REDUCING OVERALL OVERTIME HOURS ACCUMULATED BY SAN LUIS SOURDOUGH

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ABSTRACT

The packaging department of San Luis Sourdough Company was redesigned to increase bread throughput and decrease overtime hours issued to employees. Time studies were performed to get an accurate representation of the average throughput of bread with the current packaging conveyor system. After collecting data and surveying the employees and management, we came up with three design solutions to improve their current packaging system. The first design recommendation has a low-investment and is quick to implement as it pertains to changing the worker’s schedule to alleviate the employees from working long hour shifts while increasing the bread throughput. The second recommendation with a little higher of an investment cost associated to it is to create a new tracking system as there currently is no way of the company knowing how many bread they have packaged and how close they are to finishing an order. The third and most expensive recommendation is to purchase more conveyor lines. This recommendation was found after running a simulation of the packaging department with different constraints and flexibility. All three of these recommendations save the company money as they would cut down on the amount of production hours needed to complete orders.
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I. Introduction

San Luis Sourdough is a local bakery that sells to vendors all over the California coast. Operating since 1983, all SLS bread is hand-formed and locally-made, using a slow baking process to give it that authentic Sourdough taste and texture. In the packaging center, there are three stations that package at least 43,000 loaves of bread that SLS produces daily.

The food industry is unlike other manufacturing industries; food perishes, and areas must be kept clean of contamination to ensure edibility and quality for the end user. This extra constraint to food products makes common production line methods unacceptable. Perishable food, unlike other manufactured items, cannot sit in storage for indefinite amounts of time. This report will explore the possible methods used in manufacturing factories to reduce cycle time, waste, and direct labor, which can be altered to meet the extra criteria of keeping the products edible.

The Problem

San Luis Sourdough (SLS) currently does not have in place bread processed standards or methodology for workers to use in the packaging department. Production goals and current percent completion of finished goods are both unknown. After hearing the description of this project from the manager, it was clear that work flow was stop-and-go most days. After seeing this process flow, we will design a standardized packaging system to reduce overtime hours issued weekly from 380 to 150.
Objectives

To solve this overtime problem, we first must determine the current state of the factory. After gathering as much accurate data as possible, we must analyze it to determine the time it should take to output the bread needed for the daily bread shipments. From there, several designs will be conceptualized and tested, from schedule reorganization to facility layout re-design to production tracking. Each design will be tested to determine the total reduction, if any, in accumulated overtime hours. Further analysis will be done to quantify the cost benefits of the best designs (minimum of 2). At the end of the project, we will have completed a worker schedule and facility design suggestion for San Luis Sourdough (SLS). SLS will be given a presentation, this report, and a confidential final design packet.

Expected Deliverables

For our deliverables, we must complete the following:

- Summarize results of current-state data collection
- Redesign a facility plan for packaging and shipping area
- Suggest new work schedules
- Design an appropriate production plan
- Summarize results of proposed design simulations
- Present findings to SLS

Solution Approach

To have a solid foundation for meeting our objectives, current state data must be collected. To understand the current process and state, we will
- Run a time study to determine the average amount of bread a workstation processes in each interval
- Gather the current schedules of packaging and shipping line employees, the current facility layout, and the most recent orders to SLS
- Analyze the gathered data to create a current state of the system
- Design several ways to improve the facility and organize workflow to reduce total number of hours needed
- Use simulation tools to determine the savings (in dollars and hours) each plan will produce
- Determine if solutions can be combined
- Test created combinations

In the next section, we will dive into the beginning of SLS. Following that, a look into past research in related topics to overtime and SLS factory. From research, results of the current state of SLS will be shown and discussed. Design ideas are presented in our design section, to be tested in Methodology. Finally, a conclusion on the best solution or conglomerate of solutions is presented, along with a new standard daily processing speed.
II. Background

Overtime Hours

According to Business Insider, the average worker in 1890 worked over 100 hours during one work week. This practice did not change until 1940, when the 8-hour work-day, 40-hour work week became standard practice. Generally, humans can handle working 60 hours per week for 3 weeks before production takes a nosedive (Lebowitz, 2015). Overtime hours, one result of standardized work-days/weeks, have become a double-edged sword. Workers enjoy time-and-a-half pay for these hours, and businesses can get more work hours out of the day. Contrariwise, businesses pay more for those hours, and workers risk their mental and physical health to work more hours. In a study comparing workers with overtime hours to those working normal hours, overtime workers had significantly higher depression and anxiety levels (Kleppa, 2008). Physically, overtime hours increase risk of injuries and exhaustion (Dembe, 2005). This double-edged sword becomes simpler problem explaining the reason standardized work shifts are so commonplace; the negatives hurt the workers and the business more than the benefits help either.

Production Tracking

There are several promising methods that can be used to track daily production in real-time. RFID is a possible route: it is very commonplace, and can be implemented and installed easily. RFID allows users to track production on the line in real time, even in the food-bev industry (Ha, 2013). We may be able to implement this technology in each stage of the packaging process. because it is non-intrusive, it won’t contaminate food by
being implemented. The data gathered can alert management to when supplies are low; though this is more useful for the baking stage and is thus out of scope. In the packaging area, RFID may be used to track current production and help both workers and management see how far they are from a daily goal. With a counting system, we want to test the feasibility of using cloud computing to make data instantly available to many employees. An issue with cloud computing is security. Because it is online, there must be tight security to ensure privacy and secure data (Moctar, 2018). This increased security threat may make or break our decision to use cloud computing to track production.

Facility Layout Considerations

Possible changes to the facility layout range from adding lines to doubling specific capacities to removing excess tools. Nanotechnology has been used to micro control processes of food packaging (Mlalila, 2016), and would be excellent for a larger scale factory. Due to a low budget and a small factory space, we won’t be taking nanotechnology options into consideration. Introducing (or better implementing) Lean Six Sigma into packaging may be useful for the company in the long run. Utilizing this tool allows SLS to know the current product averages and whether or not the process is in control (Adeyeri, 2015). This is, however, not a solution within the scope of our project. It has to do with baking quality more so than throughput, so we will steer away from this area. Our layout must be able to accompany human workers, time sensitive products, and high volume (Wanniarachchi, 2016). Bread must have a place to cool before it is sliced or it will not have time to let air create sourdough bread (Rumtscho, 2012). There is already a design for the layout in place, so our design must be better than the current layout; this
gives us a minimum throughput goal to reach (Vetencourt, 2004). As technology improves, so may factory machines. Even within food processing, a factory must be capable of upgrading machinery and techniques to better suit modern times. A successful factory layout must take this flexibility requirement into account (Editor, 2012).

**Just In Time Production**

Just-in-time (JIT) is an inventory strategy companies employ to increase efficiency and decrease waste by receiving goods only as they are needed in the production process, thereby reducing inventory costs. *Toyota Production System: An Integrated Approach to Just-In-Time* by Yasuhiro Monden is a textbook about push production systems in large scale production. The textbook talks about various topics which are relevant to the project in workforce flexibility, Kanban systems to maintain JIT production, and adapting to changing production qualities (Monden, 2014). This will help use construct a plan where they can have smooth production while also in accordance to market demand. In “Toyota Production System and Kanban System Materialization of Just-in-Time and Respect-for-Human System” the Toyota Production System and Kanban System introduced in this paper was developed by the Vice-President of Toyota Motor Company, Mr. Taiichi Ohno. It was under his guidance that these unique production systems have become deeply rooted in Toyota Motor Company in the past 20 years. There are two major distinctive features in these systems. One of these is the ‘just-in-time production’, an especially important factor in an assembly industry such as automotive manufacturing. In this type of production, “only the necessary products, at the necessary time, in necessary quantity” are manufactured, and in addition, the stock on hand is held down to a
minimum. Second, the System is the ‘respect-for-human’ system where the workers can display in full their capabilities through active participation in running and improving their own workshops (Sugimori, 2007).

In researching JIT systems, it was important to keep in mind the differences in normal manufacturing and production involving food. To highlight any differences in food manufacturing we referenced “Hybrid Just-in-Time Logistics Systems and Information Networks for Effective Management in Perishable Food Industries.” This paper reaches the following conclusions concerning the use of network systems in perishable food supply: 1. Sales networking, especially with convenience chain stores has spread to necessitate information systems embracing customer stores. 2. It is therefore now possible to set timely supplements in production to meet precise customer demand. 3. Very precise forecasts can be made of demand, leading to a minimization of discards of unsold goods (only 0.7% on average). This is because the orders from outlying regions whose quantities tend to vary, can be captured relatively early in the day, so that the total forecasting error can be minimized. Further, it is even possible to increase efficiency in the production of long-life products by utilizing unused ingredients in them (Iijima, 1999).

**Lot Sizing**

Lot sizing is one of the most important and also one of the most difficult problems in production planning. Lot size refers to the quantity of an item ordered for delivery on a specific date or manufactured in a single production run. In other words, lot size basically
refers to the total quantity of a product ordered for manufacturing. One factor that is tied to lot sizing is capacity planning. Capacity planning is the process of determining the production capacity needed by an organization to meet changing demands for its products. In the context of capacity planning, design capacity is the maximum amount of work that an organization is capable of completing in a given period. “Capacitated lot sizing and scheduling with parallel machines and shared buffers: A case study in a packaging company” by: Fabrizio Marinelli, Maria Elena Nenni, & Antonio Sforza is an article written that tackles some key issues with capacity planning. What is important for my project is the focus on a very flexible supply chain configuration, while still offering a wide range of products and to greatly shorten delivery time. On one hand, speaking about “quick response” to the market does not make sense if customers do not really have a choice of products. On the other hand, the reduction of the lead time makes the wide range of products more appreciable to the customer. Therefore, the “time factor” summarizes the competitive strength of a supply chain, and flexibility helps the company apply to a larger market (Marinelli, 2007).

Recently, significant research has been undertaken to study EMQ models under assumptions that conform more closely with real-world situations. Considerable attention has been paid to models with an unreliable production facility (maintenance issues) and to models with production processes subject to random deterioration (quality issues). In “Optimal Lot Sizing and Inspection Policy for an EMQ Model with Imperfect Inspections” under the assumptions of a constant production rate, exponential failure and repair time distributions and compound Poisson demand process, Posner and Berg
obtained some important system characteristics related to machine utilization and service level to customers. It compares the optimal inspection/lot sizing policy with the optimal periodic policy and the policy with no inspections during production and perform sensitivity analysis of the model developed in this paper (Makis, 1998). For this project, we also researched single-level lot sizing problems, their variants and solution approaches. In “The Capacitated Lot Sizing Problem: A Review of Models and Algorithms,” the article goes in depth what happens after introducing factors affecting formulation and the complexity of production planning problems, and introducing different variants of lot sizing and scheduling problems. One relevant section that we will apply is the discussion of single-level lot sizing problems, together with exact and heuristic approaches for their solution found by the authors of this paper (Karimi, 2003).

**Electronic Record Management System**

We determined that this project needed some sort of system in pace so that they would not revert back to the old ways after the completion of our project. In order to set up this system we researched into creating an Enterprise Resource Planning system for SLS to use. “Enterprise resource planning: Implementation procedures and critical success factors” by: Elisabeth J Umble Ronald R Haft and M.Michael Umble deals with the complications of implementing an Enterprise Resource Planning (ERP) System to a new company. The implementation of these systems is a difficult and high cost proposition that places tremendous demands on corporate time and resources. Many ERP implementations have been classified as failures because they did not achieve predetermined corporate goals (Umble, 2003). This article identifies success factors,
software selection steps, and implementation procedures critical to a successful implementation. This article will be useful to me so that I can try to avoid some of the pitfalls of the companies whose ERP system did not work.

After reading an article about ERP systems and talking with the company, we determined that an ERP would not be the best system. Instead, we would focus on a Record Management System (RMS). RMS is the management of records for an organization throughout the records-life cycle. The activities in this management include the systematic and efficient control of the creation, maintenance, and destruction of the records along with the business transactions associated with them. Considered a key component of operational efficiency, record management adds more value to organization’s information assets. In researching this topic, we came across an article from Baylor University. Student Record Management System (SRMS) gives a straightforward interface to support of student data. It might be utilized by instructive universities or colleges to keep up the records of students effectively. The information which is stored in the database can be accessed any time by using this system. There is no wastage of resources in colleges and universities. There is no need to arrange the students record manually this system will give better performance in arranging the student record (Walia, 2014). This can easily be manipulated to fit the San Luis Sourdough process and be used as a tool for storing collected time study data. Another useful reference was a patent. This patent is for a method, apparatus, and article of manufacture for managing electronic records on a computer network. The method works like a hash table where the electronic record is given a certain tag that can be used to quickly look up this record
later. The method further performs the steps of analyzing a network user's workstation specifications, analyzing a network user's user profile, and generating a reference code, wherein the electronic tag is generated from information analyzed in the network user's workstation specification, the network user's user profile and the reference code (Jacobson, 2010).

**Facility Design**

Another component that we would like to look into are ways to optimize the physical layout of the packaging department to alleviate congestion and increase productivity of the workers. Currently, the packaging department consists of four operating assembly lines that are encircled by a conveyor. Between the assembly lines are stacks of ready-to-use pallets that the finished good bread will be placed on. Unfortunately, the stacks are tall, bulky, and take up most of the space that would otherwise be used as walkways for the workers. Likewise, much of the area surrounding the packaging department is crowded with loosely placed baskets and carts obstructing any clear pathways for workers to navigate through.

According to OSHA, the recommended width of aisles is at least 3 feet wider than the largest equipment to be utilized, or a minimum of 4 feet. The measured width of the pallets is approximately 3 feet, so the aisles need to be at least 6 feet wide. Accessing the current layout to OSHA standards can pinpoint areas of the factory that need to be redesigned. Having OSHA as a guide for constraints and requirements can help us come up with effective alternative plant layout designs that would then increase workflow, productivity, and foremost increase workers' safety.
Because several supervisors at San Luis Sourdough believe that the current layout is unorganized and inefficient, we researched layout planning models that would accommodate food processing facilities. In the research report, “A Layout Planning Framework for Food Processing Industry” by W.N.C. Wanniarachchi, a methodology is formulated to resolve facility layout problems. The “diamond model” was created after heavy analysis of existing layouts in food processing facilities in today’s industry. Four primary factors make up the diamond model: material movement, personnel movement, department space allocation, and safety. After data collection of these four criteria, the departments are then configured in a way where the most active departments are placed adjacent to one another and the other departments are placed in accordance to their relations with the rest. The diamond model was then implemented in a case study in Sri Lanka where they saw a 60% increase in overall equipment efficiency (Wanniarachchi, 2016). At San Luis Sourdough, much of the equipment goes unused for large amounts of time and it is partly to do with the location they are in (Figure 16). Following a similar methodology of creating an activity and space relationship diagram to then produce a systematic layout, like the research report describes, could very much increase the equipment and space utilization at San Luis Sourdough.

**Equipment and Space Allocation**

Approximately 45% of the space in the packaging department at SLS is filled with idle equipment. Workers have to periodically stop doing their part in the production line to move equipment out of the way. Because there is a large amount of equipment stored in
the packaging department that restricts workflow and productivity, we researched layout planning models that would increase equipment efficiency in food processing facilities. In the research report, “A Layout Planning Framework for Food Processing Industry” by W.N.C. Wanniarachchi, a methodology is formulated to resolve facility layout problems. The “diamond model” was created after conducting in depth analysis of existing layouts in food processing facilities in today’s industry. Four primary factors make up the diamond model: material movement, personnel movement, department space allocation, and safety. After data collection of these four criteria, the departments are then configured in a way where the most active departments are placed adjacent to one another and the other departments are placed in accordance to their relations with the rest. The diamond model was then implemented in a case study in Sri Lanka where they saw a 60% increase in overall equipment efficiency (Wanniarachchi, 2016). Following a similar methodology of creating a systematic layout from activity and space relationship diagrams, could very likely produce an alternative layout design that would improve the equipment and space utilization at San Luis Sourdough, and ultimately increase productivity.
III. Design

Current State

Our project does not include any baking, so the beginning of our scope is when the bread loaves are sitting in the cooling racks waiting to be packaged. Once the rack has sat for long enough a worker will grab it and roll it over to one of four packaging stations. On a typical day only the first three stations will be running. The breads sit 80 to 100 loaves per rack (dependent upon bread shape), in 20 trays of 4 to 5 loaves of bread. The first worker takes each tray and places the bread onto a short conveyor belt to be sliced. After the bread is placed on the short conveyor, the tray is thrown or slid onto a different conveyor, shared between all packaging stations, which sends the trays off to be cleaned and used for the next batch of bread. The unsliced bread will funnel into the slicing machine. Once sliced, the second worker will slide the bread into its corresponding bag (preloaded by the workers) that the bread is transported in. The bag is kept open through a blower, making inserting the bread easier for the worker. Bagged bread is placed on a separate conveyor belt and run through a packaging machine which closes the top of the bag with a bread tab. At the end of the conveyor, a metal detector performs a final inspection before the bread is put into a basket in groups of 6 to 9 (depending upon bread shape) by the third worker and sent off to shipping. The basket is sent down a large conveyor where the baskets are stacked and moved into shipping trucks.

For baseline data, the first tool we used were time studies. At least once per week all three of the stations were measuring bread per minute the worker processed. After the time study is complete the next worker was observed until all three at the package station
workers have been recorded. We've been tracking the number of loaves processed per worker in 30-minute intervals. The focus of our time studies has been on three workers in the packing department loading, bagging, and packing.

Currently, the averages for station 1, station 2, and station 3 are 690, 524, 605, per 30 minutes respectively (Table 1). We have noticed there is high variability in the amount of bread processed depending on the time and day.

The facility layout (Figure 1) shows us that a large portion of production space is allocated to packaging and shipping. Most of the space is taken up by shelves, pallets, and unused machinery.

Figure 1: 4 line facility layout and space utilization
After gathering a week’s worth of bread orders to fulfill from the company, we discovered the highest selling breads for the company (Figure 3). This is important to know if we want to reorganize the product processing order. Using the 80-20 rule, we found the top 4 breads (Figure 2) accounted for 80% of sales.

*Figure 3: Total bread sales per item over 10 days of data*

*Figure 2: Pareto chart showing the top grossing bread types*
**Constraints**

San Luis Sourdough strives off their classic bread recipe, so keeping that information confidential and out of the public eye is imperative to them. We have been told not to visit or take pictures of the bread making area of the facility. That area is out of the scope of our project anyway, so there has been no need for us to observe the bread making operations. Within the packaging area, the number of stacked pallets are unpredictable as the suppliers drops off different quantities each time they return. In designing space allocations to equipment like the pallets, there will need to be room to accommodate this variability. The packaging department is set up in a way where bread types are processed one at a time. The current system is not flexible which means the workers must bag the total demand of one bread before moving onto the next.

**Recommendations**

As for recommendations, no jobs will be cut at San Luis Sourdough. All current workers will remain employed at the factory. We have also been asked to make the recommend solutions be as quick and low cost as possible.

**Design Ideation**

Possible designs include:

- Redesign of workers’ schedules based on performance metrics: workers are paid to package a daily quota of bread
- Create a new tracking system (possibly RFID) and real-time electronic board to show worker progress throughout the day
- Create a production plan based off current data
- Redesign facility layout of packaging and shipping department to better utilize the space
- Re-design cooling stations for bread to decrease cooling time without decreasing quality
  - possibly invest in overhead fans or air circulation products
IV. Methodology

New Schedule

The current schedule has employees in the packaging department working 12-hour shifts, 5 days a week. Because of these long shifts, SLS experience a 46% turnover rate in employees. SLS has only three conveyors to package all the bread orders each day which is why the facility is forced to run close to a 24/7 production just to keep up with the customer demand. Management is looking for ways to cut down the overtime issued weekly to the packaging department. The only constraint the packaging department has is that there must be a minimum of three employees required to operate a single conveyor. Our team created an alternative schedule that would allow employees to work shorter, more reasonable shifts and be able to package more bread per hour with the same amount of staff in the packaging department.

Our solution to combat the problem of cutting hours of operation but also increasing the bread throughput is to implement a staggered schedule. Instead of the current schedule with just having two shifts in the day, either 2AM-2PM or 2PM-2AM, now there are four shifts. The packaging employees with be assigned to Group A, B, C, D depending on their skill level and availability. Based off their assigned group, they will come in 5 days a week at a certain time to work a 9 or 10-hour shift.

The groups will consist of either four or eight employees. Each conveyor is assigned four employees, which is one more person than the original schedule calls for. The fourth person on the line will serve as an alleviator when someone needs to take their 10 or 30-minute break and will help facilitate the workflow by feeding carts of unpackaged bread.
and empty pallets to their designated spots on the conveyor line. With the new schedule, the conveyor line will be operating without breaks and stops in production. Ultimately, this will increase the bread throughput done in each shift.

Our team tested this alternative schedule design by surveying the managers and employees in the packaging department. We wanted to see if this schedule would be a realistic implementation and if the packaging department supported the staggered schedule. A list of a few simple, unbiased questions were given to the employees and management to receive feedback (Figure 20, 21, 22, and 23). We set up the survey so that they have to circle a single answer, that way we eliminate any confusion or misinterpretation of how they feel. We collected 17 responses from the total pool of the 24 packaging employees and 3 supervisors. The following (Figure 4) is a mock schedule to show the employees and management in the survey we conducted.

![Figure 4: Potential schedule made after worker surveying](image)

**New Tracking System**

Part of the problem as to why San Luis Sourdough does not have much relevant processing information, is because they have no system to record data. For this project, all time trials were taken by standing close enough to the packaging line to actually count
the bread as it went by. They have no sensors, mechanisms, or anything to measure performance. Even the actual machines such as the slicer, packaging machine, or metal detector lack any form of measurement sensors. The first task for the team was to establish a system to record those measurements, even when we are not there.

Our solution turned out to be a simple mechanism that acts like a computer mouse. This device would be mounted after the metal detector section of the packaging line, and would have a small rod which would be trigger every time a piece of bread passed by and hit the rod. This placement was chosen because, at that section of the line, there is an angle which forces the packaged bread to be funneled into a single file line. Also, this section is the last part where the bread is in the packaging center before moving on to shipping which means that this is a very accurate section for the bread to be measured. If there are any defects in the bread, they should be caught before this section, including the metal detector which freezes the conveyor when metal passes through the detector (this was observed during regular testing of the packaging line in between bread type switches).

The device itself is inexpensive and not too difficult to assemble. The main component is an Arduino Board, which runs for around $24 (Figure 6). This device takes the input and converts it to a .csv file which we used in the Excel application. Another important feature of this device was the button which was $8 (Figure 5). This button is the exact same thing found in computer mice and would send the signal to the Arduino board anytime the button was pressed. Resting on the button would be the rod which would be pressed by the bread passing by. Finally, there is the cost of wires and a case which can
hold all the components and protect the insides from outside elements. On the Arduino website these components are priced at approximately $4 (“Arduino”, 2018). So, this assembly costs around $36 and all the tools to assemble it can be found at Cal Poly. The code required for the board is also found on forums about similar projects and can simply be copied and pasted into our software. This data is then sent in a .csv file. Unfortunately, due to regulations for devices that touch food, the device was unable to be tested for the project.

The data from the Arduino board is sent to an excel file that we have created. This file lists the amount of bread that needs to be processed per batch and then updates as the counter tracks the bread. It works by using the Macro feature within Excel. This macro takes the count from a .csv file and continuously updates as the button is pressed. All files from Arduino are uploaded to a single excel page. As the number of bread processed counter increases, there is a second column which counts down from the expected number of bread and lets the employees know how many pieces of bread have been completed and how many are remaining. There is no need for anyone to manually enter
data, except the number of bread that needs to be processed for that order. After a period, which can be determined by the line manager, a “Done” message box appears. This will allow the line manager to be aware of the crew’s progress and there is no longer a need to wait on the shipping department to inform the line to stop and switch bread types.

After extensive research done in the literature review and after speaking with the company, the scope of our system changed. There were things in the ERP system that needed to be addressed. ERP systems track business resources such as cash, raw materials, production capacity as well as the status of business commitments like orders, purchase orders, and payroll. These applications that make up the system share data across various departments (Møller, 2005). However, our project was to focus on the bread packaging process only. There were no financial data available for us to use in the project, and the only department we had to be worried about was the packaging and to make sure communication was clear between the packaging and shipping department. Instead, a system that could track bread data and act as more of a receipt between the two departments would be more useful. And due to this it was determined that the ERP system was not the most effective tool to help address these problems.

Instead, a simple system to track the amount of bread processed was needed. Our team researched the advantages of a Record Management System. A record management system (RMS), is essentially an integrated set of digital applications that the retailer uses to operate their business. One of the primary benefits of using RMS capabilities, is that all retail operations occur in the same technology footprint allowing the retailer to run the business end-to-end with one system (Megill, 2005). Elimination of redundant data. This
system will help increase of productivity and accountability in the organization. Resources are saved from time consuming research for data retrieval.

After concluding that an RMS system was the correct approach, the next step was to determine which one. There are countless options for RMS software and many software companies advertise as “record management systems,” but while researching it can be hard to determine what retail features are included in the software.

**Packaging Facility Designs**

Because we are unable to physically test layout design options, Simulations must be made. To do this, Simio 9 was used to recreate the current layout and test the effect of 1) doubling bagging capacity and 2) adding more lines. To accurately model the lines, the proper data had to be collected. We gathered 100-time samples of each workstation and machine, and arrival time of bread. The proper distributions were found using StatFit Chi Squared tests (Table 1,3). Constant times and distances, along with any other required data, was found the same way (Table 2). To get the times, a stopwatch was used. Each time one bread was processed, the “Lap” button was hit, indicating one process time without restarting the time. Once the current line was properly simulated, we ran a Simio experiment to determine how double the bagging capacity would affect the throughput. Because more complexity crashed Simio, we had to extrapolate the amount one line, on average, was expected to make during a 12-hour shift. By doing so, we determined the impact adding one more line would have. By using the boxplots of the doubled capacity, we determined the effectiveness of that design. Through simple calculations, we determined the effect of adding another line.
V. Results and Discussion

Scheduling

Based on our survey, it is unanimous that both the employees and management would like to have shorter shifts and are okay if that means fewer overtime hours issued (In Appendix). Because we found that 82% of the packaging staff are unsatisfied with their current schedule of working 12-hour shifts and that 52% would prefer to work 9-hour shifts, we constructed the new, stagger schedule with 9-hour shifts (Figure 7). The new schedule would use all 24 packaging employees in a day, like the old schedule system, but now their shifts are cut to a more reasonable length. With the new schedule configuration, 60% of the production day utilizes all three conveyors and the other 40% of the day only 2 conveyors are operating. Instead of the facility running a full 24 hours in a day, it is now cut to 22.5 hours.

<table>
<thead>
<tr>
<th>Group Name</th>
<th># of Employees in Group</th>
<th>Number of Conveyors Utilized</th>
<th>Clock In</th>
<th>Clock Out</th>
<th>Length of Shift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td>8 people</td>
<td>2</td>
<td>5am</td>
<td>2:00pm</td>
<td>9 hours</td>
</tr>
<tr>
<td>Group B</td>
<td>4 people</td>
<td>3</td>
<td>9:30am</td>
<td>6:30pm</td>
<td>9 hours</td>
</tr>
<tr>
<td>Group C</td>
<td>8 people</td>
<td>3</td>
<td>2:00pm</td>
<td>11pm</td>
<td>9 hours</td>
</tr>
<tr>
<td>Group D</td>
<td>4 people</td>
<td>2</td>
<td>6:30pm</td>
<td>3:30am</td>
<td>9 hours</td>
</tr>
</tbody>
</table>

*Figure 7: New staggered schedule*

Even though all three conveyors aren’t running the whole production day with the new schedule, the throughput will be higher than that of the old, 12-hour schedule. The other adjustment of assigning 4 employees to work on each conveyor, rather than the previous
minimum of 3, is why this is possible. The reason for adding another employee to the conveyor line is because there were several stops in production due to the lack of hands. For example, when one person takes their 10 or 30-minute break, the conveyor line is temporarily down for that period because two employees cannot possibly do all the necessary work by themselves. Scheduling four employees to work one conveyor will therefore increase the workflow and throughput by creating a constant level of production. When one person needs to take a break, the fourth person fills in for their spot. When there are three employees on the conveyor line, the fourth person helps facilitate the line by bringing empty pallets and carts filled with unpackaged bread to the workstations on the conveyor (Figure 21).

The following charts break down how much time is really being used for production with the old, 12-hour schedule with three employees per conveyor, a possible 10 or 9-hour shift with three employees per conveyor, and then the new alternative schedule of a 9-hour shift with four employees on each conveyor. With the old schedule of 12-hour shifts, the conveyors are only operating for 9 hours and 54 minutes, once breaks are factored out. In that amount of time they can package 69,018 bread a day (the number 71,280 in the chart does not include the reduction of bread production due to turnover delays). With the alternative schedule of 9-hour shifts with four employees per conveyor, the amount of bread that can be packaged is 70,200 (Figure 8). Also, when comparing the overtime cost issued with the 12-hour shift and the 9-hour recommended shift, the company saves 864 dollars a day with the 9-hour shift.
With our data and new schedule, we created a matching layout (Figure 21). Because the conveyors would be operating at a constant production level without any breaks, the total amount of bread packaged is calculated to be 70,200. This bread amount packaged is more than the highest daily order from SLS’s historical data. After comparing the throughput and the number of overtime hours issued between the current schedule and the alternative schedule, there is a significant improvement with the alternative schedule.

**Tracking System**

Based on observed time trials, the three packaging lines operated at different speeds and processed different amounts of bread. The number of bread processed average for station 1 was 690 / 30 mins. The number of bread processed average for station 2 was 524 / 30 mins. The number of bread processed average for station 3 was 605 / 30 mins (Figure 9).
All this data was taken over various days and averaged for each station regardless of the workers and bread type.

<table>
<thead>
<tr>
<th>Station 1</th>
<th>Number of Bread Processed</th>
<th>Station 2</th>
<th>Number of Bread Processed</th>
<th>Station 3</th>
<th>Number of Bread Processed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Study 1</td>
<td>398</td>
<td>Time Study 1</td>
<td>664</td>
<td>Time Study 1</td>
<td>600</td>
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<tr>
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<td>Time Study 2</td>
<td>933</td>
<td>Time Study 2</td>
<td>642</td>
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<tr>
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<td>513</td>
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<td>513</td>
<td>Time Study 3</td>
<td>467</td>
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<tr>
<td>Time Study 4</td>
<td>645</td>
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<td>497</td>
<td>Time Study 4</td>
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<td>869</td>
<td>Time Study 5</td>
<td>648</td>
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<td>608</td>
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<td>406</td>
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<td>556</td>
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<tr>
<td>Time Study 7</td>
<td>540</td>
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<td>690</td>
<td>AVERAGE</td>
<td>524</td>
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<tr>
<td></td>
<td>AVERAGE</td>
<td>AVERAGE</td>
<td>605</td>
<td>AVERAGE</td>
<td>605</td>
</tr>
</tbody>
</table>

*Figure 9: Time studies per workstation*

Another important factor recorded in our time trials was to calculate the delay between the shipping department and the packaging center. This was done by observing our observed time trials and then referring to the shipping department for how many they had ordered. The number of bread that was processed for more than the order required was the amount of delay. This was then taken and converted to a unit of time based on the processing rate for that given day. Over the course of the times the delay was calculated, it was found that the largest delay lasted up to 14 minutes, and the shortest was 3 minutes. The team calculated the amount of bread that they could have started packaging for the next batch. In station 1 the amount of bread was between 69 and 322 pieces of bread. In station 2 the amount of bread was between 52.4 and 244.5 pieces of bread. In station 3 the amount of bread was between 60.5 and 282.3 pieces of bread. Out of the 5
data points, the average was 7 minutes. We took all the stations data and set out to find how much bread per minute was produced on average. Our finding show that that is 20.2 bread per minute (Figure 19).

Based on these findings, the team set out to find the amount of bread that could have been produced per day, but were instead necessarily made before the order came in. This was done by looking at the amount of times that the bread was switched and then taking the average delay (Figure 18). The amount of time worked out to be 112 minutes. The amount of bread packaged per minute was used to calculate the amount of bread per day. This was 2262 pieces per day (Figure 17). This 2262 pieces is for only one station, when this number is extrapolated to all three stations, San Luis Sourdough could potentially increase throughput to 6789 pieces. To put it into perspective, that is approximately 10.37% of daily production in their current system (Figure 10).

2262 Bread/Day made before ordered per station

Total Bread Production/Day = 32,692 (loaves per 12 hours per 3 lines) * 2 (for a total of 24hrs)

Total Bread Production/Day = 65384 loaves

Increase Throughput = (2262*3)/65384 loaves = 10.37%

*Figure 10: Throughput increase possible after Arduino implementation*
Facility Layout

From the Simio results, our experiment’s box plot showed that doubling the capacity will have no significant improvement in throughput (Figure 11).

![Boxplot of current facility layout vs doubling the capacity at the bagging station](image)

*Figure 11: Boxplot of current facility layout vs doubling the capacity at the bagging station*

Because the implementation of this design would involve capital investment, it is more reasonable to do nothing when comparing the two. Although the design was promising in elevating the bottleneck, the results showed that it is not ideal for the factory. On to the next design.

From the simulation results (Table 4), we can extrapolate the expected throughput per line to be an average of 10,897 loaves per 12-hour shift (Figure 12). Adding that to the current line layout, we get an average of 43,589 loaves per 12-hour shift for 4 lines. This is an improvement of 33% what is currently made. Because the unused line is said to be slower than the others, we can assume this to be a higher amount that actual, with the
actual throughput being as much lower as the line is slower than the others. Because this solution requires no capital investment in machinery, and only the time to setup the machines again, this solution is excellent for achieving the company’s goals.

![Extrapolated amount per line:

32,692 (loaves per 12 hours per 3 lines) / 3 (lines) = 10,897 loaves per 12 hours per 1 line

Adding one more line:

32,692 + 10,897 = 43,589 loaves per 12 hours for 4 lines

Figure 12: Throughput per line based off data and Simio simulation]

Some unusual conditions we were unable to program were the varying setup times for new batches. To minimize these times and the variances in them, we suggest a thorough training for all employees on how to setup the machines. Even just a refresher course would aid in reducing variances. Additionally, having the same shape of bread be processed before changing to a different bread shape. For example, all round breads should be processed back to back until there are no more round shaped breads to package: then continue to stick breads, then deli, and so on for each bread shape (as opposed to type as they currently do). This reduces the setup time of each batch because the slicer only must be calibrated for the few shape changes.

Because the layout requires simply utilizing the machines available, this solution, if adopted, will be highly successful at improving throughput. Some problems we foresee would be a decrease in workers, or low utilization of the additional line. Should the
company choose not to move night shift workers into day shifts, this layout will fail because of the lack of machine utilization. Without the combination of this facility layout and the new schedule system, this layout is unlikely to make a lasting impact.
VI. Conclusions

Summary

To summarize; our goal was to improve San Luis Sourdough’s packaging line by increasing throughput and decreasing overtime hours accumulated. We had to do this without giving a solution that resulted in the firing of employees. Our objective was to improve throughput, decrease overtime hours, and present the best option for the least amount of money and time. By mapping out issues with a fishbone diagram (Figure 26), we identified the main issues within the packaging department. We determined that our solution must be to redesign the employee schedule, redesign the facility layout, and introduce a live tracking system to reduce confusion and over/underproduction. We created a new schedule that minimized machine downtime and gave workers enough hours to make a living while still being able to maintain a life/work balance; thus, reducing turnover. Our facility layout design was simple: despite a machine’s performance, setup and constantly use all available machinery, and move the best night shift workers to the added lines during the daytime. Finally, we introduced an RMS system and counting device to allow the daily production goals to be monitored in real time. The combination of each solution Promises significant improvement when compared to the current layout’s worker turnover, daily throughput, and production awareness.
Conclusions

- After comparing the throughput and the number of overtime hours issued between the current schedule and the alternative schedule, there is a significant improvement with the alternative schedule of 9 hours per worker.
  - Overtime was significantly reduced. The amount went from 1008 overtime cost per day to 144.
  - The average throughput was only decreased by 1080 pieces of bread for 70200 total pieces. This is already more than their current daily orders, even on the busiest of days.
- By implementing a new tracking system using a simple Arduino device, bread processed per day before order can be reduced by 2232 pieces per station.
  - When extrapolated to all three stations and compared to their current system, that is 10.37% of daily production in their current system.
  - At San Luis Sourdough the largest delay between packaging and shipping lasted up to 14 minutes, and the shortest was 3 minutes. The average being 7 minutes.
  - The total cost for each device is around $36 per station
- The implementation of more workstations would involve a large capital investment
  - It is more reasonable to do nothing when comparing solutions.
  - Although the design was promising in elevating the bottleneck, the results showed that it is not ideal for the factory.
Recommendations

Overall this project was extremely beneficial to the whole team. Everyone could practice the various industrial engineering tools we have learned in our various classes. It was also a bonus that the project was so relevant and something we could all picture ourselves doing in the future. However, that did not mean that everything went smoothly. Our first change would be to have more consistent meetings and communications. Near the end of the project, once everyone had a different task they wanted to focus on, weekly meeting began to stop. A set time each week that wouldn’t deviate could have helped alleviate this problem. Communication was always difficult for the group. Since everyone had different schedules and meeting became difficult, many progress reports were done over text. This method made it hard to explain exactly what everyone was working on and the amount of progress made.

In terms of the actual project and what we could change, it mostly came to the amount of time we had available. It would have been very nice to have more time trials to get more exact figure that we based our finding on. It would have also been nice to have permission from management to implement some of our solutions, but due to the regulations surrounding food processing, we never were able to hear back in time to implement them. We were also limited on our abilities in Simio. For future projects, we would recommend that they spend more time developing a simulation which can look at more aspects in the packaging center, but due to our skills and time limit, we made the best simulation with the available software.
REFERENCES


Kleppa, Elisabeth, et al. Working Overtime Is Associated With Anxiety and Depression: The Hordaland Health Study., 2008


APPENDICES

<table>
<thead>
<tr>
<th>Station Name</th>
<th>StatFit Best Fit</th>
<th>Simio Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>WS1</td>
<td>Lognormal(1.25, -0.351, 1.45)</td>
<td>1.25+Random.Lognormal(-0.351, 1.45)</td>
</tr>
<tr>
<td>WS2</td>
<td>Lognormal(1.23, -0.998, 1.14)</td>
<td>1.23+Random.Lognormal(-0.998, 1.14)</td>
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<tr>
<td>WS3</td>
<td>Lognormal(0.308, 0.013, 0.571)</td>
<td>0.308+Random.Lognormal(-0.013, 0.571)</td>
</tr>
<tr>
<td>Pallet arrival</td>
<td>Lognormal(1.35, 0.868, 0.354)</td>
<td>1.35+Random.Lognormal(-0.868, 0.354)</td>
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*Table 1: Distributions found from StatFit for each workstation*

<table>
<thead>
<tr>
<th>Description</th>
<th>#</th>
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<tr>
<td>Walking speed</td>
<td>3.00</td>
<td>mph</td>
</tr>
<tr>
<td>Conveyor 1 speed</td>
<td>16.47</td>
<td>ft/min</td>
</tr>
<tr>
<td>conveyor 2 speed</td>
<td>26.40</td>
<td>ft/min</td>
</tr>
<tr>
<td>C3 speed</td>
<td>39.00</td>
<td>ft/min</td>
</tr>
<tr>
<td>Kwiklock speed</td>
<td>1.70</td>
<td>s</td>
</tr>
<tr>
<td>WS2 bag switch</td>
<td>17.50</td>
<td>s</td>
</tr>
<tr>
<td>slicing speed</td>
<td>4.00</td>
<td>s</td>
</tr>
<tr>
<td>Breads per pallet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>rnd</td>
<td>9.00</td>
<td></td>
</tr>
<tr>
<td>stick</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>stubby</td>
<td>10.00</td>
<td></td>
</tr>
<tr>
<td>Buffers</td>
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<td></td>
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<tr>
<td>WS1 input</td>
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<td>bread</td>
</tr>
<tr>
<td>WS2 input</td>
<td>10.00</td>
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*Table 2: Distributions*

<table>
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<tr>
<th>autofit of distributions</th>
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<tr>
<td>distribution</td>
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<tr>
<td>Lognormal(1.25, -0.351, 1.45)</td>
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<td>Exponential(1.27, 1.87)</td>
</tr>
<tr>
<td>Normal(3.14, 3.35)</td>
</tr>
<tr>
<td>Uniform(1.27, 22.5)</td>
</tr>
</tbody>
</table>

*Table 3: Example of how we found the correct distribution using StatFit*

*Table 4: Example of how we found the correct distribution using StatFit*
Figure 13: Unused machines. Found scattered around the packaging facility

Figure 14: Unused machines. Found scattered around the packaging facility
Figure 15: Throughput per station with delays

20.2 bread/min * 112 min delay/ day
2262 Bread/Day made before ordered per station

Figure 16: Throughput per station with delays

Figure 17: Average delays per day from changing bread type

Observed Average: 7 Minutes
Bread Types produced per day: 17
(16 bread changes per day)
7 Minute Delay * 16 Changes = 112 Minutes

Figure 18: Average delays per day from changing bread type

Figure 19: Total average bread per minute found

Average Bread/ Minute:
23 bread/min Station 1
17.5 bread/min Station 2
20.2 bread/min Station 3
Total Average: 20.2 bread/min

Figure 20: Total average bread per minute found
Figure 23: Line worker layout with new schedule

Do you like your current work schedule of working 12 hour shifts?

Answered: 17  Skipped: 0

<table>
<thead>
<tr>
<th>ANSWER CHOICES</th>
<th>RESPONSES</th>
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<tr>
<td>Very satisfied</td>
<td>0.00%</td>
</tr>
<tr>
<td>Satisfied</td>
<td>5.88%</td>
</tr>
<tr>
<td>Neither satisfied nor dissatisfied</td>
<td>11.76%</td>
</tr>
<tr>
<td>Dissatisfied</td>
<td>82.35%</td>
</tr>
<tr>
<td>Very dissatisfied</td>
<td>0.00%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>17</td>
</tr>
</tbody>
</table>

Figure 21: Question 1 of worker survey

Figure 22: Question 1 of worker survey
Figure 27: Question 2 of worker survey

Figure 25: Question 3 of worker survey

Figure 26: Question 3 of worker survey
Figure 29: Question 4 of worker survey

Figure 30: Question 4 of worker survey
<table>
<thead>
<tr>
<th>Time</th>
<th>Group/s Working</th>
<th>Number of Employees Working</th>
<th>Number of Conveyors Utilized</th>
<th>Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>5am-9:30am</td>
<td>Group A</td>
<td>8 employees</td>
<td>2 conveyors</td>
<td>1200<em>4.5</em>2 = 10,800 bread</td>
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<tr>
<td>9:30am-2pm</td>
<td>Group A, Group B</td>
<td>12 employees</td>
<td>3 conveyors</td>
<td>1200<em>4.5</em>3 = 16,200 bread</td>
</tr>
<tr>
<td>2pm-6:30pm</td>
<td>Group B, Group C</td>
<td>12 employees</td>
<td>3 conveyors</td>
<td>1200<em>4.5</em>3 = 16,200 bread</td>
</tr>
<tr>
<td>6:30pm-11pm</td>
<td>Group C, Group D</td>
<td>12 employees</td>
<td>3 conveyors</td>
<td>1200<em>4.5</em>3 = 16,200 bread</td>
</tr>
<tr>
<td>11pm-3:30am</td>
<td>Group D</td>
<td>8 employees</td>
<td>2 conveyors</td>
<td>1200<em>4.5</em>2 = 10,800 bread</td>
</tr>
</tbody>
</table>

**Consideration:**
This production level surpasses the highest order demand from Total Production 70,200 bread

*Figure 31: Throughput possible with new schedule*

*Figure 32: Throughput possible with new schedule*
Figure 3: Fishbone Diagram to find Cause and Effects
Table 7: Simio Results of current throughput data

<table>
<thead>
<tr>
<th>Object Name</th>
<th>Data Source</th>
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