Process Improvement at Saint-Gobain

A Major Qualifying Project

Submitted to the faculty of

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of science in Industrial Engineering

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Date:

3/23/2023

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Abstract

The goal of this project was to reduce waste and add transparency around tunnel kiln operations at Saint Gobain's grinding wheel abrasives plant, supporting efforts to improve utilization. We applied business intelligence (BI), 5s, and DMAIC methods to analyze and implement solutions. Our proposed solutions included a tracking system for the batts that carry material through the kiln, visual management aids to identify incoming orders, and a kiln utilization BI dashboard.

Acknowledgments

We want to express our gratitude to the entire team at Saint Gobain for their help and support over the course of the project. We are proud to have had the opportunity to work alongside such dedicated professionals. Your willingness to share your expertise and knowledge, as well as your patience were invaluable to our project. We would specifically like to acknowledge the following people:

Thomas Moll - Manufacturing Manager, Saint-Gobain Abrasives

Omkar Bandal - WCM Engineer, Saint-Gobain Abrasives

Dave Goding – Floor Manager, Saint-Gobain Abrasives

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Dan Doherty - Combustion Engineer, Saint-Gobain Abrasives

Joe Burnett - Associate Team Lead, Saint-Gobain Abrasives

Saint Gobain Operators

Sharon Johnson – Project Advisor, WPI

Leadership Statement

All team members worked on the project collectively. At the beginning of the project everyone worked together while defining and understanding the manufacturing process at Saint Gobain. Later, the team was divided into two research focus groups. Gabriel and Holly focused on the kiln utilization dashboard, while Irune and Nicole focused on the queuing area visual management and batt disposal proposals. By dividing the project into smaller, more manageable tasks, we were able to focus and produce high-quality work in a shorter amount of time.

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1. Introduction

Present in 75 countries with more than 166,000 employees, Saint-Gobain is a global leader in light and sustainable construction. Saint-Gobain has been designing, manufacturing and distributing materials and services for industrial markets for the past 350 years. Their solutions are found everywhere: in buildings, transportation, infrastructure and in many industrial applications (Who Are We?, n.d.).

One of the solutions Saint-Gobain provides is high quality grinding wheels. At the former Norton Abrasives campus, in Worcester, Massachusetts, Saint-Gobain carries out the manufacturing process for vitrified grinding wheels. These wheels are processed with a mixture of glass and ceramic, then fired to finish. Grinding wheels are used in the manufacturing setting to shape and finish metals and other materials. Examples of industries that commonly use grinding wheels are automotive, aerospace, and construction (Who Are We?, n.d.).

Problem Statement

Saint-Gobain currently uses two types of kilns in the vitrified grinding wheel manufacturing process, continuous (tunnel) and periodic kilns. Materials are sent through the kilns which fire and complete the vitrification process in manufacturing grinding wheels. The tunnel kiln at Saint Gobain has the potential for improved utilization. Managers in the vitrified grinding wheel plant asked the project team to identify possible areas of impact, such as inventory management methods that could be used to track orders on the manufacturing floor.

Project Goal & Objectives

The overall goal of the project was to improve utilization of the tunnel kiln at Saint Gobain. To achieve this long-term goal, we concentrated on specific objectives. These objectives were to reduce waste, optimize the front end of the grinding wheel process, add transparency among manufacturing floor workers, and recognize bottlenecks within the system. Following the DMAIC process, we developed an understanding of three different improvement opportunities.

Project Deliverables

The team implemented three separate solutions to optimize, add transparency and reduce waste in the front end of the grinding wheel process. Soft time and cost savings are the metrics by which the project's success was measured. To accomplish these objectives, projects completed by the team include a visual management aid using flags that will organize material in queuing sections and a tracking system that will provide management with insight as to when they should release or order new batts, a flat object used to carry wheels within the kiln. Lastly the team was able to create a dashboard that will be shown on the manufacturing floor, that summarizes the utilization of the Saint Gobain tunnel kiln. The project deliverables consist of standard operating procedures (SOPs) for the Queuing Area Visual Management and Batt Disposal System projects that were implemented on the facility floor, a Dashboard Demo, and a Manual on how to build the dashboard. Along with these final deliverables, the team provided Saint Gobain with a list of recommendations to support continued advancement of each project discussed within this report.

2. Background & Literature Review

Throughout the team's report, several industrial engineering methodologies and manufacturing processes are discussed, specifically the manufacturing process of grinding wheels. The information provided in this section provides a foundation for the team's methodology and findings.

Manufacturing Process of Grinding Wheels

Grinding wheels provide an efficient way to shape and finish metals and other materials. Many manufacturers today use grinding wheels somewhere in their process, to sharpen tools, prepare surfaces, or cut metal. The manufacturing process of a grinding wheel is a lot like baking a cake. The manufacturer receives an order, makes a recipe, measures the ingredients, mixes the ingredients together, pours the mixture into a mold, and puts the mold in an oven. After the mold is removed from the oven, finishing touches are made, then it is packaged and given to the customer (Grinding Wheel Basics – What's in a Wheel, 2021). **Figure 1** shows the manufacturing process of grinding wheels at Saint Gobain, Worcester, MA, Plant 7.

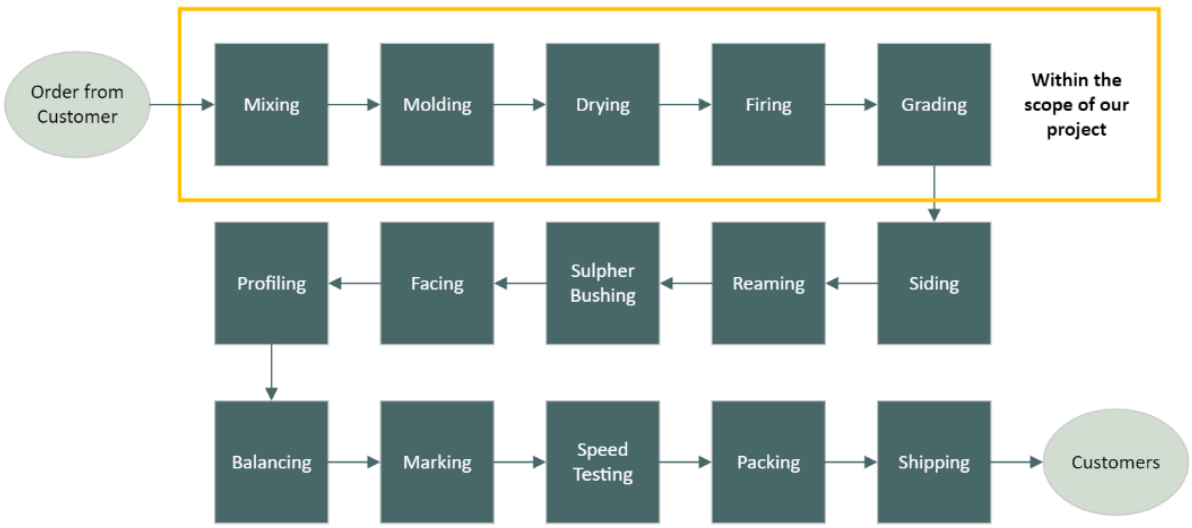


Figure 1: Manufacturing process at Saint Gobain.

Order Creation

Each order Saint Gobain receives is unique. What a customer orders depends on what they will be using the grinding wheel for. Some may want a vitrified bonding agent, aluminum abrasive grain, with a small circumference, while another may want an organic bonding agent, diamond abrasive grain, and large circumference.

Mixing/Materials

Grinding wheels can be customized to achieve different customers specifications. The combination of grains and bonds depends on the applicability of the grinding wheel and their

required precision. Abrasive grains, bonding agents, and air make up any grinding wheel. **Table 1** provides some examples of each, and why they are needed.

Table 1: Examples of key materials in grinding wheels and why they are needed.

Abrasive Grains	Bonding Agents	Air/Empty Space
Aluminum oxide Silicon carbide Zirconia Ceramic alumina Diamond	Vitrified – glass-like bond. Organic – resin or another agent	Materials that vaporize during the firing step Creating Voids or porosity
"Teeth" that cut material	Binds abrasive grains together	Allows grinding to be faster and cooler

Molding

Once mixed to the required consistency, the mixture is measured and pressed into the desired wheel size. The grinding wheel will eventually be sent through the kiln which will be described in greater detail later in this chapter.

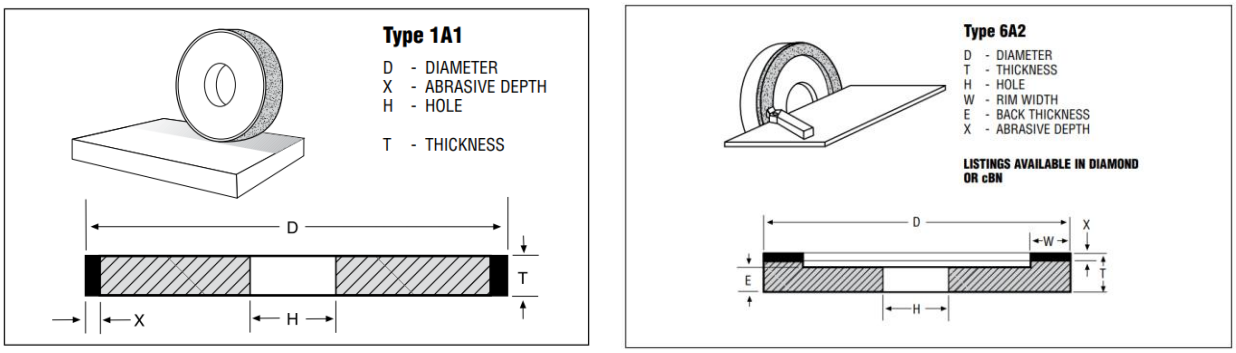


Figure 2: Typical grinding wheels, showing the dimensions that would be set during molding (Diamond and cBN Superabrasives, 2014).

Drying

Before the grinding wheels can enter the kiln, they need to be dried. Once off the molded platform, the batch of wheels will almost immediately be sent to the drying rooms. Once in the drying rooms the wheels will stay there for a pre-determined amount of time, depending on their size and composition.

Firing

After the grinding wheel molds have been dried, they are sent to a kiln. The purpose of the kiln is to vitrify the bonding material. Before this process the wheels are soft enough that they could break by hand. Firing the wheels bonds the abrasive grains and bonding agents together so that the wheel will hold its shape (Schneider, 2020).

Finishing

After firing, wheels are moved to a finishing area, where the wheel is modified to meet the customers specifications. Steps may be necessary to correct thickness, adjust the circumference, create special contours, or balance the wheels to reduce the vibration that occurs when the wheel is spun on a grinding machine. Once the wheels have been adjusted to their specific needs, they are ready for shipment to the consumer.

Current Floor Layout

The current process layout is presented in the spaghetti diagram in **Figure 3** and shows the material flow through the different processes. Understanding the floor layout allowed us to visualize how people and information move through the plant. Each colored box in **Figure 3** represents a process a grinding wheel needs to go through; the orange lines represent the flow of material on the floor.

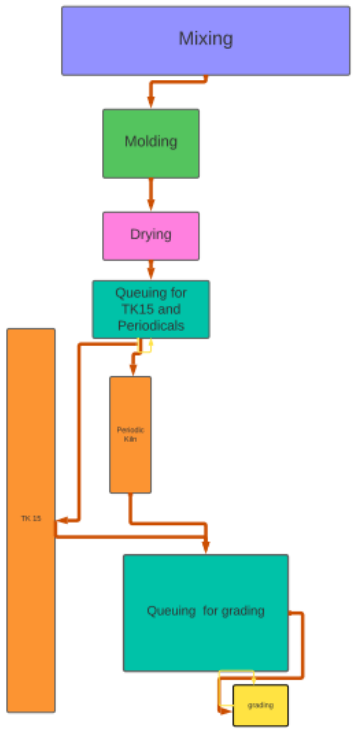


Figure 3: Spaghetti diagram of front-end steps in the abrasive process.

Tunnel Kiln Operations

Saint Gobain puts their grinding wheels through a tunnel kiln, or continuous kiln that runs 24/7. In a tunnel kiln, a car is assembled with wheels and loaded at a regular interval, then pushed through the kiln for its designated firing time. After, it comes out the other side of the kiln ready

to be disassembled. The process of assembling a car requires the operator to be taught layouts that optimize the square footage of the cars based on the size of wheels being assembled. A car cannot be sent through the tunnel kiln without material on it, and the kiln can never be shut off because it will disrupt the heat transfer and the vitrification process within the kiln. Therefore, when there are no orders ready to be sent through the kiln, Saint Gobain assembles the car with dummy material, material scraps that take up volume within the kiln.

A car is defined as underutilized whenever its square footage is not being optimized or is assembled with dummy material. Whenever space is being taken up by air or material that doesn't add any value to Saint Gobain, utilization decreases. Throughout kiln operations, unorganized queuing/holding areas and lack of ready materials can contribute to bottlenecks causing kiln underutilization.

The SIPOC diagram in **Table 2** describes the suppliers, inputs, process, outputs, and customers of Saint Gobain's tunnel kiln.

Table 2: SIPOC diagram to help explain the scope of our project.

Suppliers	Who supplies the inputs?	- Mixing + molding - Drying - Setting
Inputs	What inputs are required?	- Molded + dried + set grinding wheels - Information on what orders should go into the kiln next - Batts
Tunnel Kiln Process	Firing major steps:	- Select order to set - Plan the car's layout - Check MO - Visually inspect wheels - Select the proper bats for the kiln - Select proper setting medium (tabular alumina) - Select proper air ring to handle wheels - Surround wheel if MO states it - Select kiln blocks - Setting wheels - Transport stack to queuing area - Sign off MO - Taking orders off the cart
Outputs	What does the process output?	- Fired + hardened grinding wheels - Batts - Information about when this order should be graded
Customers	Who receives the outputs?	- Grading - Back-end department

Queueing Areas

Between each of the major steps in the manufacturing process, the grinding wheels are placed in a queueing area. For example, after the products are dried in the drying room, they get placed in a queueing area prior to being set for the kiln. Queueing areas around Saint Gobain are difficult to organize due to variety in product type, size and burn time. Unorganized queueing areas contribute to time spent searching for products for the next manufacturing step.

Batts

A crucial part of the grinding wheel manufacturing process includes the use of batts. A batt is that platform that grinding wheels sit on while being sent through the kiln. Batts can withstand the extreme temperatures within the kiln. Having access to functioning batts is essential to the firing process. The different types of batts in Plant 7 can be found in **Appendix D**.

There are two batt types that are extremely similar: solid batts and fluted batts. The primary distinction is that fluted batts have perforations on the bottom, making them lighter and using less fuel during the burning process. In contrast, the solid batts are more durable. However, the fluted batts are less expensive than the solid batts.

Certain varieties of batts break due to consistent usage. Currently, there are various locations across the plant where broken batts are disposed. There is no way to record the number of broken batts or their types.

DMAIC Process

The DMAIC process, which stands for Define, Measure, Analyze, Improve, and Control, is a problem-solving methodology. Throughout our project the team used the DMAIC approach to guide the projects process. The following describes each step-in detail:

- Define: The first step in the DMAIC practice is finding the problem, opportunities for improvement, and desired goals. In this step teams establish customer requirements and can create materials such as a team charter or value stream maps to completely understand what problems they will be targeting.
- Measure: This step focuses on measuring process performance. During this time metrics and measuring tools that will be used are defined. Current company processes are measured and data is collected.
- Analyze: During this phase of the DMAIC method, gathered data is analyzed and specific needs/ areas in a process is targeted. Iterations of implementations are assessed, and potential opportunities are revealed.
- Improve: In this step implemented solutions and factors within implemented projects can be advised once more information is found.
- Control: The last step in the DMAIC method is about controlling and maintaining implemented solutions and ensuring future performance. This is where the aforementioned 5S method can be used.

DMAIC focuses on process improvement using data-driven practices that break down processes in five different stages in order to improve, pivot, or discover setbacks and opportunities (Jacobson, 2016). Using this method, employees and managers are able to break down each step of any process and easily identify constraints. This method works toward continuous improvement of quality on manufacturing floors ("Define, Analyze, Measure...", Asq.org).

Lean Tools to Develop Process Understanding

Spaghetti charts are a process mapping tool that visually represents the flow of people or material through a process. The chart consists of a floor plan or a map of the process area with lines tracing the path of movement of the people or materials. A study by Hussain et al. (2016) found that these are useful in identifying inefficiencies in the process, such as backtracking or unnecessary movements. They help in identifying areas where changes can be made to streamline the process and eliminate waste.

Value stream maps and flow charts are two different tools used in process improvement and process mapping. While they share some similarities, they also have some important differences.

Flow charts are useful in illustrating the steps of a process, sequence of steps, decision points, and activities involved in a process. It usually includes symbols to represent different types of actions, and arrows to show the direction of flow between steps. Masri et al. (2015)

Flowcharts have limitations in terms of analyzing the efficiency and effectiveness of the process. They may not capture all the sub-steps or decision points, making it difficult to identify inefficiencies. Additionally, they may not differentiate between value-add and non-value-add activities, making it challenging to identify areas where value can be added, or waste can be eliminated.

A Value Stream Map (VSM) is an essential lean tool that identifies every step of an engineering process and whether or not value is added during the step, following a flow chart format. When created correctly a VSM can identify waste, reduce process cycle times and implement process improvement (What is Value Stream Mapping? ASQ). Creating a VSM should be a team effort in order to ensure transparency throughout the entire manufacturing process. The following lists key information that should be included in ones VSM:

- Cycle time or processing time
- Changeover time
- Reliability of equipment
- First pass yield
- Quantities
- Number of operators and shifts
- Hard copy information
- Electronic information
- Inventory levels
- Queue or waiting times

In summary, both flow charts and value stream maps can be used to map processes and identify areas for improvement. VSM provides a more comprehensive and detailed analysis of the process by focusing on the value stream and value-added activities in a process.

5S and Visual Management

Visual management aids provide multiple key principles that support efficiency throughout manufacturing facilities and manufacturing processes. First, visual aids provide self-explanatory cues, reiterating certain processes and/or safety procedures. They also work to make information accessible for all employees. Depending what type of visual aids are created, they can provide real time information, stand out data, and create a visually engaging and motivating workplace.

5S is a type of methodology that focuses on creating clean and organized workspaces. Each S in the five-step process represents; sort, set in order, shine, standardize, and sustain. This lean manufacturing process is designed to focus on the value of products and services for the customer. Using the 5S process can promote efficiency and eliminate waste throughout different departments ("5S Lean Methodology").

To implement 5S methods in a manufacturing setting it takes a dedicated team that is designated to oversee the implementation process. 5S requires adequate training for employees to ensure that lean goals and certain processes/methodology are transparent among employee levels. Experimental trials should be conducted and from trials clear metrics for specific goals can be created. Without specific guidelines implementing 5S implementation can cause confusion and frustration among employees. When done right 5S can improve productivity, enhance safety, reduce waste, and improve employee and customer satisfaction.

Business Intelligence

Business intelligence (BI) is a broad term that covers the technologies, applications, and processes for gathering, cleaning, storing, analyzing, summarizing, and visualizing data to help make better decisions. Analytics tools are used to visualize and explore the patterns and trends in data to predict future business outcomes as well as automate and optimize business processes. Successful companies use their data and analytics tools to gain competitive advantage within their industry (Sahay, 2018).

BI dashboards are one of the primary ways that businesses connect with actionable and relevant data. Selecting the relevant data, deciding what information the organization needs, developing the dashboard's structure, getting feedback, and adjusting the interface are typically the steps involved in creating a dashboard. Dashboards should be designed with clear language and visual representations that make the data easy to comprehend (Froese et al., 2016).

In manufacturing facilities, BI dashboards allow the data to be collected, analyzed, and presented in real-time, enabling managers to make informed decisions quickly (Conner, 2020). Dashboards can provide insights by presenting information in a way that highlights patterns, trends, and anomalies in the data. They can address the needs of the business by presenting data that highlights inefficiencies or bottlenecks in the manufacturing process. Overall, BI dashboards provide a valuable tool for manufacturing facilities, as they help managers to track key metrics, identify areas of improvement, and make data-driven decisions.

3. Methodology

To achieve our project objectives of adding transparency, identifying bottlenecks, reducing waste, and optimizing the front end of tunnel kiln operations, we followed the DMAIC process. The following chapter outlines the process the team used to complete the project during a five-month period.

Define

At the outset of the project, the team began researching and understanding the entirety of the grinding wheel production process. The team started conversations with management to determine their business needs and understand which areas to prioritize.

With the help of management, the team was able to define the problem, scope, and ideal goals to complete the project. Once the project goals were established, we were able to create a timeline using a Gantt chart for completing the project over the five-month period.

Measure & Analyze

The measure and analyze steps are critical components of the problem-solving process. We took the following steps:

- Identified inputs and outputs of the kiln, kiln utilization records, batt disposal records, and employee feedback about queuing areas/kiln as data we needed.
- Collected the data by asking for records from management, interviewing employees, and observing the process.
- Analyzed the data to understand the problem and identify trends.
- Used tools such as a SIPOC diagram and a process map to identify areas responsible for low utilization, waste production, long cycle time, and bottlenecks; these can be found in **Chapter 2.**
- Developed and evaluated potential projects based on recognized areas of improvement.
- Established 3 projects to move forward with. The methodology for these projects is described below; findings can be found in **Chapter 4**:
    - Kiln Utilization Dashboard
    - Visual Management for Pre-Kiln Queuing Area
    - Batt Disposal Tracking

Improve & Control: Kiln Utilization Dashboard

To implement a utilization dashboard the following steps were taken:

- Determined what visualizations to use on a dashboard, thinking about what type of insight management and operators want from the dashboard.
    - The current state of the kiln
    - Historical data on utilization
- Designed a wireframe of the initial user interface in PowerPoint.
- Received feedback from Saint Gobain management and made changes to the interface.
- Explored different platforms such as Excel (VBA), Python, and Power BI to create the dashboard.

- Determined Power BI was the best platform to create a BI dashboard within Saint Gobain's IT infrastructure.
- Created a working prototype in Power BI.
- Developed a manual (Found in **Appendix A**) to explain the insight each graphic on the dashboard provides, how Microsoft forms, Excel and Power BI are connected, and how to prepare the data in Power BI so that it can be used to make the visualizations.

Improve & Control: Visual Management for Pre-Kiln Queuing Area

In order to improve and control the queuing area visual management the follow steps were taken:

- Developed several proposals by collecting information about how material in the queuing area might be organized.
- Implemented flags, focusing on one type of product material for initial trials.
- Three iterations of flags were tested over the course of two months.
- Updated visual aid based on feedback by improving color contrast/visibility and color designations for material.
- Created a Standard Operating Procedure (SOP) for visual management in the queuing area that describes how it used and how to maintain the system.

Improve & Control: Batt Disposal System

To improve and control the tracking of batts on the manufacturing floor the following steps were taken:

- Understand the current batt disposal system used on manufacturing floor, including:
  - Location
  - Recording system
  - Types of batts
- Conducted a Gemba walk around the manufacturing floor to update the existing document that lists current types of batts. (Found in **Appendix D**)
- Proposed 3 new systems to record broken batts.
- Received feedback from management about the system that would work best with their IT infrastructure.
- Decided Microsoft forms and two disposal sites should be implemented to track broken batts.
- Created a pivot table using artificial data, and recommended Saint Gobain performs cost vs quality analysis once data is collected.

4. Findings

To achieve our project objectives, the team followed a DMAIC methodology and applied various tools to collect and analyze data. This chapter presents the key findings of the project. The findings also serve as the basis for recommendations for continued implementation.

Kiln Utilization Dashboard

To improve the utilization of Saint Gobain's tunnel kiln we created a visual dashboard that shows the real time utilization of the kiln. This dashboard will allow managers and operators to monitor performance, notice trends in data, predict future production, and optimize the kiln process.

The team's deliverable was a dashboard prototype using fabricated data on the utilization of the tunnel kiln. **Figure 4** shows a wireframe of the dashboard created in PowerPoint to help design the dashboard's appearance.

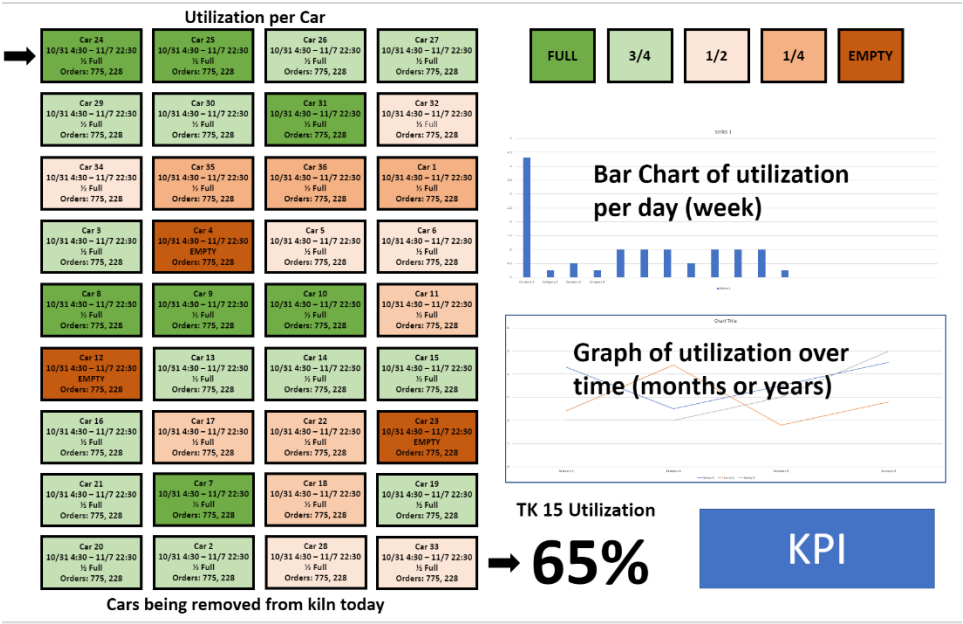


Figure 4: Wireframe of future dashboard in PowerPoint.

When designing the wireframe, we considered what type of insight management and operators want from the dashboard. They wanted to be able to see where orders are in the kiln at any given moment, as well as determine the current utilization of the kiln and then track it over time. The kiln is considered underutilized whenever its square footage is not being optimized or is assembled with dummy material. Whenever space is being taken up by air or material that doesn't add any value to Saint Gobain, utilization decreases. Utilization is calculated by recording the square footage of value adding material on each car and dividing it by the square footage of all the cars in the tunnel kiln.

The current state of the kiln is represented in the Car Train and Utilization KPI (Key Performance Indicator). These charts give management insight into the utilization (color coded) and position of each car, what cars are exiting the kiln next (the car next out of the kiln is at the

bottom right), as well as what orders are within the kiln. This graphic provides transparency and tracking capabilities on the manufacturing floor.

Historical data on utilization of the kiln is represented in the Average Utilization by Week Over Time chart, and the Utilization of Car by Day of the Week chart. These charts will show trends, patterns, and anomalies in the data that can help management identify bottlenecks and inefficiencies on the floor.

Given the positive feedback from Saint Gobain managers on the initial design, we created the first iterations of the dashboard. The first two iterations were created using VBA and Python. While successful in producing a dashboard with these tools, we ran into issues with implementing a dashboard on the Saint Gobain floor. For example, Saint Gobain does not allow python script running constantly on their manufacturing floor due to security concerns.

To create the final prototype we used Power BI, a Microsoft application that summarizes and visualizes data to help make more coherent and visually pleasing visualizations. An image of the final dashboard is shown in **Figure 5**.

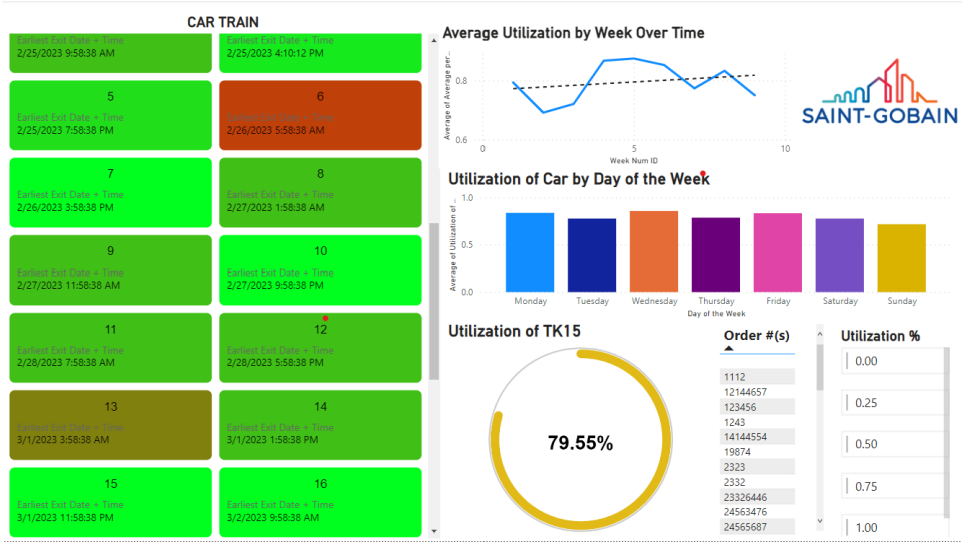


Figure 5: Final user interface of dashboard in Power BI.

The process by which the dashboard gets used starts on the manufacturing floor. A Microsoft form will be displayed on the computer on the floor next to where the cars are assembled and disassembled. Each time a new car is sent through the kiln the operator will need to fill out the form with the car number, the utilization of the car, and the order numbers that are on the car. This will automatically populate an excel sheet. This Excel sheet is then imported into Power BI to create a visual dashboard. After importing the raw data from excel there are multiple steps that need to be taken to prep the data for visualizations within the dashboard.

Once dashboard is made and implemented Managers can interact with it. They can click on a car in the Car Train and the orders and utilization will pop up in the bottom right. Or inversely search for an order and the car will be highlighted in the Car Train. Implementing this dashboard

on the floor will enable visibility into operations, and insights flow from visibility (Conner, 2020).

A TK15 Utilization Dashboard Manual, which is included in **Appendix A** provides detail about how we developed the utilization dashboard, the insights it offers, how Microsoft forms, Excel, and Power BI are connected, and how to prepare the data in Power BI so that it can be used to create the visualizations.

Recommendations

Based on the findings of this project, several recommendations can be made to Saint Gobain to sustain the dashboard moving forward:

- Set up the dashboard in Saint Gobain's SharePoint and implement automatic updates to improve the accuracy and timeliness of the data collected and provide real-time insights into the process.
- Integrate the dashboard into the existing IT infrastructure, get it up and running on the floor.
- Address the underutilization strategically, with a focus on improving the workflow and removing bottlenecks in the process.
- Set up a support and feedback system for workers, with the goals of improving morale and increasing engagement, leading to a more productive and efficient manufacturing process.
- Ensure the dashboard is updated to ensure it continues to meet the needs of the business.

Queuing Area Visual Management

We recognized the setting process as a bottleneck in Saint Gobain's kiln operations. The setting process involves taking material from the drying rooms and storing them in the queuing area (just outside the drying room) before they are sent to their designated kiln. To increase the capacity of the setters (an employee who sets orders in the queuing area) on the manufacturing floor we implemented a visual management system using flags within the previously unorganized queuing area. This system reduces motion waste by allowing setters to spend less time searching for their next order as well as waiting waste by reducing the time firemen (an employee who sets carts and sends material through kilns) spend waiting for ready material. In return, this produces soft cost and time. This allows setting operations to run according to schedule, which can lead to less dummy material needing to be sent into the kiln. This is important due to cars needing to be sent through the kiln at set times.

The team created a visual management aid using flags that eliminates time wasted due to previous inorganization. Before deciding upon a final proposal, the team introduced two other visual management aids, seen in **Figures 6** and **7**. The first uses projectors and posters to designate color coded floor space, and the second uses colors to designated certain orders on an MO sheet that corelate with color designated floor space. Ultimately these two alternatives did not create the needed level of organization the team had hoped for and were difficult to adjust to account for product overflow.

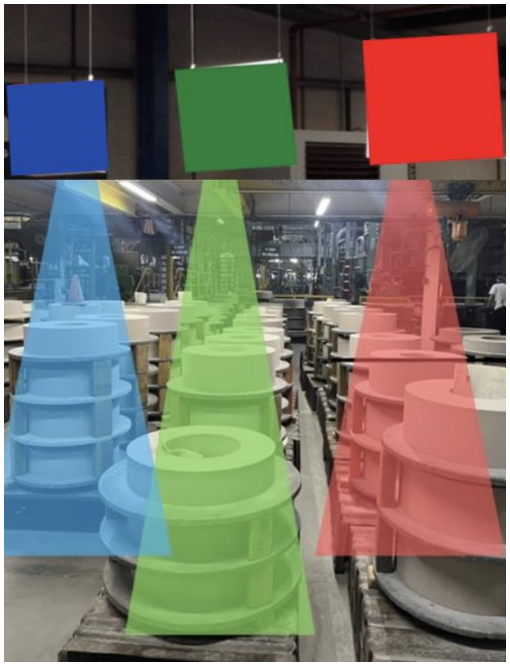
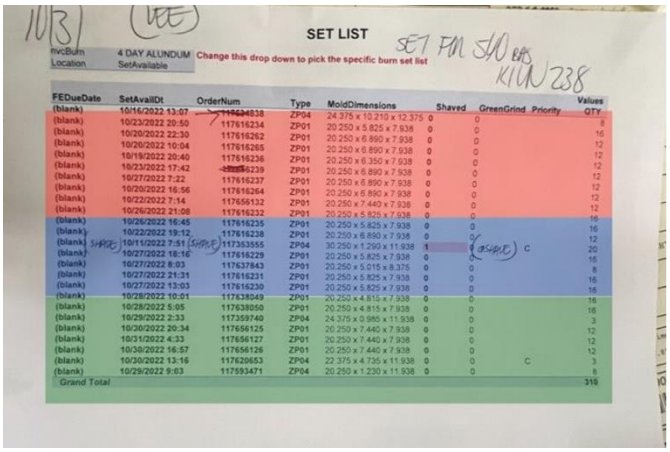


Figure 6: Visual management using projectors.



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(blank)	10/26/2022 16:45	117616235	ZP01	20.250 x 5.825 x 7.938	0	0		16
(blank)	10/22/2022 19:12	117616238	ZP01	20.250 x 6.890 x 7.938	0	0		16
(blank)	10/11/2022 7:51	117353555	ZP04	30.250 x 1.290 x 11.938	1	0	C	12
(blank)	10/27/2022 18:16	117616228	ZP01	20.250 x 5.825 x 7.938	0	0		20
(blank)	10/27/2022 8:03	117637843	ZP01	20.250 x 5.015 x 8.375	0	0		16
(blank)	10/27/2022 21:31	117616231	ZP01	20.250 x 5.825 x 7.938	0	0		8
(blank)	10/27/2022 13:03	117616230	ZP01	20.250 x 5.825 x 7.938	0	0		16
(blank)	10/28/2022 10:01	117638049	ZP01	20.250 x 4.815 x 7.938	0	0		16
(blank)	10/28/2022 5:05	117638050	ZP01	20.250 x 4.815 x 7.938	0	0		16
(blank)	10/29/2022 2:33	117359740	ZP04	24.375 x 0.985 x 11.938	0	0		3
(blank)	10/30/2022 20:34	117656125	ZP01	20.250 x 7.440 x 7.938	0	0		12
(blank)	10/31/2022 4:33	117656127	ZP01	20.250 x 7.440 x 7.938	0	0		12
(blank)	10/30/2022 16:57	117656126	ZP01	20.250 x 7.440 x 7.938	0	0		12
(blank)	10/30/2022 13:16	117629653	ZP04	22.375 x 4.735 x 11.938	0	0	C	3
(blank)	10/29/2022 9:03	117593471	ZP04	20.250 x 1.230 x 11.938	0	0		8
Grand Total								318

Figure 7: Visual management using color-coded order sheet.

The chosen visual management aid, the team used bright-colored flags that are placed on orders to identify which kiln they need to be taken to next. These flags were cut and laminated then placed on the floor. The colors are designated as shown in **Figure 8.**

Figure 8: Final colors of flags used to organize the queueing area.

Using restaurant order stands, the flags can be seen from any point of view within the queueing area. In order to store the flags and make the process more organized we designated a small bin beside the drying area where flag stands are placed; see **Figure 9**. The team also created a visual aid board that displayed what color flags are designated for each type of order, along with a small folder where extra flags were kept, as shown in **Figure 8**.

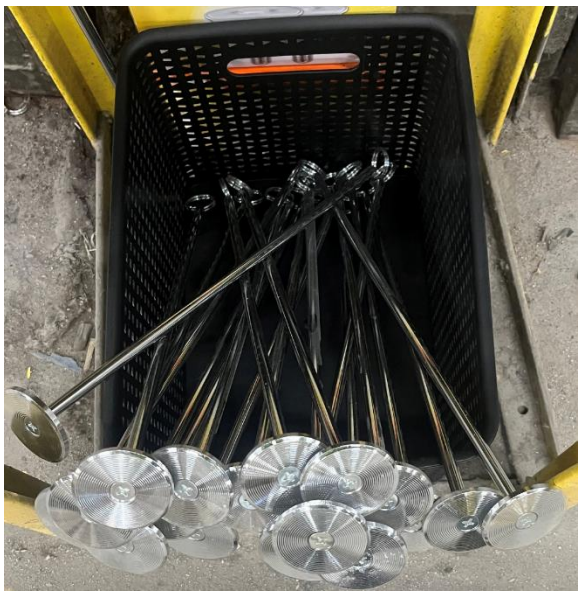

Figure 9: Container designated for flag stands.

The team went through three iterations implementing the flags. The first time our team implemented flags we designated one color, neon orange, for kiln TK15 for five weeks. To test this implementation the team and management visited the queuing area regularly at the

beginning and end of the five weeks and ensured that the flags were being used in the correct way. This iteration can be seen in **Figures 10** and **11**, which show a closeup of the flags and their use in the queuing area.

Figure 10: 1st flag iteration.

Figure 11: Flags on material in queuing area.

Once the singular flag testing proved successful, in the second iteration, the team chose four colors for the four different kiln burns. The team wanted to choose colors that were not used anywhere else in the factory and wanted to avoid colors such as red and green to not cause any confusion regarding order status. Our first set of colors came out as purple, blue, gold, and red.

As a final iteration, we decided to change these colors because the original colors them blending into the facility background. The final colors can be seen in **Figure 8**.

The team discovered that factory floor personnel quickly adopted the new visual aid with the assistance of the floor manager. The team frequently talked with floor employees and asked what we could change or add, not only to make the visual aids more effective, but to accommodate what works best for employees. To ensure uniform use of the visual management system, we designed a Standard Operating Procedure (SOP) as shown in **Appendix B**. Key elements instructed in the SOP include where to find the stands, how to assemble a flag, and which colors corelate with which products.

Unintentional organization was a further discovery resulting from the implementation of visual management. The employees began placing orders in "designated" areas according to the type of burn required for each product. Due to this new organization with visual management, anywhere from two to ten minutes are saved in searching for products. Due to the variable quantity of products in the queueing area, the amount of soft time and cost savings varies.

It is also important to note that flag creation by the setter can add time when adding a flag to product orders. Although the flags would cause added time, the time saved by other employees responsible for identifying and taking material away from the queuing area is much greater.

Recommendations

To ensure continuous improvement and maintenance of the visual management within the queuing area, the team leaves Saint Gobain with the following recommendations:

- Make the SOP an official document and continue to update this document as the visual management grows or changes. We also recommend that this document be used as learning material for new employees.
- The team recommends continuous maintenance of the flags. This includes ensuring all stands are checked after long term use and flags are checked and changed after wear; this is due to flags becoming flimsy after constant use. Another part of this recommendation would be to consider the use of hard plastic to use as flags instead of laminated paper.
- Our final recommendation would be to explore a more ergonomically appropriate place for the flag stands, as well as introducing different areas that flags can be placed throughout the queuing area.
- To control the visual aid, flags should be screened regularly to ensure flags are being used in the appropriate areas.
- In every shift the employee who takes out products from the drying room is designated to create flags. This includes taking a stand and the appropriate colored flag and then placing it on material before storage.
- Check flags for any damage and remake flags after long term use.

Batt Disposal System

When material is sent through the kiln, each grinding wheel is set on a batt and then loaded onto a car. The continuous pressure from the weight of the grinding wheels results in batts breaking

often. Currently, when a batt breaks, it is unknown what type of batt and how many broke, which is problematic since management does not know whether to order batts in advance or when to release inventory. Sometimes, the firemen who operate the kilns or the setters who prepare materials are unable to set materials due to a lack of batts, which reduces kiln utilization and complicates management monitoring.

To improve existing documents listing the types of batts used on the floor, the team did a walk around the facility to gather the names and images of the various sorts of batts used. We created a document describing the type and size of each batt.

This knowledge allowed the team to understand and develop a tracking system by setting up a Microsoft form on a computer directly next to the Kiln area where workers can input the type of broken batt and its size. The form is shown in **Figure 12.** The team also recommended designated areas for batt disposal around the facility. In order to ensure uniform use of the system, we designed a Standard Operating Procedure (SOP) as shown in **Appendix C**.

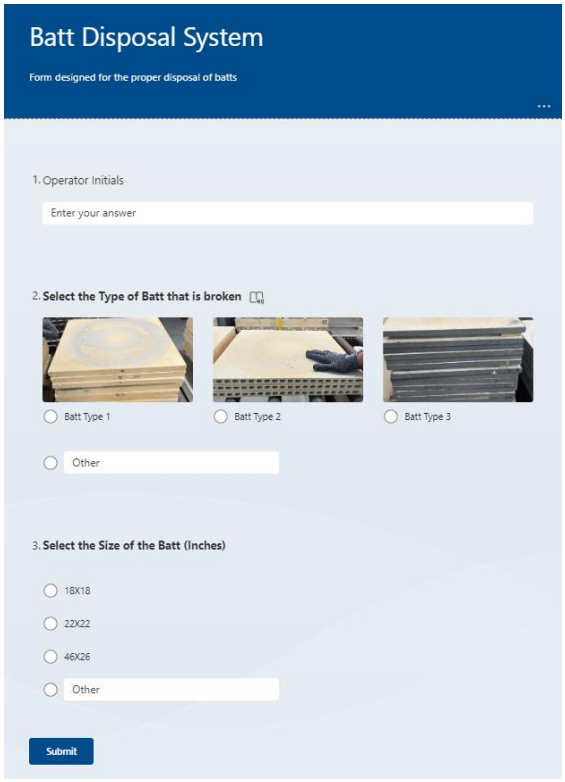

Figure 12: Batt disposal form, operators will fill out on floor when a batt breaks.

Based on the number of broken batts provided by the tracking system, Saint Gobain's management may conduct a cost-benefit analysis to determine if the existing types of batts should be changed. The tracking can also assist management define a reorder point. The team was not able to collect sufficient feedback on the functionality and long-term use by the workers. However, the Saint Gobain management will be able to determine whether the tracking system meets their business requirements.

Recommendations

In order to successfully implement the batt tracking system the team recommends that Saint Gobain:

- Make the created SOP an official document. With this, current and future employees will be able to easily learn and adapt to the tracking system.
- Use historical data collected in form, seen in **Figure 12** to analyze trends regarding the most common types of broken batts. An example of this analysis can be seen in **Figure 13.**
- Use the data collected to establish when to release new batts on the floor as well as to establish a reorder point for purchasing new batts.

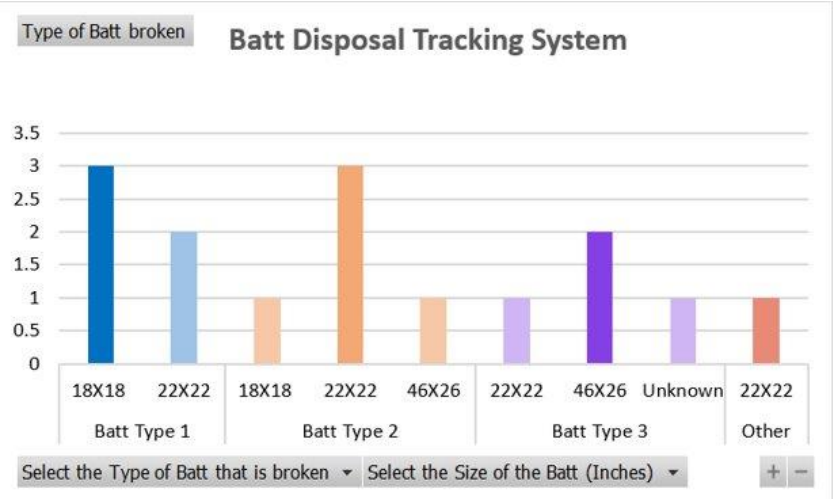

Figure 13: Figure 13: Potential analysis using batt disposal form data.

5. Conclusion Recommendations & Reflections

In this chapter conclusions are drawn from the findings, recommendations are proposed, and the reflections focus on what was learned during the project and what could have been done differently. The chapter summarizes the main points of the project and provides actionable steps for future improvements.

Conclusion

In conclusion, the project successfully achieved its goal of improving the utilization of the tunnel kiln at Saint Gobain. By focusing on specific objectives such as reducing waste, optimizing the front end of the grinding wheel process, adding transparency among manufacturing floor workers, and recognizing bottlenecks within the system, the team was able to identify three different improvement opportunities. By following the DMAIC process and applying various tools to collect and analyze data, the team implemented visual management within a queuing area, a BI dashboard that will add visibility on the manufacturing floor, and a batt disposal system that could lead to further cost vs quality analysis. As a result, the team was able to reduce waste, optimize the front end of the grinding wheel process, and add transparency to manufacturing operations for managers and floor workers. This project has not only helped to address opportunities to improve utilization of the tunnel kiln but has contributed to a more effective and efficient manufacturing process overall.

Recommendations

In summary, the team recommends that Saint Gobain revise the standard operating procedures (SOPs) created and seek to have them approved as official documents. The SOPs should be continuously updated and used for training new employees. The team also suggests maintaining the flags in the queuing area by regularly checking them for wear and changing them as needed, as well as exploring more ergonomic flag stand placements. Additionally, the team recommends setting up the dashboard in SharePoint and integrating it into the IT infrastructure. The dashboard should be used to support future decisions regarding the utilization of the TK15. These recommendations aim to sustain the solutions created and to improve the accuracy, timeliness, and productivity of the manufacturing process at Saint Gobain.

Reflections

Design in the Context of the Project

The engineering design process is a systematic approach to creating a product or solution. We used this approach while we implemented visual aids in the queuing areas, built the TK15 Utilization Dashboard Demo, and created a disposal system for the batts.

Design process steps taken by the team for each subproject (Steps Saint Gobain will continue are shown in purple):

- Understanding the problem:
    - Dashboard - Identified the specific business needs and goals that the BI dashboard is intended to address, gathered information from stakeholders, and defined requirements.

    - Batt Disposal - Identified how tracking the batts can support management in future decision making.
    - Queuing area visual management – Identified how organization of the queuing area will allow employees to maximize the volume of material being set for kiln firing. This eliminates time waste and allows for easy identification of orders by management.
- Ideation:
    - Dashboard - Generated ideas for potential data to include in the dashboard and how to represent it visually.
    - Batt Disposal - We proposed several disposal methods for broken batts that can also track how many of each batt type broke.
    - Queuing area visual management – Created and proposed several different visual management aids for the queuing area.
- Design and prototyping:
    - Dashboard - Created a detailed design of the BI dashboard, including its user interface, data visualization elements, and underlying data structures. We created a functional prototype to test the design and refine it based on feedback.
    - Batt Disposal- Ordered supplies and installed a manual tracking system on the manufacturing floor.
    - Queuing area visual management – Developed a visual aid using four different colored flags for orders designated to different types of burns. Used the colors, neon pink, neon purple, neon yellow, and neon blue as well as restaurant order stands to hold the flags. This design was finalized after multiple iterations and weeks of testing.
- Testing and validation:
    - Dashboard - Evaluated the BI dashboard's performance and usability based on feedback from Saint Gobain management.
    - Batt Disposal - Evaluate Microsoft Form tracking system using and feedback from Saint Gobain operators.
    - Queuing area visual management – Tested multiple different colored flags and changed to brighter colors that would be more noticeable. Designated a storage area for flag stands. Found that the visual aids created un-intentional organization within the queuing area space. It was also discovered that anywhere from 2-10 minutes was being saved when locating needed orders.
- Implementation and deployment:
    - Dashboard - Build the BI dashboard and integrate it into Saint Gobain’s IT infrastructure. This step involves configuring data sources and conducting final testing before deployment.
    - Batt Disposal – Implement the Microsoft form provided, if the policies regarding security change as well as make sure that the green waste and batts are separated from each other and inform workers regarding the two areas of disposal around the facility.

    - Queuing area visual management – Implemented on the floor in late December. Implementation was advanced by management who explained the visual management aids to floor employees.
    - Batt Disposal & Queuing area visual management – Provided a Standard Operating Procedure to create a more organized work environment and provide guidelines to the systems implemented by reducing errors and increasing the efficiencies.
- Maintenance and support:
    - Dashboard - Ongoing support and maintenance of the BI dashboard should be set up to ensure it continues to meet the needs of the business.
    - Batt Disposal – Ensure tracking system continues to meet the needs of the business and, update with new technology to make job of the manager easier.
    - Batt Disposal & Queuing area visual management - Make the presented SOP an official document and continue to update it if the system so requires.
    - Queuing area visual management – Continual management of damaged or lost flags will need to be provided. As the queuing area continues to grow more colors for different categories can be added to the visual management system.

The engineering design process provided a structured and iterative approach to creating a BI dashboard, ensuring that the final product is well-designed, effective, and meets the needs of the business.

Constraints in the Design

Industrial engineering is a field of study that involves an in-depth understanding of every aspect of a process to improve it. Defining constraints is one of the most important phases in any improvement project. A major roadblock in this project was the time it takes to fully understand a process and the terminology and jargon used in the plant. In this section additional constraints that the team worked to overcome throughout the project are defined.

Saint Gobain Abrasives manufactures specialized grinding wheels. Due to the variety of uses of grinding wheels, every order is customized based on the needs of the customer. The high customization means that the flow of the process changes with every order. The variability of the abrasive, bond, size, drying time and different burn type makes it a challenging to standardize the process.

Another constraint linked to the manufacturing process is the continuous use of the tunnel kiln. The tunnel kiln is running continuously, meaning that any changes made to the process will need to be adapted without stopping production.

Another considerable constraint is that Saint Gobain does not allow any internet or script to run on the plant floor. That means that any digital tool the team designed needed to be verified by the IT department to be used on the floor. The team was more comfortable using python as the main software to create the dashboard but due to the restriction of no running script allowed, the development of the dashboard was shifted into Power BI, which is a software that is allowed to be used on the manufacturing floor.

New Knowledge

Industrial Engineering is a field of study that involves designing and improving systems, processes, and products to optimize efficiency and productivity. The primary focus in IE courses is on theoretical concepts and mathematical models. While the classroom provides a broad understanding of the field, including its history, philosophy, and key methodologies, it cannot provide us with the hands-on experience and practical training of a manufacturing facility.

Working at Saint Gobain has given us the opportunity to observe processes and systems in action and gain insight into the challenges and opportunities of working in a manufacturing environment. We have had exposure to new technologies and equipment, and opportunities to network and build relationships with industry professionals.

A specific technology we now have exposure to is Power BI. Businesses are becoming more and more data centric and using platforms like Power BI to improve their analytics capabilities and decision-making. Power BI is the leading analytics and business intelligence platform based on the 12 critical characteristics outlined in the "Magic Quadrant for Analytics and Business Intelligence Platforms" (Kronz & Schlegel, 2022). Having experience with the Power BI platform will be applicable in our future work experiences.

No one on our team had used Power BI prior to the start of the project. During the first several months, we faced a lot of difficulties because of our inexperience. We overcame these challenges by watching tutorial videos online and seeking assistance from professors and managers who had used similar platforms previously.

Teamwork

Good teamwork is essential for the success of any project. It involves effective communication, collaboration, and a shared sense of responsibility among team members. Throughout this project the core group of four students met at least twice a week to plan and do research, then assign tasks for individual work. We would also collaborate with sponsors onsite once or twice a week on average. Using Microsoft Office and online resources we were able to create a workspace where all members of the team and sponsors at Saint Gobain would have access to the project information.

Eventually we had three different project proposals planned and split the work among team members, this allowed for the efficient use of our resources (people). For example, two team members focused on Power BI, while another focused on implementing visual aids in the queuing area. By dividing the project into smaller, more manageable tasks, we were able to focus and produce high-quality work in a shorter amount of time.

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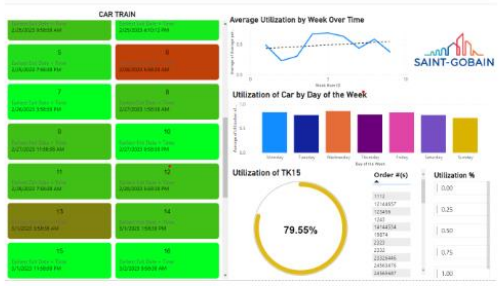
Appendix A: TK 15 Utilization Dashboard Manual

TK 15 Utilization Dashboard Manual

Microsoft Forms, Microsoft Excel, and Power BI were used to create the TK15 dashboard. This graphical interface can be used by operators and managers to view the current utilization and historical trends to support making better business decisions.

Project Details

Dashboard Design & Insights



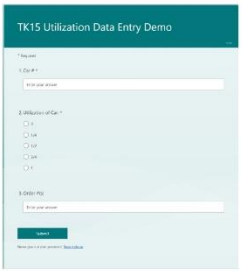
Each visualization within the dashboard can help managers track key metrics, identify areas of improvement, and make data-driven decisions.

The current state of the kiln is represented in the **Car Train** and **Utilization KPI**. These charts give management insight into the utilization and position of each car, what cars are exiting the kiln next, as well as what orders are within the kiln. If management wants to know when an order will come out/what car an order is on, they can simply find the order in the **Order #(s)** List, click on it, and it will be highlighted in the car train. This adds transparency and tracking capabilities on the manufacturing floor.

Historical data on utilization of the kiln is represented in the **Average Utilization by Week Over Time** chart and the **Utilization of Car by Day of the Week** chart. These charts show trends, patterns, and anomalies in the data which can lead management to notice bottleneck and inefficiencies on the floor.

Microsoft Forms & Excel

With Microsoft Forms, you can create surveys, quizzes, and polls, see real-time results as they're submitted, and automatically export results to Excel for additional analysis. For the TK15 Dashboard, each time a new car is sent through the kiln the operator will need to fill out the following form with the car number, the utilization of the car, and the order numbers that are on the car.

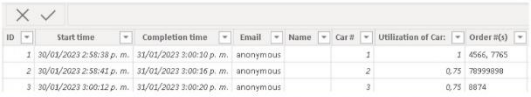


This will automatically populate an excel sheet. Each form submission will create a new row within excel with an automatically generated ID, Start time, Completion time (date and time of submission), Email, and Name, as well as the answers to the form questions. The raw data on how the TK15 kiln has been utilized should look like the excel sheet below:

Uploading Data to Power BI

This Excel sheet is then imported into Power BI to create a visual dashboard. To connect the excel in Power BI Desktop, select **Get data** > **Excel** from the Home ribbon. Select your workbook from the **Open** dialog that appears. You can select the **Load** button to import the data, or if you want to clean the data, select **Transform Data** (the excel created should not need to be cleaned).

When complete, the Power BI Desktop displays the tables and fields it imported from your Excel workbook in the data window: After importing the raw data from excel



ID	Start time	Completion time	Email	Name	Car #	Utilization of Car:	Order #(s)
1	30/01/2023 2:58:38 p. m.	31/01/2023 3:00:10 p. m.	anonymous		1	1	4566, 7765
2	30/01/2023 2:58:41 p. m.	31/01/2023 3:00:16 p. m.	anonymous		2	0,75	78999898
3	30/01/2023 3:00:12 p. m.	31/01/2023 3:00:20 p. m.	anonymous		3	0,75	8874

Prepping Data in Power BI

After importing the raw data from excel there are multiple steps that need to be taken to prep the data for visualizations within the dashboard.

- Create a new column using DAX (Data Analysis Expressions) called "Day of the Week."

```
1 Day of the Week = FORMAT('TK15 Utilization History'[Start time],"dddd")
```

rt time	Completion time	Email	Name	Car #	Utilization of Car:	Order #(s)	Day of the Week
023 2:58:38 p. m.	31/01/2023 3:00:10 p. m.	anonymous		1	1	4566, 7765	Monday
023 2:58:41 p. m.	31/01/2023 3:00:16 p. m.	anonymous		2	0,75	78999898	Monday
023 3:00:12 p. m.	31/01/2023 3:00:20 p. m.	anonymous		3	0,75	8874	Monday

This column uses the "Start time " column (Date and time when the form was filled out) and returns what day of the week that date was. This

- Create a table that only looks at the last 44 data entries (44 cars that are currently in TK15). In order to create this table, the following DAX code was used:

```
1 TK15 Current Utilization = CALCULATETABLE('TK15 Utilization History',
,'TK15 Utilization History'[ID]>(MAX('TK15 Utilization History'[ID])-44))
```

This table will show the current utilization of the kiln, while the original table keeps track of the utilization of the kiln historically.

- Create a new column within the new table that calculates the expected "Exit Date and Time" of the car using DAX.

```
1 Exit Date + Time = 'TK15 Current Utilization'[Start time]+0.25
```

This code adds 8.25 days to the "Start time" column within the new table, this is approximately how long it takes 1 car to exit the kiln.

- Create a new column within the new table that shows the "Position" of the car in the kiln using DAX.

```
1 Position = COUNT('TK15 Utilization History'[ID])-('TK15 Current Utilization'[ID]-1)
```

Use the following DAX code to create the utilization average per week.

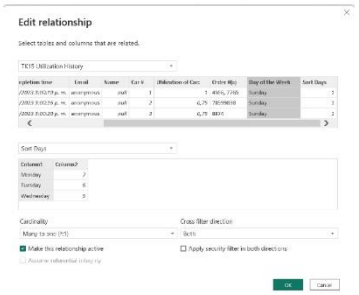
```
1 Average per week = AVERAGEX(
2     KEEPFILTERS(VALUES('TK15 Utilization History'[Week Num ID])),
3     CALCULATE(AVERAGE('TK15 Utilization History'[Utilization of Car:]))
4 )
```

To return the current position of the car in the kiln this code references the IDs in both the original table and the new table and subtracts them from each other.

- Create the "Sort Days" table using **Enter Data** or **New Table** in the toolbar and input the following:

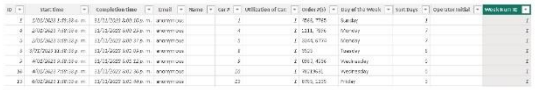
Column1	Column2
Monday	7
Tuesday	6
Wednesday	5
Thursday	4
Friday	3
Saturday	2
Sunday	1

  - Then form a relationship between the original table and the "Sort Days" Table.



The link will be using the Primary Keys "Column 1" in the "Sort Days" table "Day of the Eeek" on the original table. Use the many-to-one relationship with filter direction to both.

Create a new column within the TK 15 Utilization History that gives an ID to the week where the data input was made.



Appendix B: Standard Operating Procedure (SOP) for Visual Aid Management System

Standard Operating Procedure (SOP) for Visual Aid Management System

Purpose: The purpose of this SOP is to provide a step-by-step guide for the proper management of visual aids in the queuing area. The visual aid entails the operator to retrieve a stand with proper color to assign to designated orders in the queueing area. This system will allow management and operators to find orders quickly and allow the Kiln Utilization to be higher.

Scope: This SOP applies to all personnel involved in the queuing area.

Equipment and Materials:

Location Queuing area next to the drying room

- Basket for stands.
- Visual aid stands.
- Colored cards for stands.
- Whiteboard with legend for queuing area.

Procedure:

1. **Collecting stands from the basket:**
   a. Approach the basket containing the stands in between the dry room doors.
   b. Collect the stand(s)

Figure 1 Stand Located Between Dry Rooms

2. **Identifying the visual aid colors on the whiteboard:**
   a. Locate the whiteboard in the dry room door.
   b. Check the color code of the required visual aid against the whiteboard also seen below in Table 1.

Table 1

Neon Blue	TK15 Unshaved
Neon Pink	TK15
Neon Purple	7 Day Hax
Neon Yellow	4 Day Alundum

Figure 2

3. **Placing the stand in the queuing area:**
   a. Look for the product order in the queuing area.
   b. Place the stand in the correct type of order based on the color code.
   c. Place the stand in the Grinding Wheel containing the Manufacturing Order
   d. Ensure that the stand is secure and will not fall over.
4. **Replenishing the basket:**
   a. Once a stand is no longer in needed and the order moves to the next step, separate the colored card from the stand and place colored card in folder located in the dry room door. See figure 1 & 2.
   b. Place the stand(s) in the basket located in between the drying room doors. See figure 1 & 2.
5. **Cleaning up:**
   a. Ensure that the area around the basket and queuing area is clean and tidy.
6. **Reporting any issues:**
   c. If any visual aids are missing or damaged, report this to management.
   d. If any issues arise during the process, report them to management and follow any further instructions given.

Note: This SOP is subject to change based on the specific requirements of the visual aid management system. All personnel must adhere to the latest version of this SOP.

Appendix C: Standard Operating Procedure (SOP) for Filling Out a Microsoft Form for Disposing of a Broken Batt

Figure 1

9. In the next section, enter the size of the broken material.
10. If the size of the broken material is available, enter the size in the space provided. See Figure 2
11. If the size of the broken material is not available, select the "Other" option. See Figure 2

Figure 2

12. Review the form to ensure all necessary information has been provided.
13. Submit the form.

Note: If the image or size of the broken material is not available, it is important to select the "Other" option and provide any additional information that may be useful for the disposal of the broken battery.

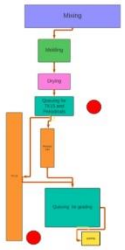
Conclusion: By following this SOP, operators will be able to fill out the Microsoft form for disposing of a broken batt accurately and efficiently, while ensuring the safety of themselves and others in the facility. The requirement of disposing of the battery in one of the two designated locations helps ensure that batt is properly disposed of. While filling out the form after the batt has been disposed of in a bag this helps prevent the waste around the facility as well as the tracking for re-ordering purposes.

Standard Operating Procedure (SOP) for Filling Out a Microsoft Form for Disposing of a Broken Batt

Purpose: This SOP provides a step-by-step guide on how to fill out a Microsoft form for disposing of a broken batt. The form requires the operator to select an image of the broken battery and select the size of the broken material. In case the image or size is not in the available options, the operator is to select "Other." The batt must be disposed of only in one of the two designated locations inside the facility, and the form must be filled out after the batt is disposed of in a bag.

Procedure:

1. Check the broken batt to ensure it is safe to handle and dispose of. Follow appropriate safety protocols.
2. Pick up the broken batt and dispose of it in one of the two designated locations inside the facility.
3. Ensure the batt is disposed of in a bag that is designated for this purpose.
4. After disposing of the batt, go to the nearest designated computer (Represented by the red dots on the diagram bellow)



5. Open the batt disposal Microsoft form.
6. On the form, locate the section that asks for an image of the broken battery.
7. If the image of the broken batt is available, select the corresponding image. See Figure 1
8. If the image of the broken batt is not available, select the "Other" option. See Figure 2

Appendix D: Table of Batt Types and Sizes

Type of Batt	Size (in)	Picture
Fludid	18X18 22X22 46X26	
Base (Cordeorite)	18X18 22X22 46X26	
Crystar	18X18 21.5X23.5 22x22 46X26	
Crystol	22X22 46X26	
Quarter Right (Beige)	23.5X28.5 21.5X24.5 31.5X33.5	

Fluids Crystolon (Corner Missing)	Unknown	
7 Day Deck Crystolon	Unknown	
Medium Section Crystal	Unknown