Process Waste Reduction at Stacy's Pita Chips

Major Qualifying Project Submitted to the Faculty of

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In Partial Fulfillment of the Requirements for the Degree of Bachelor of Science

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Abstract

The objective of this MQP was to identify operational improvement opportunities in PepsiCo's [redacted] plant, in [redacted] Massachusetts. The rationale for this MQP was that the operational metrics for the sponsor's facility indicated that some of their production lines were not fully optimized and the site was well-positioned for process changes. The state of the art indicated that there were many process improvement activities on going, but none specifically applied to [redacted] waste issues. The team delivered information enabling the sponsor to increase revenue through process improvement by utilizing methods of axiomatic design, process experimentation and time value-cash flow analysis. The results of the methods showed that there were significant opportunities for process optimization in the [redacted] plant by investing in more data collection infrastructure and leveraging operational data more frequently in production decision-making. The conclusion of this MQP was that it is possible to make a significant impact on the cash flow and production system development by emphasizing the importance of transitioning from reactive to proactive strategies in the manufacturing environment.

Acknowledgments

Our team would like to thank to our advisors, Professors Walter Towner and Helen Vassallo for their guidance. Additionally, we would like to thank the entire PepsiCo team, and extend a special thanks to Jose Orbegozo and Ian Weaver for their contributions to the success of this project. Without their help, our team would have been unable to overcome the obstacles

which arose throughout the course of this MQP, and each member of our team would like to express our most sincere gratitude for the continued support.

Introduction

Stacy's Pita Chips is a consumer goods company which has produced a wide variety of bread products, including pita chips, since 1997. In 2005, PepsiCo acquired Stacy's Pita Chips. They have since expanded the number of products and volume of production. Currently, the largest volume of pita chips is produced at their manufacturing facility based in Randolph, Massachusetts.

Problem Statement

[ ] operates as a [ ] manufacturer, fulfilling demand for [ ] products. [ ] To meet this high demand management runs the facility with reactive management strategies to address problems. These strategies often lead to a lack of waste data collection earlier in the [ ] baking process which decreases the profitability of making [ ]. The loss of profitability is attributed to deficiencies in the production capacity. The management team believes that some deficiencies can traced to external ambient conditions due to minimal climate control mechanisms but have limited data to support their hypothesis. Following their current management strategies, [ ] allocates a number of process controllers (PCs) to address these process defects as they arise per shift, instead of engaging in proactive process improvement. [ ]. Stacy's Pita Chips has partnered with Worcester Polytechnic Institute to sponsor this MQP team, aimed at identifying opportunities for data

collection and quantifying the impact of ambient environmental factors on resting work-in-progress in the factory.

Project Overview

The MQP team designed and conducted a study encompassing process improvement opportunities with the goal of decreasing waste in the [redacted] baking process. [redacted] of the PCs. The MQP team focused on identifying under-regulated, out-of-control process areas that create waste. The MQP team aimed to provide solutions based on factual evidence gathered to allow for better and more accurate decision making. To make their recommendations, the MQP team utilized lean management principles, proactive management concepts, and experimentation to relate factory climate to process time. Through financial benefit analyses, the MQP team justified the implementation of the recommended process changes.

Project Goals and Objective

The overall goal of this project is to eliminate waste in the pita bread baking process of [redacted] production. The MQP team used axiomatic design to define the problem and develop an approach to eliminate waste in the [redacted] process. Points were identified along the process where management lacked waste and data collection procedures. Through a series of interviews, data analysis, and experimentation the following three project deliverables were produced to convey to management:

1) Identify inefficiencies and non-value added processes and provide recommendations to minimize waste.

2) Create a financial analysis by developing a systematic evaluation of the financial benefits to support recommendations and to assist management in decision making.

3) Recommend management strategies to facilitate implementation and sustainability of the proposed process improvement projects that is compatible with [redacted] company culture.

Background

In 1965 Pepsi-Cola and Frito-Lay merged to create PepsiCo, Inc. Pepsi-Cola was founded by Caleb Bradham in the 1890s and featured three flagship products; Pepsi, Diet Pepsi and Mountain Dew. Frito-Lay, Inc. was created via a merger between H.W. Lay Company and the Frito Company in 1961 and featured five products; Lay's potato chips, Fritos corn chips, Ruffles potato chips, Roald Gold pretzels and Cheetos snacks. At the time of the PepsiCo merger, Donald Kendall (former Pepsi-Cola CEO) became the new CEO of PepsiCo. Former CEO of Frito-Lay, Herman Lay, became the new chairman of the board of directors for PepsiCo. In 1965, PepsiCo had 19,000 employees and annual sales of $510 million. As of 2017, PepsiCo has 263,000 employees and $63 billion in net revenue. PepsiCo is a global brand and has 22 billion-dollar brands in their portfolio. These brands include the original flagship brands, new products and additions such as Quaker Oats, Gatorade, Brisk iced tea and Starbucks (PepsiCo-Our History, 2018). Another brand that has not reached the billion dollar mark but is quickly growing in an expanding market is [ ]. PepsiCo continues to expand their food and beverage portfolio and fuel innovation to improve, making them a leader in the food and beverage industry.

Stacy's Pita Chips History

Stacy's Pita Chips was founded by Stacy Madison and Mark Andrus in 1997. Both Stacy and Mark aspired to have careers in the food industry but did not have the capital to start a restaurant. As a result, they decided to open a pita bread roll-up sandwich vending cart in the financial district of Boston, MA called [ ]. Quality food and good service made for long lines during lunch breaks. To convince people to [ ]

Mark made their pita chips from the leftover pita bread. The demand became so high for these chips, that the two started to produce different flavors, and ultimately decided to solely focus on producing [ ]. In 1998, [ ] purchased an old mattress manufacturing facility in [ ] and began to make and sell wholesale [ ]. Success ensued, as they employed over 300 workers, and were selling more than $65 million in chips annually. The number one complaint from customers were that chips were hard to find and that they wish they were sold in more locations [ ]. On [ ] PepsiCo announced its agreement to purchase [ ]. The brand has since expanded, and produces not only pita chips, but pita thins, bagel thins, and other new products. The brand proudly supports the PepsiCo Smart Spot, as it does not contain cholesterol or trans fats. They still remain unique by following the process of seasoning before baking the [ ] [ ].

Company Culture

Stacy's Pita Chips Company Culture

PepsiCo's mission is to create the best working environment by ensuring; high levels of employee engagement and satisfaction, a safe workplace by continuing to reduce injury rates, the fostering of diversity and inclusion and the support of ethical and legal compliance through annual training in their Code of Conduct (PepsiCo, 2012). These goals outline PepsiCo's commitment to human rights policy, treating every employee with dignity and respect. Observing the manufacturing process and interviewing employees has allowed the MQP team to understand [ ] culture under the umbrella of PepsiCo's guidelines.

At Stacy's Pita Chips, all of the employees follow PepsiCo's culture guidelines. Management treats the employees with dignity and respect, and vice versa. When plant managers or quality control staff walk around the plant floor, many employees share smiles and have spontaneous conversations.

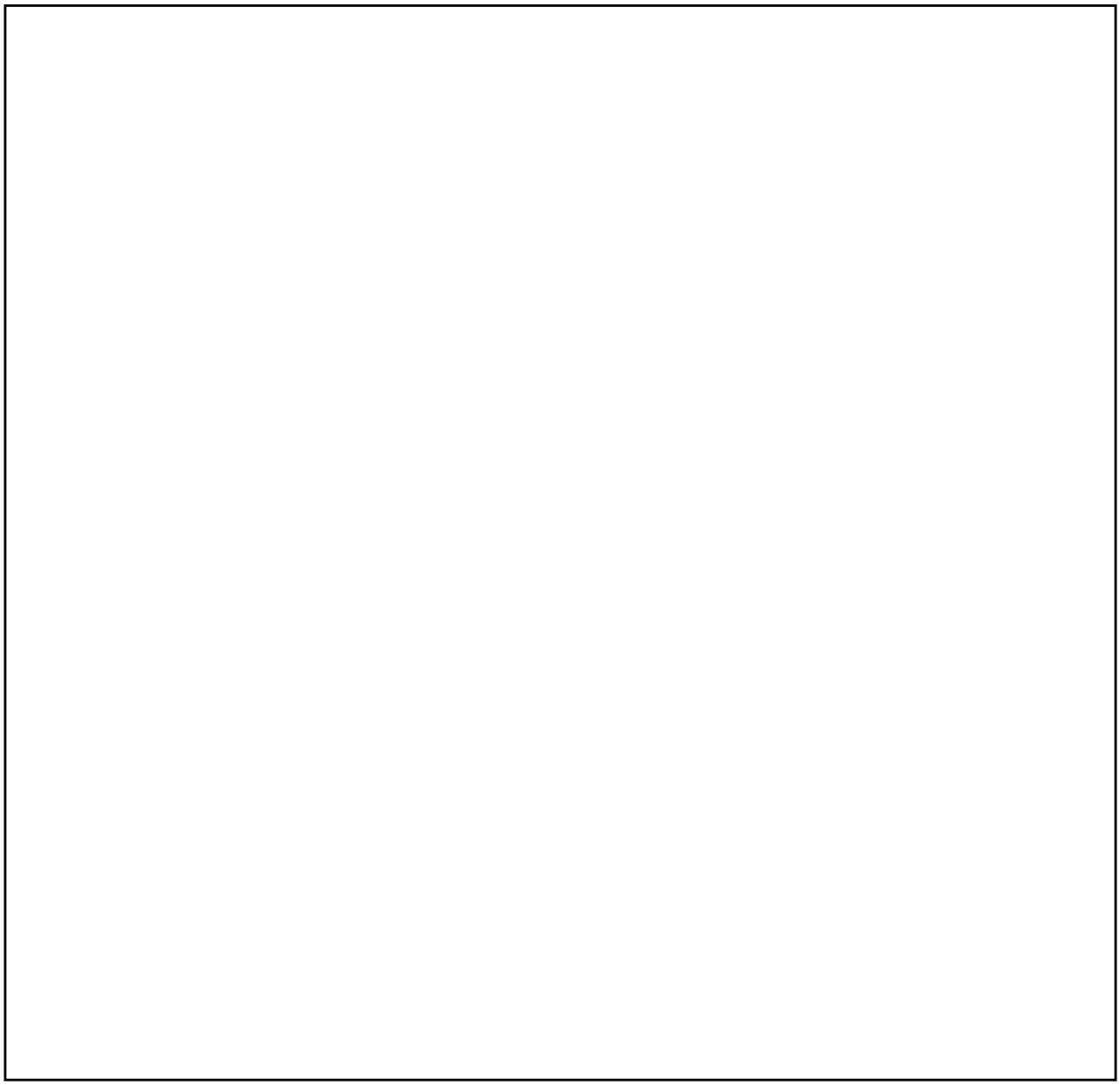
The plant manager spoke about why the plant has been successful in the past. First, company culture plays a role in motivating employees to improve the quality of products. Because the employees are treated with respect, they tend to care more about the final product. The employees at Stacy's Pita Chips take pride in achieving set goals which are recorded and posted on the plant walls. Second, the company sets high training standards for employees. Although there is not a set protocol, employees are trained to look at the product at different points during the baking process and predict whether the product's physical makeup will be successful downstream. If the bread product is not in a desirable physical state, "tribal knowledge" of employees defines the appropriate steps process controllers use to alter the product.

Stacy's Pita Chips Company Communication Methods

Through interviews and observations, the MQP team concluded that [redacted] company culture aims to encourage and motivate employees to improve processes but lack the proper communication tools and procedures. Currently, [redacted]. Knowing this, the MQP team identified the opportunity to improve vertical and horizontal communication.

The Benefits Behind Changing Stacy's Pita Chips Cultural Habits

Changing certain operational procedures and practices can provide [ ] with significant benefits. First, the process of identifying and disposing of [ ] product is a reactive process, not a proactive one. By interviewing quality control employees, the MQP team learned about various quality measures in [ ] The interviewees explained



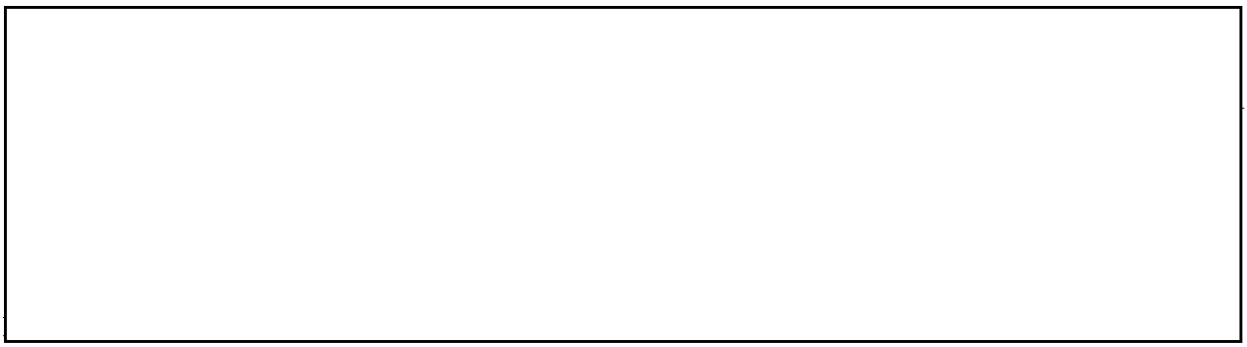
Culture to Embrace Change

At [redacted], employees practice reactive manufacturing, as they alter the process line in a similar manner. One study has shown that companies who produce, test and alter a product in a proactive manner are more successful (Ewenstein, Smith and Sologar, 2015). One direction that might be possible for [redacted] is to embrace a new company culture where all the testing and alteration are made in a proactive manner. Since most change programs fail, according to a McKinsey Report, up to 70% of change programs fail, for predictable and avoidable reasons, a company culture change may be difficult. Change implementations fail due to: a lack of goal alignment, a lack of holistic approach to parallel efforts, a lack of interest from leadership and the employees' resistance to change (Ewenstein, Smith and Sologar, 2015). People in general tend to resist change in many ways for example, according to a Harvard Business Review there are a few common ways in which an employee can manifest their resistance to change (Kanter, 2012). Although leaders cannot force people to accept the implemented changes, they can minimize discomfort and increase the success rate for programs.

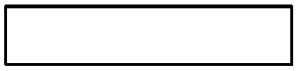
How Can Change Be More Easily Embraced

Since [redacted] follows PepsiCo's company culture guidelines and boasts positive employee satisfaction, they have a good base to introduce change. However, when implementing process changes it is important to consider the following three concepts.

First, in company culture changes, quick decisions should be avoided. Employees affected by change need to be made aware of the benefits of potential changes. Research has shown if you have a meeting to discuss a predetermined process change with employees who have no prior knowledge of the matter, the employees will resist the change (Potrivaev, 2018).

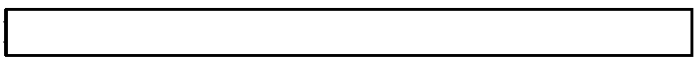


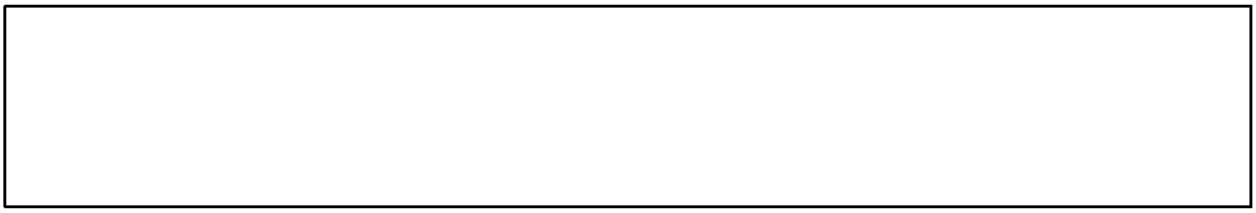
Secondly, employees can feel a loss of control when change is first implemented. In an article published in Harvard Business Review, it explains that "change can interfere with autonomy" and that employees may feel they have "lost control of their own territory" (Kanter, 2012). After having done a certain job a certain way for an extended period of time, employees develop rhythms and routines that they often do not want to change. Successful leaders account for employee input when proposing process changes (Kanter, 2012).



Thirdly, management must convey that change will require more effort. Change is most widely accepted at its "inspiring beginnings and its happy endings" (Kanter, 2009). Change is hardest to defend in the middle of the process change, when it is unknown if the process change will be successful. Similar situations were exemplified when the MQP team would ask

collected a certain type of data.



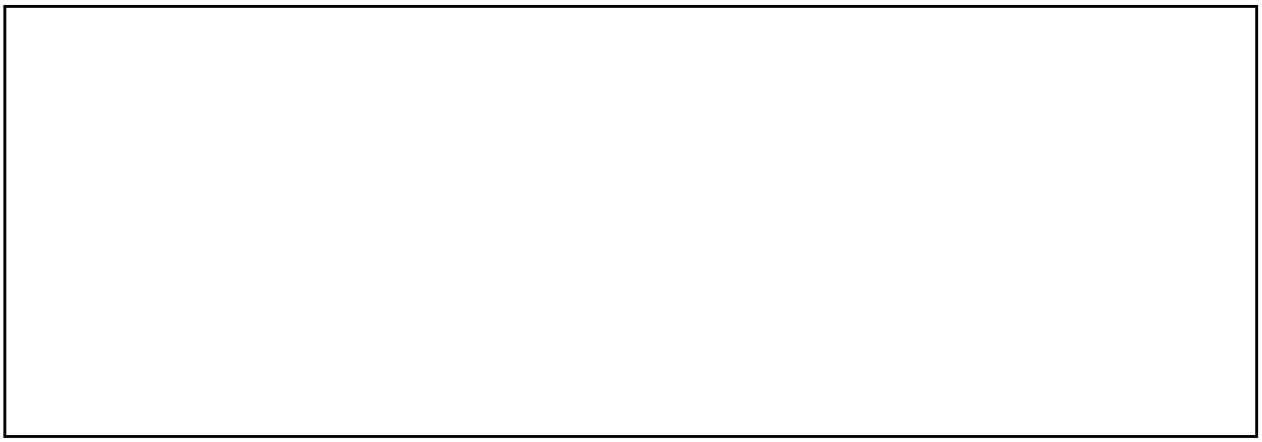


Pita Bread Baking Process

The industry standard of pita bread production begins with the mixing of dry ingredients. These include yeast, sugar, flour, and salt. Followed by the addition of water forming a "shaggy mass". Then the mixing process begins, usually with large, automatized kneading-arms, to achieve the desired elasticity (Tanis, 2018). Following this, the dough is fed into an extruder that forms it into tennis-ball sized portions. During the first proofing the dough balls are allowed to rest and rise for around 15 minutes, regardless of whether it is made at home or in a commercial bakery (Tanis, 2018). The dough balls are flattened into circular disks of dough that travel on a linear conveyor belt. The flattened dough balls pass under a series of rollers that press the mass in the desired circles. The rollers press them to a thickness of approximately 0.125" (McNulty, 2007). The circular dough moves towards a second proofing stage, where they rest to increase their volume again. They leave the proofing stage and are transported to the oven. Most pitas are baked at high temperatures between 450–500 °F, but in a commercial oven they can reach up to 800-900°F (McNulty, 2007). At this temperature, the pita moves quickly through the oven exposing it to the high temperatures for about one minute. During the baking process, the high temperature transforms the water in the dough into steam, thus causing the pita to "puff up" by separating the upper and lower crust. When removed from the oven, the baked pita moves in a system of conveyor belts for about 20 minutes until the rounds have cooled and can be handled. Throughout the cooldown, the pita bread stays separated inside. Finally, the baked and separated (McNulty, 2007).

Stacy's Pita Chips Bakery Process Flow

For the purpose of the project, the MQP team focused on the , which is the older lines that the plant has in operation. This line is so-named because is transported along the conveyor, a . The different colored green highlights denote the physical makeup of the ingredients at different points along the process. At the first step of the



Due to unexpected levels of dough adhesion, some batches are susceptible to process errors at this location because the balls stay stuck to the rack for longer than intended. As a result, the dough balls fall onto the floor.

. The doughballs are then flattened into disks and transferred to conveyor belts, again with minimum complexity. Once successfully transferred to the conveyors, the flattened disks are transported over to the "proofing area" where the s in a climate-controlled environment on conveyor belts to ensure consistency of the dough before being baked. Once baked, the cools off and are then stacked for an process to ensure proper moisture distribution throughout the bread.

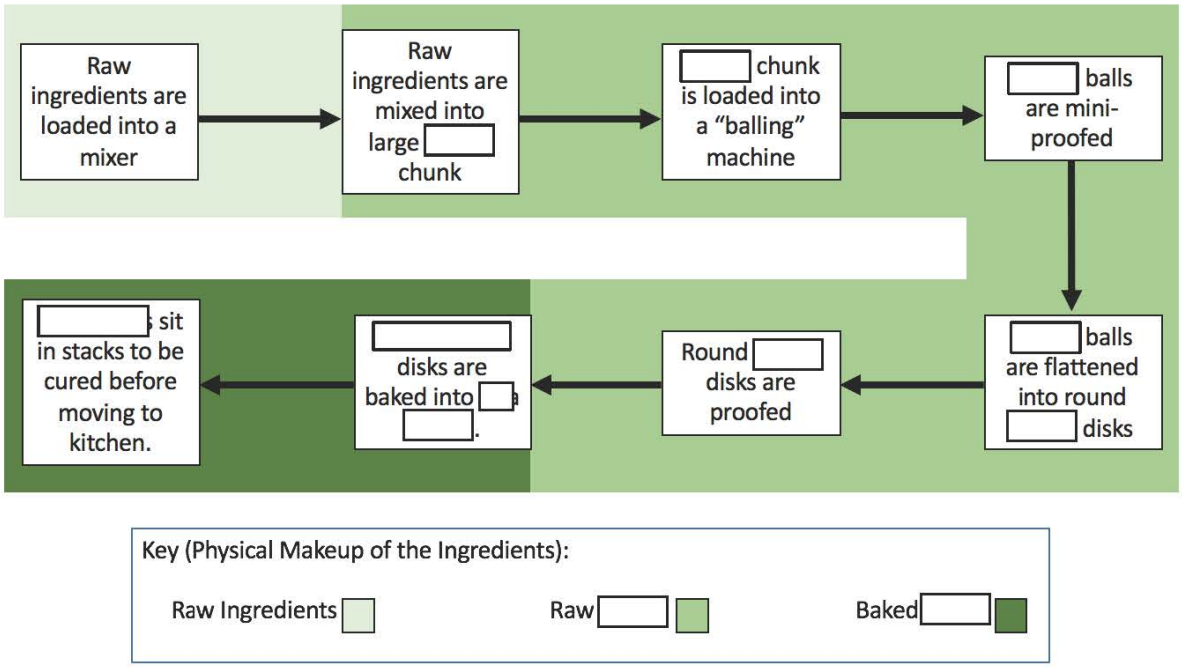


Figure 1 Stacy's Pita Chips line 1 graphical interpretation

The sections of the process map that the MQP team takes into account are circled in the diagram in red are the two areas of the that our project focused on. These locations were the bread mixing area, and the bread curing station.

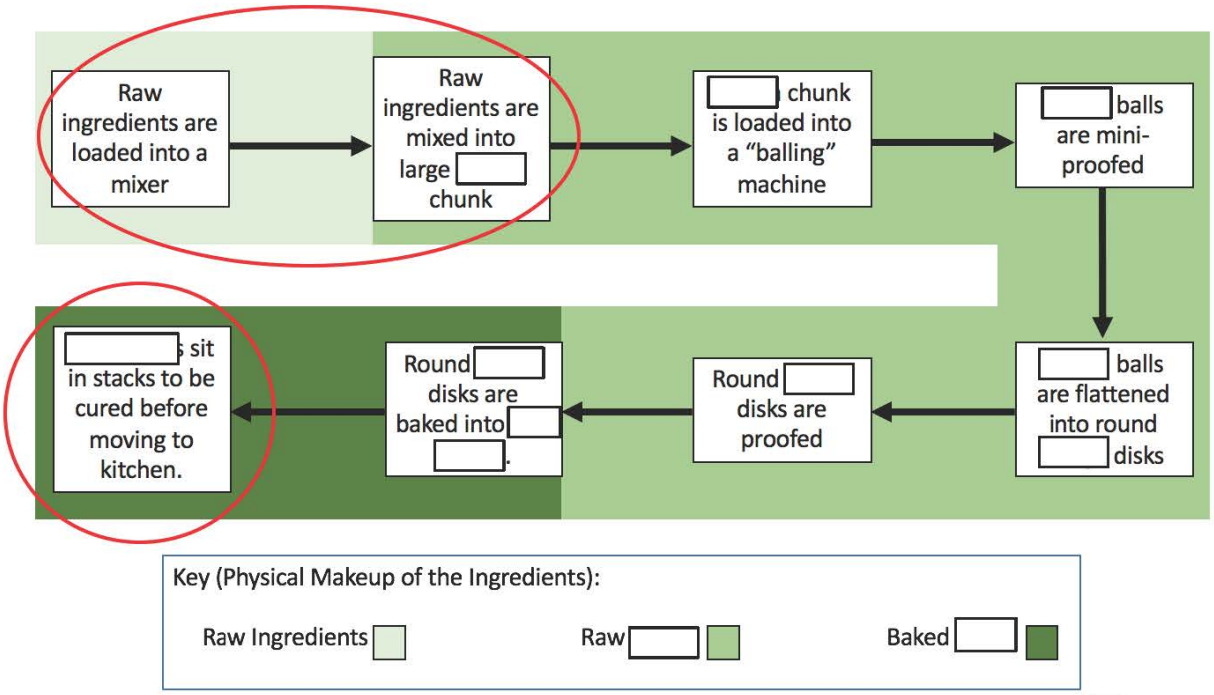


Figure 2 line 1 graphical interpretation & areas considered

Bread Mixing Area

Many of the metrics that the Quality Control team analyze are collected too late in the process. Although the metrics that the facility currently collects are important to identify bad batches of pita breads, the quality control team is lacking a method of identifying low-quality batches earlier in the process. The MQP team concluded that more research should be conducted about what metrics and indicators should be collected to avoid the opportunity cost of aborting a batch of product late in the process.

Bread Curing Process

According to , the purpose of curing pita bread is to allow for the even spreading of moisture throughout the bread. Currently, aims to let their bread

cure for 8-10 hours. New management have not been provided with a logical explanation for this particular curing time interval. The MQP team contacted multiple manufacturers for insight on their curing process. According to three contacts from other manufacturers, they cure or "stall" to improve the "texture". Most answers were vague and not supported by scientific evidence. The MQP team concluded that more information about the specific time interval needed for proper bread curing must be gathered.

Lean Manufacturing & Wastes Concepts

Lean manufacturing is a category of operational procedures which are prevalent in the majority of the manufacturing world. From a popular operations textbook, *Operations and Supply Chain Management*:

> Just-in-time (JIT) production was the major breakthrough in manufacturing philosophy. Pioneered by the Japanese, JIT is an integrated set of activities designed to achieve high-volume production using minimal inventories of parts that arrive at the workstation exactly when they are needed. The philosophy—coupled with total quality control (TQC), which aggressively seeks to eliminate causes of production defects—is now a cornerstone in many manufacturers' production practices, and the term lean manufacturing is used to refer to the set of concepts (Jacobs and Chase, 2010).

Due to the corporate operational structure of PepsiCo nationally, there are varying degrees of lean implementation across their different locations and brands, depending on the type of operation, source of the plant and a number of other factors.

Lean is often implemented initially as a reactive measure, and then later ingrained in organizational culture as a staple for operational excellence. Under PepsiCo, has not experienced any difficulty in moving finished product and has not been put in a position where lean implementation would be a requirement for operational success. More specifically,

since there are so few competitive sources of pita chips when compared to the product demand, [redacted] is able to successfully produce on a push system, instead of the pull system usually necessitated by highly-competitive environments. In this context, pull refers to a plant producing in volumes projected to meet customer demand, as opposed to push which refers to producing at process capacity regardless of direct demand, in addition to making batch and volume decisions on a reactive basis.

Muda is the lean terminology for all forms of waste, especially when generated as a product of manufacturing operations, and anything that does not generate value from the consumer's perspective. What is unique about [redacted] operations is that they do not operate on a takt time, the production pace needed to satisfy customer demand, because they're running on a push system. In any normal lean operation, as soon as cycle time begins to exceed takt time the line managers are able to identify areas of significant muda or operational failure. Because this line does not have a takt time to serve as a key performance indicator (KPI), it is significantly more difficult to identify muda, as well as being more difficult to make proactive business decision-making projections.

Kaizen Boards

Many manufacturing companies use a tool called a kaizen board as a medium for stronger communication regarding process change. A kaizen board is a physical board that is placed in a visible setting in the manufacturing floor which includes specific goals and lean-driven process changes that encourages continuous improvement of value added activities. These lean-driven process changes are called kaizen events, and the board provides a way to easily visualize and understand the events. Each event usually displays when it was created, who is responsible for

the idea, the purpose and the timeline of the event. In order to effectively implement a kaizen Board, these are the recommended steps (Colaci, 2011):

1. Measure operational performance
2. Set performance goals
3. Obtain feedback from all employees involved with innovative ideas
4. Standardize all new procedures
5. Repeat

Throughout the manufacturing industry, many organizations have experienced the benefits of using kaizen boards and conducting kaizen events. Kaizen boards are generally created by a kaizen team, which consists of operation managers, engineers, operators of the floor, quality manager and quality employees (all employees affected by process changes) (Colaci, 2011). Visualization, images, diagrams and animations are helpful techniques to effectively communicate ideas and action plans (Abdulmouti, 2018). The kaizen board uses visualization, 5S techniques and clear communication to achieve continuous improvement goals (Dev Singh, Singh, Chokshi, Chavan, & Dabhi, 2015). The 5S' are: sort, straighten, shine, standardize, and sustain. Successful kaizen board implementation can lead to an increase in annual production, reduction in expenses and process errors and improvements in quality of production (Dev Singh, Singh, Chokshi, Chavan, & Dabhi, 2015). An increase in employee involvement with process changes leads to a higher likelihood of success.

Reactive vs Proactive Management

In the manufacturing industry, company management is constantly trying to balance addressing immediate issues with the potential benefit of enacting preventative measures in their

operations. Furthermore, this dilemma can also be encountered by any level of employee, as nearly every problem that may arise can be addressed in either a proactive or reactive manner.

A team of employees can run around putting out fires as they appear, or they can engage in a mindset and behavior where they "anticipate outcomes and prepare for the consequences," (Scivicque, 2017). Research into supply chains of the manufacturing industry have shown that, "companies tend to use reactive rather than proactive strategies because reactive strategies are easier to carry out, require less time and resource investment, but may not be better in the long term," (Angkiriwang, Pujawan and Santosa, 2014). Both approaches have their place in a company. Sometimes an unforeseen "fire" will arise, and a good manager or company will react accordingly to put out the fire and adapt to a changing environment. The best managers can then further adapt and implement procedures to prevent this problem from occurring again or at least have a plan for when it does. The downfall to having a reactive mindset in a management or manufacturing environment is that there will always be another fire or problem to fix. This can cause managers, or the entire facility, to fall behind in production, which could lead to future issues such as missing deadlines or failing to meet customer demand. It becomes nearly impossible to get ahead of the problems (Kothari, 2018). A shift to a proactive mindset can save a business from countless headaches and increase the bottom-line in the future. This mindset can be accomplished by following the 5 P's to management. Predict potential problems, prevent problems from occurring when possible, plan, participate in the situation and perform appropriate actions (Scivicque, 2010).

Axiomatic Design Overview

When defining a project goal, axiomatic design allows all areas of a project to be transparently organized for every stakeholder involved. The scope, requirements, potential roadblocks, and solutions are brainstormed, and then fully defined. One of the most common ways to create this analysis is using Acclaro® DFSS to specify the functional requirements and design parameters in an axiomatic design decomposition (Acclaro, 2018). In the first stage of a project, the MQP team clearly defined the goals, which then became the base functional requirement. For the purposes of describing the use of Axiomatic Design in the food production environment, we used "Reduce waste in the Pita bread baking process" as an example of an objective. This was defined as FR0. Under FR0, the goals are broken down hierarchically into seven other FR's. Each FR having a various number of subsets of goals associated with them. FR1- FR5 are focused on reducing forms of waste outlined by the Toyota's production system and the concepts of lean manufacturing (McBride, 2003). FR6 aimed to define a relationship between external environmental factors and the baking process final product. In the example, the identified factors were humidity, external temperature and water temperature, defined as FR6.1, FR6.2, FR6.3 respectively (the example decomposition tree can be seen below). The goal was to develop a set of metrics and data collection techniques to identify how the process is being affected by these external environmental factors. This data could then be used to develop a standard operating procedure to replicate the perfect baking process accounting for external variables. Following the defining of the functional requirements, design parameters were developed to demonstrate how to achieve the goals. Axiomatic design aids in effective problem analysis because it helps clearly lay out what needs to be accomplished to reach the desired goal and helps reveal hidden requirements to the solution, which might not have been seen initially.

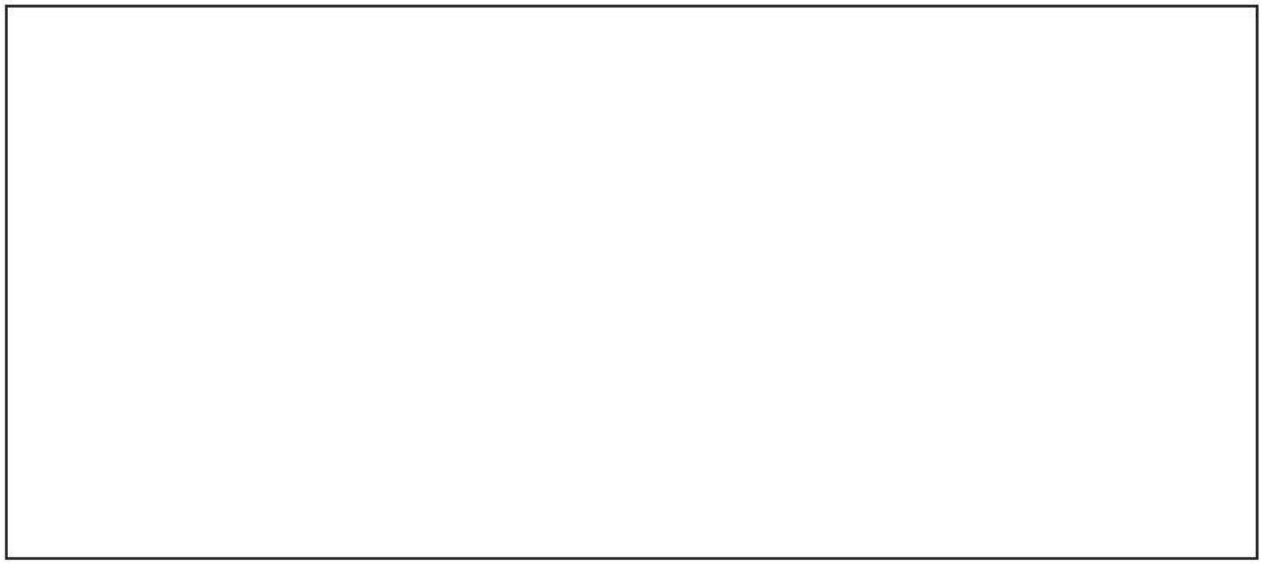


Figure 3 MQP team first axiomatic design

Methods

This project was completed by conducting two examinations of the pita bread production process consisting of a curing time experiment and a process analysis. The MQP team completed both examination by following these two approaches:

1. Development - this component consisted of in-depth research on the topic to diagnose the problem and validate assumptions about the process. At this phase, axiomatic design was a key tool for understanding the problem. By analyzing the problem in this manner, the MQP team was able to move on to the second phase of the method.
2. Data collection - in this component the focus was on validating the preliminary hypotheses through a span of data-collection methodologies.

The collected data was analyzed, both scientifically and financially, to confirm the hypotheses and generate the base for the recommendations. The following sections of the methodology explain in detail the steps taken to formulate recommendations on curing time process improvement and further opportunities for data gathering.

Curing Time Analysis

The curing process is the longest step of the baking process. It is the process of letting the bread rest until the bread's final texture is improved. It takes place directly after the pita bread is cooled and stacked into racks. These racks rest and wait [redacted] n one of the plant's inventory management locations for the curing process to be complete.

There are two questions that the [redacted] management team had regarding the curing process. First, why is the curing time 8-10 hours and can it be shortened? There was no

supporting literature on why the curing process is this length of time, nor did the [redacted] [redacted] quality control team carry out data collection to prove that [redacted] was the proper time to let the bread cure. Second, does the climate in which the bread cures have an effect on how long it takes for the bread to properly cure? The [redacted] management team understood that the curing process takes place in a non-climate controlled area and that the conditions outside the factory, such as temperature and humidity, could have an effect on the curing area climate. They were considering enclosing the curing station in a climate controlled area if deemed necessary.

The experiment was carried out to identify the effect of temperature and humidity on the pita bread curing time. The MQP team took three pallet stacks of bread from the curing line as soon as the stacks were wrapped with plastic at "time zero". To compare physical and chemical characteristic changes over time, the stacks of bread were placed in three different climate locations. One stack was placed in the proofing room where the temperature and humidity were on average 88°F and 51% respectively. Another stack was labeled for experimentation and left near the curing inventory location where the temperature and humidity were on average 81°F and 33% respectively. The third stack was placed in the quality control room where the air conditioning unit kept that average temperature and humidity at 76°F and 42% respectively. With the three different curing climates, the results of the experiment could be compared between the three locations. The MQP team was additionally able to analyze the time it took for the bread to properly cure in those different climates.

To measure the bread moisture, an HF-83 machine was used. The MQP team inputted samples of the pita bread to test and the machine would output a moisture reading given in percentage form. The two different bread moistures the MQP team collected were samples of the

whole bread versus a sample of the inner portion of the bread. These steps were taken for all three different stack climate locations, for a total of 6 breads tested per hour. The experiment lasted for 8 hours. The MQP team graphed the data points over time. The Split Ratio Index (SRI), which is defined as the ratio of the top piece to the bottom piece when splitting the bread in half was also measured. An ideal SRI would be 50% because the bread should be an equal thickness on the top and bottom pieces to ensure quality final product.

For any improvement opportunities for the curing process, the MQP team would proceed to create a financial analysis to demonstrate the financial benefits associated to either decreasing the time or controlling the climate of the curing process.

Process Observation & Analysis

By using a series of observations, experiments and interviews with process controllers, the MQP team attempted to prove the following hypothesis: [redacted] baking process could be improved from its current state by adding sources of data or sensors to detect certain KPIs within the process. By adding more sources of data and sensors, various metrics would be obtained, that would allow [redacted] to detect potential defects earlier in the process. The goal was to identify sources of variation in the process, that could be controlled with the application of more data quantification. The MQP team performed a cost analysis to show the financial benefits of having more data sources. By reducing variation and collecting more data, [redacted] would significantly decrease their operating costs. The process observation and analysis were accomplished by the following methods:

1. Develop a set of topic questions on data collection and process variances.
2. Interview and obtain process-related information from plant manager and quality manager.

3. Perform cost benefit analysis on the benefits of increased data collection.

To facilitate efficient and successful root-cause analysis after KPIs were identified, the MQP team interviewed [redacted] plant manager to evaluate the communication methods used for process improvement action plans. The interview allowed the MQP team to understand the non-tangible communication methods in the plant such as: team meetings, flow of information and problem-solving techniques. Through a guided tour and independent visits, the MQP team observed and photographed all tangible communication efforts including: [redacted] The MQP team researched essential variables of successful lean manufacturing to evaluate different lean tools to increase the communication of process improvement plans within the plant. Researching different case studies involving different lean principles and tools like the kaizen board and 5S allowed the MQP team to confirm which methods were successful across many industries, especially manufacturing, for the creation of adequate recommendations for [redacted].

Axiomatic Design Implementation

The MQP team used the axiomatic design method to understand the different aspects of the process and generate a solution. It also allowed the advisors and sponsors to have a single understanding of the MQP team's perspective and approach. Using a hierarchical decomposition program, Acclaro® DFSS, the MQP team was able to clearly organize the functional requirements and the design parameters (Axiomatic Design Solutions, 2016). Axiomatic design is comprised of four different domains, customer, functional, physical and process. The MQP team utilized the functional and design domains. Functional requirements state what the MQP team wants to achieve. Functional requirements should be minimized, collectively exhaustive

and mutually exclusive. Design parameters state how to achieve each functional requirement (Towner, 2013).

Axiomatic Design Thinking at Stacy's Pita Chips

The MQP team's axiomatic design and decomposition tree evolved over the course of the project. The early stages of the project were focused on eliminating waste in the baking process by identifying external variables that affect the baking process. The MQP team identified loss points in the process and used lean methodology to improve these loss points. The MQP team progressed in their understanding of the [redacted] baking process. Thus, their thinking evolved to reflect this new knowledge. Midway through the life cycle of the project, the focus of reducing waste in [redacted] baking process remained the same, but the methods shifted. The MQP team focused on the reactive nature of [redacted] production process and the shortcomings associated with addressing product issues in this manner. The MQP team shifted the axiomatic design to focus on creating a more proactive manufacturing solution by recommending an increase in data sources. An experiment was then performed to identify an optimal curing time for the baking process. The MQP team was able to show the need for curing, but also identified the optimal curing time, which could allow [redacted] to reduce their cycle time.

The decomposition tree (shown below) evolved as the project goals and objectives shifted to meet the needs of the sponsor. A decomposition tree is a dynamic industrial engineering tool, because as the project and thought process of a team change, so does the axiomatic design needed for the project. The former goal of the project was to reduce the reactive nature of the baking process by increasing data sources and analyzing the current curing process. These goals were reflected in the final axiomatic design. FR0 was achieved by accomplishing the sub goals

of FR1-4, with corresponding design parameters developed to meet the functional requirements. To achieve FR0, the MQP team determined that the following must be met:

1. Increase in data collection metrics using KPI
2. Reduce waste in the curing process through experimentation
3. Increase communication between process actors using tools such as a kaizen board
4. Increase proactivity of the process

The axiomatic design the MQP team used to illustrate the thought process and goals of the project changed dramatically over the course of seven months. The use of axiomatic design was critical to help the MQP team maintain scope and direction of the project.

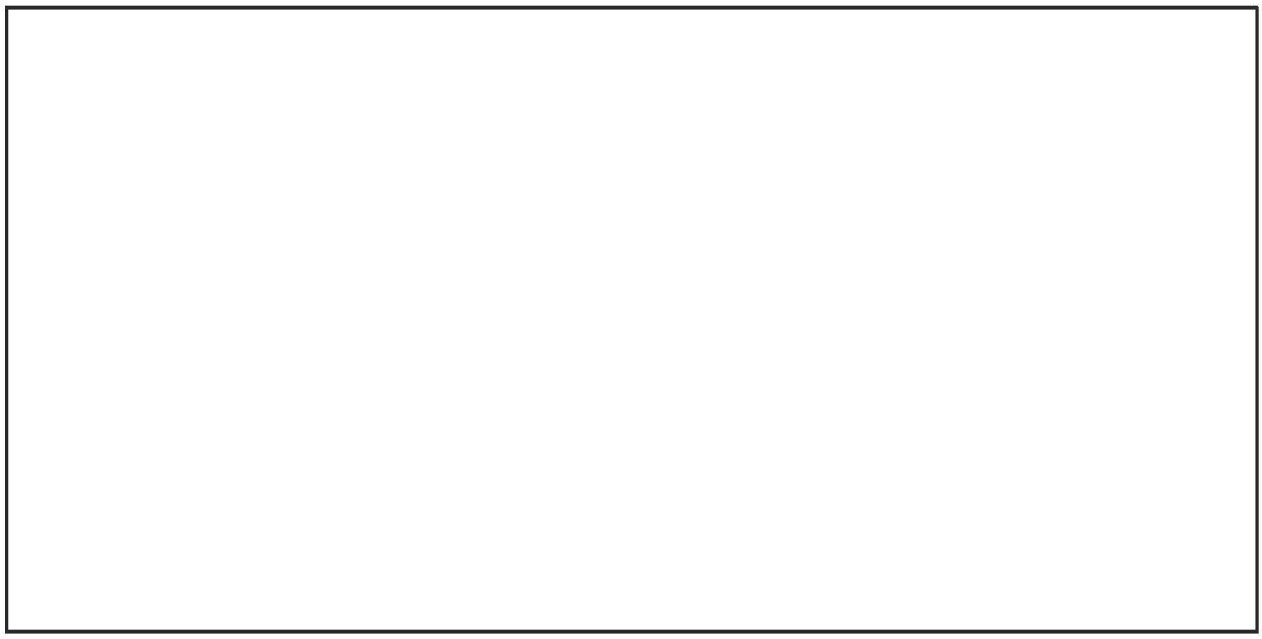


Figure 4 MQP team final axiomatic design

Axiomatic Design Process Nuances

One of the major considerations throughout the MQP team's axiomatic design decomposition was the fact that the [redacted] process was composed iteratively, with

additions on a strictly demand basis. As the business expanded to meet demand, machines were added in whichever way was most feasible, with integration strategy being dependent on the introduction team, which has a number of specific implications.

The first implication is that each axiomatic decomposition point has to be relevant to every generation of technology and process that has been integrated in the current line. In the future this will require a span of lean methodologies to address similar concerns, since there is such a range of technologies in place. In order to meet a single functional requirement consistently throughout the process, the MQP team leveraged a combination of process management tools and analytics.

The second implication of this iterative approach was that, since expansion was guided by a bottom-line focus, analytic platforms were not organically incorporated in the process. For the MQP team to have an idea of where to develop and focus the subsequent functional requirements, it was necessary to use a combination of observation and interviews. As with the previous concern, in order to efficiently leverage process management technologies, the MQP team had to develop its own analytical resources and methodologies.

The final process nuance in relation to the decomposition was the [redacted] worker base. The organization was dependent on highly-skilled workers, so it was important to design the functional requirements in a manner that provided support towards the MQP team in a holistic decomposition. Especially in companies like [redacted] where the workers were fully cooperative and invested in the process improvement, one of the largest project considerations was team buy-in.

Results

Curing Time Experiment

The goal of the curing time experiment was to gather data points that would prove or disprove the MQP team's hypothesis that the pita bread did not need to cure for 8 hours. Additionally, the experiment also served as support to answer management's question regarding the length of time needed for the bread to cure and whether that length of time would change depending on ambient conditions in the factory.

Through research, the MQP team concluded that the even distribution of moisture in the bread is a key characteristic of a properly cured bread. The MQP team refers to evenly distributed moisture in the bread when the moisture of the inner shaving (the soft inner core of the pita bread) and the whole bread moisture are approximately uniform. Since there is no statistical standard measurement of an acceptable percentage difference between these two moisture levels, the MQP team was compelled to use one standard deviation (SD) from zero as an acceptable range of uniform moisture in the bread. From the experiment the MQP team gathered key data points that helped summarize the physical and chemical changes over time in the pita bread during every hour over an eight-hour period. The data points gathered from the curing time experiment were whole bread moisture, inner shaving moisture, core weight, top weight, SRI, environmental temperature and humidity. These data points were evaluated to form a summarized table containing the percentage difference in the bread moisture over time.

The results from the MQP team's analysis are summarized in the following table and graph. The below figure shows the summarized table that the MQP team created from the data gathered. In this table the MQP team color coded the percentage difference to represent the

standard deviation from zero at each percentage represented. In the color code, green is associated with one or less SD, yellow is associated with between one and two SD and red is associated with between two and three SD. The MQP team focused on the average percentage differences from each of the three different curing locations. It was determined that after four hours of curing time the environmental factors have negligible impact in the curing process of the pita bread. Additionally, the MQP team also interpreted that the marginal utility of curing time trends to nearly zero after four hours in the test batch.

Rooms / Time (hours)	1	2	3	4	5	6	7	8	Avg. humidity	Avg. temp	Avg. SRI
Air Conditioned	12%	9%	10%	1%	0%	0%	0%	3%	42%	76	59%
Proofing Room	7%	13%	14%	10%	1%	2%	8%	1%	51%	88	59%
Curing Area	11%	11%	7%	3%	2%	0%	3%	4%	33%	81	59%
Avg.	10%	11%	10%	5%	1%	1%	4%	3%			
SD	0.042529	4%									

Figure 5 Summarized table containing the percentage difference in the bread moisture over time

The experiment provided information about the potential of decreasing the total curing time to 4 hours. The financial analysis provided in the next section shows the monetary benefits of the MQP team's recommendation. A limitation of the experiment was that it did not show how the bread would react in the kitchen, given that the bread did not cure for the [redacted] hour period.

Process Observation & Analysis

Through a set of interviews with process controllers, quality control specialists and upper management, combined with self-observations of the baking process, the MQP team identified where KPIs were being collected. KPIs such as: split ratio index, dough moisture, core weight, taste and temperature were collected during the baking process for quality control purposes.

In addition, the MQP team identified the areas lacking KPIs. An area lacking crucial KPIs is the mixing station, the first step in the baking process; another area lacking crucial KPIs

is the curing station, the last step before the pita breads are transferred to the kitchen to make pita chips.

It is important to measure KPIs to identify poor batches of pita bread at the earliest stage in the bakery process and poor batches of pita chips at the earliest stage before the kitchen. Calculating these proactive KPIs will prevent Stacy's Pita Chips from losing the opportunity cost associated with sending bad pita bread or chips through the entire process.

The MQP team performed a financial analysis to show the importance of eliminating low-quality pita bread early in the production process. The financial analysis was designed to motivate management to further increase the collecting, tracking and acting upon of new, useful data points, otherwise known as KPIs.

Work-in-Progress Inventory Management

The curing time experiment and analysis quantified a number of opportunities for future work, but it also allowed the MQP team to make a number of observations about the curing process. One of these key observations was in regards to the facility's current inventory management system, which is currently managed manually. The MQP team observed that all pallets of pita breads in curing storage were labelled by hand with all information relevant to the pallet. At the time of relocation, the same process was used with the new inventory, each pallet was tagged by hand for communication purposes. Two significant observations made about the limitations of this system were: the challenges of decoding each operator's handwriting and the difficulties of digitizing these data points for the purposes of database management and tracking.

Conclusion & Recommendations

The manufacturing environment is complex, regardless of the industry sector or geographical location, with many levels of evaluation and consideration needed to understand any facility. Throughout any endeavor which requires a comprehensive understanding of a manufacturing plant, such as a process change or capital project, it is important to understand as many components of the operation as possible. For the purposes of this project, the MQP team took waste levels, production variability, and financial impact into account, with the most complex level of analysis resulting from the financial component of the projected impact of these recommendations.

In analyzing any process change, it is important to consider the financial details in order to improve profitability. The profitability of the proposed projects is one of the major influences in deciding whether to implement the process change. Therefore, the objective of this financial analysis is to assist the manager in the evaluation of implementing the proposed initiatives by providing a systematic analysis of the economic benefits directly associated with the projects. This analysis would guide management through the benefits, costs, assumptions and possible financial outcomes of the recommended changes in order to understand the amount of resources, capital and labor, that should be allocated for each project. For every recommendation, the MQP team worked under certain assumptions as needed to estimate the possible financial outcome. These assumptions were gathered through industry research, manager input and the MQP team's scrutiny. A detailed list of the assumptions will be discussed under each recommendation. Although these assumptions were used for the MQP team's analysis, management can change these assumptions to better represent their current situation.

Conclusion

The goal of this MQP was to provide [redacted] with a quantification of the factors that contribute to variation in pita dough quality in their manufacturing facility. The scope of this project covered a segment of the dough processing line, excluding areas that are well understood or not thought to contribute significantly to product quality variability.

This project was proposed as an initiative to better understand methods with which [redacted] might be able to reduce waste in their facility, as well as stabilize their product consistency. This was needed since the initial state of their production was one that tended to be subject to high process loss.

The MQP team was able to perform multiple analyses while at the plant location over the duration of the project, as well as perform a number of interviews and observational studies. Using the results from these methods, the MQP team was able to deliver to the sponsor key recommendations, supported by the work extending over the previous three academic terms. The MQP team's analyses indicate that operational efficiencies would increase significantly if these recommendations were to be successfully implemented, with a quantitative net-present-value impact projected about $4.8 million over a period of 12 quarters.

In summary, after extensive evaluative work, the MQP team was able to provide data-backed recommendations that would significantly increase the sponsor's revenue. Additionally, the members of the MQP team were able to derive a number of key insights that both add to the operational understandings of the plant and to their own understandings of process management and improvement.

Recommendations for Curing Time Sampling Data

Reiterating the MQP team's interpretation of the cure time sampling experiment, the team observed negligible impact of ambient factors on the curing process, as well as the marginal benefit of curing time trend to nearly zero after four hours in the test batch. Due to timeline limitations, the MQP team was not able to proceed with testing further batches, as a single test required an entire day of active sampling. However, given the impact of the behaviors observed in the single test batch, the MQP team strongly recommends pursuing further research into the marginal benefit of each hour of curing time by [redacted]. The current "tribal knowledge-based" practice has a minimum of eight hours, and if [redacted] were to be able to fully vet and validate a shorter duration, the increase in plant production capacity would be significant.

From the one-time experiment, the MQP team recommends assembling a climate and humidity control area for the purpose of increasing the probability of a pita bread curing in a four-hour period. As the MQP team analyzed the manufacturing process of [redacted] various financial details were obtained from management to give insight into which areas within the baking process contribute value, and which steps generate waste. This insight facilitated the understanding of the financial cost associated with the curing time, and waste created from a naturally idle process. Additionally, the MQP team was also able to identify the financial benefits of reducing curing time to four hours. As explained previously, curing process is crucial for the final product since it directly affects the texture of the final product, and thus cannot be removed from the production line. However, the time reduction in this process component has a significant impact on the overall manufacturing cycle.

The long pita bread curing time affects the total work-in-progress on the manufacturing floor and delays the total process cycle time of the product. However, one of the core assumptions made by the MQP team was that a reduced curing time would decrease total cycle time, and therefore increase throughput. The increased throughput would equal the product of the number of hours reduced from the original curing time, and the number of pounds of pita bread the plant could produce in an hour. Additionally, these recommendations assume that the facilities can keep up with the increase in the throughput of pita bread. If the manufacturing line cannot keep up with this increase of bread, management could invest in more robust production equipment to increase this production process capacity. With these assumptions in mind, the MQP team was able to estimate that the net present value of the curing time reduction change would be about $4.5 million over 12 quarters. The following figure shows all other assumptions used to calculate this financial impact.

Assumptions used to determine the financial benefits			
Annual Rate			16%
Rate per period			3.78%
Number of of periods annually (Quarterly)			4
Total periods of analysis			12
Hours reduced from process			4
Initial investment		$	(200,000)
Quarterly gain		$	499,200
Yearly gain		$	1,996,800
Net present value		$	4,545,351

Figure 6 Assumptions used to determine the financial benefits of reducing curing time

Key Performance Indicators

Key performance indicators (KPI) are a type of metric that has become a staple in the operations and business community, allowing quantitative change tracking across almost any type of organization or system. KPIs are developed by comparing or contrasting two or more variables, where at least one variable is dynamic to the other in order to gauge specific change(s) in a system. KPIs are a fundamental component of lean methodologies, being one of the more prevalent methods of measuring process efficiencies, as well as process improvement impact. By placing data collection points at key locations in a system, it is easy to use KPIs to gauge whether the process is operating within control limits (no excessive production variation) or to the expected standards.

Currently in the [redacted] there are a few specific KPI being implemented by their team, mostly for quality purposes. Examples of this are their split ratio index, dough moisture, core weight, taste and temperature. Together, these measurements are used to track production performance, make process adjustments, and a number of other quality and efficiency-centric endeavors. These values are all referenced multiple times per day, or with the relative frequency of all of their quality-regulation measures.

Moreover, from the MQP team's observation and research, the team recommended the addition of KPIs at the early stage of the process. The details of what KPIs to monitor in the early dough stage is beyond the scope of this project. However, it is a factor that the MQP team identified that could greatly influence the process and would reduce the overall waste created at any stage in the process. [redacted]

For the financial analyses, the goals of adding these KPIs are to increase dough quality, and to identify early defective dough that would otherwise yield waste later in the process. The MQP team identified two sources of savings that will be created by implementing these KPIs. The first source of savings is the early discarding of dough, this is defined by the MQP team as any dough chunk that will not move forward through the processing machines. Since the process depends on a live ingredient, yeast, it will react differently every time a batch is created and moved through the process. With the new KPI, only dough with good probabilities of becoming high-quality bread will advance to the process, thus increasing the overall net output quality. The MQP team's assumption is that the present causes of waste can be identified and prevented from impacting the process, resulting in savings. Additionally, after discarding the defective dough, the MQP team estimated that some percent of dough that has been discarded can then be replaced by new dough (with a higher probability of success), creating ancillary revenue. This increase in bread quality will also affect the quality of the pita chip process. Therefore, as a second source of savings, the MQP team assumed that some percentage of the current waste of chips would not be discarded since the dough quality has improved, thus yielding savings. Moreover, the same chips produced by ancillary line capacity would later contribute to finished product output, where it would create a source of revenue.

The MQP team has assumed that the project would need an initial investment of X amount of dollars to identify, place, react and train employees to the new KPI. Along with some other assumptions on the cost, revenue, interest rate and learning curve, the MQP team produced

a financial equation that will estimate the net present value of this change. The equation used by the MQP team for net present value is "uniform series present worth" (P/A,i,n) minus "initial investments" (Doremus, 2018). A list of the MQP team assumptions can be seen below figure 8. The MQP team created three different combinations of saving percentage, initial investment, and an array of other assumptions to demonstrate three different scenarios for the outcome of this project. These can also be seen in following figure 7.

The most likely scenario from the MQP analysis reflects that these new KPIs will identify defective dough batches before it continues through the process 60% of the time, and 90% of this early defective dough will be replaced by an improved batch, which will generate an increase of pita chips quality by 10%. The MQP team expects this scenario to require an initial investment of $75,000. The outcome from this scenario over 12 quarters is a net present value of $315,000 with a return on investment by the second quarter. More scenario analysis by the MQP team is shown in figure 7. The cash flow representation for the most likely scenario is displayed in figure 8. Additional assumptions critical to the financial analysis are shown in figure 9.

	Low	Most Likely	High
Identify waste in early stage (before baked)	50%	60%	70%
Successfully replace early waste	80%	90%	95%
Increase quality of pita chips	7%	10%	13%
Initial investment needed	$ (100,000)	$ (75,000)	$ (75,000)
Net present value	$ 193,817	$ 315,380	$ 408,240
Payback Period (Quarter)	3	2	2

Figure 7 Financial outcome from three scenario as defined by the MQP team

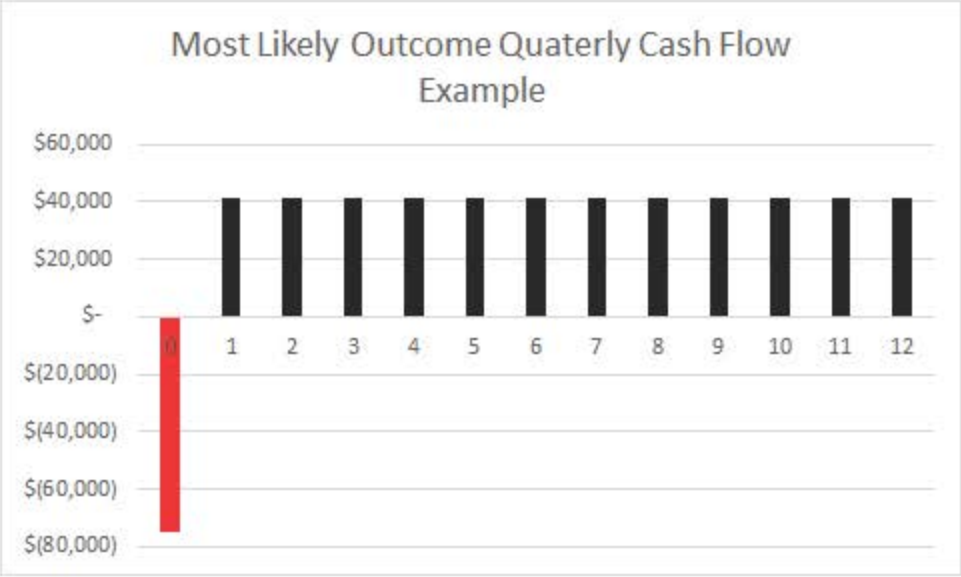


Figure 8 Cash flow representation example for most likely scenario

Assumptions used to create the financial analysis	
Rate Annual	16%
Rate per period	3.78%
# of period (Quarterly)	4
Total period of analyses	12
Profit/cost per pound, break down	
Early stage total cost	
After baked cost	
Chips for cost	
Waste in lbs. for different stage	

Figure 9 Assumptions used to create the financial analysis for the implementation of new KPI

Smart Inventory

Inventory management is one of the important components in supply chain management and the success of a business. The use of a comprehensive and complete inventory management system, which includes techniques such as just-in-time and first-in first-out, along with the use of tracking software can help transform the inventory management of a company (Reeves, 2019). Smart Inventory can help a company, "control costs and fuel growth by giving management greater visibility and data on consistently changing inventory," (Skuvault, 2019). Some smart inventory systems could include the use of QR codes, bar codes, radio frequency identification (RFID microchips/tags), microchipped pallets or scales or a combination of the former. These codes or microchips could be placed on each batch as it goes into inventory and include detailed information such as the product, weight, time of production and any other pieces of information that could help track inventory and support cleaner communication among employees and management (Donadio, 2016). The MQP team recommends using RFID tags in pallets along with a scale which can be placed on the stacks of pita bread after a pallet is completed. This system would allow for the stack to be tracked in inventory as the bread is cured and could also track the weight of each stack as a moving average to use as a quality control check. This time tracking system for curing would eliminate the need for handwritten tags on the stacks, which could have led to incorrect transfer of product information, such as reading start time of the curing process. Using a combination of smart inventory techniques and equipment to manage inventory and track KPIs will lead to an increase in transparent communication and help the bottom line of the company.

Sustaining Process Change Through Kaizen Boards

When recommendations are implemented at [redacted], the process, work pace, and routines that employees currently maintain will change. Thus, a more robust communication method must be implemented to persuade employees to willingly make the necessary changes to their daily routines. Improved horizontal and vertical communication is needed to increase the success rate of continuous improvement efforts and can also generate moral and economic benefits.

In the background section titled "[redacted] Company Communication Methods", the MQP team described the current communication methods that [redacted] utilizes. The MQP team recognized the lack of visual process improvement tools that can currently be used by any level of employee to evaluate line output and performance. The MQP team strongly recommends introducing a kaizen board, a lean manufacturing tool, to further improve the communication methods between all [redacted] employees.

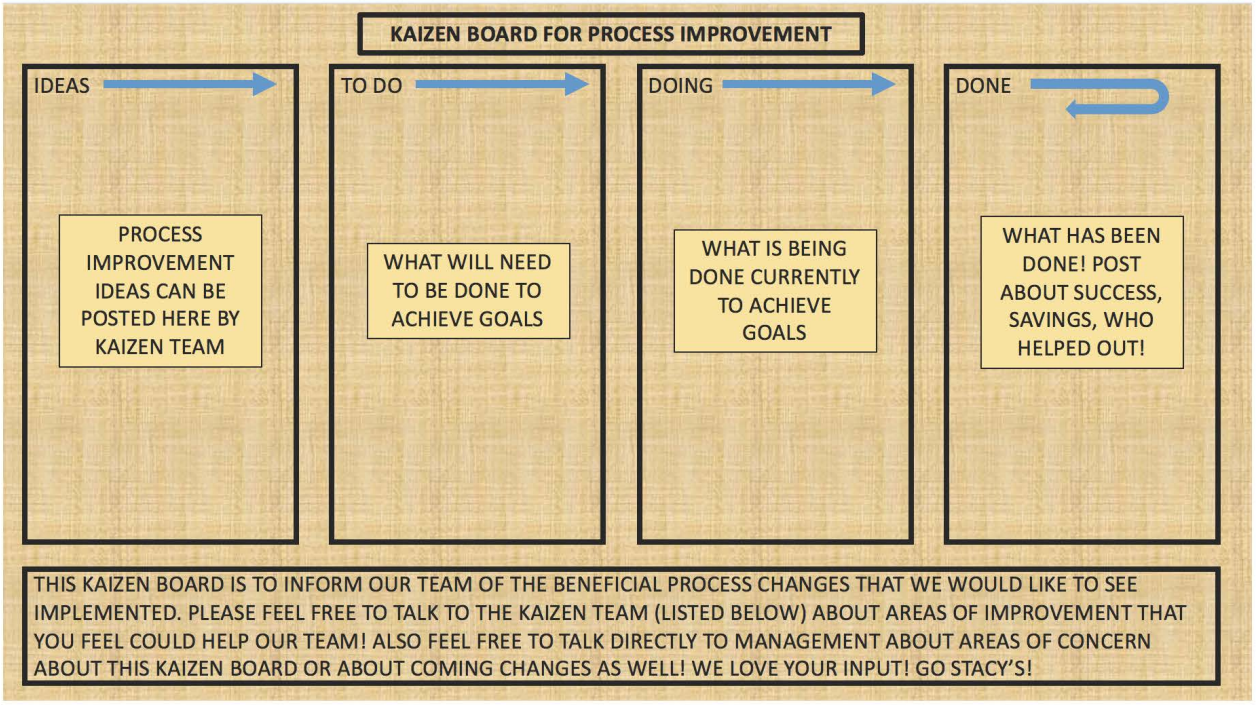
The recommended process for implementing a kaizen board in any organization can be described through a series of steps. For the purposes of an example relevant to this project, the process to track curing time experimentation impact would start with a first step of measuring operational performance and posting it on the board.

The MQP team recommends that [redacted] management first pick a single data point that could be gathered by quality control employees, which would provide a performance standard baseline on how the pita breads react to the kitchen processes over an 8-10 hour curing interval. Baseline performance standards could include split ratio index of the pita breads, chip moisture following cooking, bread or chip tasting trials conducted by the quality control team, or any other relevant data point.

The second step of implementing a kaizen board is to set performance goals. From step one, the quality control team could use the baseline performance standards to measure whether the bread responds in a similar manner to the kitchen process, given that it has only been cured for 4 hours. These data points would be collected using a separate sampling methodology, as the production line does not currently operate under the 4 hour curing time condition. These new performance goals should be added to the board.

Following the conclusion of each process study, [ ] management would next obtain feedback from employees about the changes in the bakery and kitchen due to process improvement initiatives. At this point, it would be critical for management to address any immediate concerns of employees. Management should open to any new ideas from employees directly involved with the process. All of these collected ideas, concerns and observations are then added to the kaizen board, to help the employees take ownership of the ideation process. Following this, all suggestions must be time-bound, with the author of the suggestion attached, and who would be responsible for carrying out the suggestion. If all steps of the kaizen board implementation process are successfully conducted, [ ] management should use the completed kaizen board as an evaluation of whether to standardize or reject the new procedural recommendation. [ ] management should repeat the steps of the kaizen board for other desired process improvement projects.

Drawing from multiple examples of kaizen boards viewed by the MQP team members in other organizations, the team compiled an example of a format that [ ] kaizen team should use:



Kaizen board sample layout designed by the MQP team.

Project Reflection

Over the course of this project, the MQP team learned three valuable lessons about change in the context of a manufacturing environment, especially for high-volume production. The first learning point was that, if the margins are large enough, it can make sense from a managerial perspective to tolerate process inefficiencies, at least temporarily. Plant operation relies on revenue, and if the revenue stream is not endangered by the current operational state, then the best use of managerial attention is with more urgent matters.

The second learning point of the MQP team was the impact upper management can have by communicating and developing substantial relationships with employees at all levels of the organization. This interpersonal base for communication is hard to quantify on paper, and the MQP team had originally underestimated the effect that it would have on the more tangible aspects of plant operations. All throughout the project site, examples of successful and productive interpersonal communication as a component of plant operations were visible, to the extent that more robust methods of communication had never needed to be developed.

Finally, the MQP team learned about the difficulties of organizational change, especially in the middle tiers of an organization, if there are no mechanisms in place to emphasize the importance of the change. While there are any number of resources documenting the difficulties of making changes within an establish operation, the MQP team was unfamiliar with the nuances of the resistance than can sometimes be encountered in specific areas of a company. The most significant factor was that there were no established methods in this part of the process which could communicate the impact of the possible changes, which in turn made it difficult to justify the additional data collection for process improvement.

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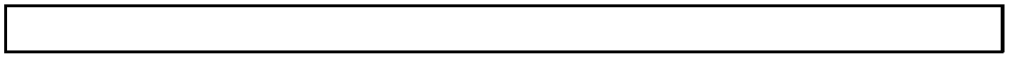

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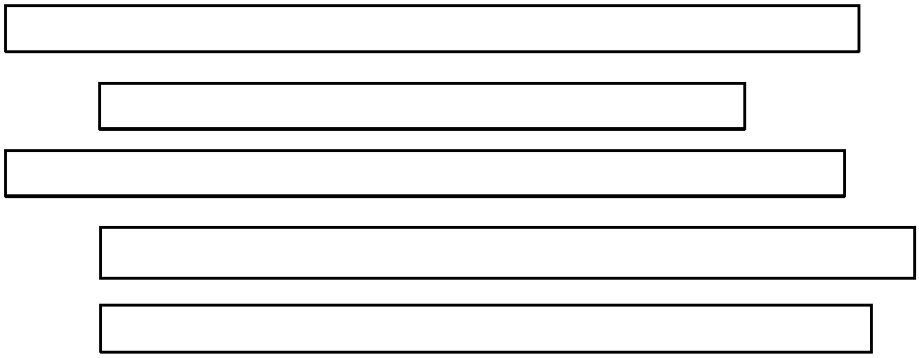

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