and expectations. The mockup design in Appendix F1 shows the whiteboard divided into the three

[18] Niederstadt, J. (2018). *A lean visual management system that supports layered audits.*

parts. The production calendar shows the daily goals compared to what was produced, and a card is used in the corner of each day to show if the daily goal was met. The quality section shows the number of redos produced so the day before, so far that day, and accumulated from the whole week along with corresponding color bars showing the percentage of redos. Finally, safety is measured by number of incidents, with red representing any day that there were more than zero incidents. Given limited whiteboard space, it was challenging to incorporate the requested information without making the board look crowded. Having an easy to understand, “at-a-glance” board and being transparent with information improves the connection employees feel to their work and encourages faster problem solving.

## User Survey

Surveys to test employee productivity and satisfaction are a tool to gather thoughts and feedback about the business from employees.[19] This is valuable to AIS for promoting employee engagement, morale, and relationships with managers and leaders. [20] The purpose of these surveys is to observe trends within the usage of the redo reporting system that will aid the design of the new UI model. We focused on a survey that consists of several scale-based questions that asks how the employees felt using the redo reporting system; the survey also includes short answers for any additional feedback and concerns. We also asked about the background of the employees, such as their position and duration of employment.

The surveys on employee satisfaction revealed distinct problems. Employees were free to express themselves through these surveys which helped us gather descriptive feedback to identify the precise root of the problem. We anticipated that the application of lean production coupled with human resource practices would increase employees' perceived job flexibility, happiness, and operational performance based on the features of the job.[19] We wanted to investigate the usefulness of the Redo Reporting System based on several observations and the

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[19] Rodríguez, D., Buyens, D., Van Landeghem, H., & Lasio, V. (2015). Impact of Lean Production on Perceived Job Autonomy and Job Satisfaction: An Experimental Study. *Human Factors and Ergonomics in Manufacturing &Amp; Service Industries*, *26*(2), 159–176. https://doi.org/10.1002/hfm.20620

[20] Nordin, N., & Deros, B., & Wahab, D. (2014). Lean Manufacturing Implementation in Malaysian Automotive Industry: An Exploratory Study. *Operations and Supply Chain Management: An International Journal*, 4(1), 21-30.

conclusion that the system is often misused. We created the online survey “AIS Redo Form Functionality Survey” that consists of scale-based questions, and feedback/suggestions.

To gauge the degree of implementation of the current system, the questions were formatted on a five-point scale as shown in the example in Figure 9. The scale ranges from 1 to 5; 1, strongly disagree; 2, disagree; 3, neutral; 4, agree; and 5, strongly agree. In creating this survey, we aimed to be succinct so we would get a good response rate.[20]

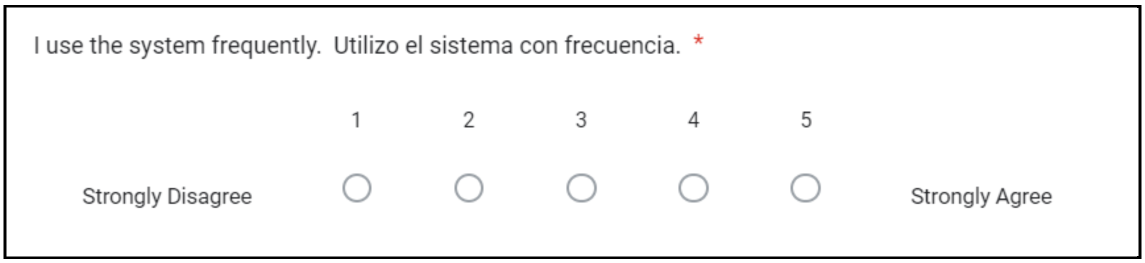


*Figure 9: Sample question from “AIS Redo Form Functionality Survey”*

Once the survey was distributed, we gathered 8 responses. We found that only line and group leaders work with the redo reporting system, which indicated that not everyone was aware of the redos that occur. Additionally, 75% of the respondents have worked over 4 years at AIS and 62.5% revealed they report redos very frequently. The results concluded a split opinion with only half identifying that they are satisfied with the current redo reporting system. One of the most revealing sections was the statement “I report redos when it happens” with the results very spread out within the scale. This further indicates why most of the short answer responses reveal that employees wish that redos are reported correctly and promptly. The full survey including questions and results can be found in Appendix I. We utilized these results to find areas of improvement within the redo reporting system and its UI design to leverage real-time data.

## Incentive Program Research

Motivation is a  management principle that can be furthered with the implementation of incentive programs. Possible incentive programs can either be through financial incentives or moral incentives, where confidence is boosted.[21] One key observation from the IRF’s 2020 Top Performer Study is that “while the use of non-cash incentives is likely not the sole cause of

[21] J Jana, P., & Jana, P. (2020, February 6). *IE in apparel manufacturing-11: Incentive schemes*. Apparel Resources. Retrieved February 13, 2023, from https://apparelresources.com/business-news/manufacturing/ie-in-apparel-manufacturing-xi/

corporate success, there is a very clear relationship between the two."[22] Companies that implement non-cash reward systems also tend to have increased employee engagement and profitability. However, this study also suggests that incentives are not a one size fits all solution and should be adapted to the specific needs of the company.

AIS currently has a payment incentive program in place. As associates gain tenure and skills within the company, they are awarded with a slightly increased pay rate. Despite the known positive effects of this type of program, associates do not feel an urgency to upkeep consistent attendance. A shortage of manual labor in the area has given employees the upper hand, so other tactics must be implemented to increase the motivation of the employees. When observing incentive programs, a number of different reward systems could be implemented for a motivating effect. Different motivators of an incentive program could include:[23]

1. Profits-interest plan: company employees receive additional earnings as a percentage cut of company earnings.
2. Small, frequent rewards: rewards for daily or weekly goals that demonstrate adherence to company values.
3. Non-pay related incentives: additional benefits given to employees that could include education, exclusive merchandise, praise, or vacations.
4. Gain-sharing: employees benefit from increased efficiency and are given bonuses that reflect improved performance.

Beyond the motivating factors of an incentive program, it is important that the implementation of the program by management produces the desired effect. The core aims of an incentive program should follow the guidelines below:[24]

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[22] *The IRF 2020 top performer study: What top performing companies do differently in incentives and rewards*. Incentive Research Foundation. (2022, July 22). Retrieved February 13, 2023, from https://theirf.org/research_post/the-irf-2020-top-performer-study-what-top-performing-companies-do-differently-in-incentives-and-rewards/

[23] Magloff, L. (2016, October 26). *How to incentivize manufacturing employees*. Small Business - Chron.com. Retrieved February 13, 2023, from https://smallbusiness.chron.com/incentivize-manufacturing-employees-25496.html

[24] *Warehouse incentives: How to create the right program*. Warehousing Insights | Material Handling Systems. (2021, June 10). Retrieved February 13, 2023, from https://www.cisco-eagle.com/blog/2015/05/07/incentive-programs-for-warehousing-manufacturing/

1. Encouragement of the improvement of the process: employees should be motivated to make the process and company more effective and efficient.
2. Incentives should target non-performers and reward performers, helping to understand why top performers are better: by revealing why some behaviors are better, employees are inspired to continue to improve by example.
3. The incentive program should be transparent to the employees: transparency prevents jealousy and helps to maintain the overall vision of the incentive program.

To determine the overall effectiveness or efficiency within a process, there must be a concrete measurement system. Similarly to how the incentives and motivations for the program itself are variable, the ways in which success can be measured is dependent upon the preferences of management.

Methods of measurement in an incentive program could include:

- Throughput: the amount of a product or service produced
- Accuracy: the frequency of quality and reliability produced
- Returns: the overall profit from the operation of the business

Safety: the number of work-related injuries produced as a product of poor safety practices

### Limitations

When implementing an incentive program, it is important to consider the consequences of adapting the culture of a company. Making changes within employee and management interaction can significantly impact the functionality of a company. The current programs in place must be observed to determine deficiencies in their incentives and continue to promote productivity in the company.

# Results

## Financial Analysis

We performed a financial analysis to measure the impact that the results and the recommendations of our project could have on the total scrap cost over the next 24 months. With the data given to us by AIS we found that over the past 32 months, the company has averaged a monthly scrap cost of $69,411; this equates to $2.2 million over that same period. To measure the financial impact of our project we observed what types of defects we were directly impacting with our solutions and what percentage of total scrap is currently caused by those defects. While the full impact of the redo reporting system will affect all types of defects, the main defects we focused on throughout our project were scratches and chips.

We estimated through our observations and data collection that scratches and chips currently account for 80% of the total scrap cost at AIS. Chips make up 45%, while scratches make up 35%. This indicates that we were affecting a total of $1.77 million of the $2.2 million total scrap cost. Although the total scrap amount caused by scratches and chips is estimated at 80%, we are aware that our project cannot fix all 80% on its own. To fully eliminate this percentage, many more changes must be made to the manufacturing process. The next step in the financial analysis was to determine a range of percentages which we could affect with our project. We estimated that our implementations would be able to eliminate 40-75% of the scratches, and 20-60% of the chips within the next 24 months. Assumptions were drawn due to the lack of metrics from the current redo reporting system and these ranges were based on the observations our team conducted. Scratches are primarily caused by handling while chips are caused by machines, and with our implementation affecting mostly handling, we estimated that we would be able to have a bigger impact on this area.

Both estimates were used as the basis to create a graph which would display the full impact of our project over the next 24 months. The chart in Figure 10 depicts the current cost per month charted over the same time period as both the high and low estimates of the impacted scratch and chip scrap costs. The red line is the current cost, the blue line is the low estimate, and the green line is the high estimate. Since the chart shows the total cumulative cost, the lowest slope indicates the highest cost savings. The high estimate saves AIS $920,000 over the 24-month period, and the low estimate saves them $383,000. However, to compute the true impact we must also introduce the cost of implementation.

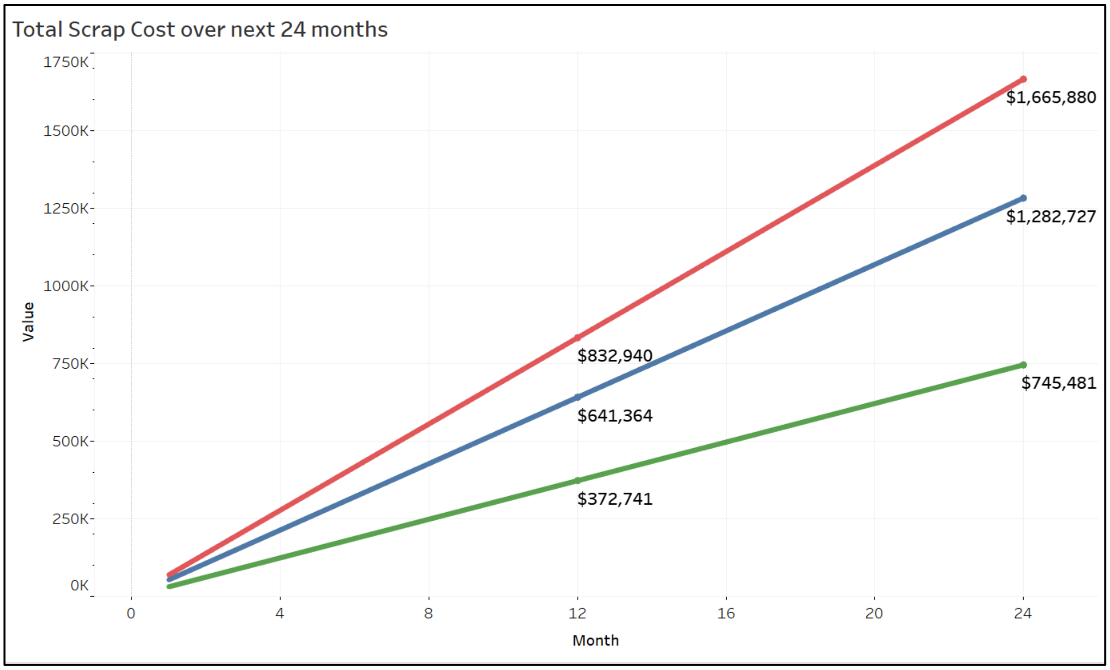


*Figure 10: Scrap Cost Savings Estimate*

Included within the costs for our implementations are the costs of materials and the costs of the labor. The costs are depicted in Table 1 below and they account for the implementation of the redo reporting system, digital display systems, standard work visualization, daily production meetings, and the incentive program. The values were found by conducting research online as to find the material costs for our implementations. The labor costs for the implementation are represented as zero since AIS already has the necessary personnel staffed to complete the implementation of our project.

To show the cost of implementation and the expected return on investment, we produced a discounted cash flow diagram as seen in Figure 11. The discounted cash flow shows the value of the investment today.[25] The annual interest rate chosen determines the discount rate applied to the future returns.

[25] Fernando, J. (2022, August 11). *Discounted Cash Flow (DCF) Explained with Formula and Examples*. Investopedia. https://www.investopedia.com/terms/d/dcf.asp

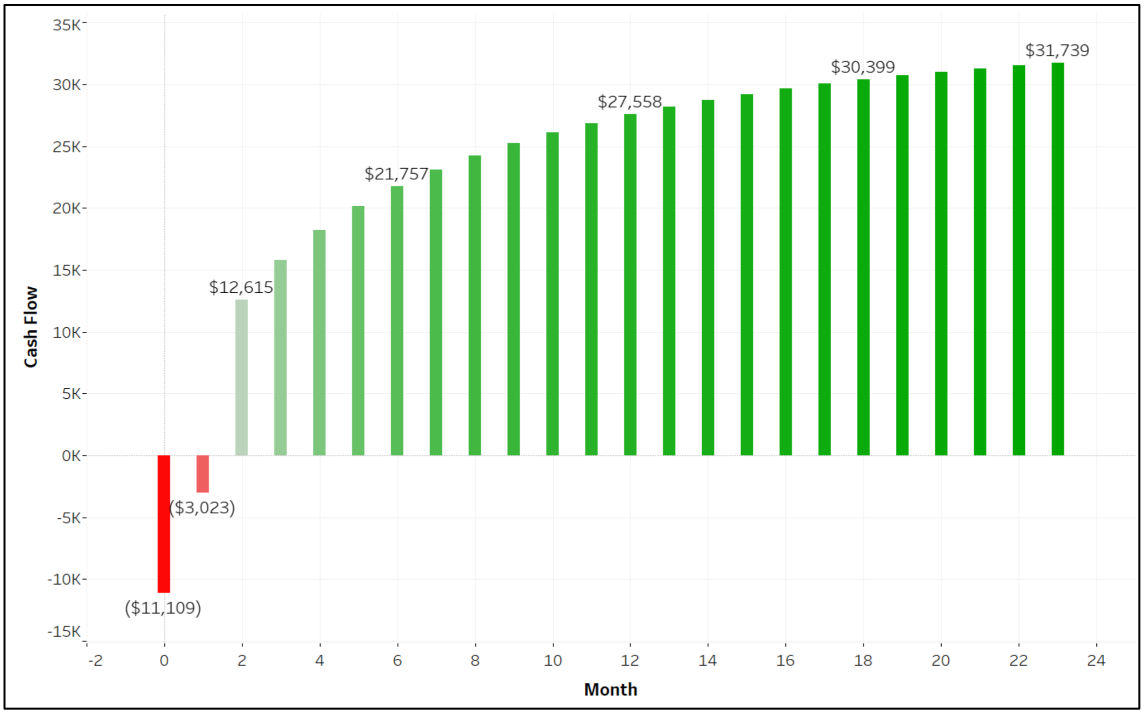


*Figure 11: Discounted Cash Flow Diagram*

| Materials | | Costs | | 20% Safety Cushion | |
|---|---|---|---|---|---|
| Digital Displays | | | | | |
| | Monitors | $ | 15,000.0 | $ | 18,000.0 |
| | Brackets | $ | 1,500.0 | $ | 1,800.0 |
| | Cables | $ | 1,500.0 | $ | 1,800.0 |
| | | $ | 18,000.0 | $ | 21,600.0 |
| Must Do's | | | | | |
| | Print outs & Lamination | $ | 10.0 | $ | 12.0 |
| | Stands | $ | 400.0 | $ | 480.0 |
| | | $ | 410.0 | $ | 492.0 |
| Managament Board | | | | | |
| | Magnetic Tape | $ | 10.0 | $ | 12.0 |
| | Magnets | $ | 20.0 | $ | 24.0 |
| | Megaphone | $ | 75.0 | $ | 90.0 |
| | | $ | 105.0 | $ | 126.0 |
| | Total | $ | 18,515.0 | $ | 22,218.0 |

*Table 1: Implementation Costs*

With the costs included, we calculated the break-even point of our project implementation. The break-even point is how long it would take to recover the initial investment of the project through cost savings of the scrap. An additional cost was a safety cushion of 20%

so that in the event of rising costs the break-even point would still stay accurate. With a total implementation cost of $22,218 the break-even point occurs between months 2 and 3.

# UI Design

## Prototype

Once we identified some stress areas in the current reporting interface, we created a prototype for the proposed interface to see what the changes would look like after implementation. The full prototype can be found in Appendix H, and the first display can be found in Figure 12. One of the main changes from the original redo reporting form to the first prototype is the separation of the information that the form is trying to get out of the user. The multiple focus points indicate cause for rush and negligence through completion of the form when having multiple questions on the same page. By separating each question onto its own page, we are reducing the number of elements present on the screen at once, as well as the density of those elements.

To simplify the "Reason" drop down menu, we separated the type of defect and the location in which the defect occurs into two questions instead of having them paired. The first asks, "What machine did the defect occur on?", and the second asks "What type of defect is it?". The answers for these questions were changed from a drop down menu to a separated static list box. The static list box allows us to display all the possible choices on the screen without having to click on a button to display them.[26] This separation simplifies the choices in the list of possible defects from 78 to 16. Another key component of the prototype is the ability of the form to switch between English and Spanish. With the click of a single button on the screen, the text changes to the other language. This can help promote a better response rate since most employees on the production floor are primarily Spanish speaking. Lastly, the defect reporting system form asks for the name of the operator who observed the defect instead of the name of the employee filling out the form. This change was made so that the engineering team could more

[26] Kaley, A. (2020, April 12). *Listboxes vs. Dropdown Lists*. Nielsen Norman Group; Nielsen Norman Group. https://www.nngroup.com/articles/listbox-dropdown/

easily investigate the root cause of defects by speaking directly to the employee who observed the defect.

Another addition to the redo reporting system is an extra question which asks for which side of the particle board the defect occurred on. This question serves to collect more in-depth data which can be used in later analyses.

With this prototype made, the next step for the team at AIS is to use this prototype as a framework for the new interface. While the prototype itself highlights what the new interface should look like, it is simply a graphical representation of what is possible. The real interface is coded with the .NET Framework which only the AIS software developers can make changes to. After constructing the prototype, it was presented to one of the lead software developers to ensure that our proposed changes could be made in the .NET Framework. He confirmed that it was possible and that it would be added to his task list to complete within the coming months.

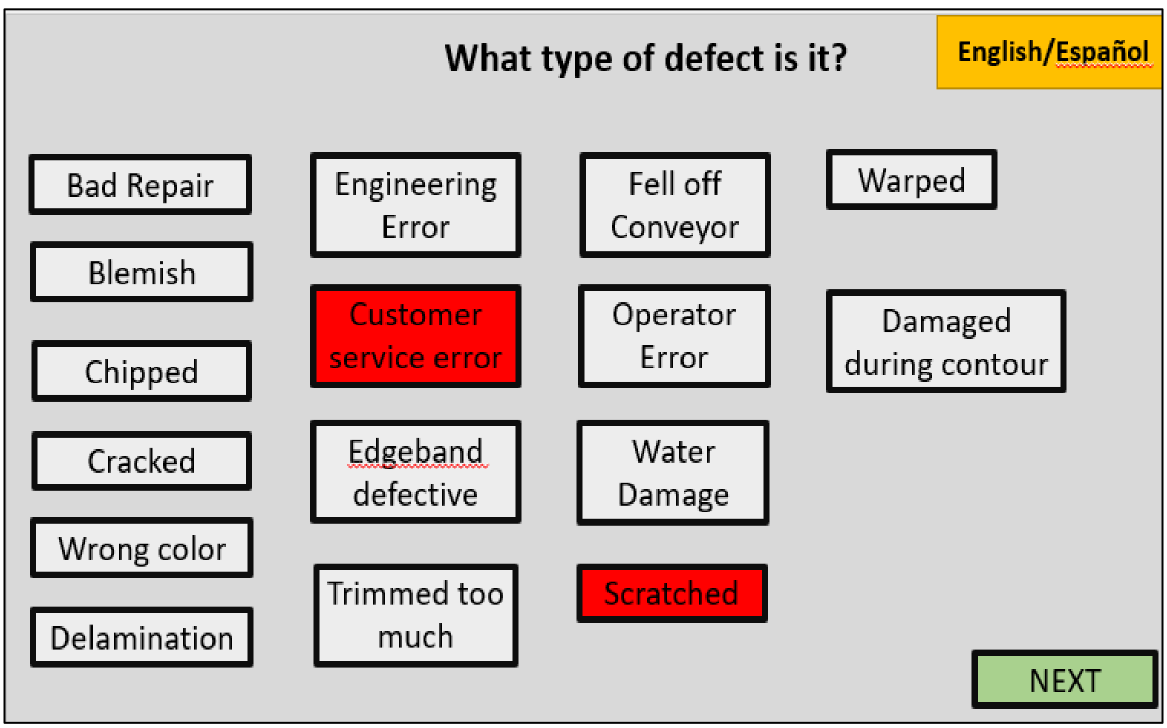


*Figure 12: Prototype of redo reporting system interface*

## Recommendations

What this new interface will bring to AIS is accurate and dependable data collection. Currently the data collected from the current redo reporting system is seen as faulty to the engineering team and operators; one engineer has described the data accuracy as "extremely suspect" and operators have mentioned that "if the redo isn't entered correctly, it makes the planner job very hard" within the redo survey that was conducted. This feedback is important because it is the only way in which the operators can document their firsthand accounts of witnessing defects occur. These firsthand accounts allow the engineering team to locate the problematic areas within the manufacturing process so that they may be able to resolve the issue before it causes more defects.

Along with having more accurate data from the redo reporting system, the new interface will bring additional data. Since the location and the type of defect will be two separate questions within the interface, the SQL server which stores the data must be updated to reflect the new data collection. Once stored within the server, this raw data is ready to be processed and analyzed. Processing this raw data is a crucial step for the analysis because in its raw form data is not perceptible. To base decisions on the data, the processing step must occur. This step involves applying a mathematical formula to the raw data collected to rearrange it into an organized manner which has meaning[27]. Without the processing step, the raw data points fail to present an overview of what is occurring in the manufacturing process over a period. To display the processed data, AIS will use dashboards to show real time data which reflects how and where defects are being reported. This dashboard will be created within Tableau, and it connects seamlessly to the SQL server. With real-time data viewing, the managers and line leads can stay up to date with the latest data being reported. These dashboards update automatically and require no maintenance to keep them running with the current data processing setup. This ensures that once we leave AIS, the manufacturing managers and operators will still have access to the data.

## Limitations

With the redo reporting system, the reason why it would not work is due the resistance from the managerial team at AIS. To ensure that redos are being reported using the redo reporting system, the managers and line leads must train the employees to report the defects they observe in real time to them so that all the details about how and where the defect occurred are as accurate as possible. If the managers and line leads do not push the employees to report the observed defects, the employees will go about their regular workday and push the defects further

[27] Xu, K. (2020). *Advanced Data Collection and Analysis in Data-Driven Manufacturing Process*. Chinese Journal of Mechanical Engineering. https://cjme.springeropen.com/counter/pdf/10.1186/s10033-020-00459-x.pdf

down the line until they get discovered at the end of the production line. If the defects are first discovered at the end of the production line, the details about how and where they occurred will be lost. These details are the backbone of the data collection in the redo reporting system.

# Daily Production Meetings

## Implementation

The implementation of the Daily Management Board required multiple iterations to achieve the best combination of content, readability, and usability. The supervisor communicated to us that she would like to have the number of redos, daily production goals, and safety cross, and with that information we created the first draft of the board using Canva shown in Figure 13 below. Appendix F contains all iterations of the Daily Management Board.

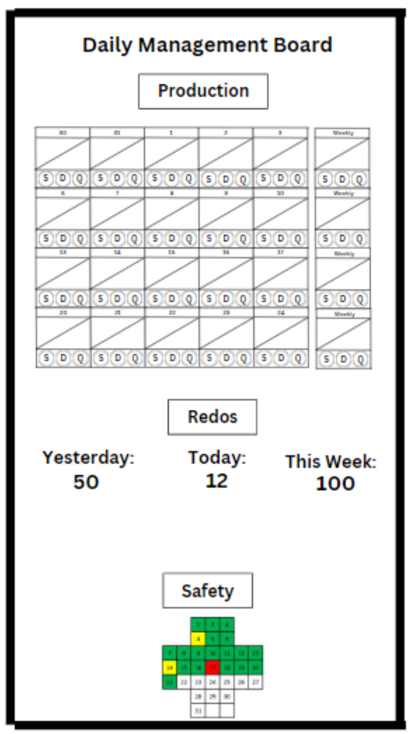


*Figure 13: Daily Management Board Draft 1*

We realized that operators could not easily read the board, so we decided to separate "Redos" and "Production" into two separate sections. It was a challenge to find an effective way to display percentages because the supervisor advised that most operators did not fully understand percentages and to avoid showing too many numbers. To address this, we implemented a bar with red, yellow, and green, which represented, 8+%, 6-8%, and 3-6% scrap rate as shown in Figure 14 below. The rates were updated to 0-4%, 5-7%, and 8+% in the next iteration of the board.

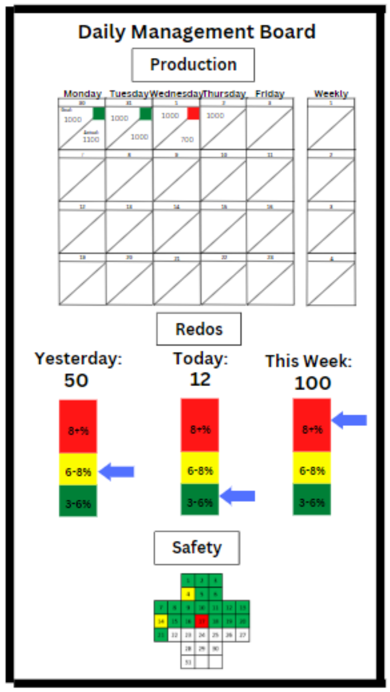


*Figure 14: Daily Management Board Draft 2*

Once the board was introduced at morning meetings, we noticed an increase of attentiveness and engagement. It is also now easy to see when there is any variation in the daily routines whether it be positive or negative. One of the most important areas of the board that needs a few more modifications, is the action item section under redos. When an issue gets reported, operators are alerted of the action item that day and will encourage prompt problem solving in the future. The board helped operators be able to see and understand this data, so they knew they were contributing to solving problems to improve the overall process. The final board implemented on the manufacturing floor is shown in Figure 15 below.


*Figure 15: Daily Management Board Implementation*

## Limitations

The limitation of the Daily Management Board, like any lean manufacturing tool, then the process will not be working at its highest potential when there is not buy-in from the whole team. For example, if there is one person who does not understand the board and its purpose and they are tuned out at every morning meeting, they may be producing the majority of the defects. It's not until they feel like they are contributing and understand their impact on the team will the process reach its potential success. It is up to the supervisor and us, the industrial engineers, to educate the operators and try to create a culture where they care about their work and strive to improve.

## Recommendations

The next step after implementation is to undergo an iterative modification process based on operator feedback and collaboration with the supervisor. The daily management board should be expanded to other departments and undergo modification until it fits the data and informational needs of each specific department. The board we created was only for first shift, so we recommend making it for all shifts as well. It is important to remember when expanding to always once the process is established, we recommend a digital daily management board because the data can be updated real time and is easier to make changes to.

## Standardization in Manufacturing

Our team studied their current standard work procedures and compared it to our observations of their daily operations to come up with a plan to help reduce defects and improve their current manufacturing process. It was observed that AIS had little to none process standard work posted at any of the processes in the worksurfaces department. Since they are a majority manual labor manufacturing facility, this means that the only way the employees could access these sheets were on a computer located at the start of a process. Collecting all these files digitally is inconvenient as not all employees have access to them during a shift and they are not constantly on display, defeating the purpose of encouraging daily goals and process instructions.

### Implementation

AIS had retired a concept called "must-dos" when they moved all the standard work onto the digital platform. A must-do utilizes the same data from the standard work as it pulls only the most important tasks to remember to do when performing this step of the process. A must-do is a reminder for the employees about crucial steps in their job.[2] Appendix L contains some examples of AIS' current standard work.

We studied their most recently updated standard work and created must-do's for each process in the worksurfaces department. All these must-dos were standardized to ensure they were consistent, visual, and only reinforced necessary steps, rather than repeating the entire standard work process. A must-do was created for the following processes: router, edgebander, contour, clean & pack, ABD, and end panels. All of our must-dos were created in both English and Spanish to ensure effective communication to all employees. Figure 16 below represents the English must-do created for the Router. All our must-dos can be seen in Appendix M.

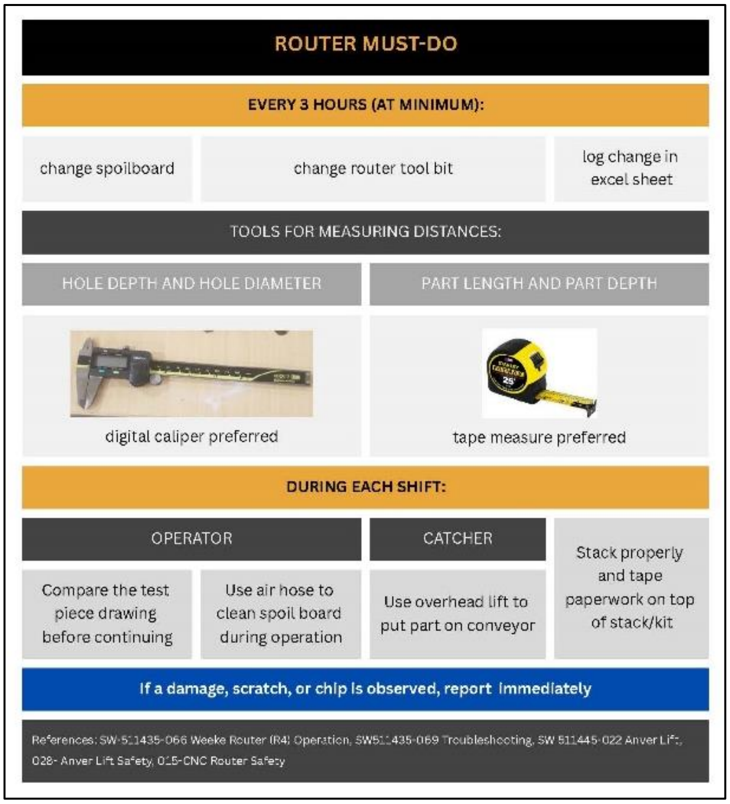


*Figure 1616: Router Must-Do*

## Recommendations

We recommend that AIS implement our must-dos by permanently posting them at each of the associated locations. Posting these provides the employees with a visual reminder of the crucial steps of their job, which will lead to a more consistent pattern in their day-to-day labor. AIS would benefit from official “must-do stations” at each process because it would ensure consistency across the floor and the must-dos would be easily noted at each location. It is also important that AIS keep their standard work and the must-dos updated with any changes in the process. This new implementation is the most effective way to communicate standard work that is both accessible and concise.

Another recommendation is incorporating their quality assurance team checks into their standard work, and in result, the must-dos. quality assurance has questions that they review for each process to check that the operators are following the correct steps. As our must-dos were created solely from the standard work, the quality assurance review was not incorporated. The standard work and the quality assurance questionnaires should match up to ensure consistency in the employee’s work routine, which would then be reflected in the must-dos.

## Limitations

Introducing change into any organization creates challenges and requires employee involvement to ensure success. Our goal through creating these must-dos was that the employees would look at them every day and adjust their work routine accordingly. An important factor that our implementations are limited by is the employees' lack of motivation to change their work style. Reading a must-do does not correlate with a change in work behavior.

Change in the workplace has to be managed and practiced to continue to be successful. We were limited in our deliverables as we did not get the opportunity to manage the implementations and adjust through feedback. Our must-dos need to be refined through feedback from floor supervisors and employees, whereas ours were created working with the Value Stream Manager. The must-dos require more quantifiable evaluating than our project had the time for.

# Incentive Program Recommendations

To further motivate the AIS associates, we recommend that management implement an incentive program into their operations. The criteria and rewards of the incentive program are dependent upon the area of manufacturing that the program is designed to target. Management must consider what they understand about the nature of their employees before introducing an incentive program.

When asked, AIS management mentioned  that they had considered incentive programs in the past, but no specific efforts were made to pursue ideas further. The programs implemented throughout AIS' current operations are targeted towards their attendance and training. As reinforcement for our efforts to improve the redo reporting system, AIS should implement an incentive program regarding accurate redo reporting. There are many ways to approach inspiring employees to be more careful with this accurate redo reporting, but some practices may include:

1. Irregular check-ins praising employees
2. Redeemable "tickets" for valuable items i.e., company merchandise, small gifts, gift cards
3. Acknowledging the integrity and accuracy of defect inputs in the reporting system

4. Building relationships between managers and employees through positive reinforcement statements and individual praise
5. Emphasis on why this is helpful, indicative of why others are failing to gain reward
6. Friendly department competition
    1. Average throughput rate per operator can be used to judge productivity in each department
    2. Winning department gets rewarded with pizza, merchandise, or other small items
    3. Encourage a fun environment with quality performance
    4. Learn about communication issues on floor

# Machining in Manufacturing

As previously mentioned, our Analytical Hierarchy Process indicated that tooling issues should be addressed by assessment of effort and value. Our team did not have much knowledge in manufacturing science or computer numerical control (CNC) machining, so we decided to outsource to Adam Saar, a mechanical engineer undergraduate and manufacturing graduate student at WPI, to observe the process at AIS and make recommendations. Although there are several engineers and technicians at AIS that focus on this line of work, it can be inferred that they might share the same ideas. In spite of this, these employees are accustomed to the process, and it would be valuable to have Adam draw his own conclusions as someone who has never seen the process before. Better known as Jishuken, an activity based on kaizen principles, is a way to gain help who can bring a fresh eye.[28]

Adam conducted his own observations at AIS and focused on tool life and material storage. As revealed through stakeholder meetings and observations, tooling becomes an apparent problem due to operator errors, tool life, material, and improper maintenance. As a result, Adam had suggested to do the following:

1. Analyze utilizing resharpened versus new tools
2. Implement proper chip evacuation
3. Emphasize cleaning boards and pipes
4. Collect data and create a reliable set of information to which machine learning algorithms can be trained. These techniques can deem useful:
    a. In-Situ Temperature sensors
    b. Distance - Machined Analysis
    c. Visual Inspection
5. Seek alternate suppliers
6. Conduct small scale studies to understand facility conditions
7. Designating room for long-term storage

For more detailed conclusions on tool life and material storage analysis, refer to Appendix N.

[28] Marksberry, P., Badurdeen, F., Gregory, B., & Kreafle, K. (2010). Management directed kaizen: Toyota's Jishuken process for management development. *Journal of Manufacturing Technology Management*, *6*, 670–686. https://doi.org/10.1108/17410381011063987

# Reflection on the Project

## Data Analysis

While focusing on the data analysis portion of this MQP, we referred back to many of our courses to fully encapsulate what it means to have good data collection. Some of the skills and lessons we learned in our courses to make this project become a reality include, how to properly use Excel (BUS 2080, OIE 3600), what is considered good data (MIS 584), how to create a financial analysis (OIE 2850), and how to clean and organize our data to be able to make decisions (OIE 3600, MIS 584). This data collection and analysis allowed for us to communicate what we saw through real data and charts to the people at AIS. Without the core knowledge gained through these courses, we would not have been able to understand what it meant to have a proper data collection system in place. Alongside being able to create a data collection system, these courses mentioned above allowed us to connect with every department in a company. Using analytics to drive decision making is something that happens in engineering, financial, executive, and sales departments at almost every successful company, so having this base of tools and knowledge gave us the opportunity to succeed with whatever path we choose next.

## Lean

As Industrial Engineers, many of our academic influences are based on lean manufacturing. Specifically in Achieving Effective Operations, BUS3020 taught by Professor Walter Towner, we learn about the need for organization and standardization in a manufacturing environment. Though the concepts presented are applicable within many disciplines, their presence was clear in our work at AIS.

BUS3020 simulates a manufacturing facility. Through the manipulation of toy clocks, students are exposed to how inefficiencies can cause bottlenecks and how standard work is crucial to an effective process flow. At AIS, the clocks are just like the worksurfaces being produced and the same teachings remain true. Defects occurring in the system lead to a buildup of work-in-process (WIP) that decreases throughput. We observed a lack of effectively implemented standard work, causing confusion and disruption in the flow of AIS' production on a daily basis. Similarly, to the BUS3020 lab, in which students observe points of improvement in their process and make adjustments to eradicate them, AIS has lots of room for improvement that can be tackled with time and individual projects like our own.

Beyond our classes, a number of our group members are Lean Green Belt certified. This certification, which is highly renowned in the industry, gives the individual credibility in their ability to lead Lean improvements in the workplace. As a leader, understanding the capabilities of followers and the implications of management implementation is important. A lot of our lean recommendations encountered pushback, as associates are quick to think that lean improvements mean a cut in pay or jobs. Industrial Engineers, though we seek to cut down on the total time in a process, look to increase efficiency so that manpower may be used more effectively elsewhere.

## Quality

Quality assurance is a crucial step of manufacturing which we incorporated quality in many aspects of our project. In our project, our team found ourselves using many of the approaches to quality learned through our Industrial Engineering studies.

We were taught that quality should be enforced by everybody in a company, not just management, and teamwork and partnerships must exist across all sectors (OIE3420). With our objectives, we focused on ways that we could really implement this mindset at AIS. It was important that we could improve the quality of not only the product but also the quality work culture. Since AIS is a mostly manual labor manufacturing facility, it was important to remember that everyone is responsible for quality.

Another learned concept that we used was the idea that “quality is free.” If a product is made right the first time, in a perfect process, the quality of that product would be of no additional cost to the manufacturer. What costs money are the defects and failure to follow the process correctly. This was very important to remember when focusing on our project’s must-dos and studying the current standard work, in addition to creating a financial analysis.

## Work Culture and Dynamics

Our project required us to use concepts we have learned in our courses about fostering a positive work environment and managing dynamics in groups and with individuals. During our OBC506 course, we learned which interpersonal skills will allow us to act as leaders in different situations. These skills helped us reach outside of our comfort zones when developing and proposing our ideas. We could understand who the hidden leaders are and how to navigate meetings with operators, engineers, managers, and the COO to best enact positive change. Employees need to understand and believe in our ideas for them to be effective, so we needed to figure out how to guarantee employee support. Along with our interface design, we recommended an incentive program that would encourage employees to use our updated interface and be rewarded for increased awareness of redos. This is a tool we used to boost employee morale and improve engagement to benefit the overall work culture. The systems approach we learned to implement change even with resistance was valuable to this project.

## Facilities Planning

A facility's layout and design are crucial to AIS' overall operations because they may both suit the needs of employees and maximize the efficiency of the production process. Currently, the layout at AIS is a complicated structure with numerous mechanical and design components due to the sheer volume of products that AIS offers. The main goal of the layout is to make sure that work, materials, and information flow through a system smoothly. The area where a business' operations take place is the basic definition of a facility. Facility layout is an ongoing problem at AIS as customer demand continues to increase. As previously mentioned, problems such as WIP and tripping hazards are contributed by the arrangement of the production floor. The way the job is done—the way supplies, information, and work are moved around the system—is significantly impacted by the architecture and design of that area. A variety of facility layout design methods are taught in OIE 3405; these foundations for efficient layout include method analysis, work measurement, material handling. By doing so, integrating the requirements of people (staff and customers), materials (raw, finished, and in-process), and equipment in such a way that they form a unified, efficient system is the key to good facility planning and design.

## Project Experience

With the conclusion of our MQP, our team has learned to become more well-rounded, cooperative individuals. Prior to our project, some members were close while others had yet to build connections with the other members. Our team enjoyed working together to the point where we had group bonding and hangouts to destress. We are glad to have created new connections with other industrial engineers that will continue to be our peers in the future. After three terms, our group has learned to accommodate each other's learning and working styles, utilize strengths and weaknesses, and motivate others with effective leadership styles. These skills will serve us well in our full-time positions in the future, as we have experienced what it is like to be exposed to a foreign environment, work with individuals with different mindsets, and adapt to varied personality types.

As industrial engineers, our confidence in our ability to assess and propose solutions for quality problems has improved significantly. If we were to approach this project again, we now know more about the most effective plan of action for assessing the full scope of problems on a manufacturing floor. The biggest takeaway being the need to interpret every stakeholder's experience and opinion on the changes that need to be made in the system. For AIS, stakeholder interpretations were best observed through the creation of our fishbone diagram. Going forward, we will need to learn more about what challenges different industries and facilities present. When working with a facility that produces potato chips, for instance, the product, defects, and specific skills sets required in manufacturing are much different than those at AIS. In our approach future projects with other businesses, however, we are better equipped to fast-track our problem comprehension by going right to the source, the individuals who are operators and stakeholders in the system.

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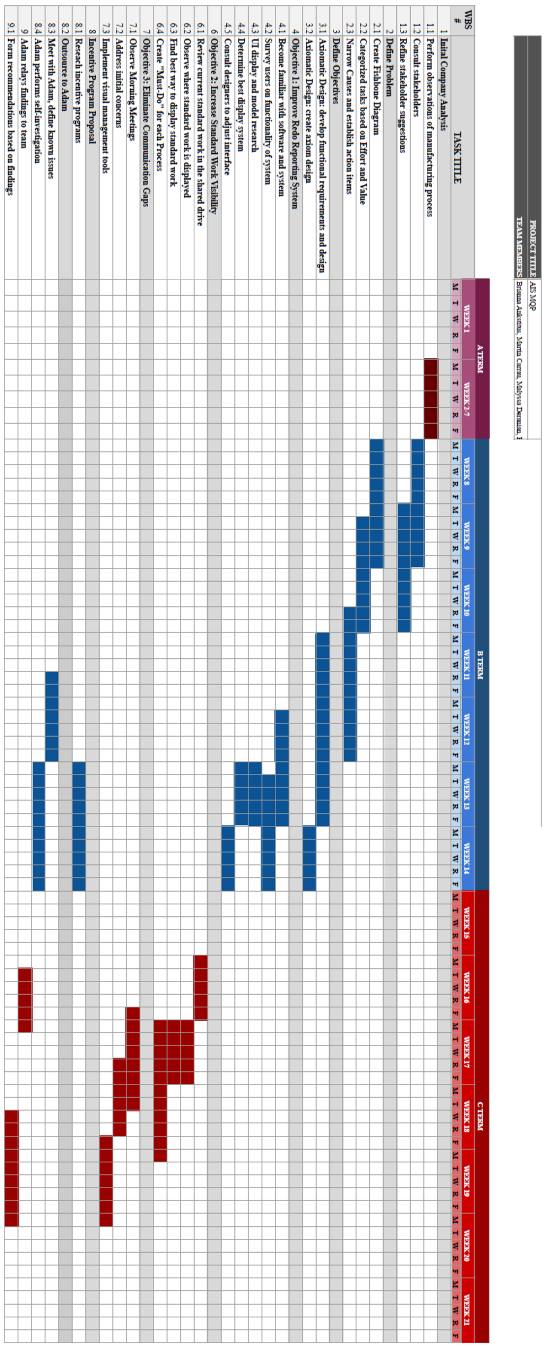
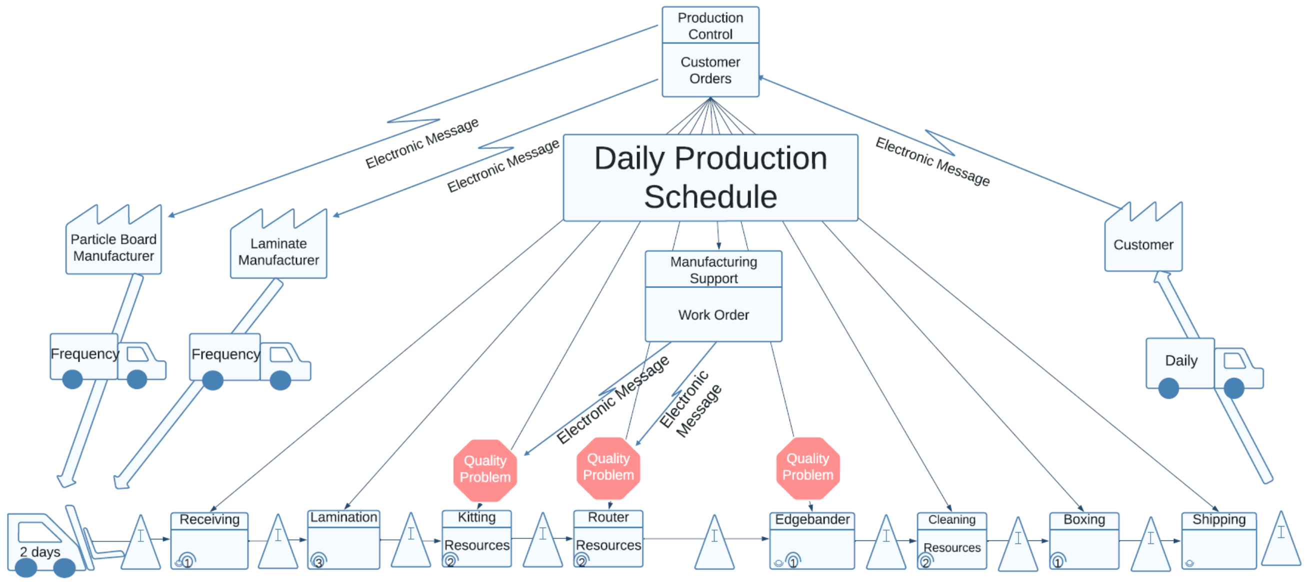
# Appendix

## Appendix A: Gannt Chart

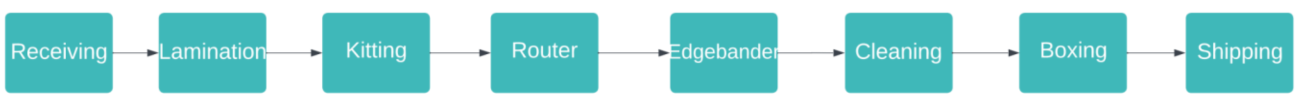


# Appendix B: AIS Process Map

# Appendix B1: Value Stream Mapping




# Appendix B2: Process Map



# Appendix C: Hierarchal Decomposition

## Appendix C1: Functional Requirements & Design Parameters

FR0: Reduce scrap rate *(get metric after implementing UI system updates)*
FR1: Collect accurate scrap generation data
    FR1.1: Updating the reporting system UI
    FR1.2: Train employees to use reporting system
    FR1.3: Encourage employees to report defects on time
FR2: Regulate system
    FR2.1: Training standard work
    FR2.2: Redo reporting standard work
FR3: Improve communication between the hierarchy of employees

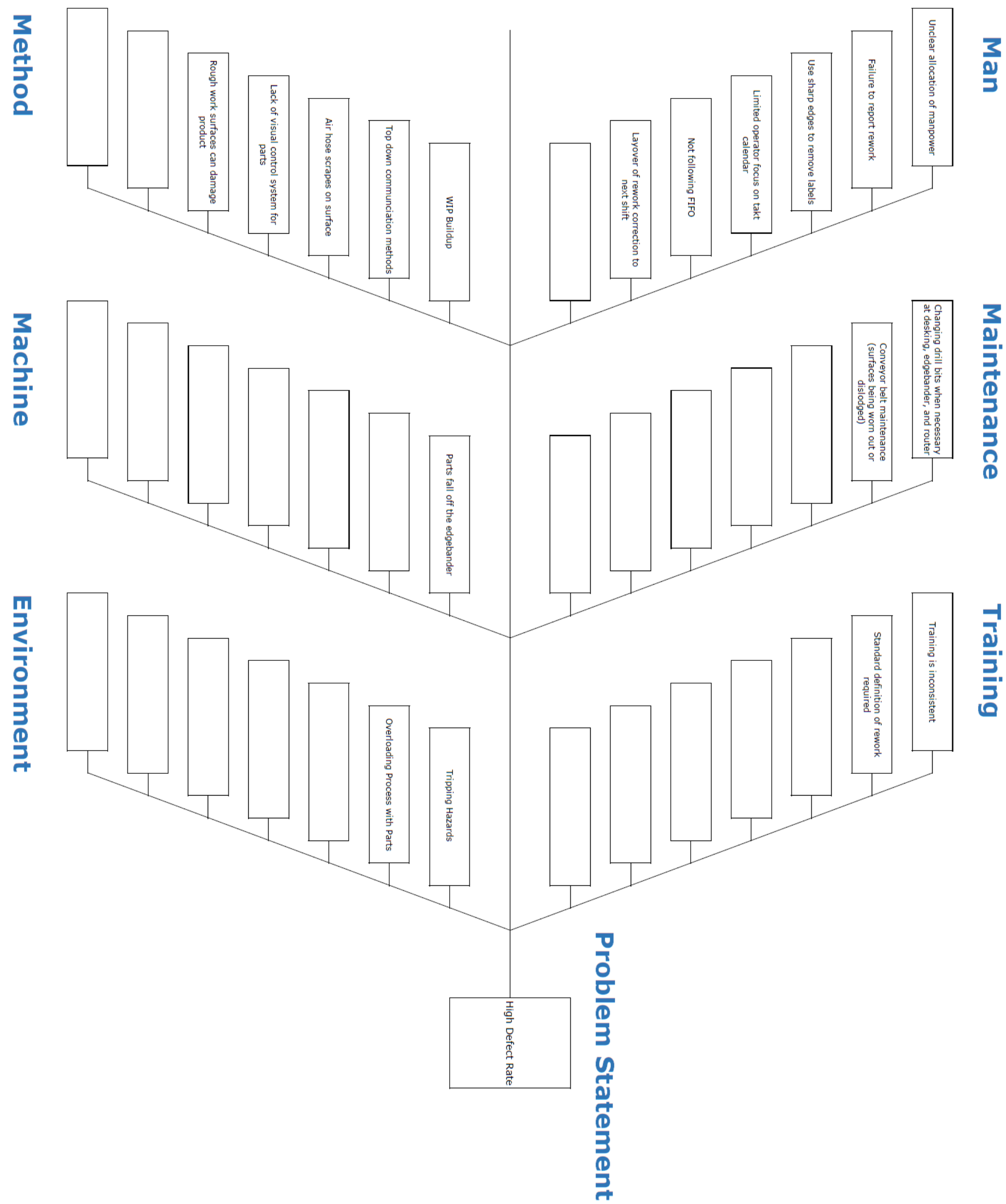
DP0: Standard system to reduce scrap rate
DP1: New reporting system
    DP1.1: New UI layout to facilitate easy reporting
    DP1.2: Standard work for training on reporting system
    DP1.3: Incentive program for on time defect reporting
DP2: Define processes with standard work
    DP2.1: Standard work for training
    DP2.2: Standard work for redo reporting process
DP3: Daily Gemba walkthroughs with the employees by shop floor management to increase awareness and cost to the company

## Appendix C2: Coupling Matrix

| | | Daily gemba walkthroughs with the employees by shop floor management to increase awareness and cost to the company | Define material handling processes with standard work | Incentive program for on time defect reporting | New reporting system | New UI layout to facilitate easy reporting | Training standard work for processes |
|---|---|---|---|---|---|---|---|
| | | DP3 | DP2 | DP1.3 | DP1 | DP1.1 | DP1.2 |
| Improve communication between the hierarchy of employees | FR3 | x | | | | | |
| Material Handling | FR2 | | x | | | | x |
| Encourage employees to report defects on time | FR1.3 | | | x | | x | x |
| Collect accurate scrap generation data | FR1 | | | x | x | x | x |
| Improve the reporting system UI | FR1.1 | | | | x | x | |
| Train employees to use reporting system | FR1.2 | | | | | | x |

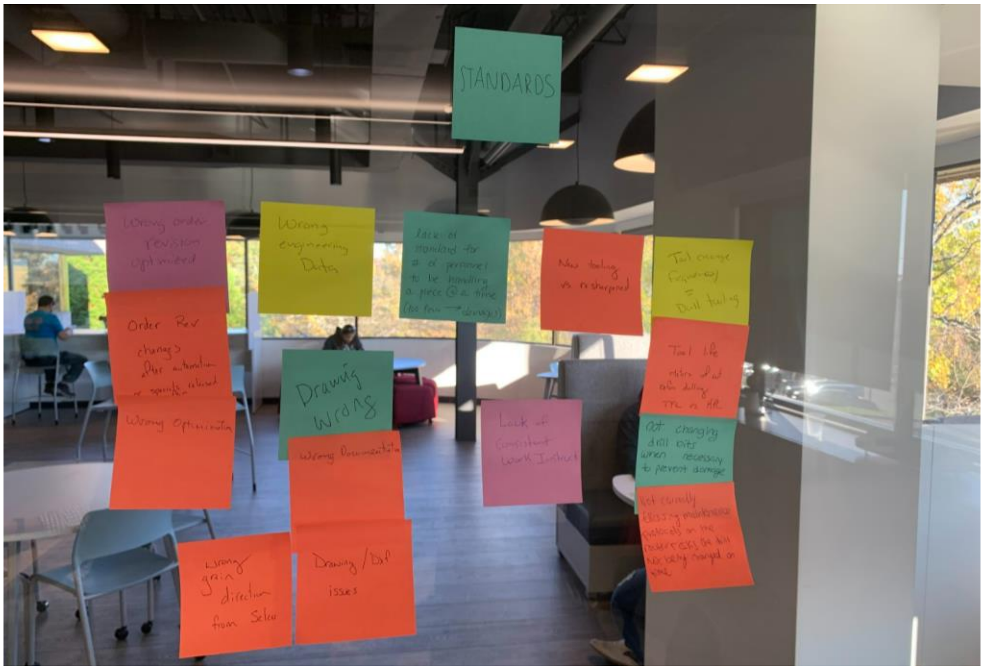
# Appendix D: Fishbone Diagram

## Appendix D1: Fishbone Diagram Draft 1



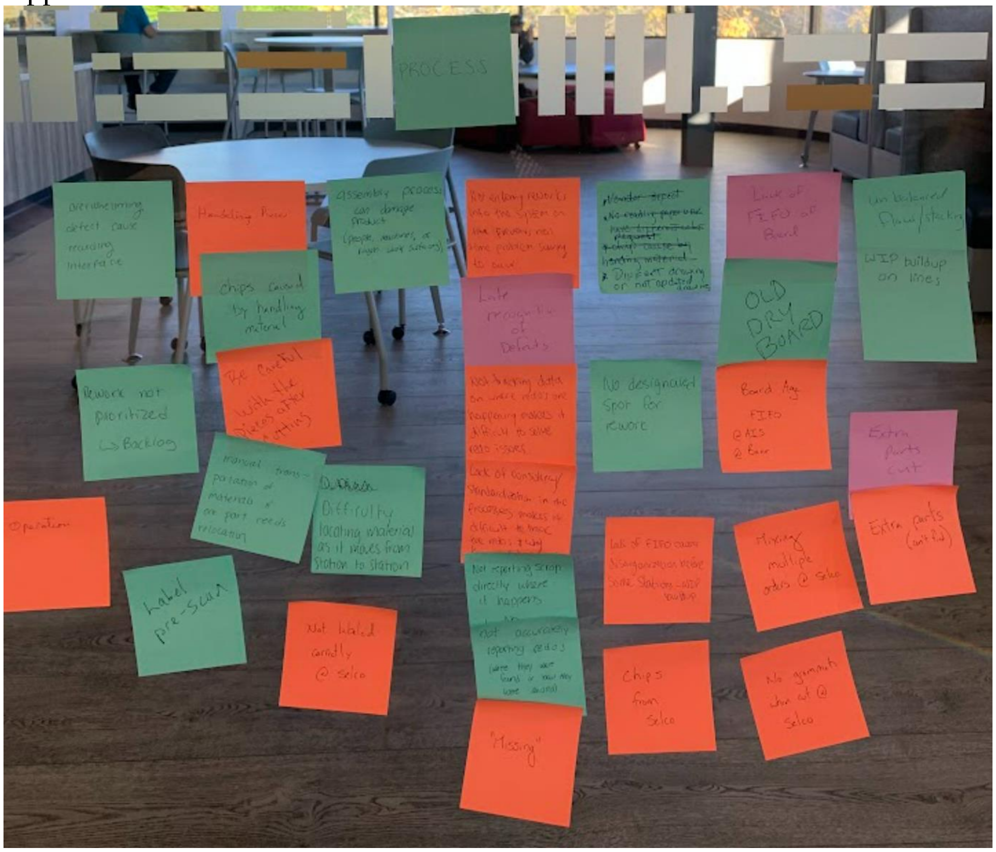
# Appendix D2: Causes Identified during Stakeholder Meeting

Appendix D2.1. Issues identified in standard work

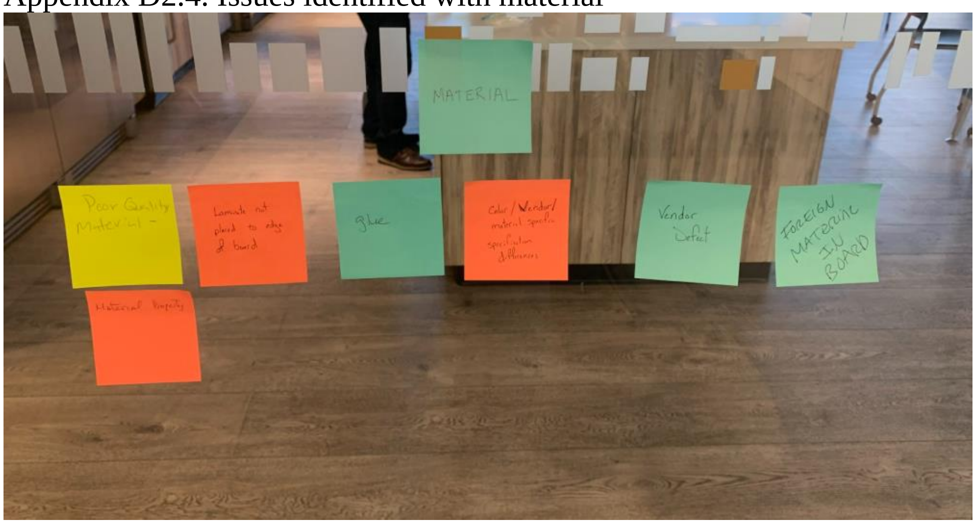



Appendix D2.2. Issues identified in machining

Appendix D2.3. Issues identified in the Process




Appendix D2.4. Issues identified with material

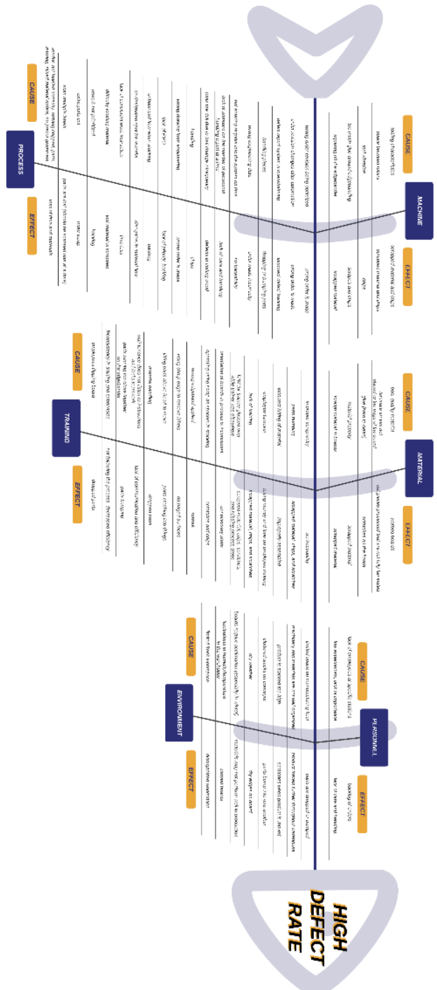


Appendix D2.5. Issues identified with the work environment


Appendix D2.6. Issues identified with process maintenance

Appendix D2.7. Issues identified with the employee training

# Appendix D3: Final Fishbone Diagram



# Appendix E: Analytical Hierarchy Process

Effort: 1-5 scale, 1 being the most effort put into a task

Value: 1-5 Scale, 1 being the least value we're going to get out of this

**Material**

| Cause | Effect | Rating: Effort | Rating: Value | Score |
|---|---|---|---|---|
| Poor Quality Material | Warped Boards | 1 | 1 | 2 |
| Laminate arrives not placed to the edge of the board | Cut pieces processed not fully laminated | 1 | 2 | 3 |
| Glue (Hard to clean) | Scratches on the board | 1 | 2 | 3 |
| Material Property | Scrapped Material | 1 | 3 | 4 |
| Foreign Material in Boards | Scrapped Material | 1 | 1 | 2 |

**Machine**

| Cause | Effect | Rating: Effort | Rating: Value | Score |
|---|---|---|---|---|
| Tooling characteristics | Scrapped Material & Chips | 4 | 4 | 8 |
| Space Between Rollers | Scrapped Material & Chips | 3 | 2 | 5 |
| Tool Vibration | Chip? | ? | ? | #VALUE! |
| Too much glue around edgebanders | Scrapes & Chips | 4 | 1 | 5 |
| Squaring off the edgebander | Scrapped Material | 3 | 2 | 5 |

**Training**

| Cause | Effect | Rating: Effort | Rating: Value | Score |
|---|---|---|---|---|
| Improper Scrap Entry | No Traceability | 2 | 5 | 7 |
| Parts Bumping | Scrapped Material, Chips, Scratches | 3 | 3 | 6 |
| Incorrect kitting of material | Improperly asembled | 2 | 5 | 7 |
| Employee turnover | Losing money and time on employee trainin | 1 | 5 | 6 |
| Lack of training | Scrapped Material, Chips, Scratche | 2 | 4 | 6 |
| TPM for trainee glossed over while trainer was elsewhere | Scrapped Material, Chips, Scratches, Missing Process Steps | 5 | 3 | 8 |
| Orientation of boards and process is inconsistent | Uneccesary steps | 4 | 2 | 6 |
| Operating using scrap as spacers in stacking | Scratches & Chips | 2 | 2 | 4 |
| Wrong edgeband applied | Rework | 4 | 4 | 8 |
| Using sharp edge to remove labels | Damaged surfaces | 4 | 4 | 8 |
| Moving work above their heads | Pieces crashing into things | 1 | 3 | 4 |
| Material Handling | Dropped parts | 1 | 5 | 6 |
| Maintenance not listening to intructions and no teamwork | Lack of communicatio n and efficiency | 1 | 4 | 5 |
| Parts running too close together on the edgebander | Parts bumping | 4 | 3 | 7 |
| Inconsistency in training and supervising | Not following process/not efficient | 2 | 4 | 6 |
| Employees flipping board | Dropped parts | 1 | 5 | 6 |

**Process**

| Cause | Effect | Rating: Effort | Rating: Value | Score |
|---|---|---|---|---|
| Wrong order revision being optimized | Wrong order is made | ? | ? | #VALUE! |
| Order revision changes after automation | Wrong order is made | ? | ? | #VALUE! |
| Defect report system is overwhelming | Incorrect defect tracking | 3 | 5 | 8 |
| Handling pieces | Dropping/ bumping parts | 1 | 5 | 6 |
| Wrong engineering data | Order made incorrectly | 1 | 2 | 3 |
| Not entering reworks into the system on time | No traceability | 2 | 5 | 7 |
| Lack of standard for the number of personnel handling piece | Lack of care and handling | 2 | 4 | 6 |
| Tool change frequency vs dull tooling | Defects in cutting wood | 4 | 4 | 8 |
| Handling | Chips | 1 | 5 | 6 |
| Wrong drawing engineering | Wrong order is made | 1 | 2 | 3 |
| Lack of FIFO | Lack of priority, backlog | 2 | 4 | 6 |
| Unbalanced flow when stacking | backlog | 2 | 4 | 6 |
| No designated spot for reworks | Disrupt in material flow | 3 | 5 | 8 |
| Lack of consistent work instruction | Time Loss | 2 | 4 | 6 |
| Difficulty locating material | Lost material scrapped | 1 | 4 | 5 |
| Rework not prioritized | Backlog | 4 | 4 | 8 |
| Extra parts cut | More scrap | 1 | 4 | 5 |
| Scan multiple labels | Losing parts (should be scanning one at a time) | 4 | 3 | 7 |
| Vendor: not labeled correctly, arriving chipped, parts missing, mixing material orders, Don't precut grommets | | 1 | 3 | 4 |

**Environment**

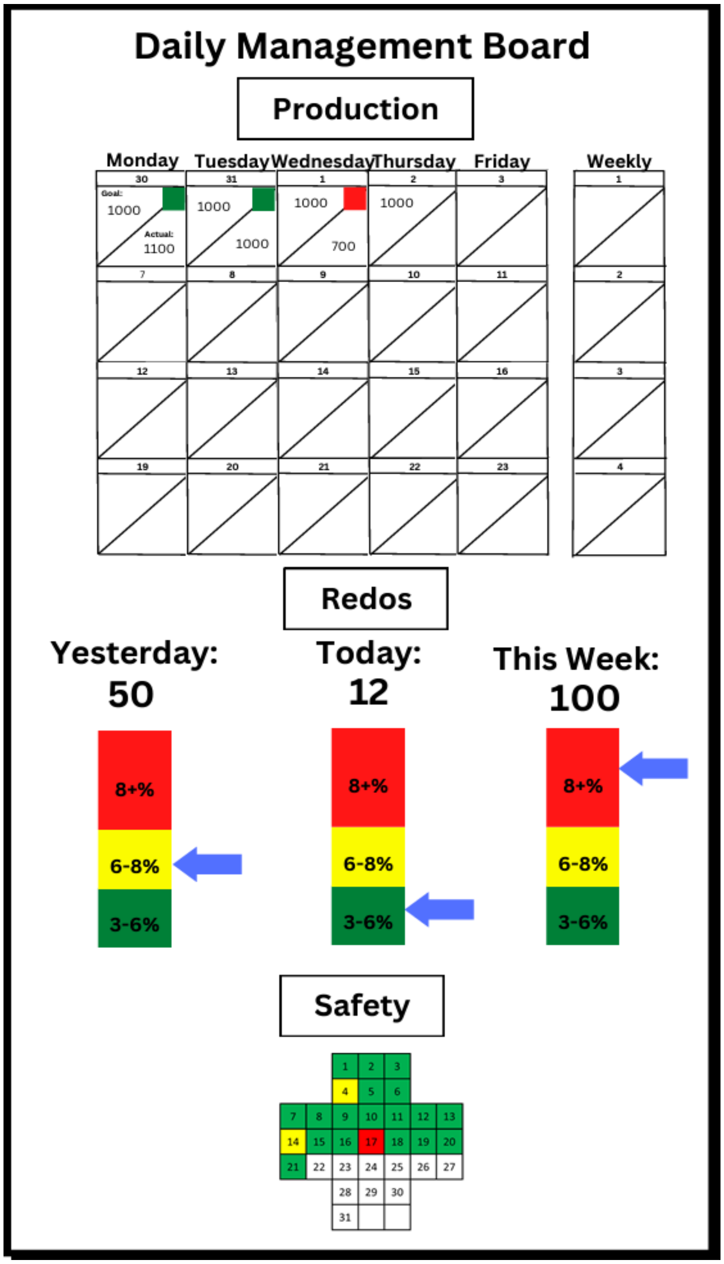
| Cause | Effect | Rating: Effort | Rating: Value | Score |
|---|---|---|---|---|
| Lack of space on manufacturing floor | Parts are dropped or bumped | 2 | 5 | 7 |
| Machinery and materials not well organized on floor | Product travels further throughout warehouse | 2 | 5 | 7 |
| Product stacked too high | Scratches when product is moved | 3 | 3 | 6 |
| Cluttered stacks on conveyor | Parts bump into one another | 2 | 4 | 6 |
| Dry weather | Dry edges on board | 1 | 2 | 3 |
| Boards require acclimation (espcially in winter) | Materials may not perform well in production | 1 | 2 | 3 |
| Fluctuation in humidity/temperature in the warehouse | Warped boards | 1 | 2 | 3 |
| Limited free workspace | Disorganized workstation | 2 | 5 | 7 |

**Personnel**

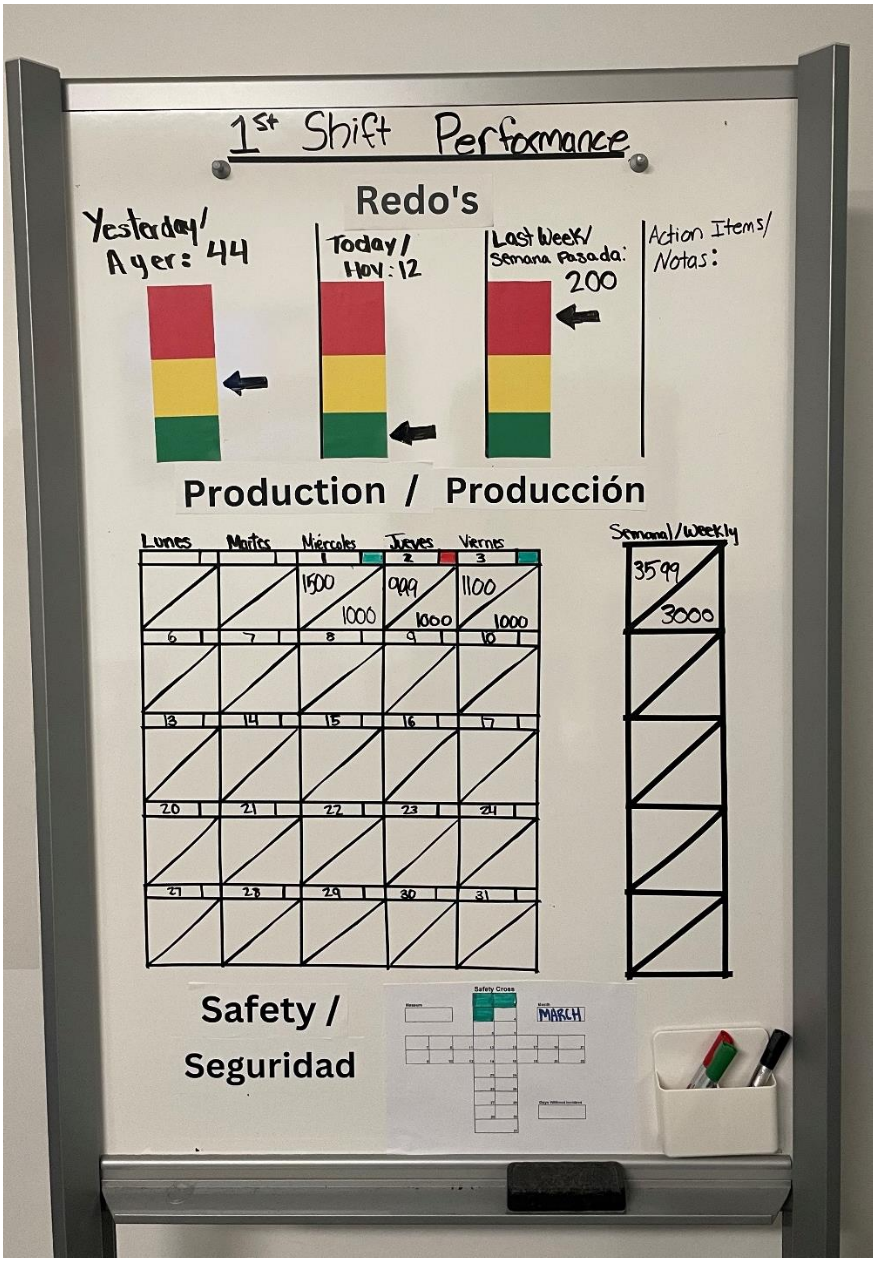
| Cause | Effect | Rating: Effort | Rating: Value | Score |
|---|---|---|---|---|
| Lack of employees at certain stations | Backlog of orders | 1 | 4 | 5 |
| Low expectations, lack of importance | Lack of care and handling | 2 | 5 | 7 |

# Appendix F: Visual Management System

## Appendix F1: Daily Management Board Mockup

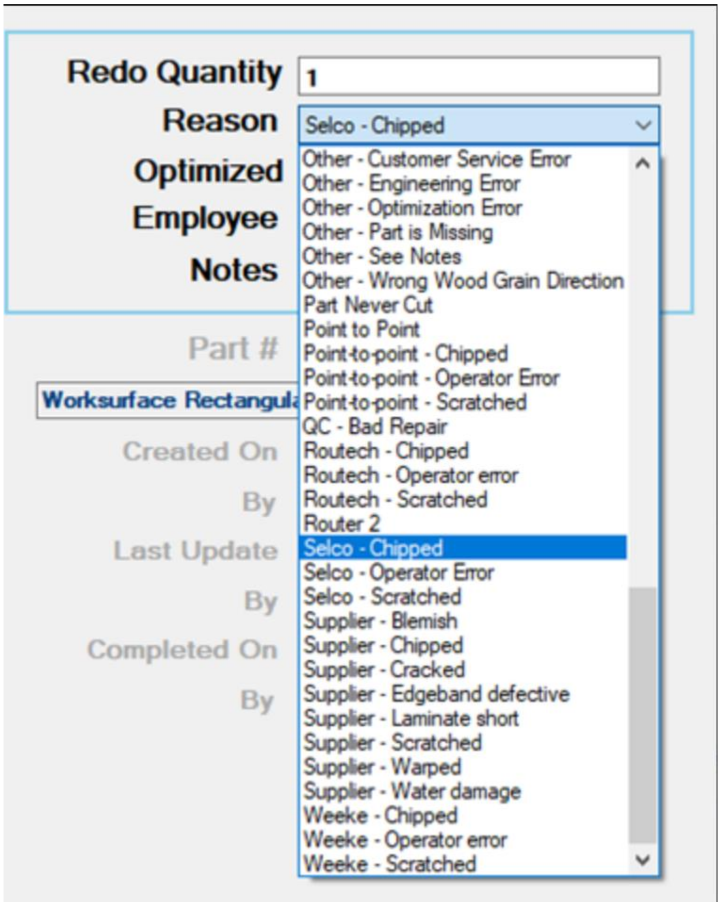


**Appendix F2: Daily Management Board Implementation**

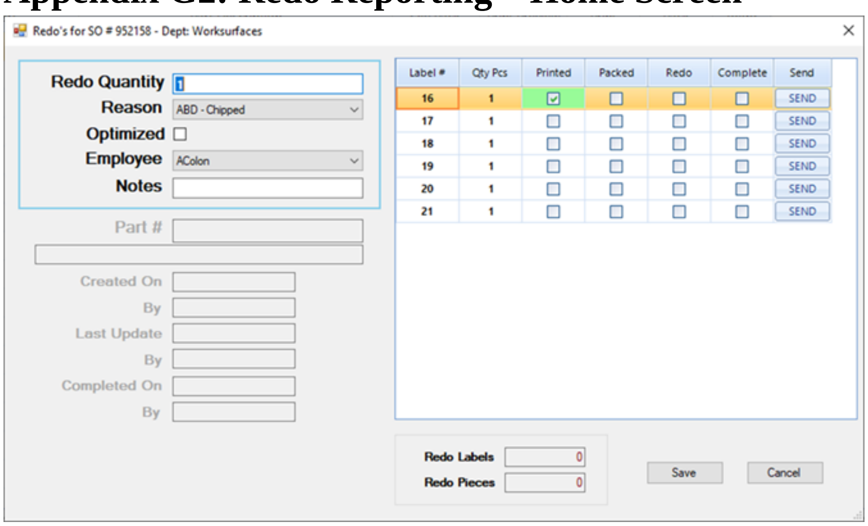


# Appendix G: Original Redo Reporting System

## Appendix G1: Drop Down Menu

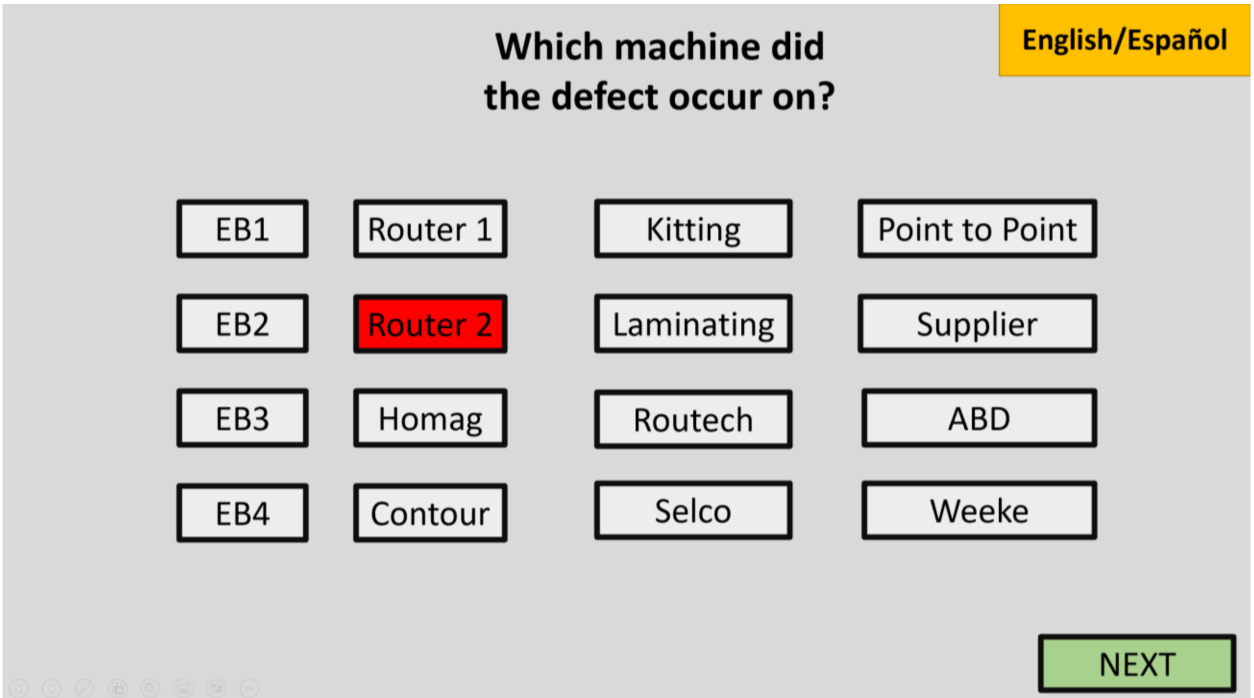



## Appendix G2: Redo Reporting – Home Screen

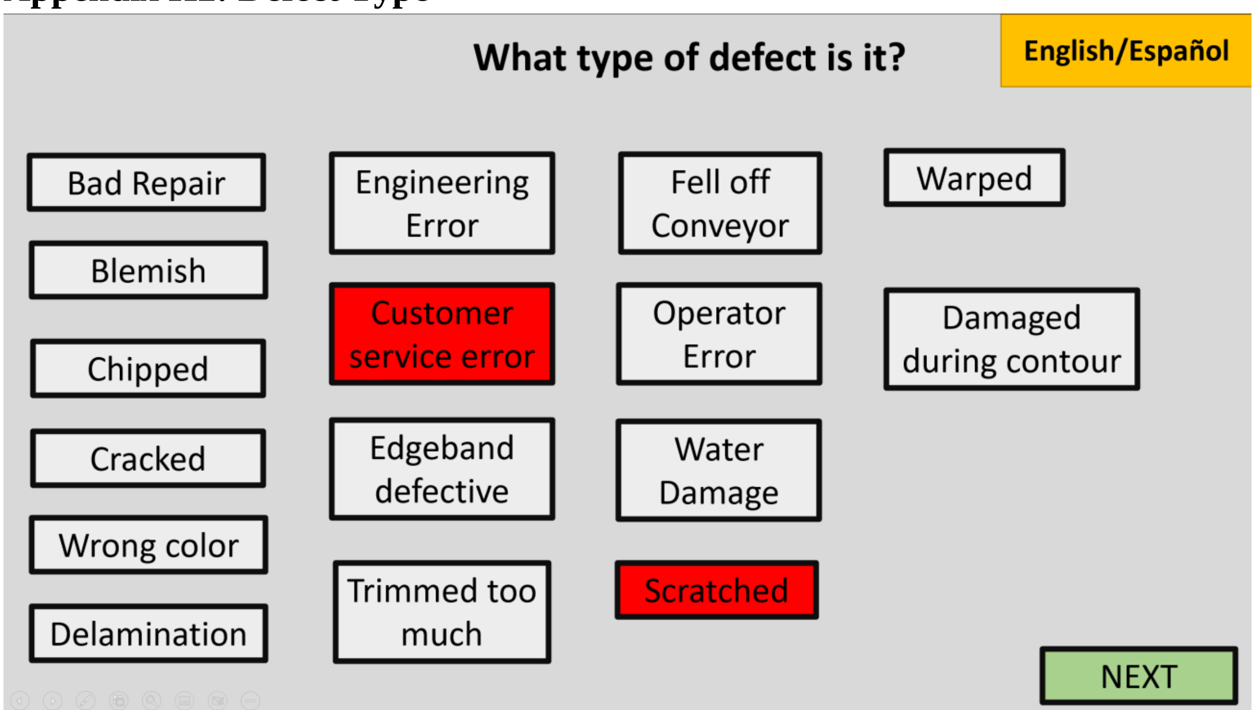


# Appendix H: New Redo Reporting System Prototype

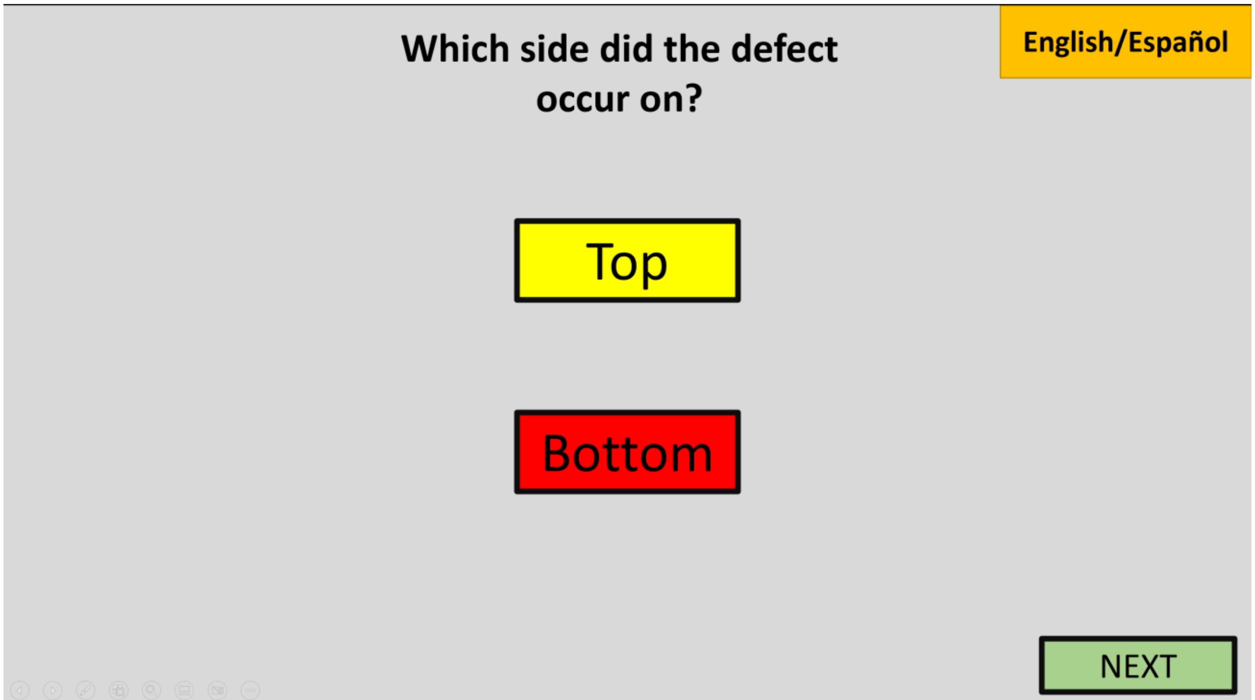
## Appendix H1: Defect Machine



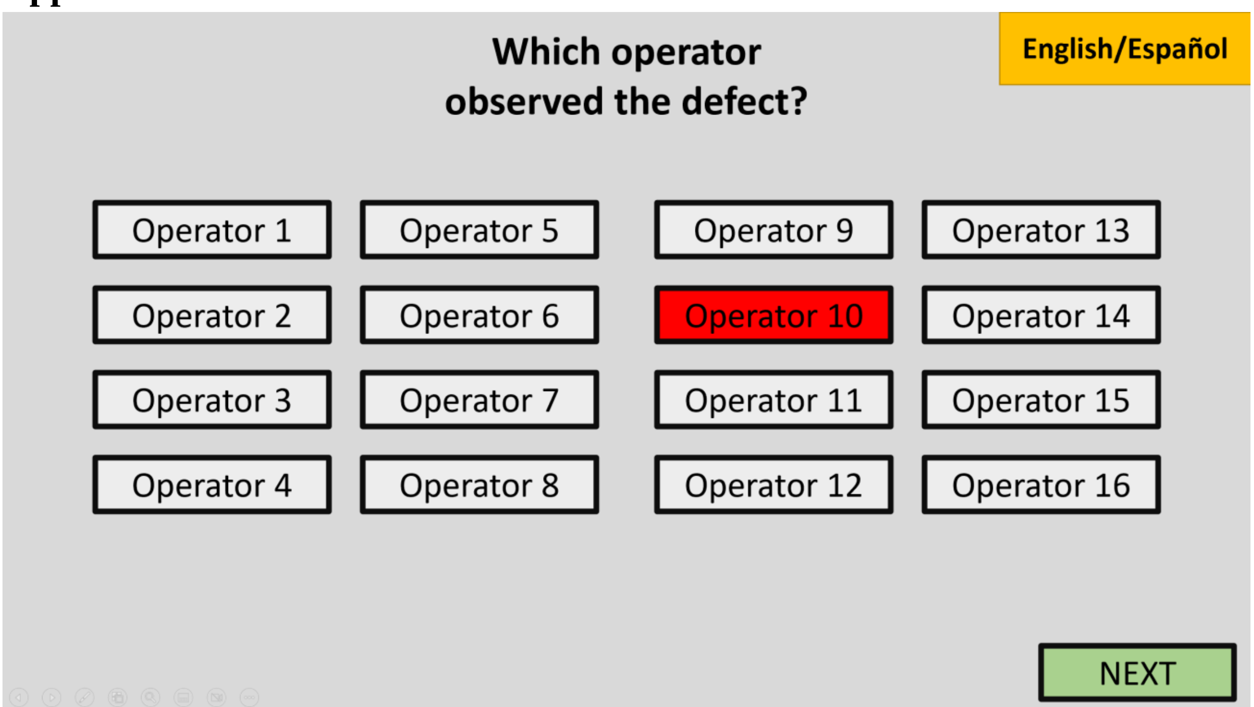

## Appendix H2: Defect Type



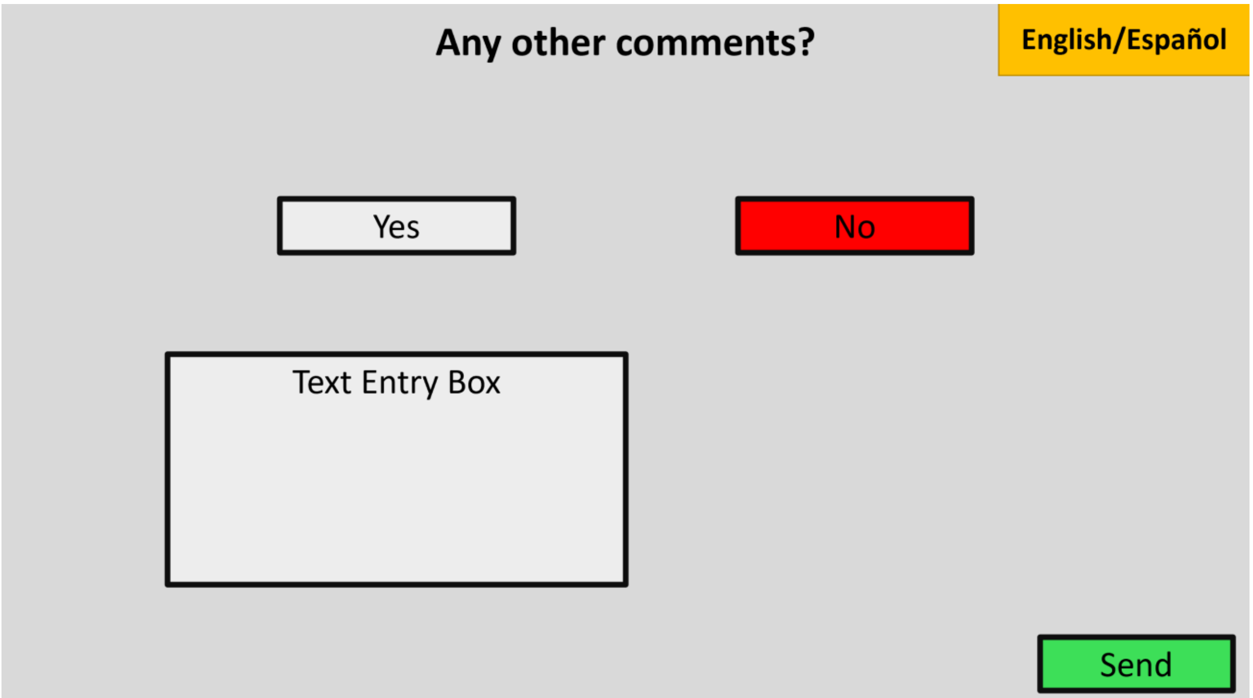
## Appendix H3: Defect Board Side




## Appendix H4: Defect Observer



**Appendix H5: Defect Notes**



# Appendix I: AIS Redo Form Functionality Survey

## Appendix I1: Survey Questions

Q1. What is your title/position in the company? ¿Cuál es su posición en la empresa?

*Short answer*

Q2. Years of Employment? Años de empleo?

*6 months- 1 year, 1 – 2 years, 2 -4 years, > 4 years*

*The following are Scale Based Questions: Please read the following statements and select the best option that applies to you.Por Favor. Lea las siguientes y escoge el mejor opción se aplica a usted.*

*1 - Strongly Disagree- Totalmente en desacuerdo*

*2 - Disagree- Desacuerdo*

*3 - Neutral*

*4 - Agree- Acuerdo*

*5 - Strongly Agree- Totalmente en acuerdo*

Q3. I use the system frequently. Utilizo el sistema con frecuencia..

Q4: I think the system is unnecessarily complex. Pienso que el sistema es innecesariamente complejo.

Q5: I think the system is easy to use. Pienso que el sistema es facil para usar.

Q6: I am satisfied with the current system. Estoy satisfecho con el sistema actual.

Q7: I am familiar with the process to report redos. Estoy familiarizado con el proceso para reportar "Redos"

Q8: I report redos when it happens. Lo reporto cuando sucede.

*The following are Short Answer Questions: Respuestas cortas.*

Q9: What are some issues or concerns you've encountered with the current system, if any.

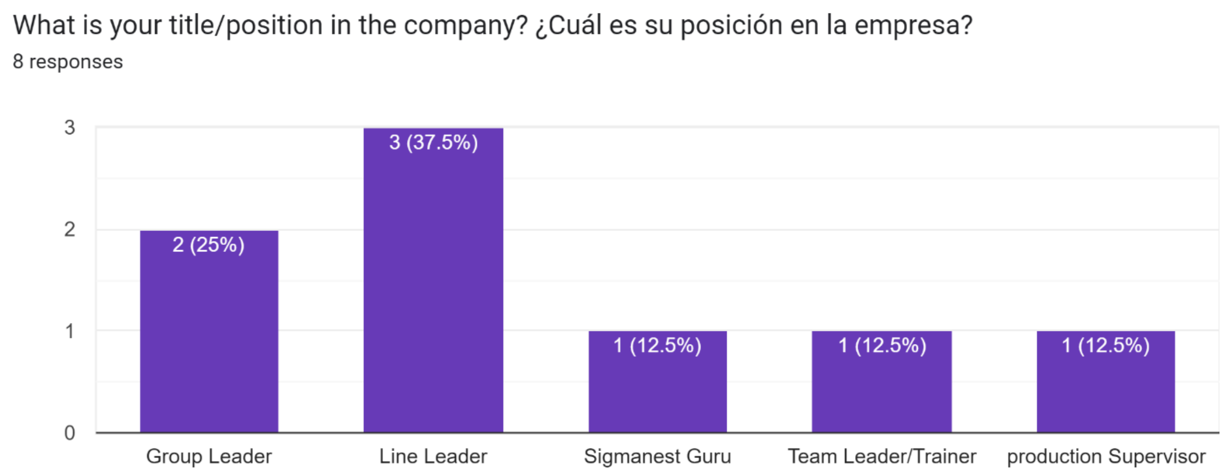
¿Cuáles son algunos problemas o inquietudes que ha encontrado con el sistema actual, si los hay?

Q10: What are some changes you would like to see with the current system?

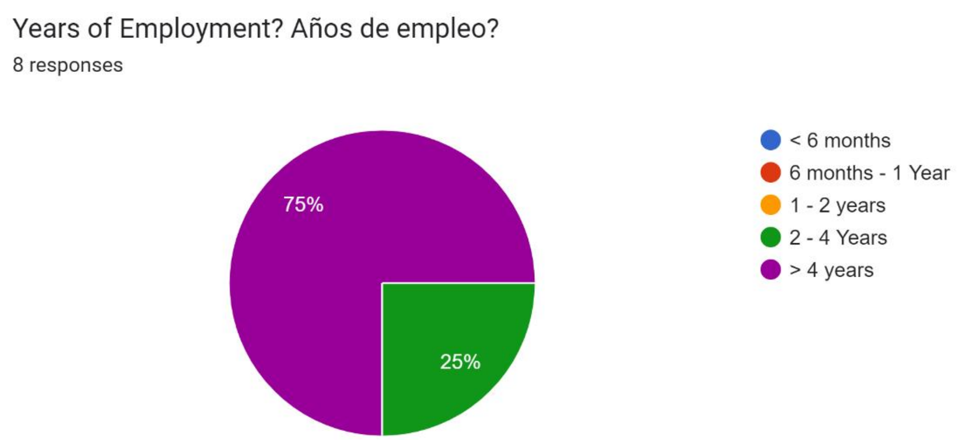
¿Cuáles son algunos de los cambios que le gustaría ver con el sistema actual?

# Appendix I2: Survey Responses

Appendix I2.1: Q1 Results



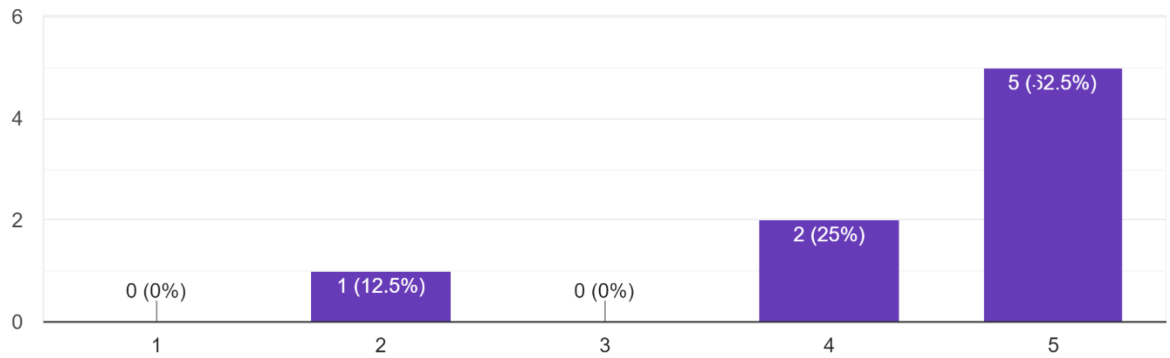

Appendix I2.2: Q2 Results



## Appendix I2.3: Q3 Results

I use the system frequently.  Utilizo el sistema con frecuencia.

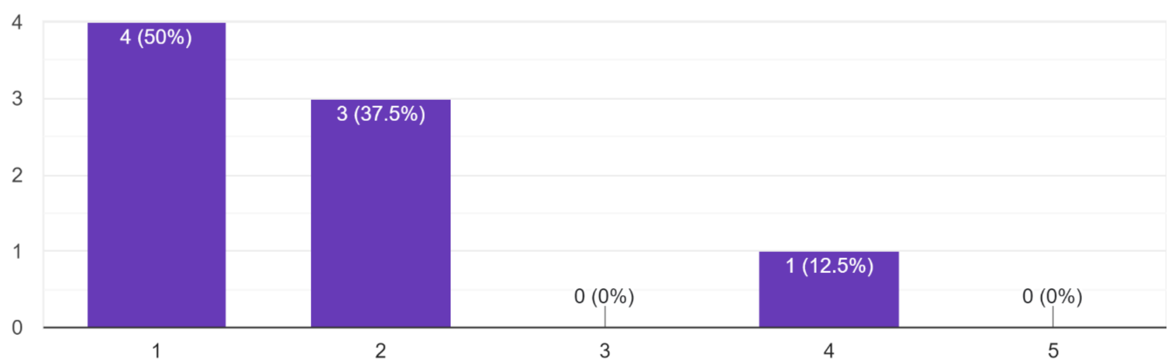
8 responses




## Appendix I2.4: Q4 Results

I think the system is unnecessarily complex.  Pienso que el sistema es innecesariamente complejo.

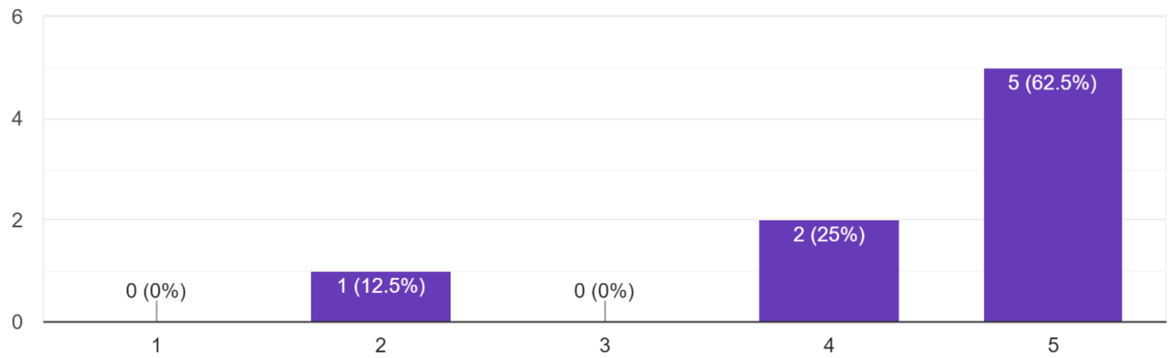
8 responses



Appendix I2.5: Q5 Results

I think the system is easy to use.  Pienso que el sistema es facil para usar.

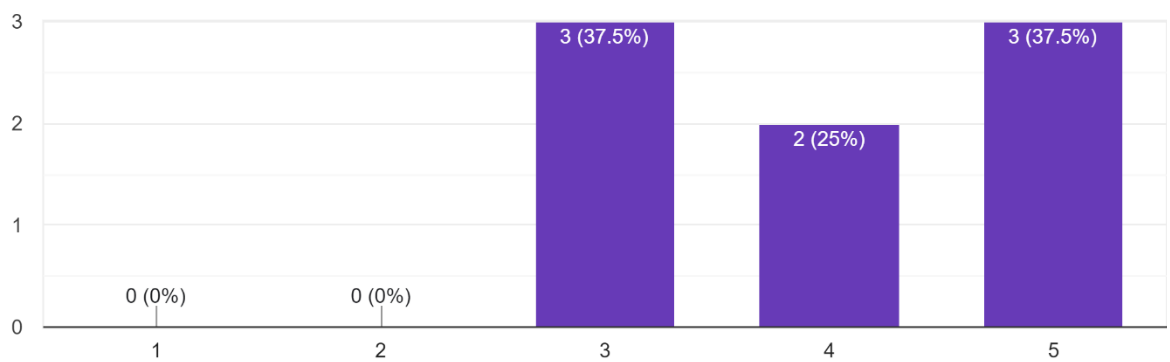
8 responses




Appendix I2.6: Q6 Results

I am satisfied with the current system. Estoy satisfecho con el sistema actual.

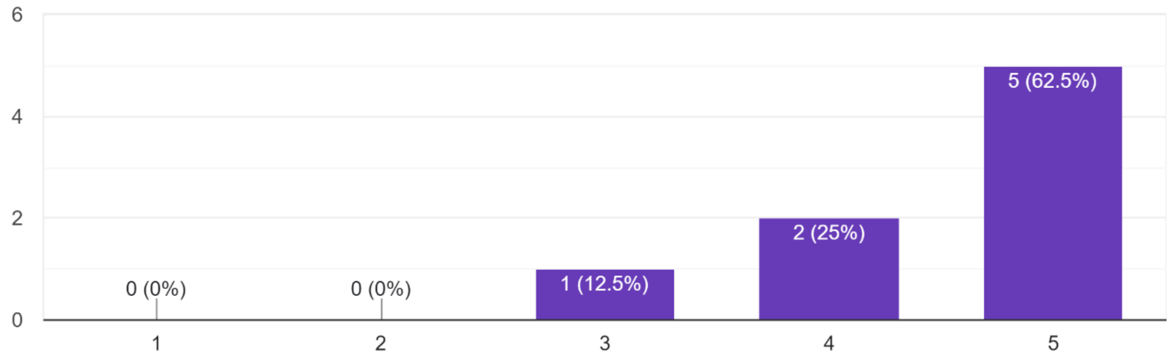
8 responses



Appendix I2.7: Q7 Results

I am familiar with the process to report redos. Estoy familiarizado con el proceso para reportar "Redos"

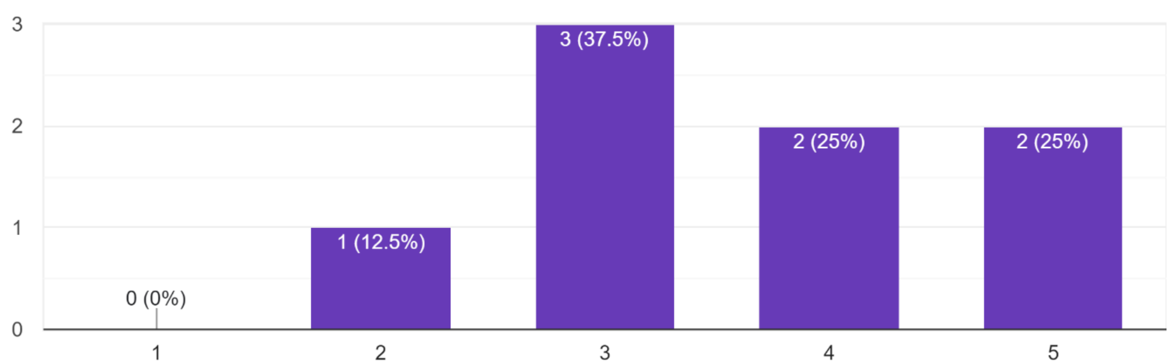
8 responses




Appendix I2.8: Q8 Results

I report redos when it happens. Lo reporto cuando sucede.

8 responses



Appendix I2.9: Q9 Results

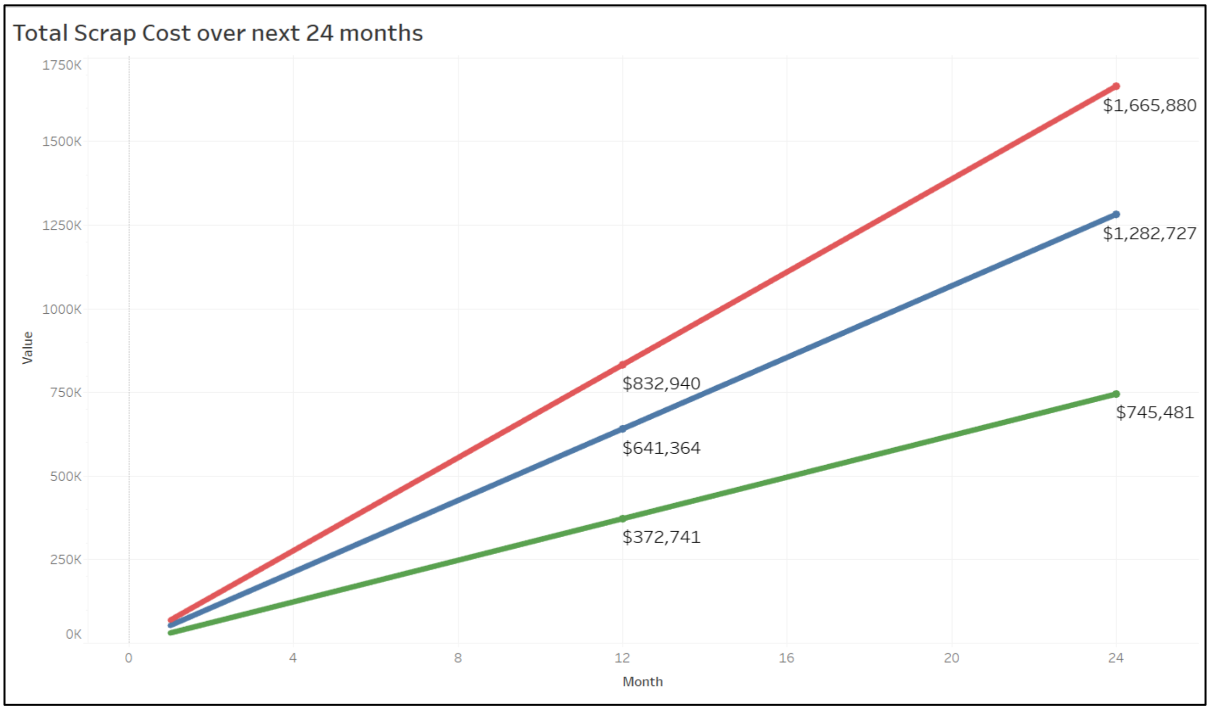
No hay
Esta nada mas en ingles
Esta en ingles y hay muchas opciones de rasones para los redos
If on the line they don't report the redos then i have to look around for what happened to the part.
If the redo isn't entered correctly it makes the planner job very hard
I have no concerns
during last couple of month you placed a redo and when cut if more than one redo same part only one printed label.
None

Appendix I2.10: Q10 Results

Nada
pon una opcion en espanol
Opcion en espanol y menos opciones de rasones para los redos
Report the redos exactly when they happen
I think it is fine the way it is
when place the redo system send the requested to sigmanest automatic
None

# Appendix J: Financial Analysis Calculations

## Appendix J.1: Scrap Cost Savings Estimate

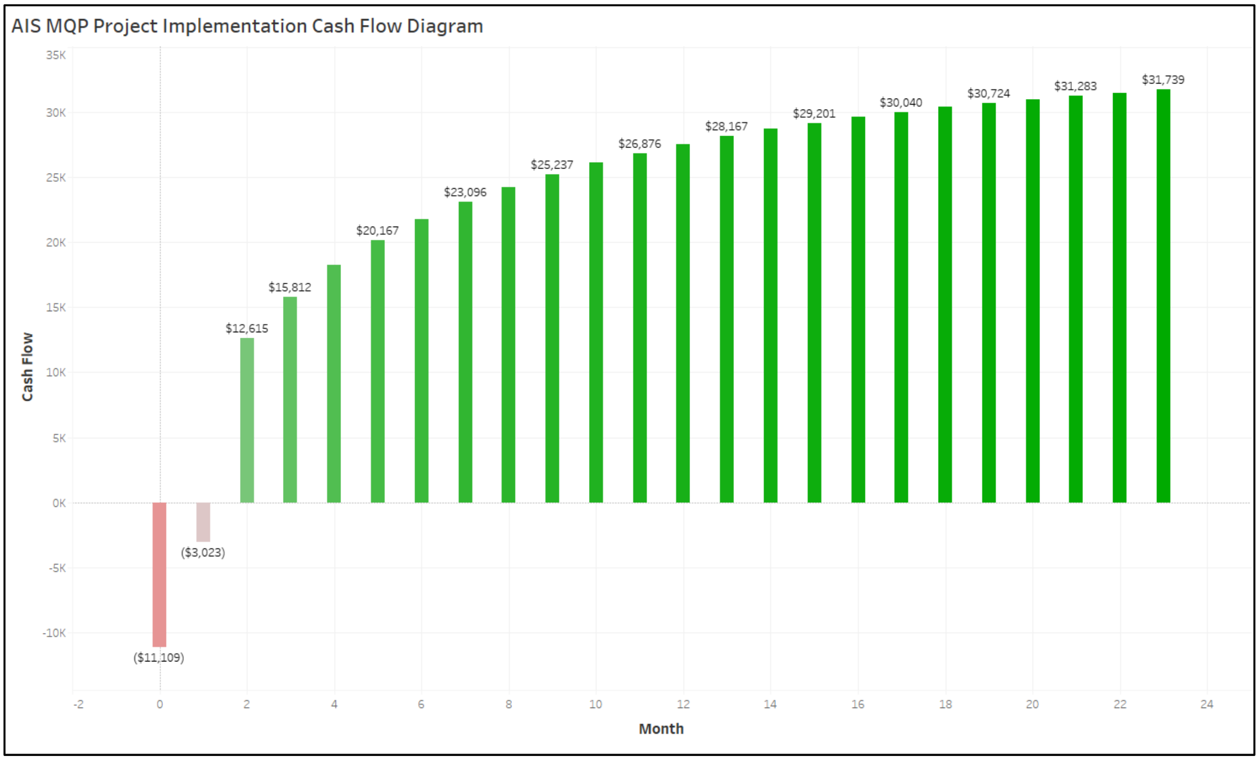



## Appendix J.2: AIS Financial Analysis Excel

| | | | |
|---|---|---|---|
| | Assumptions | | |
| Defect Type | Scratch | Chip | Other |
| Reason | Handling | Machine | N/A |
| % of total defects | 35% | 45% | 20% |
| Sq Ft of scrap | 672,578.43 | 864,743.69 | 384,330.53 |
| Cost of Scrap | $ 777,410.44 | $ 999,527.71 | $444,234.54 |
| Per monrth cost | $ 24,294.08 | $ 31,235.24 | $ 13,882.33 |
| | | | |
| Do we affect it? | Yes | Yes | Yes |
| | | | |
| What percentage? | | | |
| High estimate | 0.75 | 0.6 | 0.1 |
| Low estimate | 0.4 | 0.2 | 0 |
| | | | |
| Total Savings per year | | | |
| High Estimate | $ 218,646.69 | $ 224,893.74 | $ 16,658.80 |
| Low Estimate | $ 116,611.57 | $ 74,964.58 | $ - |

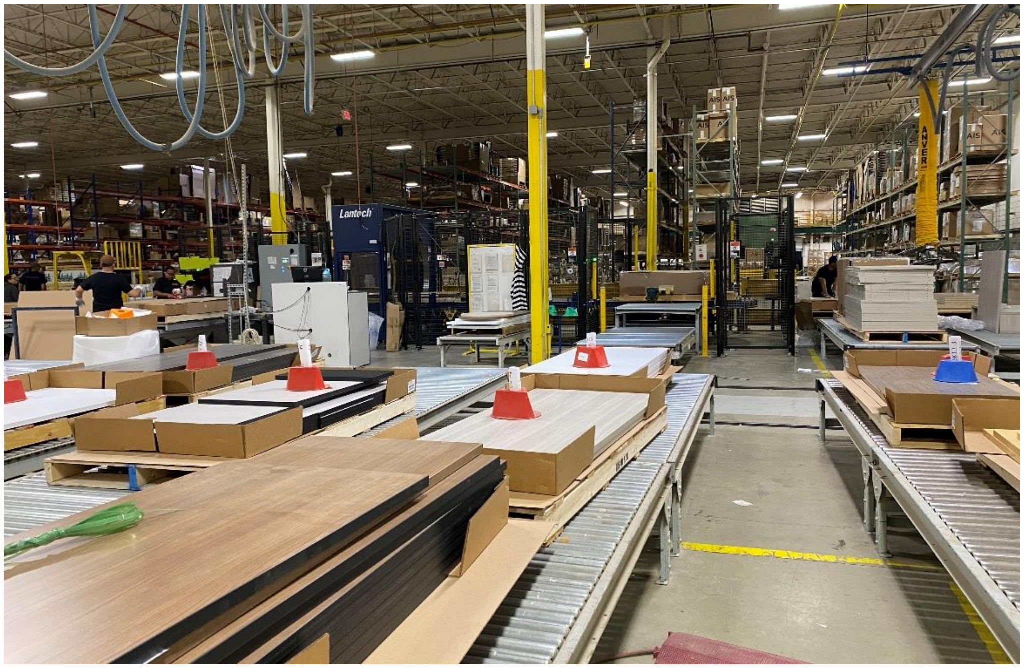
| | |
|---|---|
| Known Facts | |
| Time (months) | 32 |
| | |
| Total Order amount sq ft | 34,545,872.95 |
| Total Scrap Amount sq ft | 1,921,652.65 |
| | |
| Average cost per sq ft | $ 1.16 |
| | |
| Scrap % | 5.56% |
| Scrap Cost | $ 2,221,172.70 |
| Cost Per Month | $ 69,411.65 |

## Appendix J.3: Discounted Cash Flow Diagram

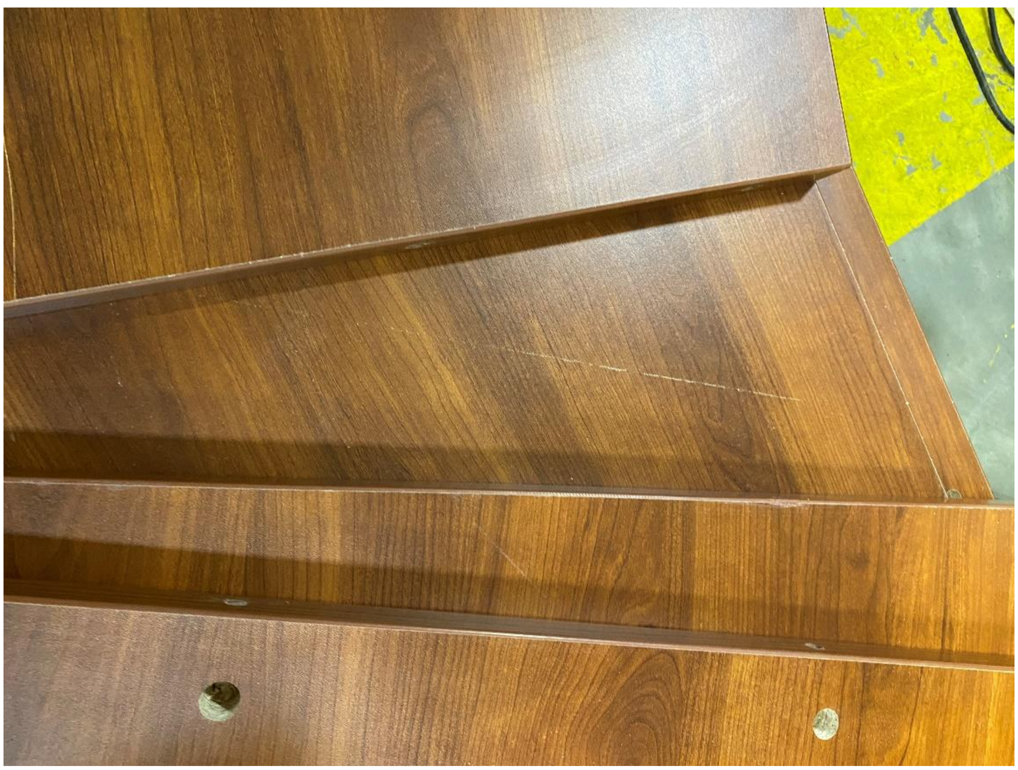


# Appendix K: Examples of Defects

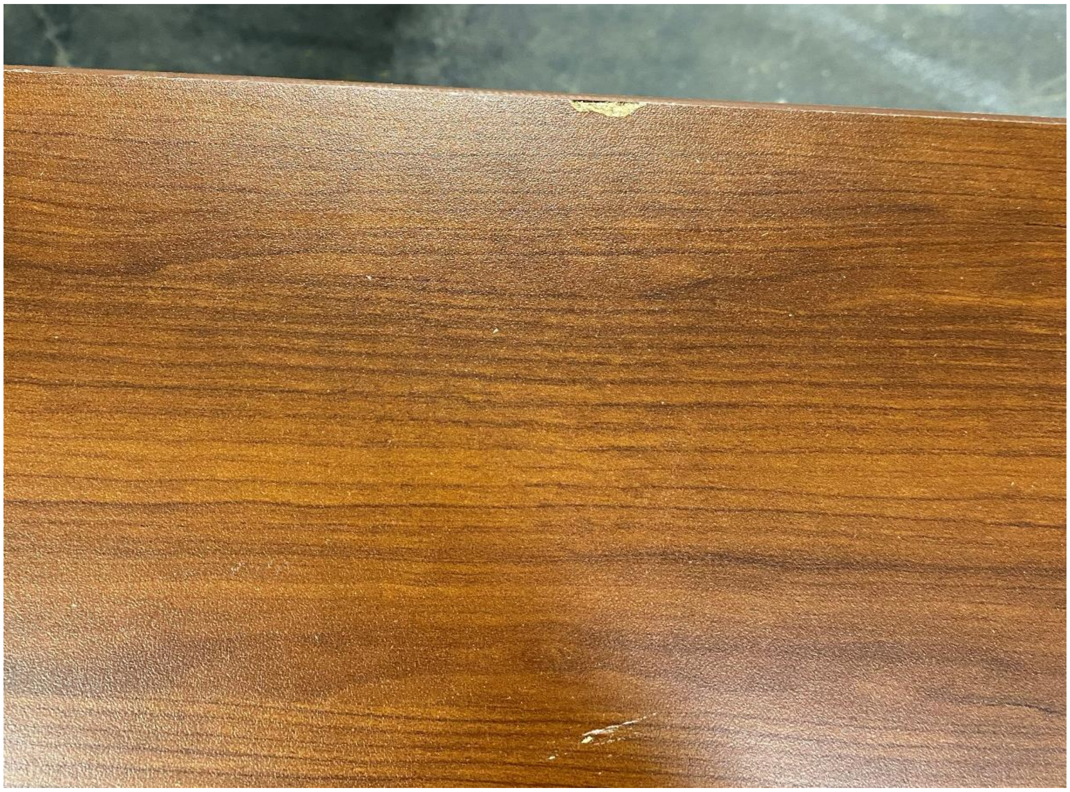
## Appendix K1: Visual Defect Tracking




## K2: Scratch Defect



## Appendix K3: Chip Defect



# Appendix L: Original AIS Standard Work Examples

## Appendix L1: SW511435-097 Worksurfaces Department Cleaning & Flipping

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| AIS STANDARD WORK | | Effective Date: | 8/14/2019 | Process: | Worksurfaces Cleaning and Flipping part | | File # : | SW511435-097 | |
| | | Revision Date: | 8/14/2019 | Department: | Manufacturing Support | | | | |
| Safety/Ergonomics | | SW Initiator: | | Date | Sup. App: | Date | Quality Rep Approval: | Date | |
| Quality Check | | Pedro Garcia | | 8/13/2019 | Larry Scangas | 8/13/2019 | | Rev A | |
| Work Elements | | Health & Safety Approval: | | Date | Env. Qty Rep App: | Date | Modified | | |
| Environmental | ISO 14001 | | | | | | | Total Pages: | 1 |

| | |
|---|---|
| PURPOSE: | |
| SCOPE: | |
| REFERENCES: | SW-511435-042 Worksurface Chip Repair |

PROCEDURE

| Icon | Work elements | Steps | Description |
|---|---|---|---|
| | Inspecting 1.0 | 1.1 | Inspect the part for any damage, scratches or chip<br>NOTE: To Repair the Chip damages follow the SW511435-042 |
| | Cleaning and flipping procedure 2.0 | 2.1 | **Use the cloth and the cleaner as per SW511435-011 to clean the worksurfaces. It must be cleaned by TWO employees if the part:**<br>**- Rectangular greater than 48"**<br>**- Round table grater than 36"**<br>**- Corners greater than 36"**<br><br>**Note: In case the part is lower than those sizes, carefully use the Velcro in the conveyor edge as support to flip them (See the picture 2.1a). This procedure it can be performed by one employee** |
| | | 2.2 | Both employees must clean their sides to eliminate any debris, glue, etc. |
| | | 2.3 | Both employees must flip the part carefully. |
| | | 2.4 | Then, clean the another side to eliminate any debris, glue, etc. |
| | | 2.5 | **It is not permitted to flip the part by one employee. ALWAYS ask for a helper to flip the part when is necessary** |

# Appendix L2: SW511435-066 Weeke Router (R4) Operation Rev. D

| | | | | | | |
|---|---|---|---|---|---|---|
| STANDARD WORK | Effective Date: | 3/23/2020 | Process: | R4 Operation | File #: | SW-511435-066 |
| | Revision Date: | 3/23/2020 | Department: | Worksurfaces | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Safety/Ergonomics | | SW Initiator: | Date | Sup. App: | Date | Quality Rep Approval: | Date |
| Quality Check | | AAlonso | 3/23/2020 | Jason Truscott | 3/23/2020 | | Rev D |
| Work Elements | | Health & Safety Approval: | Date | Env. Qty Rep App: | Date | Modified | |
| Environmental | | | | | | AAlonso | Total Pages: 30 |

| Icon | Work Elements | Steps | Description | |
|---|---|---|---|---|
| ◆ | Offloading | 11.1 | WARNING:<br><br>Review: SW511445-022 Anver Lifts Operation and 028- Anver Lift Safety<br><br>This page needs to be initialized by trainee<br><br>Use the outfeed overhead lift to lift the part off the outfeed conveyor and onto the stacking conveyor. While the part is in the air, use the opportunity to check the bottom of the board for quality and/or defects |    |

# Appendix  L3: SW511435-007 EB1 Operation

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| STANDARD WORK | | Effective Date: | 1/16/12 | Process: | EB1 Operation | | File # : | SW-511435-007 |
| | | Revision Date: | 4/17/19 | Department: | Worksurfaces | | | |
| Safety/Ergonomics | | | SW Initiator: | Date | Sup. App: | Date | Quality Rep Approval: | Date |
| Quality Check | | | Alexandre Cote | 4/17/19 | Jason Truscott | 4/17/19 | | Rev B |
| Work Elements | | | Health & Safety Approval: | Date | Env. Qty Rep App: | Date | Modified | |
| Environmental | | | | | | | 4/17/19 | Total Pages: |

| Icon | Work Elements | Steps | Description | |
|---|---|---|---|---|
| | | | Follow the steps below to turn off the machine | |
| | Turn Off | 1 | At the end of the shift press stop track and then control voltage power off button. |   |
| | | 2 | Turn the glue pot to the off position |  |
| | | 3 | Open up program "ALL OFF" and set the height to 55. This allows better access for cleaning the machine |  |
| | | 4 | Open up the edgebander doors. This allows the operator to get inside the machine and clean it. Once the machine is cleaned, shut the doors | |
| | | 5 | Wait until the application roller on the glue pot stops spinning. This means the machine is safe to shut down. |   |

# Appendix L4: SW511435-006 Contour

| STANDARD WORK | | | | | | | |
|---|---|---|---|---|---|---|---|
| Effective Date: | 9/5/2012 | Process: | Contour | | | File # : | 511435-006 |
| Revision Date: | 9/4/2020 | Department: | Worksurfaces | | | | |
| Safety/Ergonomics | | SW Initiator: | Date | Supervisor App: | Date | Qual. Rep App: | Date |
| Quality Check | | Odinir Braz Jr | 5/25/2012 | Jason Truscott | 9/4/2020 | | |
| Work Elements | | Health & Safety Approval: | Date | Env. Qual Rep App: | Date | | Rev B |
| Environmental | | | | | | | |

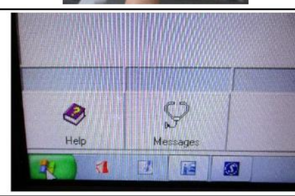
1 of 2

| ICON | NO. | WORK ELEMENTS<br>Series of Steps to Complete Job |
|---|---|---|
| ● | 1 | Step 1.) Make sure that the following match on the Sales Order and on the label:<br>A.) The order number<br>B.) The color of the T-Mold |
| ● | 2 | Pick T-mold from the Rack area and place it on the hanger above the cell table.<br>Note: Rack is labeled with the name of the edgeband, but make sure by checking the name on top of the roll. |
| ● | 3 | Move the part from the conveyor onto the routing table's suction pads and turn the air on to secure part. |
| ● | 4 | Measure the part and check the Grommet hole by using the measuring tape and the "Grommet Hole Gauge" (located above the cell routing table). |
| | 5 | Set up the hand router by following the steps below:<br>A.) Pick a scraped part as a test piece. |

VISUALS

# Appendix L5: SW511435-047 ABD 3 Operation

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| STANDARD WORK | | Effective Date: | 2/1/18 | Process: | ABD 3 Operation | File # : | SW-511435-047 |
| | | Revision Date: | 4/26/19 | Department: | Worksurfaces | | |
| Safety/Ergonomics | | SW Initiator: | Date | Sup. App: | Date | Quality Rep Approval: | Date |
| Quality Check | | Alexandre Cote | 4/26/19 | Alexandre Cote | 4/26/19 | | Rev C |
| Work Elements | | Health & Safety Approval: | Date | Env. Qty Rep App: | Date | Modified | |
| Environmental | | | | | | 4/26/19 | Total Pages: |

| | | | | |
|---|---|---|---|---|
| | | 4 | Turn on the overhead vacuum lift |  |
| Icon | Work Elements | Steps | Description | |
| | | | Follow the steps below to turn off the machine | |
| | | 1 | Press the control voltage off button |  |
| | Turn Off | 2 | Press the windows button |  |
| | | 3 | Select and press the shut down button |  |

# Appendix M: Standardized Must-Dos

## Appendix M1: ABD Must-Do (English)

### ABD MUST-DO

**BEFORE EACH SHIFT:**

| RUN SHIFT TEST: | MORNING TEST: |
| --- | --- |
| load “Morning_test.mpr” from MP4 folder | measure and compare the test piece drawing before continuing |

**If a damage, scratch, or chip is observed, REPORT IMMEDIATELY**

**REMEMBER TO:**

| | |
| --- | --- |
| Set foot clamps 1/4” above the part | Use a support stand when a part is longer than 48” |
| read label to identify specific details or unique parts | Read the part label to determine what program needs to be loaded |

References: SW511435-047 ABD 3 Operation

## Appendix M2: Clean & Pack Must-Do (English)

**CLEAN AND PACK MUST-DO**

**READ LABEL TO VERIFY EDGEBAND, LAMINATE, AND GROMMET CHOICE**

| | |
|---|---|
| every part should have a label | there are never extra parts |
| measure first part to ensure proper cut | use the cloth and cleaner to remove any glue or debris on both sides |

TOOLS FOR MEASURING DISTANCES:

| HOLE DEPTH AND HOLE DIAMETER | PART LENGTH AND PART DEPTH |
|---|---|
|  digital caliper preferred |  tape measure preferred |

**Inspect entire part for damages, scratches, or chips REPORT IMMEDIATELY**

**FLIP LARGE OR HEAVY PARTS WITH 2 PEOPLE**

GENTLY place the part on the conveyor

References: SW511435-097

## Appendix M3: Contour Must-Do (English)

**CONTOUR MUST-DO**

**READ LABEL ON TOP OF STACK FOR COLORS**

TOOLS FOR MEASURING DISTANCES:

| HOLE DEPTH AND HOLE DIAMETER | PART LENGTH AND PART DEPTH |
| --- | --- |
|  digital caliper preferred |  tape measure preferred |

**If a damage, scratch, or chip is observed, REPORT IMMEDIATELY**

References: SW511435-006

# Appendix M4: Router Must-Do (English)

## ROUTER MUST-DO

### EVERY 3 HOURS (AT MINIMUM):

| | | |
|---|---|---|
| change spoilboard | change router tool bit | log change in excel sheet |

### TOOLS FOR MEASURING DISTANCES:

| HOLE DEPTH AND HOLE DIAMETER | PART LENGTH AND PART DEPTH |
|---|---|
|  digital caliper preferred |   tape measure preferred |

### DURING EACH SHIFT:

| OPERATOR | | CATCHER | |
|---|---|---|---|
| Compare the test piece drawing before continuing | Use air hose to clean spoil board during operation | Use overhead lift to put part on conveyor | Stack properly and tape paperwork on top of stack/kit |

**If a damage, scratch, or chip is observed, report immediately**

References: SW-511435-066 Weeke Router (R4) Operation, SW511435-069 Troubleshooting, SW 511445-022 Anver Lift, 028- Anver Lift Safety, 015-CNC Router Safety

# Appendix M5: Edgebander Must-Do (English)

## EDGEBANDER MUST-DO

**REMEMBER TO:**

**READ LABEL ON TOP OF STACK FOR EDGEBAND REQUIRED**

| | | |
|---|---|---|
| input all workpiece thicknesses in mm | ALWAYS set panel oversize at 31.5mm | never run one edgeband over another one |

**TOOLS FOR MEASURING DISTANCES:**

| HOLE DEPTH AND HOLE DIAMETER | PART LENGTH AND PART DEPTH |
|---|---|
|  digital caliper preferred |  tape measure preferred |

**WHILE OPERATING EDGEBANDER:**

| | | |
|---|---|---|
| check for appropriate board thickness | do not remove loaded parts on top of infeed sensor/pin | wait for loaded part to pass indicated mark before loading next part |

**BEFORE FEEDING A BOARD INTO THE MACHINE:**

| | |
|---|---|
| verify no metal is inserted | remove previous edgeband |

**TO FEED THE EDGEBAND:**

| ① | ② | ③ |
|---|---|---|
| stop edgeband with red button | feed in front of the metal rollers | feed under the plastic wheel |
| ④ | ⑤ | ⑥ |
| feed up to where all the channels meet | feed into the edgeband channel | feed in between the two guide rollers |

**Lower the pressure plates onto the edgeband to keep it from riding up.**

**If a damage, scratch, or chip is observed, REPORT IMMEDIATELY**

References: SW511435-007 EB1 Operation, SW511435-008 EB2 Operation, SW511435-030 EB3 Operation, SW511435-052 EB4 Operation

## Appendix M6: ABD Must-Do (Spanish)

# ABD OBLIGATORIO

**ANTES DE CADA TURNO:**

| EJECUTAR PRUEBA DE TURNO: | PRUEBA DE LA MAÑANA: |
|---|---|
| carga “Morning_test.mpr” desde la carpeta MP4 | mida y compare el dibujo de la pieza de prueba antes de continuar |

**Si se observa un daño, rasguño o astillado, INFORME INMEDIATAMENTE**

**RECUERDA:**

| | |
|---|---|
| Coloque las abrazaderas de pie 1/4" por encima de la pieza | Utilice un soporte de apoyo cuando una pieza sea más larga de 48” |
| Lea la etiqueta para identificar detalles específicos o piezas únicas | Lea la etiqueta de la pieza para determinar qué programa debe cargarse |

Referencias: SW511435-047 ABD 3 Operation

## Appendix M7: Clean & Pack Must-Do (Spanish)

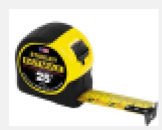
### OBLIGATORIO LIMPIAR Y EMPACAR

| | |
|---|---|
| **LEA LA ETIQUETA PARA VERIFICAR, EDGE-BAND, LAMINADO Y SELECCIÓN DE OJALES** | **COMPARE LA ETIQUETA CON EL DOCUMENTO, ASEGÚRESE DE QUE COINCIDAN** |

**RECORDATORIOS:**

| | |
|---|---|
| cada parte debe tener una etiqueta | nunca hay piezas extra |
| mida la primera parte para asegurar un corte adecuado use el paño y el limpiador para | Retire cualquier pegamento o escombros en ambos lados |

**HERRAMIENTAS PARA MEDIR DISTANCIAS:**

| PROFUNDIDAD DEL AGUJERO Y DIÁMETRO DEL AGUJERO | LONGITUD PARTE Y PROFUNDIDAD PARTE |
|---|---|
|  calibre digital preferido |  cinta métrica preferida |

**Si se observa un daño, rasguño o astillado, INFORME INMEDIATAMENTE**

**VOLTEE PIEZAS GRANDES O PESADAS CON 2 PERSONAS**

SUAVEMENTE coloque la pieza en el transportador

coloque láminas de espuma blanca entre cada superficie contorneada

toma al menos 5 fotos

Referencias: SW511435-097

## Appendix M8: Contour Must-Do (Spanish)

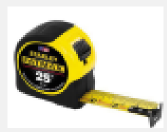
# Appendix M9: Router Must-Do (Spanish)

## ENRUTADOR OBLIGATORIO

**CADA 3 HORAS (COMO MÍNIMO):**

| | | |
|---|---|---|
| cambio de spoilboard | cambiar la broca de la herramienta del enrutado | registrar el cambio en la hoja de Excel |

HERRAMIENTAS PARA MEDIR DISTANCIAS:

| PROFUNDIDAD DEL AGUJERO Y DIÁMETRO DEL AGUJERO | LARGO Y PROFUNDIDAD DE LA PIEZA |
|---|---|
|  calibre digital preferido |  cinta métrica preferida |

**DURANTE CADA TURNO:**

| OPERADOR | | RECEPTOR | |
|---|---|---|---|
| Compare el dibujo de la pieza de prueba antes de continuar | Use una manguera de aire para limpiar el spoilboard escombros durante la operación | Use el elevador de techo para colocar la pieza en el transportador | Apile correctamente y pegue con cinta adhesiva el papeleo en la parte superior de la pila/kit |

**Si se observa un daño, rasguño o astillado, INFORME INMEDIATAMENTE**

Referencias: SW-511435-066 Weeke Router (R4) Operation, SW511435-069 Troubleshooting, SW 511445-022 Anver Lift, 028- Anver Lift Safety, 015-CNC Router Safety

# Appendix M10: Edgebander Must-Do (Spanish)

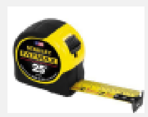
## OBLIGATORIO EDGE-BANDER

| | |
|---|---|
| **LEA LA ETIQUETA PARA VERIFICAR, EDGE-BAND, LAMINADO Y SELECCIÓN DE OJALES** | **COMPARE LA ETIQUETA CON EL DOCUMENTO, ASEGÚRESE DE QUE COINCIDAN** |

### RECORDATORIOS:

| | | |
|---|---|---|
| Ingrese todos los espesores de la pieza de trabajo en mm | SIEMPRE ajuste el tamaño del panel a 31.5 mm | nunca pase un canto sobre otro |

### HERRAMIENTAS PARA MEDIR DISTANCIAS:

| PROFUNDIDAD DEL AGUJERO Y DIÁMETRO DEL AGUJERO | LONGITUD PARTE Y PROFUNDIDAD PARTE |
|---|---|
|  calibre digital preferido |  cinta métrica preferida |

### MIENTRAS USA EL EDGE-BANDER

| | | |
|---|---|---|
| verifique el grosor adecuado de la placa | no retire las piezas cargadas en el sensor/pin | espere a que la parte cargada pase la marca indicada antes de cargar la siguiente parte |

### ANTES DE INSERTAR UNA TABLA DE MADERA EN LA MÁQUINA:

| | |
|---|---|
| Verifique que no haya metal insertado | eliminar el edge-bander anterior |

### PARA ALIMENTAR LA EDGE-BANDER MÁQUINA

| ① | ② | ③ |
|---|---|---|
| detener edge-bander con botón rojo | alimentación delante de los rodillos metálicos | alimentar debajo de la rueda de plástico |
| ④ | ⑤ | ⑥ |
| alimentar hasta donde todos los canales se encuentran | alimentar el Edge-Bander canal | avance entre los dos rodillos guía |

**Baje las placas de presión sobre la banda de borde para evitar que se suba.**

**Si se observa un daño, rasguño o astillado, INFORME INMEDIATAMENTE**

Referencias: SW511435-007 EB1 Operation, SW511435-008 EB2 Operation, SW511435-030 EB3 Operation, SW511435-052 EB4 Operation

# Appendix N: Tool Life and Material Storage Analysis

## Appendix N1: Tool Life, Resharpened vs. New

Currently AIS uses Half Inch, 2 flute, coated router tools for their main milling operations and as mentioned during the tour, their main goal is to maximize cost and efficiency over the rate at which they would want to have to change out tools due to chipping or defective cuts. Therefore it is important to analyze whether utilizing resharpened tools versus buying new tools at a more expensive price would hinder production and cost them more money in the long run. From a technical standpoint, a resharpened tool will always be smaller than the original and therefore will not be running at its most ideal feeds and speeds since a smaller diameter will require the spindle to be run at a higher speed to achieve the same cutting rate and material removal. Because of the small variations in size in each resharpened tool bit, these changes are never done and in most cases lead to slight amounts dragging on the materials surface. While in practice this is almost impossible to notice, when the tool's use is extended, in almost all circumstances, a resharpened tool will have a lower tool life and lead to earlier onset of defects than a new tool.

## Appendix N2:  Tool life, Chip Evacuation

Chip evacuation is a very important step in maintaining clean edges, limiting chipping, and early tool failure. In most machining applications this is done through the use of coolant that would be sprayed directly onto the tool and workpiece. However, for obvious reasons, this cannot be used in natural wood applications. The alternative is to use compressed air which would be directly aimed at the point of contact between the tool and the workpiece. This stream of air is designed to blow each individual chip off of the worksurface the second the tool has finished cutting it to ensure that it doesn't linger within the cut or hole and rub up against the tool to create additional wear and heat. My advice and analysis would be to look into ensuring that machines have proper chip evacuation processes in place unless they don't exist in the first place. Making sure pipes are clean from saw dust and air filters are free from debris is also important to ensure proper machine function

## Appendix N3: Tool Life, Feed Rate and Spindle Speed

Feed rate is the speed at which the machine is dragging the tool across the workpiece and spindle speed is the rate in rotations per minute at which the tool rotates around the center axis of the router's spindle motor. Both are considered the key fundamentals in producing both quality parts and keeping tool life at its maximum. Due to the grain structure of particle board and its natural variance in density and porosity, maintaining proper feeds and speeds through wood is one of the most difficult materials to develop long term analytical data from. Below are a set of techniques that can be used to better collect data and create a reliable set of information to which machine learning algorithms can be trained on in order to create more closed-loop control and prevent operator error.

## Appendix N4: Data Collection Techniques, In-Situ Temperature Analysis

Utilizing temperature sensors whether it be thermocouples placed on the workpiece or thermal imaging sensors placed throughout the machine, can greatly assist in providing a reliable set of data to which can be extrapolated for future production runs. This data can provide information on hot spots, as well as increased tool wear to which chips and defects can be detected and prevented before they occur.

## Appendix N5: Data Collection Techniques, Distance - Machined Analysis

A key metric that was being tested during my visit to the AIS facility was the use of keeping track of the distance traveled by each tool bit before they would be changed out. This is very important in understanding the limits of production for each tool since each laminated particle board can have a multitude of different sized parts on it which can lead to certain tools being used a lot more one day depending on the number of cutting passes needed. Expanding this program to every machine in the shop would be greatly beneficial in providing data to the management team.

## Appendix N6: Data Collection Techniques, Visual Inspection

At its most basic level, a visual inspection on both the tool and the workpiece is essential to prevent continuous bad parts if a tool or something else has gone bad. Taking a look at every couple of parts at the condition of the router bit is very important for an operator to gain a perspective at which level of where it is still acceptable to run and at which level its necessary to be changed. Since most production machines used what seemed like a single machining pass rather than splitting into two passes (roughing and finishing) this step is much more important.

## Appendix N7: Alternate Suppliers

In certain cases, when all other variables are accounted for, it's important to look back on the tooling bits themselves and determine whether going with a different supplier is worth the company's time and money. Different coatings offer different performance as well as the chemical composition of the tools themselves if their HSS (High Strength Steel) or Cobalt. The tools used in most applications at AIS were Cobalt which, while pricier than HSS, offers much better tool life. After studying the tool life utilizing the parameters mentioned above, it would be in the company's best interest to potentially test other products from alternative suppliers on the market to determine which tools are best suited for their application in addition to which tools will save them the most money in the long run.

## Appendix N8: Temperature effects on material (Wood/laminate)

Another key aspect in the production line is the material itself and being a massive warehouse, keeping the entire building under a constant climate control is difficult especially with the wild swings in temperature from the winter months to the summer months. While AIS does have a room for acclimating the material before being put into production. There have been times where material has been taken from cold or hot un-climatized storage and put straight into the production due to delays in the supply chain. While in practice this hasn't indicated too many issues on the production line, there hasn't been any tests or analysis done to understand how temperature affects their production line. Most often, when materials like wood get cold, they become more brittle and can sometimes chip easier. This can lead to more defects. If the material is too hot, it can lead to warping during machining. While both are not ideal in a production world, it would be in the best interest of AIS to do small scale studies on the effects of temperature in their own use cases to see whether the added cost of maintaining weeks long stock inside their climate-controlled warehouse is worth the added cost.

## Appendix N9: Storage Conditions - (Bending, Moisture Content, Dry Room)

In addition to the temperature conditions of the warehouse, the method on which the particle boards are stored are also an important parameter in how they perform on the cutting table. During my visit to AIS, I noticed several cases in which stacks of boards would be placed without supports or with improper supports underneath them while being stacked as high as the ceiling goes, this lead to significant bending and some cases cracking of boards at the bottom of the stack due to the shear amount of weight being put on them. In addition, it wasn't clear in my visit whether the moisture content and humidity of the environment was analyzed before going into production and the amount of water content within the material can have a significant effect on its long-term performance. Having a dedicated room that's sealed off from long term storage as well as the production floor would be the best way to maintain constant temperature and humidity levels to deliver a consistent product.

# Appendix O: Axiomatic Design

## Appendix O1: Axiomatic Design

FR0: Reduce scrap rate
FR1: Collect accurate scrap generation data
- FR1.1: Updating the reporting system UI
- FR1.2: Encourage employees to report defects on time

FR2: Regulate system
- FR2.1: Update standard work
- FR2.2: Increase standard work visibility

FR3: Improve communication between the hierarchy of employees

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DP0: Standard system to reduce scrap rate
DP1: New reporting system
- DP1.1: New UI layout to facilitate easy reporting
- DP1.2: Incentive program for on time defect reporting

DP2: Define processes with standard work
- DP2.1: Design must-dos
- DP2.2: Publish process standard work

DP3: Implement visual management tools to increase employee engagement in production and redo reporting

## Appendix O1: Axiomatic Matrix

| | | New reporting system | New UI layout to facilitate easy reporting | Incentive program for on time defect reporting | Define processes with standard work | Design must-dos | Publish process standard work | Implement visual management tools to increase employee engagement in production and redo reporting |
|---|---|---|---|---|---|---|---|---|
| | | **DP1** | **DP1.1** | **DP1.2** | **DP2** | **DP2.1** | **DP2.2** | **DP3** |
| Collect accurate scrap generation data | **FR1** | x | | | | | | |
| Updating the reporting system UI | **FR1.1** | | x | | | | | |
| Encourage employees to report defects on time | **FR1.2** | | | x | | | x | x |
| Regulate system | **FR2** | | | | x | x | | |
| Update standard work | **FR2.1** | x | | x | x | x | | |
| Increase standard work visibility | **FR2.2** | x | x | | x | x | x | |
| Improve communication between the hierarchy of employees | **FR3** | | | | | x | | x |