FACILITIES REDESIGN OF STOCKROOM AT ELCON PRECISION

A Senior Project submitted to

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Bachelor of Science in Industrial Engineering

by

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ABSTRACT

Elcon Precision is a company based out of San Jose, California specializing in the photochemical processing of materials and brazing of metals and ceramics for a variety of different industries. Three students from the Industrial Engineering Department at California Polytechnic State University, San Luis Obispo were contacted by Elcon Precision to help redesign their stockroom and inventory areas in their San Jose location in order to allow for the future growth of the company. Elcon asked the Cal Poly project team to help increase efficiencies throughout the stockroom by creating an alternative layout that best suited the company's needs. This report will provide an in-depth analysis of the Cal Poly project team's approach to achieve a more efficient layout for the Elcon Precision stockroom.

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I. INTRODUCTION

In the manufacturing industry, efficiency and reliability are of paramount importance to the success of a company in today's highly competitive environment. At Elcon Precision, the complete utilization of their current assets through minimizing the company's waste has become the top priority in the growing of its business. Elcon Precision is a high tech, industrial service company specializing in metallization and resistive coating of ceramics, brazed assemblies, and photochemical machining. The company takes pride in being a diverse manufacturing organization that caters to both high volume production and customized engineering solutions on an international level. As business is expected to grow by about 20% by 2020, Elcon Precision has seen the need for a redesign of their stockroom and a robust inventory management system to ensure that the company can effectively increase throughput without sacrificing quality or lead time.

The stockroom at Elcon Precision was shaped by the business's growth since the opening of the facility in the mid-1980's. Since then, materials have been managed by only a few, knowledgeable employees that are becoming stressed with the diversity of the manufacturing processes and the lack of material tracking technology as it relates to their Enterprise Resource Planning (ERP) system. Because of this, Elcon Precision is keen to create an improved inventory management system or an improved process in combination with a redesigned stockroom to accomplish the following objectives:

- Increase materials management
- Increase visual management of the stockroom
- Reduce travel distances and improve ergonomics

To the first point of increasing materials management, the project team aims to design a layout that allows the stockroom employees to keep track of material by increasing control of the material check-out system for non-stockroom employees. Coupling this logic with better visual management of the stockroom, the stockroom employees will be able to better control the flow of people and materials throughout the stockroom.

To reach these objectives, a comprehensive overview of the processes and products throughout the stockroom were analyzed to construct an improved facilities redesign of the stockroom. As Elcon Precision wishes to create a layout the utilizes the available space to accommodate for future growth, an inventory analysis of the stockroom will be assessed to optimize available shelf space to allow for future growth, as well as determining what materials are outdated and can be removed from the stockroom.

The scope of the project will not include the analysis of all processes throughout the facility. This is due to the time-frame of the project as well as the limited access to the facility, as the company is located three hours north of the project team's residence. Only the internal processes within the stockroom will be analyzed to achieve an optimized facility layout of the stockroom. Other assumptions will be stated throughout the design, methods, and results sections of the report.

This report will be composed of a more in-depth analysis of the background of the project through review of the current literature followed by describing the design process of the project, and the methods used to accomplish the objectives listed above. The report will also include a discussion the business improvements and the impact of each of the alternative solutions for a redesigned stockroom layout.

II. BACKGROUND

With expected growth of the company, Elcon Precision is looking for a revised facility layout that will increase visual management of the facility as well as increasing material traceability. It is important to note that the layout of the stockroom at Elcon Precision manifested itself through the growth of the company over the years. This information is important because it signifies that there was little consideration for the layout design based on quantitative information. Rather, the layout of the stockroom was formed based on the opinions of the employees working in the stockroom.

In order to learn more about the stockroom processes and the product lines, meetings and conference calls with the employees involved with this project were conducted on a weekly basis. From these meetings, the project team was able to focus research into 5 main categories:

1. Inventory management
2. Facilities Design
3. Visual Management
4. Change Management
5. Human Factors and Ergonomics

The purpose of selecting these five areas for research is to bring up relevant and current literature in the field of industrial engineering as it pertains to facilities redesign and the stockroom redesign project with Elcon Precision. Additional areas of interest for research involve human factors and ergonomics because there are three permanent workspaces for employees within the stockroom.

III. LITERATURE REVIEW

Inventory Management

Material tracking is crucial to the success of any manufacturing operation as the movement and processing of material is value-added to the customer. While maintaining a record of the location inventory is throughout the manufacturing facility is not necessarily a value-added activity, a good material tracking system can eliminate wasted time searching for specific inventory items that have been improperly pulled from inventory, resulting in inventory inaccuracies in a company's ERP system. With inaccurate inventory information, the re-ordering of material and order fulfillment becomes increasingly difficult and yields a less efficient manufacturing operation. In the article "Information Inaccuracy in Inventory Systems: Stock Loss and Stockout" Yun, Kang and Stanley B. Gershwin identify some potential causes of inventory inaccuracy to be "(i) stock loss; (ii) transaction error; (iii) inaccessible inventory; and (iv) incorrect product identification" (Kang and Gershwin, 2). The stockroom at Elcon Precision sees inaccuracies throughout its stockroom and in its inventory management system (ERP) more often than in the past, as business has grown. While the company claims a 95% inventory accuracy level, that number is expected to decrease as the business grows due to a high cognitive load on each of the two stockroom employees. This article is relevant to Elcon Precision as inventory inaccuracies can affect lead time and reorder points for inventory. Many of the assemblies at Elcon Precision are kitted, meaning that a group of parts or materials are required by the manufacturing floor at the same time. With inventory inaccuracies, a kit of parts cannot leave the stockroom if there is one part in the kit that is missing.

As the stockroom at Elcon Precision was shaped by the business over the course of 30 years, material management has become a pain-point for the company. Key industrial engineering tools that can be used to increase efficiency of materials and increase material management methods such as Just-In-Time (JIT) Manufacturing and Kanban systems pose an opportunity for improvement at Elcon Precision. Just-In-Time manufacturing is a method developed by Taiichi Ohno as part of the Toyota Production System (TPS) (Kumar, 393). JIT is used to continuously eliminate all forms of waste based on reduction and decentralization of inventory throughout a production facility (Kumar, 393). The goal of the waste reduction is to ensure that the supply of the right parts in the right quantities in right place at the right time, thus eliminating the need for inventory (Kumar, 393). With JIT, production facilities will be filled with mostly work-in-process materials (WIP) because the materials only arrive at the workstation at the right time in the right quantities, rather than needed to be pulled from a central inventory location.

Facilities that embody the JIT methodology are implementing a pull production strategy, where material moves by request rather than being produced based on forecasting. In order to achieve JIT production, Kanban systems must be implemented. A Kanban system is a key industrial engineering technique that employs a signal or card that contains all of the information required for the processing of a product and the details of its path to completion (Kumar, 393). Kanban cards are also “used to control production flow and inventory” (Kumar, 393). The stockroom at Elcon precision could greatly benefit from implementation, or partial implementation of JIT and Kanban strategies to help control inventory and the flow of material throughout the facility.

In order to recommend implementing a Kanban system to Elcon, it is important to understand the idea of a pull production system. In a pull system, material is requested by the successive workstation, hence the reason why it is called a pull system. (Kumar, 394). Below is a simple explanation of a Kanban system throughout a facility.

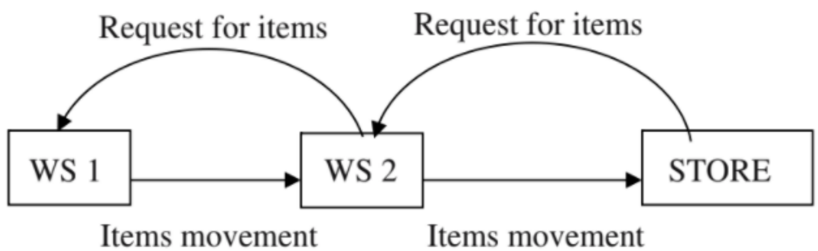


Figure 1 - Kanban Card System (Kumar, 394)

Material is never overproduced or under-produced because the “STORE” in **figure 1** requests a product from the successive workstation “WS 2”, and so on. The “request for items” is the Kanban card containing the production information pertaining to the material/product that the “store” orders. This which then works its way through the production facility in reverse order in the form of a Kanban (Kumar, 394).

When designing a Kanban system, a production facility must calculate the number of Kanbans that a production line will need. One method of calculating the number of Kanbans is the Toyota formula (Kumar, 397). The toyota formula is presented below in **figure 2**:

$$K \geq \frac{DL(1+\alpha)}{C}$$

where,
K is the number of kanbans,
D is the demand per unit time,
L is the lead-time,
α is the safety factor and
C is the container capacity

Figure 2 - Number of Kanban Cards Calculation, (Kumar, 397)

This formula is a general model that determines the number of Kanbans by understanding the demand per unit time (D), the lead time to produce the product (L), the safety factor (α), and the container capacity (c) (Kumar, 397). As this number will only pertain to one product line at a time, implementing a Kanban system throughout the entire Elcon Precision facility is out of the scope of this project. However, an analysis of the material flow throughout the stockroom could be performed to help the stockroom employees better track material throughout production, especially if the product must pass through the stockroom more than one time before becoming a finished good. This article contains a large amount of information that can be applied to the stockroom redesign project.

Elcon Precision, being a company that works with Manufacture to Order (MTO) customers, the products and materials that are processed within the facility are not always perfect quality. Through talking with one of the stockroom employees, the project team was told that it is extremely common to see material that was rejected by the quality department and must be reworked. Therefore, it is important to take rework into consideration if a Kanban system implemented at Elcon. In the article "Determination of number of kanban in a cellular manufacturing system with considering rework process" by Aghajani and Mojtaba, determining the number of Kanban cards while taking rework into consideration is addressed and analyzed in an effort to minimize total cost (Aghajani and Mojtaba, 1188).

With Elcon being a manufacturer with many different types of products that enter and leave the stockroom multiple time before becoming a finished good, it is valuable to study the control of Work-In-Process (WIP) throughout the stockroom. In the article, *Work In Process Control for a High Product Mix Manufacturing System,* the first step to increase throughput and decrease waste is to classify the type of control mechanism the facility operates on; Push or Pull (Oladipupo, 278). It is general understanding that Push production products will have a high throughput rates, while Pull production is better for minimizing system inventory (Oladipupo, 278). In terms of managing inventory, a pull system is more manageable due to the nature of the pull system, where product must be summoned by a successive workstation, where the amount of inventory is pulled on an as-needed basis as they relate to purchasing orders within the Enterprise Resource Planning (ERP) system. This article describes the benefits of using a Constant Work-In-Process (CONWIP) system, that exhibits traits of both push and pull systems. (Oladipupo, 278). CONWIP production control systems work by setting a limit on the number of items allowed on a manufacturing floor, and no new items may be released until a finished product has been released from the last processing step (Oladipupo, 278). For Elcon Precision, a type of CONWIP system in the stockroom could help set the pace of the stockroom and also relieve some cognitive stress on the stockroom employees by limiting the number of jobs and products to keep track of. By understanding the WIP materials and products throughout the stockroom, the project team will be able to take this into consideration when redesigning the facility.

Facility Design

One of the most important assets for a business is the building or facility in which the business operates. When approaching the design of a facility from a lean manufacturing perspective, it is important to understand two measures that can focus a factory toward successful operation: throughput and capacity (Duggan, 31). As throughput increases, there are more products flowing through the facility that would otherwise be occupying shelf space in inventory. This, in turn, means that the facility has more capacity for business. This direct relationship between throughput and capacity can be monitored and referenced to help management to make more informed and directed decisions for the business (Duggan, 31).

In order to best understand throughput and capacity of a facility, the first step is to define the process and product flow through the facility (Duggan, 31). Simple spreadsheets, such as Microsoft Excel, can be used to define what areas of a facility that a product will travel through before completion. In the spreadsheet, job processes within a facility are listed along the top row where products are listed down the leftmost column. This will give process improvement experts an idea of what areas of the facility see the most traffic and grouping products that travel to similar areas of the facility. There are many products at Elcon that will be moved in and out of the stockroom multiple times before the products are completed. By defining internal process maps, the redesigned layout of the stockroom will compliment jobs with similar process flows. By analyzing this process map, the facilities planners can identify shared resources. Locating shared resources within a facility is a crucial step in the flow design for the facility (Duggan, 32). In the stockroom at Elcon Precision, many different products will flow through the same areas. Given that Elcon has many products that will travel through the stockroom more than once before becoming a finished good, understanding what resources can be shared throughout this process is an opportunity for improved efficiency.

As Elcon Precision is a company that has multiple production types, one being a mass production based system, make to stock (MTS), and other that focuses on more customized products, manufacture to order (MTO), it is important to understand how to effectively manage the inventory throughout the stockroom to compliment the different styles of manufacturing. According to the president of Elcon, 50% of the business is MTS items and the other 50% is MTO items. The article "Efficient management of production-inventory system in a multi-item manufacturing facility MTS vs MTO" studies which type of production policy, push or pull, to use for MTS products and MTO in order to find efficient production/inventory control rules to minimize the total cost (Günalay, 1183). The study proposed that determining the optimum base-stock level of inventory is the first step in determining the type of production system that will be most efficient for the type of product (Günalay, 1183). For the case, the author stated that all items were either MTS or MTO and that out-of-stock items are backlogged. The results of this study concluded that manufacturing operations are most efficient when the same scheduling and inventory techniques are in place, regardless of whether the product is MTO or MTS (Günalay, 1183). When redesigning the stockroom layout at Elcon Precision, this article illustrates that maintaining the correct base-stock or inventory level is important in the overall efficiency of the production plan. With an efficient production plan and the correct base-stock level, the stockroom can then be optimized.

The foundation of any successful stockroom begins with the initiative to maximize space utilization, equipment utilization, labor utilization, material accessibility, and material protection (Tompkins and White, 416). Considering the nature of the company's service, it is important to determine whether the stockroom functions best utilizing fixed or random storage. A fixed storage method introduces a strict system in which each part is assigned to a specific location and isn't allowed to be stored anywhere else. Even if that space is available, other parts that aren't assigned to that location are prohibited to store. As a result, fixed storage is most optimal for companies with a relatively consistent demand for a set of products. A random storage method encompasses a more flexible system in which parts are allowed to be stored anywhere in the stockroom. This system is optimal for companies that have fluctuating demand or have clear seasonal variation.

As Elcon utilizes the fixed storage method, the space allocated for each part should be able to have capacity for the maximum amount on hand. The downside to this is that this requires more storage space than that of randomized storage. However, if implemented properly, fixed storage has the potential benefit of yielding a higher throughput. This is achieved by ranking part numbers by activity, or number of retrievals/ unit of time. As a result, "fast movers are up front and slow movers are in the back" (Tompkins, 419). Furthermore, one can incorporate the popularity principle to vertical traveling, taking into consideration the height of the warehouse (Venkitasubramony, 2). Thus, the less frequently pulled items would should be stored in higher locations and more frequently pulled items near chest level. This not only improves ergonomics of picking, but it can cut down time and distance an employee uses to retrieve the portable step ladder.

Essentially, this method is representative of a principle called sorting by popularity, a common technique to minimize travel distances. In addition, storing the most popular items in large storage depth areas is a method to reduce motion. Observing the following diagrams, in respect to the reference point, it is clear that in scenario (a), an employee can retrieve all items with an overall less distance traveled than that of scenario (b).

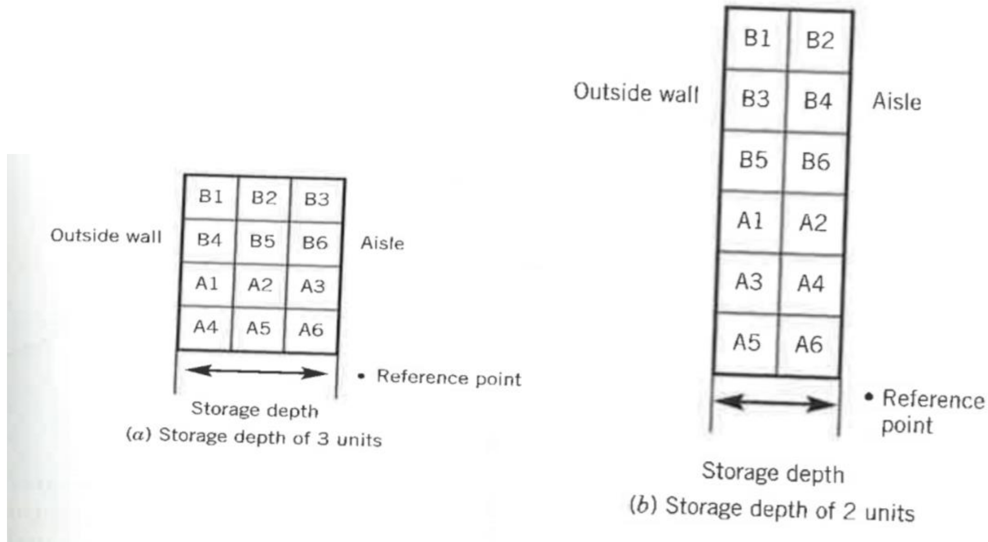


Figure 3 - Inventory Sorting Method, (Tompkins)

Other important storage principles include similarity and size. Parts that are often kitted together or ordered together should be stored within the same vicinity. Large, heavy parts should be stored near the point of use and closer to the floor. It is also essential to consider accessibility of material handling equipment as well as the ergonomics of moving material.

From a business standpoint, cost of operating a stockroom is mostly composed of labor intensive work. Often times, order picking can attribute to over 50% of this overall cost (Hsieh ,1). In order to improve picking efficiency, there are several factors to consider including cross aisle quantity, storage assignment, picker route, picker density, etc. At Elcon, since the stockroom is quite small, improving order picking will likely yield a smaller impact than that of other continuous improvement projects. Therefore, the team will weigh other design factors more heavily to maximize the project's impact.

As the global manufacturing marketplace continues to become more competitive, the utilization of computers and technology have reached the era designing a facility based on algorithms. One article by Parveen Sharma and Sandeep Singhal propose that the future of the manufacturing facilities design problem can be tackled with "computerized techniques, algorithmic approaches, and also with procedural approaches" (Sharma, 1485). This article dives into Multiple Attribute Decision Making approaches to designing a facility, names FUZZY logic and TOPSIS. In short, these approaches determine the optimal design of a facility through analyzing massive amounts of data collected throughout the facility and ranking alternative layouts based on the data (Sharma, 1486). One aspect of this article that the project team at Elcon Precision could benefit from, are the factors for evaluation of procedural approaches. The factors are as follows in **Table 1.**

1.	Initial Data Required
2.	Use of Charts
3.	Use of Graphs and Diagrams
4.	Future Expansion Consideration
5.	Constraints considered
6.	Procedure implementation
7.	Material Handling Equipment Selection Consideration

Table 2 - Factors for evaluation of procedural approaches

At the Elcon Precision project, the above steps closely outline the design of the stockroom project. While Elcon's facility is not able to take advantage of the application of computer algorithms to design the most efficient stockroom, understanding that the FUZZY logic and TOPSIS algorithms are assigning weights and ranking areas of the facility in terms of importance to the business, the project team can then understand that the most efficient or optimal method for redesigning the facility might not be the most successful design for the facility due to employee pushback at Elcon.

Another key aspect of working with facilities design is remain within the budget for the project. In the case of USC-LAC hospital, this included a downsizing budget with a goal to maximize the number of inpatient beds. "Positive results were most prominent when volume levels, the number of transfers, and restrictions on beds were reduced."(Marshall, 3) This was accomplished by looking at the key restraints and determining what could be done about them. In this project with Elcon Precision, the budget must be finalized to determine exactly how many changes can be made. Likewise, constraints must be observed to determine the most optimal changes to the facilities design by eliminating the largest constraint as the USC-LAC hospital has done.

Again, another critical factor to facilities planning is incorporating safety into the new facilities design. Generally, "Building owners, managers, and users are overwhelmed by engaging a new or newly renovated facility, and often fail to capitalize on the safety features that are integrated into the design." (Paul, 1). Given the ergonomic stresses of the materials used at Elcon, safety will have to be accounted for in the new design of the stockroom. Employees should not have to lift heavy objects from highly elevated locations and shelving should not overhang other material to cause potential dangers within the workplace.

It is known that simulation is a crucial part to facilities design. Alesia argues that "running simulation models prior to conducting layout optimization produces more realistic layouts" (Alesia, 1). Considering that simulation models real world activity, it is able to measure the impact of the product and other variables on factory performance. This is critical for factory design. Elcon Precision has many complex products and a variety of processes that can be simulated to factor against factory performance. In the case of the project, the factory performance can be the rate at which items enter and exit the stock room as well as the inventory tracking of the products themselves. Also, travel distance is another large factor that Elcon is looking to minimize which can be accomplished through simulation. Overall, there are many factors and tools that can be utilized for the facilities planning aspect of Elcon Precision's stockroom redesign.

Visual Management

Visual management plays a key role in the traceability and efficiency of a company's product tracking. "In the organizational world, visual management is a management system that attempts to improve organizational performance through connecting and aligning... management vision"(Tezel, 3). That being said, visual management can serve a broad range of functions for a business. When it concerns Elcon Precision, the aim is to identify the areas that visual management can assist in product traceability. This function is to be investigated in further, more detailed articles.

One of the major challenges that confront businesses is how to eliminate ineffective delivery of information in close-range communication. For instance, heavy textual or safety information is often overlooked by employees even though it is pertinent to their everyday jobs. One solution to this problem exists in simplified cognitive sensory information tools. These tools are also located in an unmistakable area that is close to the operation being performed. This affects overall safety as well as process transparency which Elcon seeks to achieve. "Process transparency can be increased by rendering process flows visible through removing visibility barriers, integrating information into process items, and measuring and visually displaying the measured process" (Tezel, 11). This in turn facilitates a management by sight strategy which is a major pain point to the facilitators of the stock room. By removing visual barriers and adding more informational cues to the process flow, greater process transparency can be achieved at Elcon. However, this all depends if visual management is utilized correctly.

Visual Management is a vital tool that if implemented correctly, has potential to improve organization, boost communication, and develop standard procedures. Visual management can be broken down into three major function types: displaying of information, providing work instruction, and communicating the status of ongoing operations (Hundt, 7). In respect to the project at Elcon Precision, the project team will incorporate information and status displays to the redesigned layout, as these techniques pose to be the most relevant to improving the stockroom.

The core of industrial engineering is eliminating non-value-added tasks, or waste. This waste stems primarily from information deficiency of employees. In many cases, this leads to employees wasting time searching for items, waiting to receive instruction/ information, and correcting errors (Bradley, 3). Visual Management can resolve these issues by integrating information that will provide employees the knowledge to complete their work efficiently and effectively. An increasing number of companies have begun to implement visual management systems in the form of a gemba board.

A gemba board is an information-rich board that can showcase present and past data, create an open forum about improvements, identify problems, indicate performance, and more. The board would be placed in an area in which employees regularly walk by and have easy access to view or add to the board. What several companies fail to consider, is that gemba boards have certain principles that they should abide by relating to design and psychology. The 4 main principles are to use the correct graphical tool, use color sparingly, avoid excess borders, and design the board that reflects the flow of information (Bateman, 8) Alison Graham, author of "Going to the gemba strengthens interdepartmental teamwork", presents a case study in which a gemba board is implemented in the Orlando Regional Medical Center. Although the hospital as a whole operates through the work of multiple departments, these departments often run dependently. This created a lack of understanding and knowledge between departments and in turn caused multiple communication issues. The board's objective was to promote teamwork among different departments, create processes that supported all departments, and to help departments understand limitations and obstacles faced by others. Although the gemba board was effective in problem solving, it is important to address common issues regarding implementation. Some key takeaways that the hospital noted were the importance of creating a baseline for improvement, defining metrics, and documenting processes thoroughly to monitor improvement.

In regards to this project at Elcon Precision, visual management can be pivotal in optimizing the room's operational efficiency. As employees constantly move in and out, communication amongst employees as well as the stockroom facilitator is a dire necessity. Currently, there seems to be a lack of communication and understanding of roles/processes of other departments. This in turn leads to misdirected blaming, frustrated employees, and ultimately an inefficient stockroom. These issues are exemplified in several areas that the project team examined through numerous individual interviews with employees.

One of the stockroom employees is the backbone of the stockroom, and operates with memorized information all stored in his head. This information includes when material needs to be restocked, what orders are priority, and what parts are available. This creates major issues when he is out of the stockroom on leave. Yet, some employees are convinced the majority of issues originate outside the stockroom. It is important to mention that the stockroom heavily relies on the sales department to receive travelers, or files that specify where parts are to be issued. Lack of communication among departments are leading to inaccurate data being issued, assumptions from sales that the stockroom already received travelers, and late travelers that allegedly make every order a "hot order." Improper visual transparency directly correlates to accumulated waste within a business. "A progress chart is used as an important tool for daily communication, in order to draw the plan of a project, to ascertain whether it has progressed as scheduled or not, and to reschedule it, if it is late" (Murata, 4). This progress chart can either be drawn directly on a whiteboard or printed from a scheduling software. For Elcon Precision, it will be best to come up with a Gantt chart created through Microsoft Project in order to clearly define when deliverables are to be completed. This will allow for transparency between the project group and the business which will create better communication between the two parties. The team created two Gantt Charts, one pertaining to deliverables of IME 481/482, and another catered to completing deliverables for Elcon Precision.

Change Management

Change management includes the controlled implementation of changes within a business. This directly relates to the redesign of Elcon Precision's stockroom considering that this change will directly affect many employees at the company. The physical changes that are going to be applied to the stockroom's layout will also affect employee's mental feelings towards their work environment. For this reason, the project team decided to further investigate change management and how it may relate to a stock room redesign. Robinson states that "Procrastination is rampant in the workplace" (Robinson, 3). Workers typically will only work on a project or task when the feeling is urgent enough to be completed. This destroys any contingencies of planning to have extra time allocated to tasks that expected to be completed by a given deadline. Also, multitasking can be detrimental towards any new project. If workers have their attention in multiple other jobs, lead times for projects can be increased. Conversely, "the reduction or elimination of multi-tasking can lead to dramatic reduction in cycle times and a corresponding increase in the number of projects completed in a given time period" (Robinson, 6). Therefore, Robinson argues for the implementation of critical chain scheduling. Critical chain scheduling is a method of planning and managing projects that emphasizes the resources required to execute project tasks. This relates to Elcon's stockroom redesign in the fact that there will be several steps or tasks to be competed for the project. The tasks will have to be prioritized which can be accomplished through critical chain scheduling. Essentially, taking into account the effects of procrastination and multitasking, critical chain scheduling creates a project model that "reflects a shorter overall cycle time while at the same time providing a higher degree of schedule and cost risk protection" (Robinson, 7) than what is actually expected. Using this information will hopefully result with a shorter, and more realistic project completion time.

Change management can be applied to nearly any industry. However, only specific people within projects should be delegating tasks and implementing certain change management models. This particular case study that was examined consisted of an ergonomists role in a change management model that had six phases. These phases were having "a change concept at the start of the process, knowledge of the history that led to the change concept, structuring the change process, involving relevant actors at the right time, communication, and management." (Dianne, 4). While an ergonomist many be involved in several phases, this article emphasizes that the role should be clearly defined. Dianne states that generally, “The ergonomist can act as manager of the change process or work together closely with the change manager.” This relates to the project as Elcon has recently hired on a new lean-six sigma specialized employee. As the article illustrates, it will be important to clearly define his role within this change process.

The idea behind change management is that a newly proposed design or concept is well-received with the employees throughout a company. At Elcon Precision, the project team’s work for the redesigned stockroom should be developed alongside the employees that work there. In “*Model of Resistance Dynamics in the Change Process”,* Wisniewski states that “the efficiency of a process was defined as a capability of achieving objectives with an assumed effectiveness, which depends on the appearance of negative dynamic phenomena assisting the change” (Wisniewski, 27). The negative dynamic phenomena is essentially all of the negative external factors surrounding a change to a process or design. Throughout the article, Wisniewski observes the dynamic structure of an object under implementation of changes, and finds that human behavior when facing change can be related to properties of objects of control, such as strengthening, counteracting, oscillation and overload, delay and inertia (Wisniewski, 27). This is an interesting discovery, where the project team can learn that implementing any change to the design of Elcon’s stockroom will receive some sort of backlash from the employees there. From this article, the project can learn about proper implementation of changes throughout the project in order to reduce the severity of the backlash from Elcon’s employees.

When engaged in new product development, any company must have a system in place to accommodate for any changes to the product or process (Reddi, 1225). This article studies the system dynamics of engineering change management in a collaborative environment. System Dynamics is a modeling technique used to model, study, and manage complex system by identifying variables and defines their relationships to establish the system’s structure (Reddi, 1227). For the stockroom redesign project, identifying the system and the relationships is the first thing that the project team set out to do. By working with the employees and learning the pain points about each of their tasks, changes to the inventory management process as well as changes to the design of the facility would be more well-received by employees. Below is an example of a typical feedback loop:

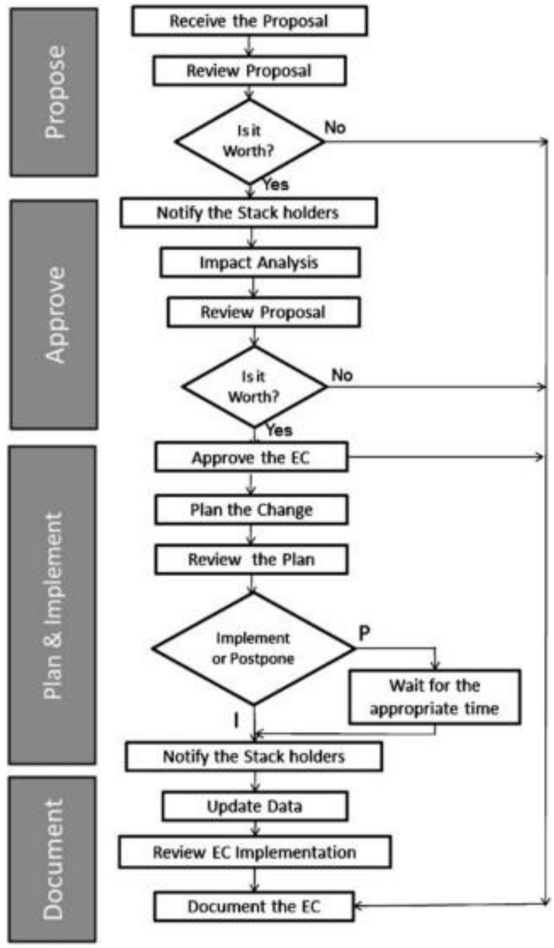


Figure 4 - Change Management Process Map (Reddi, 1226)

As shown, there are many steps to take when proposing an engineering change. After making any change, it is important to analyze feedback within the system to allow for minor changes if the original changes are not well-received (Reddi, 1227). The remainder of this article attempts to define a more complex process to approach change management which did not apply directly to the project at Elcon Precision. However, general information throughout this article will provide general knowledge to the stockroom redesign project regarding factors to be aware of for engineering changes.

Another topic of exploration included knowledge reuse. "The aim of knowledge reuse is to provide knowledge necessary for configuration of PMIS" or project management information systems (Berzisa, 1). However, considering that Elcon's stockroom redesign does not include a redesign of their information system, a broader perspective was taken to look at how knowledge reuse can be applied to different areas. The article breaks down knowledge reuse into two stages:

acquisition and utilization. Just like researching past subject, Berzisa points out the importance of gathering as much information as possible pertaining to a project and utilizing the most relevant information into a change management process. This can be seen by the several literature reviews that the project team completed prior to the project team's implementation of design.

Lastly, change occurring during the middle of a project can cause great changes to its projected outcome. "changes in projects can cause substantial adjustment to the contract duration time, total direct and indirect cost, or both" (Ibbs, 1) therefore, it is important to utilize risk analysis tools to mitigate the effect that changes can have on a project.

A very popular project management concept known as Management By Walking Around (MBWA) attempts to increase worker morale, facilitate conversation, build trust, identify problems, and overall worker productivity (AlRawashdeh, 2) . MBWA simply involves the action of managers walking around the work floor observing people, equipment and ongoing processes. This attempts to eliminate the hierarchical gap between management and workers simply through a manager's presence. In theory, the concept makes sense; however, as presented in a Harvard Business School case study, MBWA doesn't always yield a desirable result.

Anita Tucker and Sara Singer's article "The Effectiveness of Management By Walking Around: a randomized field study" introduces a case in which MBWA resulted in a negative impact on performance. 19 hospitals were chosen at random to implement MBWA and 56 work areas participated. Performance was measured by nurse perception on improvement. The study concluded that the implemented MBWA program "was associated with improved perceptions of performance under two conditions: (1) when a higher percentage of solved problems were considered "easy" to solve, enabling more problem solving, and (2) when senior managers took responsibility for ensuring that identified problems were resolved (Tucker & Singer, 2).

The study examined two approaches to problem solving: prioritizing easy to solve problems and prioritizing high value problems. The result was that prioritizing easy to solve problems enabled "frequent problem-solving cycles, which further [developed] employees' expertise at problem solving (Tucker & Singer, 5). Therefore, solving the low-hanging fruit, or easy problem fixes, employees became motivated to solve a larger capacity of problems.

In terms of manager functions, results showed that simply walking around did not correlate to improved perceptions. Managers had to be proactive, communicate with employees, and implement changes in order to make MBWA effective. Managers hold the financial resources needed to make change, and employees were happy that managers were interested in their improvement ideas.

Human Factors and Ergonomics

To better understand the ergonomic conditions for the employees in the Elcon Precision stockroom, the project team sought to address the current working conditions of the stockroom for the two stockroom employees. As it is known that there are many health concerns associated with a sedentary lifestyle, implementation of a more ergonomic workstation can lead to improved performance of employees as well as decreasing the risk for musculoskeletal disorders (Callaghan, 20). One of the hot topics in the work of ergonomics today is the recommended working position for general office work. “Is Standing the Solution to Sedentary Office Work?” is an article that analyzes three different working positions and the effect on pain and discomfort among test subjects. In **Figure 5**, the results from the study indicated that the pain rating for only seated (Blue) and only standing (Dashed Blue) positions increased dramatically during the testing time, while a rotation between sitting and standing (Red Line) significantly decreased the pain level overall throughout the testing time (Callaghan, 22).

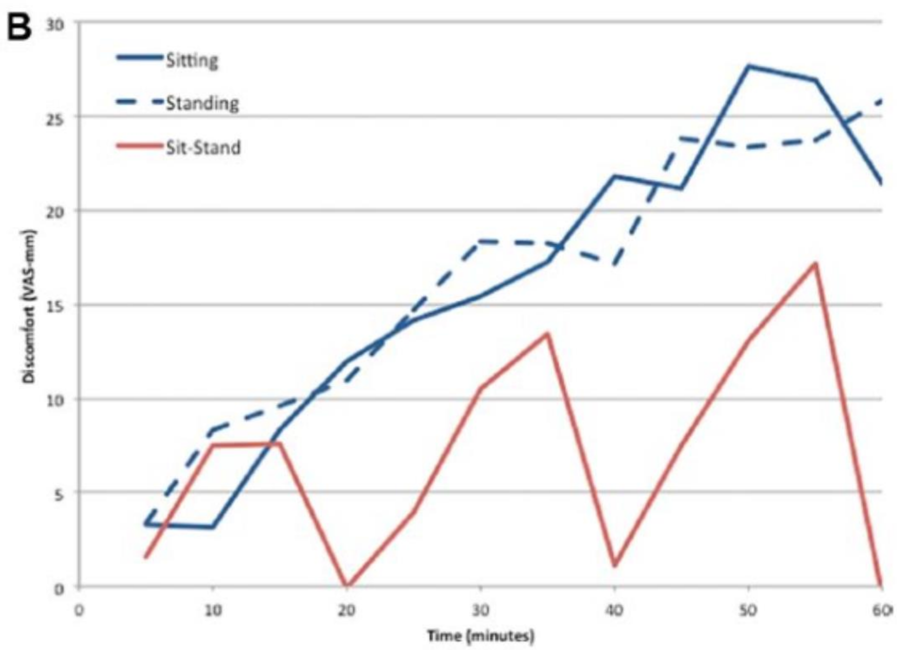


Figure 5: Discomfort vs. Time (Callaghan, 22.)

For Elcon, much of the work done in the stockroom requires the employees to be standing, which can lead to increased discomfort throughout the workday. Using information and findings from this study, the project team can observe how often the stockroom employees are sitting and how often they are standing in order to propose a design that minimizes overall discomfort.

Industrial engineering embodies a big picture approach to increasing efficiency. In many cases, the optimized and most efficient solution to a problem is not necessarily the best solution. Human factors and ergonomics is an important area of concern when proposing an improved engineering designs as the users of that design must be able to work safely (Schwartz, 2). In "Effect of a Novel Two-Desk Sit-To-Stand Workplace (ACTIVE OFFICE) on Sitting Time, Performance and Physiological Parameters: Protocol for a Randomized Control Trial," the article brings up an important issue regarding the ergonomics of an office space. At Elcon, the two stockroom employees have very un-ergonomic working conditions where the desk, chair, and monitors are non-adjustable. In the article, the impact of implementing a sit-stand desk for an active office is that employees can considerably reduce the risk for musculoskeletal disorders (Schwartz, 2). This article can be applied to the facility redesign project at Elcon as the employees that spend most of the day in the stockroom should have a workstation that does not hinder personal productivity stemming from musculoskeletal pain.

In another study at Virginia Tech, the effects of lifting with and without material rotate on and task rotation were analyzed. In the stockroom at Elcon Precision, stockroom employees are required to lift all materials without any material handling equipment. As Elcon specializes in metallization and ceramics, some of the materials used can weight upwards of 20 pounds in raw material state. Incorrect lifting of this amount of weight could result in an injury that prevents an employee from working. The experiment in the article simulated the repetitive lifting of a box at 12 lifts per minute over a 60-minute period with alteration of the lifting pattern; with task rotation vs. without task rotation and with varying weights (Horton, 97). The results of the experiment concluded that increasing the rotation between tasks and weights of materials can significantly reduce perceived discomfort over the course of a working day (Horton, 103). At Elcon, the project team can apply this logic when redesigning the layout of the material in the facility to ensure that repetitive lifting motions are avoided be the employees and that the material is placed at the most ergonomic height.

III. DESIGN

The current layout of the stockroom at Elcon Precision is becoming increasingly stressed by the growth of the company. In addition, management was unhappy with the visual layout of the stockroom because it seemed cluttered and difficult to understand the processes that were going on at any given time. The first step of the project was to define a clear scope followed by talking with each of the employees that are related to the stockroom. Through these employee interviews, the project team was able to identify the pain points of the stockroom to develop a more informed design. The team defined the need for an improved stockroom layout and inventory management process that would reduce the amount of material taken from the stockroom without proper paperwork. The inventory management process metrics include visibility of the stockroom and the flow of work. Alternative layouts are evaluated by each of the stockroom employees to determine which alternative is best for the company. The implementation of these items allow Elcon Precision to grow as a business without stressing the employees and current processes within the stockroom.

Design Constraints

At the beginning of the project, the president of the company stated that the project's design would be fully or partially implemented, and that Elcon was ready to invest in the redesigning of the stockroom. There were few design constraints associated with the project as Elcon Precision was eager to begin making changes to its layout. Though the project team had little design constraints, the main design constraint was the feasibility of implementation of the alternative layout. This was a large concern with Elcon because of the added costs associated with redesigning a facility, as well as impeding the normal business operations. With this in mind, the project team determined that the alternative layouts must be developed in close cooperation with the stockroom employees and the upper management at Elcon Precision. This was done to ensure that the proposed layout was financially feasible and well-received by the employees at Elcon Precision.

Abiding by the main design constraints of feasibility and employee satisfaction, the scope of the project became more clear. The project team aimed to minimize the data collection associated with the streamlining of workstations outside the stockroom area. Due to the limited number of facility visits, the Cal Poly project team determined that the scope of the project would be too large if the efficiencies of workstations outside the stockroom were analyzed. The project also would not recommend any changes that were not discussed with the stockroom employees to ensure that the alternative layouts were well received. This meant that a strong line of communication needed to exist between the project team and the Elcon stockroom employees to ensure that the majority of the design work took employee input into consideration.

Project Assumptions

The Cal Poly project team defines the assumptions of this project below. The assumptions are based on obstacles surrounding data collection, employee information, and the Non-Disclosure Agreement with Elcon Precision.

1. The Cal Poly project team assumes that all information provided by Elcon Precision via email or phone is correct and accurate

2. The Cal Poly project team assumes that all data collected throughout the project duration is an accurate representation the Stockroom

3. The Cal Poly project team assumes that employee from-to travel distances are non-weighted, assuming that each stockroom employee travels to each key area of the stockroom equally

4. The Cal Poly project team assumes that stockroom employee wages equal to the standard factory costs at Elcon Precision for stockroom and production employees. This standard cost is $23.00 per hour

5. The Cal Poly project team assumes that alternative layouts are completed anonymously and with integrity by the Elcon stockroom employees

6. The Cal Poly project team assumes that the average lead time for products produced by Elcon Precision did not significantly impact the raw material inventory levels during the scope of this project.

Employee Input

The project team was told that there is a high probability for the project to be implemented in the stockroom. Knowing this, individual interviews were held with employees at Elcon that were directly related to the stockroom. These individuals included the president of the company, process engineers, quality and lean engineers, and the stockroom employees. Avoiding waste of employee knowledge, the purpose of the interviews was to incorporate the ideas of people within the facility that use the stockroom on a daily basis, as these employees deeply understand the processes within the stockroom. During these interviews, questions regarding key pain-points of the current design along with recommendations for future design were discussed. Many of the responses stated that one of the major pain-points of the current layout is the lack of material tracking and the lack of visual management. One issue with the current material tracking process is that a stockroom employee must be present in order to make a material transaction. Currently, there is only one stockroom employee that receives paperwork for material. When that employee is not there, material cannot be properly transacted. In the case of priority "Hot" orders, external employees have been known to take material from the stockroom to fulfill their needs without processing the order with the stockroom employee.

Through extensive communication with the stockroom employee that deals with material transactions, the project team determined that the input from this individual must be woven into the design of an alternative layout. This alternative layout will be created to increase visual management of people and materials flowing in and out of the stockroom.

Current State

The current floorplan of Elcon's stockroom can be seen in **Figure 6**. The stockroom is divided up between raw materials, customer supplied materials, and finished goods. With only two people managing inventory and material transactions in the stockroom on a daily basis, there are many opportunities for process facility improvement. The dimensions of the stockroom are 25 feet by 35 feet, giving approximately 900 square feet of space to account for inventory. There are roughly 15 shelves utilized in the stockroom ranging from 72 inches tall in the central area, and about 90 inches tall on the perimeters of the stockroom.

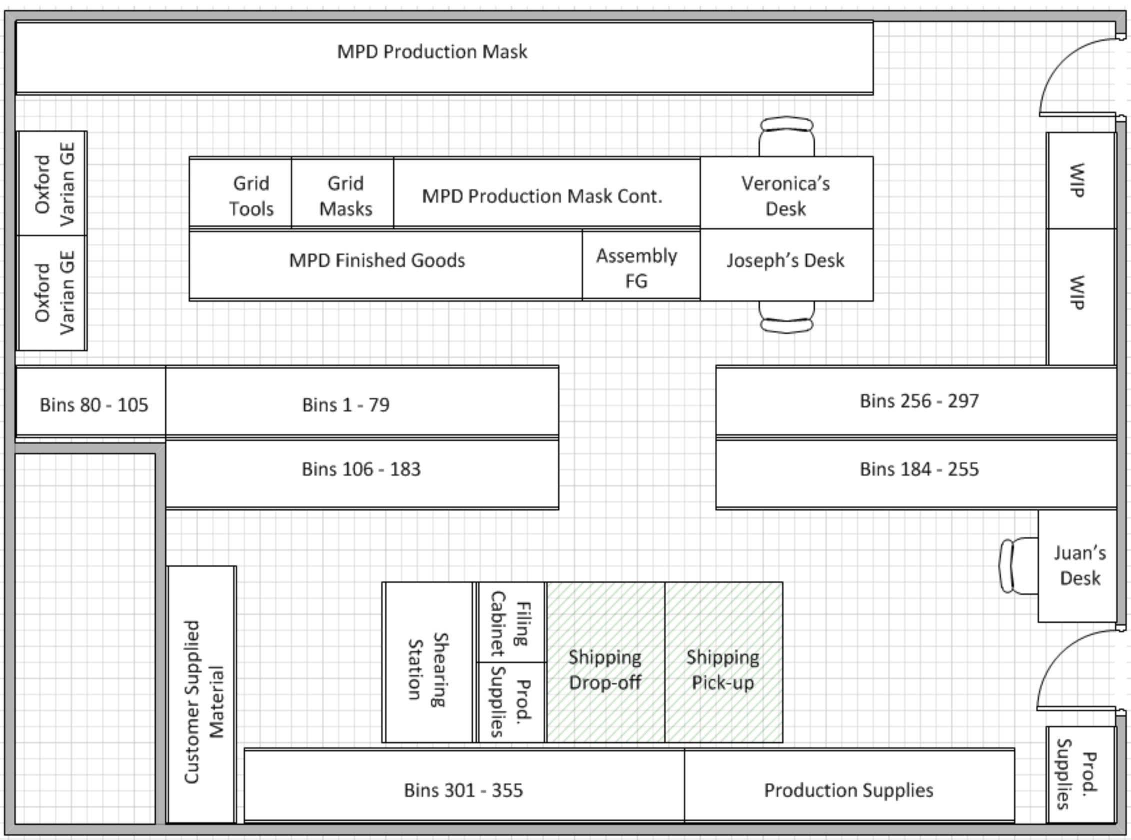


Figure 6 –Elcon Precision Stockroom – Current Layout (Mastromattei)

There are three workstations for the each of the stockroom employees. These employees manage all material transactions for the company and are the ones who are becoming stressed with the amount of pulling of material associated with the growth of the company. The current inventory management methods rely heavily on the knowledge of these employees, which is an area of high importance for this project. When one of these employees is absent from the stockroom, the stockroom does not function as it should because material is taken without being logged in the system.

Also, the shipping and receiving area of the stockroom is directly in front of the main entrance. The company has hinted at some basic 5S techniques by taping off areas on the ground for shipping and receiving, though there is room for improvement in this area. **Figure 7** and **Figure 8** show photos of the shipping and receiving areas below.

Figure 7 & 8: Designated Areas of Pick up and Drop Off (Matsumoto)

Shelf Capacity and Space Utilization

To gain a better understanding of the current space utilization of the stockroom, the project team gathered observational data on the available space of the shelf versus the space consumed by inventory. **Figure 9** illustrates this point.

Figure 9: Current Shelf Capacity – Raw Materials (Mastromattei)

The shelf in **Figure 9** is an example of typical shelf for storing metal raw materials. Note that some shelf spaces are divided into two separate bin locations in the interest of space utilization. During the first visit of the facility, the project team noticed that there is a considerable amount of excess space on each shelf that is not occupied by material. Given one of the pain-points that was listed by Elcon management was visibility within the stockroom, the height of shelves was a concern to be addressed. Taking this into consideration, a rough capacity of the space utilized by material in each shelf was recorded in a single day.

<u>*IMPORTANT NOTE:*</u> *One of the assumptions with this analysis was that the inventory did not move quickly enough with respect to lead time of orders to deem the analysis to be invalid.*

In **Figure 10** and **Figure 11**, an estimate of the capacity of bins on each shelf was transferred into a Microsoft Excel document to quantify the space utilization in terms of percent capacity.

BIN 209 - 255 INVENTORY CAPACITY ANALYSIS					
Bin Number	Percent Capacity (%)	Bin Number	Percent Capacity (%)	Bin Number	Percent Capacity (%)
255	50	239	50	182	90
254	40	238	40	183	90
253	80	237	20	184	40
252	30	236	60	185	30
251	30	235	50	186	20
250	30	234	40	187	20
249	40	233	50	188	30
248	10	232	70	189	20
247	10	231	20	190	50
246	80	230	0	191	50
245	40	229	50	192	60
244	10	228	50	193	60
243	5	227	50	194	40
242	30	226	60	195	30
241	50	225	50	196	50
240	50	224	30	197	70
		223	30	198	40
		222	20	199	40
		221	20	200	40
		220	40	201	60
		219	10	202	30
		218	20	203	20
		217	30	204	20
		216	40	205	10
		215	20	206	10
		214	20	207	30
		213	40	208	20
		212	30	209	0
		211	100		
		210	100		

Figure 10: BIN 209 – 255 Inventory Capacity Analysis, (Mastromattei)

BIN 265 - 300 INVENTORY CAPACITY ANALYSIS					
Bin Number	Percent Capacity (%)	Bin Number	Percent Capacity (%)	Bin Number	Percent Capacity (%)
300	20	285	40	270	40
299	10	284	20	269	20
298	40	283	20	268	20
297	70	282	10	267	40
296	0	281	30	266	30
295	50	280	5	265	50
294	20	279	40	264	100
293	10	278	60	263	50
292	20	277	30	262	40
291	20	276	20	261	20
290	10	275	60	260	20
289	10	274	60	259	20
288	5	273	50	258	10
287	10	272	10	257	10
286	10	271	20	256	30

Figure 11: BIN 256 – 300 Inventory Capacity Analysis, (Mastromattei)

Figure 10 and **Figure 11** note the Bin Number and the Percent Capacity for the shelf containing Bin 209 - 300. A shelf that is at maximum capacity is noted as a 100% capacity and a full blue bar. Further analysis of the data reveals that the shelf containing Bins 209 – 300 is currently operating at roughly 65.17% capacity. With 34.83% of the shelves being underutilized.

Inventory Usage

In addition to the capacity of the shelves in the stockroom, the project team collected data regarding inventory usage in the form of the bin number, which illustrates the location of the material, and the most recent date that the material was used. The inventory usage data collected was collected on the two raw material racks located in the center of the stockroom as seen in RED in **Figure 12.**

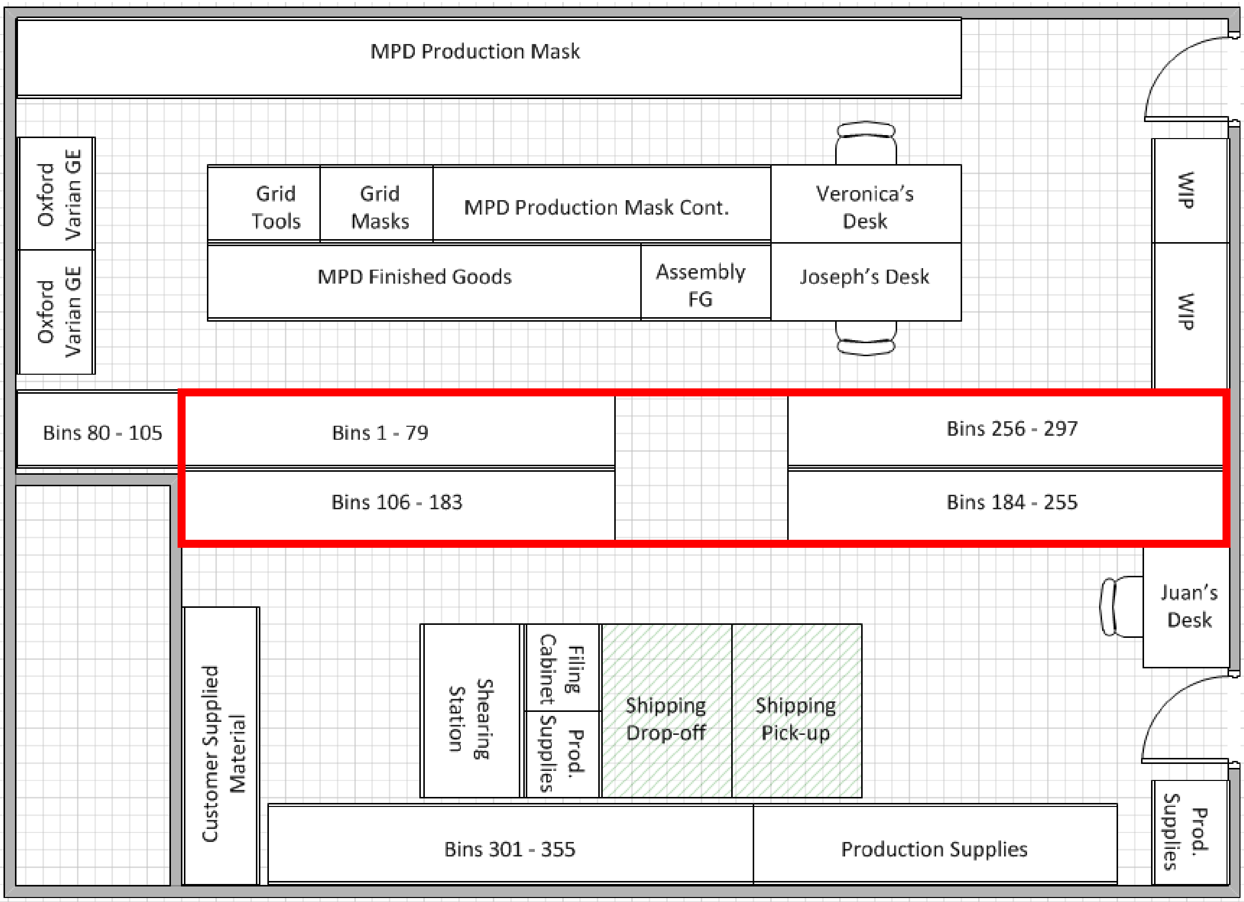


Figure 12: Metal Raw Material Location (Mastromattei)

Last Year Accessed	Percentage of Total
2011	0.36%
2014	7.50%
2015	42.86%
2016	7.50%
2017	23.93%
2018	17.86%

Table 2: Percent Breakdown by Year Last Accessed, (Matsumoto)

Directly on top of each stack of raw material, there is a Raw Material Inventory Worksheet that employees are required to log info onto when pulling material from the stack. The team chose to record the last date accessed from each bin# and calculated the percentage breakdown by year.

As shown in Table 2, the team observed that over half of inventory on the raw material shelves were last accessed between 2011 and 2015. This is considered stale inventory and it results in valuable space wasted and non-utilized cash flow. Although data wasn't taken for these areas of the stockroom, the team observed multiple finished goods and customer supplied material that also hadn't been touched in years. This will be a point of observation for future visits at the facility.

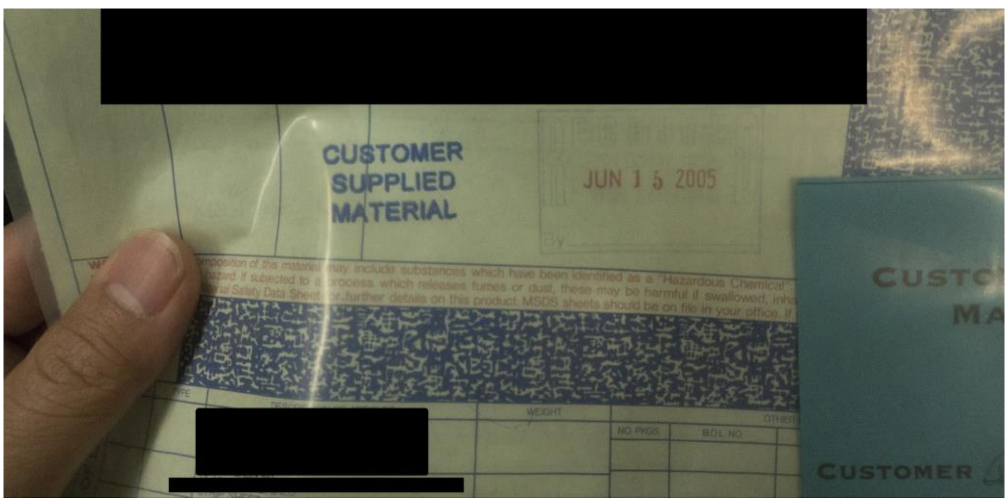


Figure 13: Stale Inventory in Customer Supplied Material Section (Matsumoto)

Figure 13 shows a certain material that is currently stored in inventory that hasn't been accessed since June of 2005. Sensitive information is censored in respect to the NDA.

Accuracy of ERP System (Sage 100)

An ERP system should present employees with accurate data that assists them in making decisions. However, at Elcon, the ERP system isn't trusted and utilized to its full potential. The morning of the day the team visited, according to Dyer, the company had missed a sale opportunity due to a mistrust in the ERP system. A sales employee had searched a product in inventory, noticed the ERP indicated it was in stock, yet ignored the system and was unable to sell off the remaining products. Dyer did not disclose how often this type of event occurs, nor did he reveal the value of orders like this. Regardless of the context, the goal for any manufacturing business is to increase throughput and make money. With the loss of orders due to false information of inventory levels, the Cal Poly project team chose to focus on providing possible solution to Elcon in order to reduce the mistrust in the accuracy of the ERP system. In the current state of the system, accuracy issue stem from two processes that are conducted in the stockroom:

- ERP system is updated at the end of each week, which does not give an accurate representation of inventory levels throughout a given week
- An accurate count of inventory was not completed this past year

After raw material is pulled, employees fill out a card that is to be entered into the ERP at the end of the week. This is most likely due to the convenience of entering data all at one time. The downside is that Elcon operates without a live and accurate inventory count and could consequently cause them to make reordering errors or relay inaccurate information to customers. Travelers have barcodes that have potential to be scanned and stored into the ERP system, eliminating the potential for human inputting error. Yet, this is not utilized for unknown reasons.

Secondly, the annual inventory accuracy count was never completed last year as Elcon never found the time to do so. As a result, Stephen, the new stockroom employee has been attempting to recount material and ensure accuracy in conjunction with the ERP system.

Safety Issues

Without machinery such as forklifts or trucks in the stockroom, there are not any major safety issues stemming from the design of the stockroom. However, there are safety concerns that stem from hazardous location of materials throughout the stockroom. The project team immediately noticed two areas of safety concerns when visiting the facility including the location of shipping and receiving, and the ergonomics of employee workstations.

Elcon current uses some 5s organization to set designated areas for pick up and drop off of material. However, as the stockroom contains people running around looking for material, often looking down at travelers, it is very likely an employee can trip over the boxes and get injured. The shipping and receiving areas in **Figure 14** are shown below.

Figure 14: Pick-up and Drop-off Safety Hazards(Matsumoto)

To prevent accidents, the team chose to include an alternative shipping and receiving area within the stockroom in the proposed layouts.

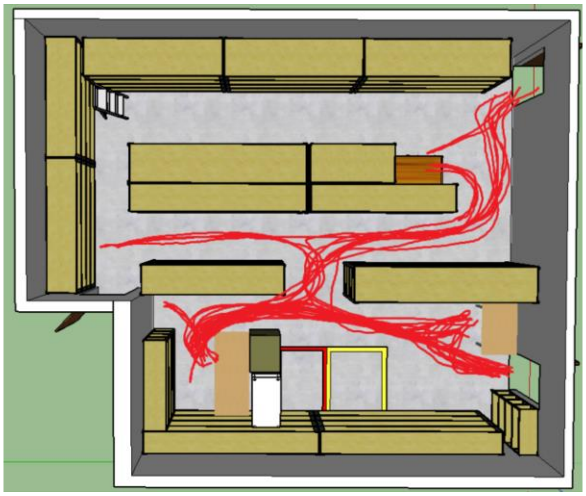
The second safety concern with the stockroom stems from the ergonomics of employee workstations. Per the project team's research on ergonomics, it is recommended that employees strive to spend 50% of their workday sitting and the other 50% standing. During the facility visits, two of the stockroom employees spend the majority of their day standing and processing material, while the third employee spends the majority of their day sitting. While these actions are reflective of the type of work that each employee is doing, the workstations do not offer ergonomic adjustments to fit the work to the worker. The employee that spends most of their day sitting does not have an updated multi-position chair, which can increase the risk of musculoskeletal injuries. This can be seen in **Figure 15.**

Figure 15: Employee Sitting at Workstation (Mastromattei)

Similarly, the employees that stand for the majority of their day do not have ergonomic products to reduce the impact of standing on the human body, such as anti-fatigue mats. The implementation of adjustable stand-up/sit down desks provide flexibility in working position and has the benefit of catering to all employee heights. Again, the lack of these ergonomic products increase the risk of musculoskeletal disorders for the stockroom employees. It is important to note that ergonomically designed products not only ensure safety in the long-run of operations, but also improves morale and productivity as well.

Employee Movement Analysis

In order to gain a better understanding of employee movement throughout the stockroom, the project team positioned a GoPro video camera in the stockroom that recorded all employee movement throughout 4-5 hours of the day. The movement of two stockroom employees were analyzed and inputted into spaghetti diagrams, show below in **Figure 16** and **17**.



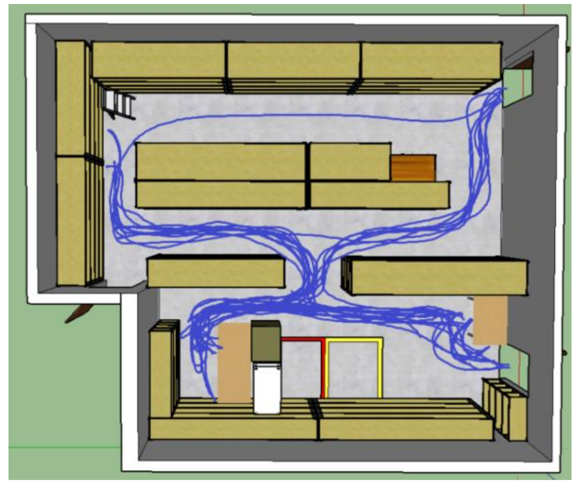


Figure 16 Employee 1(Matsumoto) **Figure 17: Employee 2 (Matsumoto)**

The spaghetti diagrams above highlight the movement of the two stockroom employees that deal with the processing and moving of material throughout the stockroom. The third stockroom employee mainly deals with the processing of paperwork and material transactions, which is primarily desk work. For this reason, the movement of the third employee was not recorded.

Taking a closer look at the diagrams, the project team noted that the two stockroom employees traveled to many of the same locations throughout the day that the GoPro was recording. Employee 1, shown in RED, primarily worked at the shearing station in the bottom left corner of the diagram. Their permanent desk is located in the bottom right corner of the diagram, causing a large amount of traveling to and from their desk throughout the day. Employee 2, shown in blue, traveled to the upper left corner of the stockroom in the diagram throughout the day, which was due to an ongoing cycle count that was taking place during the second visit to the facility. One interesting note about the employee movement was that the employees used the shearing station as a regular table more than they used it for shearing and processing materials.

Employee Travel Distances

After analyzing the spaghetti diagrams for the two employees that process and move material, the project team recorded the travel distances between different areas of the stockroom in the form of a From-To chart. This was done order to identify the average distance that the stockroom employees must travel to get to a specific area of the stockroom.

<u>IMPORTANT NOTE:</u> *The project team initially attempted to track overall distanced travelled by the stockroom employees throughout the day using a pedometer. However, since the employees often needed to leave the stockroom, the pedometer step counts were not an accurate representation of the distance traveled by an employee within the stockroom.*

The project team acquired a rolling tape measure to conduct the distances from each of the stockroom employee's workstations to key areas of the stockroom. The distances that the project team chose to focus on were those of the two employees that process and move material most often, Employee 1 and Employee 2. The key areas within the stockroom are listed below in **Figure 18** and **Table 3.**

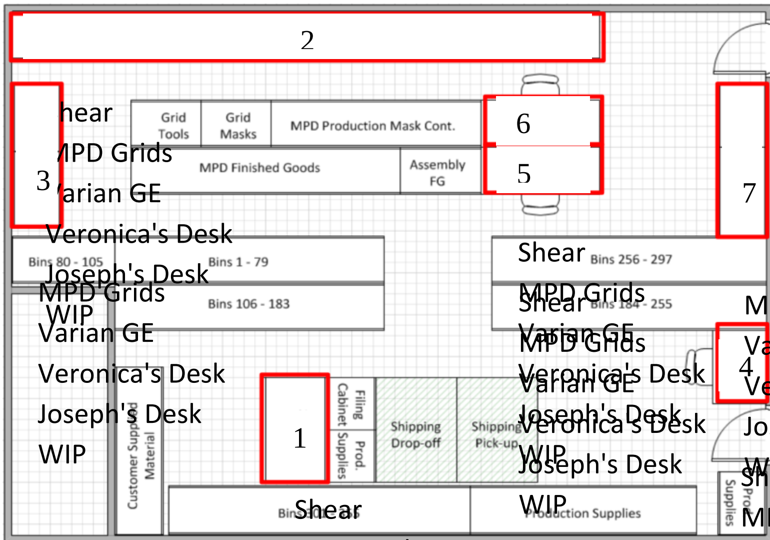


Figure 18: Key Stockroom Areas

Number	Location
1	Shear Station
2	MPD Grids
3	Varian GE
4	Employee 1 Desk
5	Employee 2 Desk
6	Employee 3 Desk
7	Work-in-Process

Table 3: Key Stockroom Areas

The distance calculations for the employees are shown in tables 4 and 5 Below.

From	To	Distance (ft.)	In
Employee 1 Desk	Shear	24	7
Employee 1 Desk	MPD Grids	47	5
Employee 1 Desk	Varian GE	35	1
Employee 1 Desk	Veronica's Desk	21	3
Employee 1 Desk	Joseph's Desk	38	3
Employee 1 Desk	WIP	37	4
	AVG	34	3

Table 4: Employee 1 From-To Chart

From	To	Distance (ft.)	In
Employee 2 Desk	Shear	22	1
Employee 2 Desk	MPD Grids	33	5
Employee 2 Desk	Varian GE	22	11
Employee 2 Desk	Veronica's Desk	16	10
Employee 2 Desk	Juan's Desk	38	3
Employee 2 Desk	WIP	7	6
	AVG	23	6

Table 5: Employee 2 From-To Chart

Analysis of the From-To charts for employee 1 and employee 2 resulted in an average travel distance of 28 feet 4 inches within the stockroom. Keeping in mind that these measurements are only considering 1 movement from an employee’s desk to a key area of the stockroom.

Alternative Layouts

The development of alternative layout was one of the main project deliverables for the project team. These alternative layouts were developed based on the project team’s research on warehousing operations, visual management, and ergonomics. In addition, the alternative layout took the stockroom employees’ inputs into consideration. Three alternative layouts were developed, each focusing on improving current pain-points in the stockroom.

Alternative Layout 1 - Communication

The first layout was designed to promote the concept of open space and visibility, as shown in **Figure 19**. The team ensured that the stockroom employees are able to communicate effectively, incorporating close proximity and the ability to have face-to-face interaction from their respective desks.

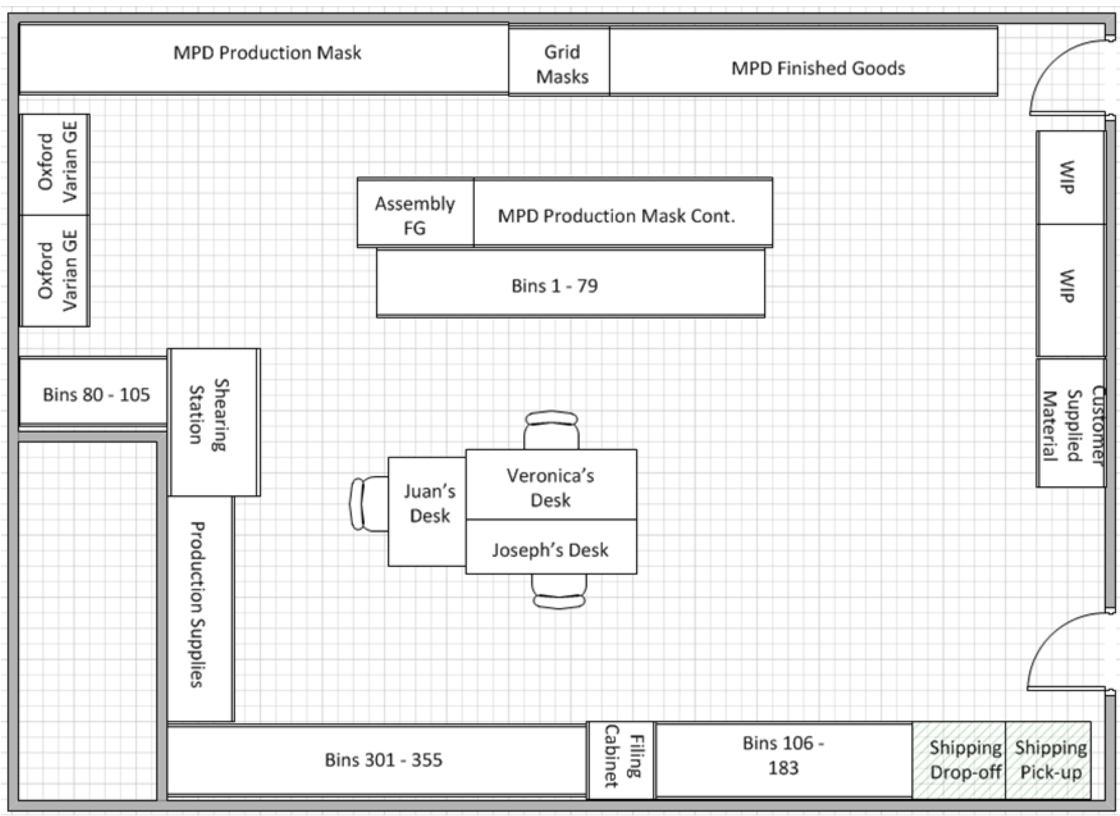


Figure 19: Alternative Layout 1

The spaghetti diagram analysis revealed that that two of the stockroom employees often use the shearing table as a regular table, never actually using the shear. As a result, the project team added an additional desk, preferably one that has adjustable height, that will serve as a multi-purpose table that can be used for any activity.

Through the analysis of inventory, the team discovered only 50% of material was touched in the past 2 years. Thus, after consolidating current and outdated material to material only used within the last two years, the above design would relocate two shelves for the material into a separate room.

Another aspect of this layout is the removal of the incoming and outgoing shipment areas off of the floor. As it poses a possible safety hazard, the shipping areas would be transferred onto shelves. The team recommends removing all office supplies from the south wall into another room and replacing that space with incoming and outgoing packages.

Alternative Layout 2 – Workflow

During the first meeting the project team had with Elcon, one of the concern with the initial condition of the stockroom was the visual appearance of the stockroom. The president of Elcon was very concerned with the appearance of the stockroom, as there are cardboard boxes and excess material stacked on top of shelves. With the boxes and excess material, the visibility of the stockroom was impacted as well. Similarly, another pain point was the visual management of the stockroom. The stockroom manager positioned their desk within the stockroom to ensure that employees could not enter the stockroom and pull material without the manager being able to see them. These points are taken into consideration in the design of the layout below in **Figure 20.**

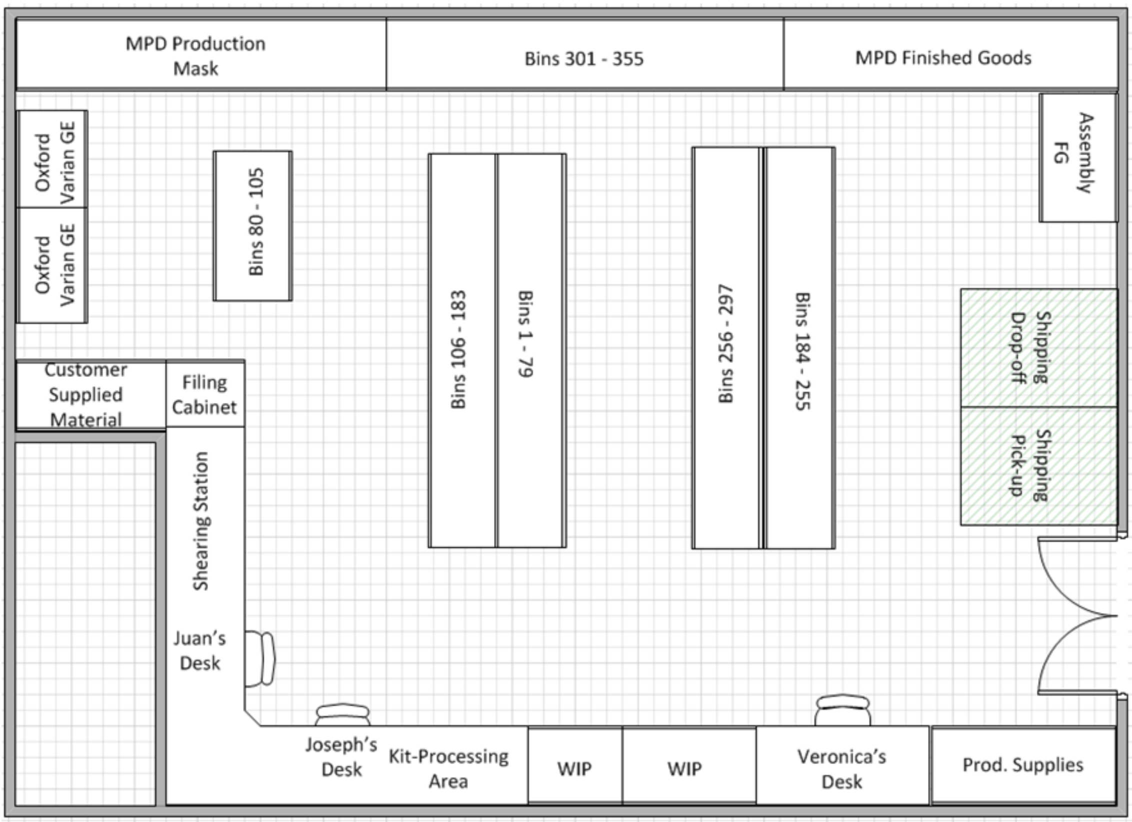


Figure 20: Alternative Layout 2

The first major change is the processing area, shown in the lower left corner of the Visio layout in **Figure 20**. The shearing station is where materials are cut down to size. Through observation of the stockroom and the spaghetti diagram analysis, the project team noticed that the stockroom employees were traveling across the stockroom to get to their respective workstations. Due to the inefficiencies associated with traveling across the stockroom, a large L-shaped workbench was added and organized so that the two stockroom employees were located directly adjacent to their workstation. The workbenches chosen in this design have a solid top, to ensure that heavy material can be processed effectively.

This design of the stockroom has a clear division of material and people. In the original design, the stockroom employees' workstations were dispersed around the stockroom wherever there was room for them. In the original design, communication among the stockroom workers was more difficult. This alternative layout places the workstations in closer proximity to one another. Through employee interviews, the project team learned that each stockroom employee oversees a different area of the stockroom. Employee 1 is in charge of processing raw material and the shearing station. Joseph is in charge of kitted parts and assemblies. With this information, this alternative layout was designed to increase communication between Juan and Joseph by moving their desks closer together while simultaneously separating their respective tasks in the stockroom, which aims to improve the flow of work. To the right of Juan's desk, the shearing station is positioned so that there is still easy access to the raw material shelves in the center of the layout. To the left of Joseph's desk, there is an area for the pre-processing of WIP and Assembly materials which is also directly adjacent to the WIP and assembly material shelves.

As the stockroom's current design was formed through the growth of the company, the placement of materials was based on available space. The layout of shelving for material is consolidated to one half of the stockroom, based on the Raw Material Inventory Analysis performed earlier. In this layout, there are no immediate shelves that obstruct the view of the stockroom manager, so the manager is better able to keep an eye on outside employees entering and exiting the stockroom. Similar to the first alternative layout, this layout consolidates current material and removes outdated inventory. Much of the shelving for raw materials is pushed to the back half of the stockroom against the wall. This allows for better space utilization and visual management. In the center of the stockroom, shelves are lined perpendicular to the employee workstations to allow for more visual management as well as easier access than if the shelves were parallel.

With the design of this layout stemming from the flow of work and materials, the raw material shelves are to be reorganized with the most recent material closest to the processing workstation. This will reduce the overall processing time of an order as well as reduce unnecessary movement of the stockroom employees. Based on the raw materials analysis of last-date-used, materials that have been used within the last two years will be located closest to the processing workbenc

Alternative Layout 3 – Ease of Implementation

An entire reorganization of the stockroom will undoubtedly prove to be a challenge. In addition to the intensive labor that will go into implementation, purchasing or renting machinery may be required to move the heavy shelves/racks. This will add high additional costs that Elcon might not be willing to pay for. Furthermore, along the wall in front of Juan's desk, there is a mounted phone as well as rows of shelves to hold paperwork. Certain areas of the stockroom may not have outlets to power their computers, printers, etc. In terms of logistics, major changes in the stockroom would result in numerous unforeseen consequences that both extend the duration of the project and spike up the cost of implementation. **Figure 21** below is the third alternative layout that was designed for ease of implementation.

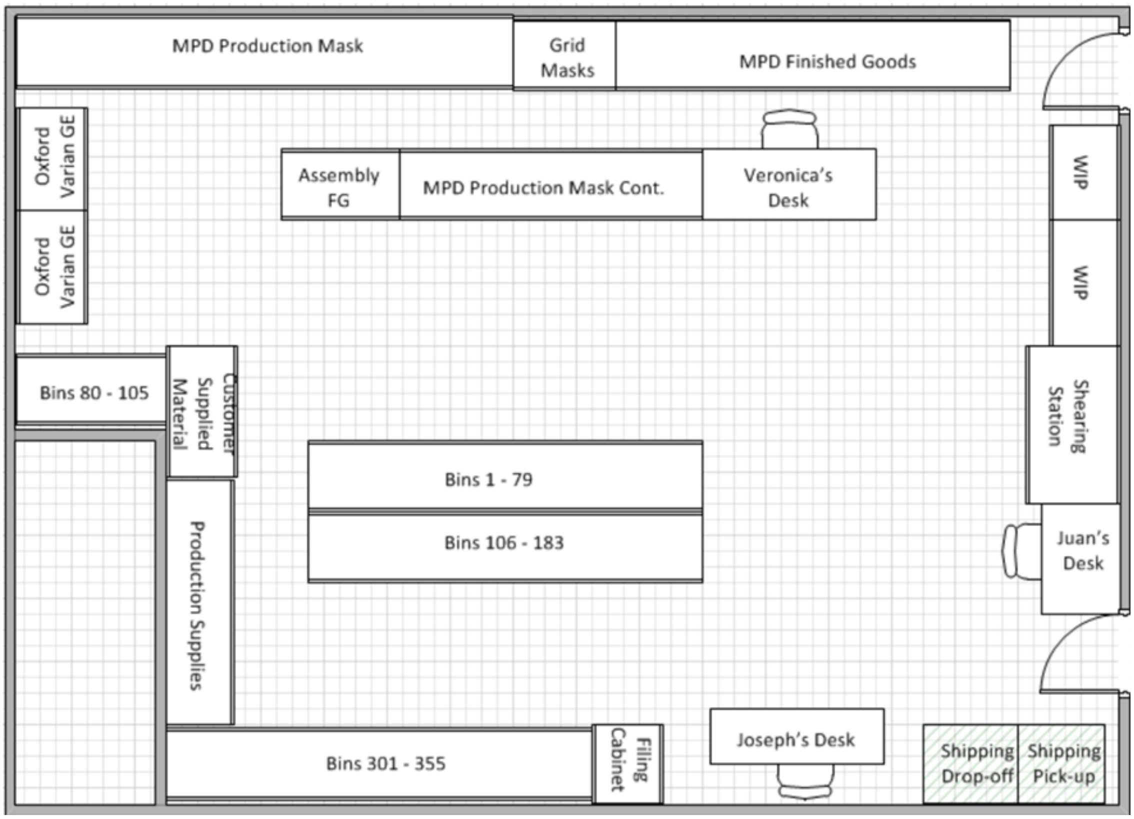


Figure 21: Alternative Layout 3

The team's objective for this layout was to redesign the stockroom in a way that improves efficiency but requires less resources needed for implementation. As a result, Juan and Veronica's desks remain in the same location. This eliminates the concern for rewiring or adding outlets to areas that don't have outlets. The team chose to move the employees' work areas closer to their respective desks and in turn would reduce travel distances.

IV. METHODS

The project team's approach to testing the alternative layouts was broken up into three methods of analysis. The first method is an employee evaluation of the of the alternative layouts. The second method is an analysis of the From-To travel distances of the alternative layouts. The third method of analysis is the comparison between the Cal Poly project team's alternative layouts and the Elcon Precision team's alternative layouts.

Alternative Layout Evaluations

In creating alternative layouts of the facility, the project team decided to create a set of metrics that could be used to evaluate each of the layouts that were create. These metrics were associated with key pain-points of the current layout of the stockroom as defined by the stockroom employees. These alternative layout evaluations were given to each of the stockroom employees, where the employees scored each layout based on their experience working in the stockroom. The evaluation metrics include visibility, communication between employees, walking space, entrances, shearing station location, flow, entrance location, kit-processing area location/size, overall layout implementation feasibility. **Figure 22** below is the evaluation form that was given to each employee.

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility		
Communication between employees		
Walking Space		
Flow		
Entrances		
Shear Location		
Kit-processing area		
Feasibility of Implementation		

Figure 22: Alternative Layout Evaluation Metrics

The alternative layout evaluation form asked employees to score each alternative layout based on the metrics and provided an area for the employees to state the reasoning of the score that they give for a given metric.

Employee Evaluations – Current Layout

Evaluation 1

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	3	Shelves may be blocking
Communication between employees	5	3 should be closer to each other
Walking Space	6	Because of the extra items, it is not great because of the big ladder
Flow	4	Not great
Entrances	9	Ok for now
Shear Location	6	Not as close to shear as possible
Kit-processing area	3	Very minimal
Feasibility of Implementation	10	Already done

Figure 23: Employee 1 Current Layout Evaluation

Evaluation 2

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	3	
Communication between employees	3	Have to walk through shelves
Walking Space	2	Too many hurtles
Flow	2	NO Flow
Entrances	4	
Shear Location	3	Transportation of parts to shear
Kit-processing area	3	My desk is processing area
Feasibility of Implementation	10	

Figure 24: Employee 2 Current Layout Evaluation

Evaluation 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**8**	
Communication between employees	**6**	
Walking Space	**10**	
Flow	**7**	
Entrances	**10**	
Shear Location	**10**	
Kit-processing area	**3**	
Feasibility of Implementation	**6**	

Figure 25: Employee 3 Current Layout Evaluation

With the current layout evaluations above in **Figure 23**, **Figure 24,** and **Figure 25**, the project team took the averages of the total score from each employee's evaluation for the current stockroom layout. The average evaluation score was 56 of 110 possible points.

Employee Evaluations – Alternative Layout 1

Employee 1

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	7	Not open space
Communication between employees	10	Very close - good
Walking Space	8	Avoid back corridor
Flow	6	Shear away from materials and kitting materials far from each other
Entrances	9	Good as is
Shear Location	7	Shear not close to all material
Kit-processing area	6	WIP scattered
Feasibility of Implementation	9	Easy to do but not best flow

Figure 26: Employee 1 Alternative 1 Layout Evaluation

Employee 2

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	4	Material too far apart
Communication between employees	4	Would be too difficult being together
Walking Space	4	Nice but not functional
Flow	3	Would be crossing paths picking up material
Entrances	3	Same
Shear Location	3	Too far from material
Kit-processing area	3	Too far from material
Feasibility of Implementation	2	Negative

Figure 27: Employee 2 Alternative 1 Layout Evaluation

Employee 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**10**	
Communication between employees	**10**	
Walking Space	**10**	
Flow	**10**	
Entrances	**10**	
Shear Location	**10**	
Kit-processing area	**0**	None in layout
Feasibility of Implementation	**3**	

Figure 28: Employee 3 Alternative 1 Layout Evaluation

With the alternative layout 2 evaluations above in **Figure 26**, **Figure 27,** and **Figure 28**, the project team took the averages of the total score from each employee's evaluation for the current stockroom layout. The average evaluation score was 68.33 of 110 possible points.

Employee Evaluations - Alternative Layout 2

Employee 1

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	4	Not clearly visibly space
Communication between employees	7	Better than now
Walking Space	7	Seems ok
Flow	0	
Entrances	0	Must have 2 doors
Shear Location	3	Far from bins
Kit-processing area	3	WIP/kitting not close together
Feasibility of Implementation	9	Easy to do it but not best flow

Figure 29: Employee 1 Alternative 2 Layout Evaluation

Employee 2

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	8	I like the double doors open
Communication between employees	9	We can see each other, and I think communicate better
Walking Space	9	Nice Open flow
Flow	8	Need a couple of carts for transportation of raw and finished material
Entrances	7	Need both doors, but I like double doors open
Shear Location	8	Where is should be, next to the operator
Kit-processing area	8	nice
Feasibility of Implementation	9	This is what I envision the stockroom will look like

Figure 30: Employee 2 Alternative 2 Layout Evaluation

Employee 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	3	
Communication between employees	6	
Walking Space	10	
Flow	7	
Entrances	0	Block entrance
Shear Location	5	
Kit-processing area	10	
Feasibility of Implementation	5	

Figure 31: Employee 3 Alternative 2 Layout Evaluation

With the alternative layout 2 evaluations above in **Figure 29**, **Figure 30,** and **Figure 31**, the project team took the averages of the total score from each employee's evaluation for the current stockroom layout. The average evaluation score was 66 of 110 possible points.

Employee Evaluations – Alternative Layout 3

Employee 1

Metric	**Score (0 = Low, 10 =High)**	**Reasoning**
Visibility	**7**	Some areas not visible
Communication between employees	**7**	Spread too far
Walking Space	**7**	Back area corridor
Flow	**3**	MPD & CPD all scattered
Entrances	**9**	2 doors good
Shear Location	**7**	Material far from shear
Kit-processing area	**6**	Some WIP far from each other
Feasibility of Implementation	**9**	It can be moved but not best flow

Figure 32: Employee 1 Alternative 3 Layout Evaluation

Employee 2

Metric	**Score (0 = Low, 10 =High)**	**Reasoning**
Visibility	**4**	
Communication between employees	**4**	
Walking Space	**3**	
Flow	**4**	
Entrances	**3**	
Shear Location	**3**	
Kit-processing area	**2**	
Feasibility of Implementation	**2**	Too close to current layout

Figure 33: Employee 2 Alternative 3 Layout Evaluation

Employee 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	5	Mask too far
Communication between employees	3	Too far away from each other, Veronica and Joseph should be closer
Walking Space	10	
Flow	3	
Entrances	10	Same
Shear Location	3	Too far from material
Kit-processing area	0	Not on layout
Feasibility of Implementation	3	Do not like layout

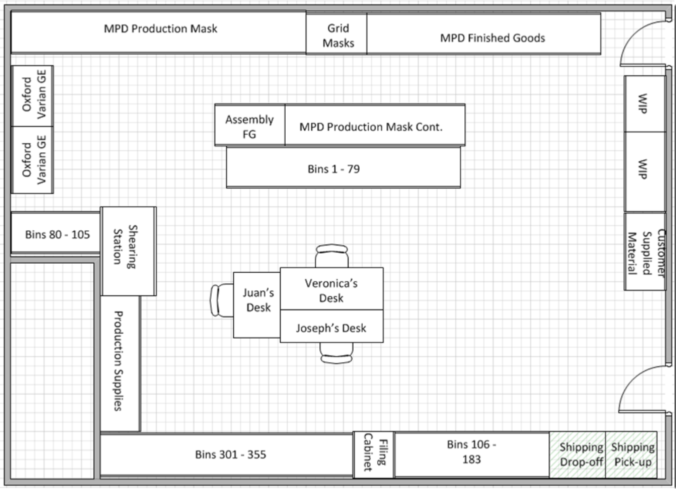
Figure 34: Employee 3 Alternative 3 Layout Evaluation

With the alternative layout 3 evaluations above in **Figure 32**, **Figure 33,** and **Figure 34**, the project team took the averages of the total score from each employee's evaluation for the alternative stockroom layout. The average evaluation score was 61 of 110 possible points.

Employee Travel Distances – Alternative Layouts

As the project team measured and calculated the employee travel distances in the current layout of the stockroom in a From-To chart, the same was done for each of the alternative layouts. The goal of this method was to highlight the reduction of distances between the employee's desks and the key areas of the stockroom.

Alternative Layout 1

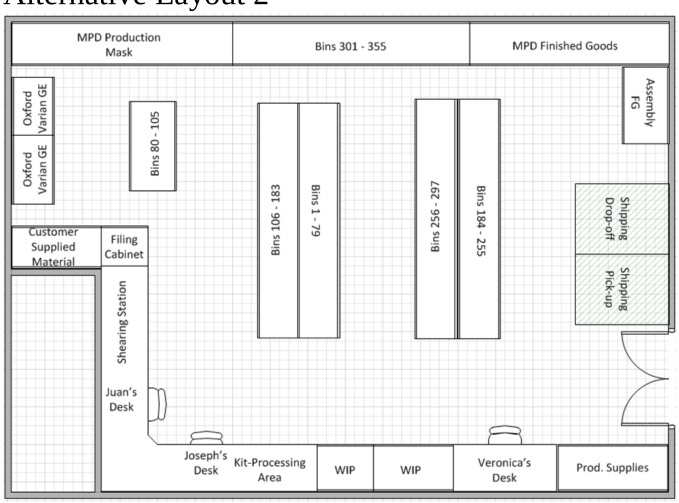


Alternative Layout 1			
From	**To**	**Distance (ft.)**	**In**
Juan's Desk	Shear	6	6
Juan's Desk	MPD Grids	28	10
Juan's Desk	Varian GE	20	9
Juan's Desk	Veronica's Desk	6	6
Juan's Desk	Joseph's Desk	6	6
Juan's Desk	WIP	24	1
	AVG	15	5
Joseph's Desk	Shear	11	6
Joseph's Desk	MPD Grids	33	10
Joseph's Desk	Varian GE	29	11
Joseph's Desk	Veronica's Desk	6	6
Joseph's Desk	Juans's Desk	6	6
Joseph's Desk	WIP	22	0
	AVG	18	6
Total AVG Distance		**16**	**5**

Figure 35: Alternative Layout 1 Travel Distances

The total average travel distances by the employees from their workstations to the key areas of the stockroom in the alternative layout 1 was calculated to be 16 feet 5 inches, as seen in **figure 35**.

Alternative Layout 2

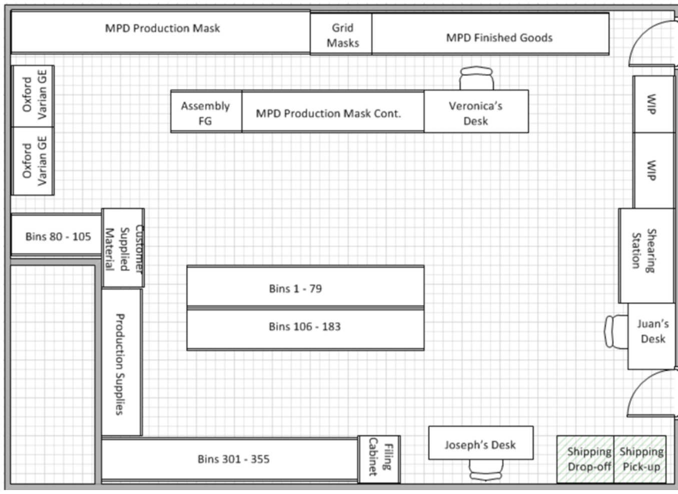


Alternative Layout 2			
From	**To**	**Distance (ft.)**	**In**
Juan's Desk	Shear	4	9
Juan's Desk	MPD Grids	24	9
Juan's Desk	Varian GE	18	4
Juan's Desk	Veronica's Desk	19	2
Juan's Desk	Joseph's Desk	5	8
Juan's Desk	WIP	9	7
	AVG	13	5
Joseph's Desk	Shear	8	1
Joseph's Desk	MPD Grids	27	4
Joseph's Desk	Varian GE	21	6
Joseph's Desk	Veronica's Desk	14	10
Joseph's Desk	Juans's Desk	5	8
Joseph's Desk	WIP	7	6
	AVG	14	6
Total AVG Distance		**13**	**5**

Figure 36: Alternative Layout 2 Travel Distances

The total average travel distances by the employees from their workstations to the key areas of the stockroom in the alternative layout 2 was calculated to be 13 feet 5 inches, as seen in **Figure 36**.

Alternative Layout 3



Alternative Layout 3			
From	**To**	**Distance (ft.)**	**In**
Juan's Desk	Shear	6	0
Juan's Desk	MPD Grids	32	2
Juan's Desk	Varian GE	25	2
Juan's Desk	Veronica's Desk	21	3
Juan's Desk	Joseph's Desk	10	0
Juan's Desk	WIP	10	3
	AVG	17	2
Joseph's Desk	Shear	12	3
Joseph's Desk	MPD Grids	40	8
Joseph's Desk	Varian GE	34	1
Joseph's Desk	Veronica's Desk	25	6
Joseph's Desk	Juans's Desk	10	0
Joseph's Desk	WIP	21	2
	AVG	24	3
Total AVG Distance		**21**	**2**

Figure 37: Alternative Layout 1 Travel Distances

The total average travel distances by the employees from their workstations to the key areas of the stockroom in the alternative layout 3 was calculated to be 21 feet 2 inches, as seen in **Figure 37**.

VI. RESULTS AND ANALYSIS

The results of the alternative layout evaluations and the employee from-to travel distances for the alternative layouts are shown in the summarized data **Table 6** below.

	Average Travel Distance	Average Evaluation Score
Current Layout	28 ft. 4 in.	56
Alternative Layout 1	16 ft. 5 in.	68.33
Alternative Layout 2	13 ft. 5 in.	66
Alternative Layout 3	21 ft. 2 in.	61

Table 6: Summarized Data

Alternative layout 1 reduced the employee travel distances from their desks to the key areas of the stockroom to 16 feet and 5 inches. This distance was 11 feet and 11 inches less than the current layout travel distance.

Alternative layout 2 reduced the employee travel distances from their desks to the key areas of the stockroom to 13 feet and 5 inches. This distance was 14 feet and 9 inches less than the current layout travel distance.

Alternative layout 3 reduced the employee travel distances from their desks to the key areas of the stockroom to 21 feet and 2 inches. This distance was 7 feet and 2 inches less than the current layout travel distance.

The highest average alternative layout evaluation score between the three employees was for alternative layout 1 at 68.33 of 110 points.

Based on the employee evaluations and the from-to travel distances for the three alternative layouts, the project team recommends that alternative layout 1 be implemented into the stockroom at Elcon Precision.

Economic Case

As the project team was unable to implement the recommended layout and test the changes in efficiency of the stockroom, other areas of economics were assessed. The Elcon Precision stockroom project was based on creating space for the future growth of the company. Per discussions with the President of Elcon, Tim Dyer, the company is projected to grow at least 20% per year over the next 5 years. If this growth holds true, Elcon will be doubling the size of their business by the year 2024.

The cost of implementing alternative layout 1 was estimated under the following assumptions. These assumptions are as follows:

1. All three stockroom employees would stop all business work during the implementation of the alternative layout
2. The estimated hourly wage of each stockroom employee is $23/hour
3. The estimated implementation time is 60 hours, or 1½ weeks

With the above assumptions, the estimated cost of implementation of alternative layout 1 can be seen in the **table** below.

Cost of Implementation	
Standard Stockroom Employee Rate Per Hour	$ 23.00
Number of Employees	3
Implementation Time (Hours)	60
Total Cost	**$4,140.00**

Table 7: Estimated Cost of Implementation

The calculation above multiplies the standard stockroom employee rate per hour by the number of employees in order to yield the cost for all employees to work on this project. Taking this total cost per hour and multiplying this by the duration of the implementation, the estimated total cost of implementation is $4,140.00. This number will serve as a figure of reference in the following calculations.

The main areas of cost savings from implementing the alternative stockroom layout stem from opportunity costs that avoid the need for renting out other buildings or storage areas in San Jose, California. At the time of this project, the cost of renting office space in Silicon Valley is $4.57 per square foot per month. Extrapolating this cost over course of a year for a similarly sized stockroom is shown in **Table 8** below.

Location - Silicon Valley	
Average Cost to Rent Per Square Foot (2017)	$4.57
Elcon Stockroom Square Footage	875
Yearly Cost (Opportunity Cost)	**$47,985.00**

Table 8: Estimated Yearly Cost of Rent (Opportunity Cost)

The current stockroom is 875 square feet in size. Multiplying the average cost of rent per square foot per month by 12 will yield the yearly cost of one square foot per year, which is $54.84 per square foot per year. Multiplying this number by 875 square feet, the estimated cost to rent a similar size area in Silicon Valley is $47,985.00.

Relating this information to the Cal Poly stockroom redesign project, the goal of the project was to free up space to allow for future growth of the company. Through the analysis of the collected data and observing the contents of the stockroom, the project team believes that the shelved and materials within the stockroom can be reduced by at least 15%. This 15% space savings equates to roughly 132 square feet of space within the stockroom. Using the same calculations for this space reduction, if Elcon can consolidate 15% of the space in the stockroom, the company would be saving roughly $7,200 per year that they would be spending to rent out 132 square feet of office space elsewhere in San Jose. Extrapolating this data can be seen in **Table 9** below.

Space Reduction	15%	20%	25%	30%
Monthly Savings	$599.81	$799.75	$999.69	$1,199.63
Yearly Savings	$7,197.75	$9,597.00	$11,996.25	$14,395.50

Table 9: Yearly Savings for Space Reduction

The Cal Poly project team conservatively estimated that 15% of the stockroom can be consolidated. **Table 9** includes the cost savings for Elcon should they reduce the size of their current inventory by 20%, 25%, and 30%.

The Cal Poly project team conservatively estimated that 15% of the stockroom can be consolidated though removal of stale raw materials. As 50% of the raw materials are stale, the project team concluded that 50% of the shelving can be removed from the stockroom. Each shelf is about 70 square feet, and there are two of these shelves that can be removed, resulting in 140 square feet of savings just from raw material consolidation.

Recommendations

Throughout the stockroom redesign project with Elcon Precision, the project team is continuously learning about the processes and functions of the stockroom. After analyzing the collected data from the stockroom, the project team came up with a list of recommendations for Elcon as they continue to move forward with the stockroom project. The project team recommends that Elcon focuses on four main areas of their business to improve the functionality and efficiency of the stockroom as they continue to grow. The four areas are:

- MRP System
- Inventory Consolidation
- Ergonomics
- Safety

The project team strongly advises the Elcon Precision team to incorporate the topics listed above as they are crucial to the long-term success of any facility.

MRP System

As businesses continue to become more data driven in decision making processes, access to company data is becoming more important. Enterprise Resource Planning (ERP) systems are excellent ways for an organization to consolidate all software application within one large software program, such as Oracle. While ERP system are a great way to organize data within departments and allow companies to operate more efficiently, not all companies need a large ERP system to increase efficiencies. In addition, ERP systems can be extremely expensive and take months to train employees on using the software. There are many iterations of software packages that are designed for certain departments within a company. In the case of Elcon Precision, the Cal Poly project team recommends that a small Materials Resource Planning (MRP) system is implemented to aid in areas such as materials management, material tracking, and reordering points for inventory.

Currently, the ERP system at Elcon Precision is tailored towards the business side of the company. In the stockroom, the employees perform cycle counts of the inventory on an annual basis. These counts can take days to complete and require the stockroom to be shut down. The purpose of these counts is to confirm the accuracy of the inventory in the ERP system to the actual on-hand inventory. One of the biggest opportunities for improvement stems from the usability of the current ERP software. After speaking with the stockroom employees, the project team learned that it is difficult for the employees to construct reports on material usage and track inventory because the software is not built to manage inventory. With this information, the Cal Poly project team recommends that a smaller MRP system be acquired.

Inventory Consolidation

The Cal Poly project team performed an inventory analysis on the raw material racks within the stockroom. This analysis revealed that much of Elcon Precision's inventory has not been used within the last two years. Based on this project's recommendations to consolidate as much inventory as possible to free up space, the Cal Poly project team recommends that future iterations of stockroom projects emphasize the consolidation and reduction of inventory based on last date used.

With the consolidation of inventory, it is important for the company to have an accurate inventory count for all of the materials. If older material is sold back to the supplier or removed from the inventory area, the stockroom employees must have a more robust way to track inventory in order to re-order material if needed.

Ergonomics

Upon observation of the general operations throughout the stockroom on a daily basis, the Cal Poly project team noted actions of the stockroom employees that were not ergonomic. Currently, the ergonomics in the stockroom can be improved upon. Between the three employees that work in the stockroom, two of them spend most of the day standing, while the third employee spends most of their day sitting. While the type of work might dictate whether an employee must stand or sit, it is crucial to ensure that the office environment is able to adjust to the work. The employee should never have to bend down or reach up to accomplish work. The goal of ergonomics is to fit the work to the worker, rather than fitting the worker to the work.

The main ergonomic recommendation for this project is to reorganize the location of materials on the shelves based on the last date the material was used. This aims to reduce the amount of bending over and reaching by the stockroom employees to retrieve material. Based on research from the NIOSH lifting guidelines, the majority of lifting should be done between the knees and the shoulders of any given employee.

Per Raw Material Inventory Analysis, over 50% of the raw materials have not been touched or moved since 2015. Under the assumption that material older than 2 years old can be removed from the stockroom or consolidated to a different shelf, the project team recommends that the materials that were used between 2016 and 2018 are organized to promote ergonomic lifting techniques.

Due to the inaccessibility to the ERP/MRP data on the inventory, the project team assumes that the most recently moved material correlates with the more frequently accessed material. The following inventory organization recommendation is made to reduce the impact of the work on the worker when lifting materials. In future projects, it is strongly recommended that any material reorganizations stem from the most current information of materials within the ERP/MRP system rather than from the Last Date Used sheets on the inventory.

The project team recommends that the most recent material is located in the center of the shelves to reduce the number occurrences that employees must bend down or reach up to retrieve material on a daily basis. In **Figure 38** below, a basic illustration of the raw material organization can be seen.

Last Date Accessed	Percent of Total Inventory
2016	15.22%
2017	48.55%
2018	36.23%

Figure 38: Ergonomic Material Organization

It is important to find a balance between sitting and standing throughout the day to reduce the risk of musculoskeletal injuries. As noted in Section II of this report, it is recommended that employees strive to spend 50% of the day sitting and 50% of the day standing in an office environment. This ratio of sitting versus standing has been shown to reduce the overall discomfort as well as reducing the risk of MSD's. Ergonomic workstations are available that raise the working surface desk to the employee's standing height.

When incorporating a standing workstation into any working environment, anti-fatigue mats are a simple, cost effective, solution to help reduce discomfort while standing. An anti-fatigue mat is a mat designed to reduce fatigue caused by standing on hard surfaces. By implementing anti-fatigue mats to a workspace where there is prolonged standing will reduce the impact on the employee and thus reduce the risk of musculoskeletal injuries.

The combination of the sit-stand desk and the anti-fatigue mats can increase the comfort of the stockroom employees at Elcon Precision as well as reducing their risk of developing a musculoskeletal disorder.

Safety

In respect to the six basic principles of lean known as 6s, safety is by far the most important. A lean facility embodies a clutter-free, safe work environment and primarily aims to improve efficiency in all areas.
During the first visit, the team observed that the shipping and receiving areas were taped off on the floor. Every day, the mail deliverer would walk into the facility and drop off packages directly on the floor. Similarly, Elcon Precision employees would drop their package in the shipping section to ship out material. This setup results in numerous packages lying on the ground during the day, which can be a hazard

Dynamic Stockroom – Future Recommendation

The redesigned layouts that were created during the course of this project assume that all elements throughout the stockroom are fixed in place. With the limited size of the stockroom at Elcon precision, a possible opportunity to increase the efficiency of the stockroom is the implementation of movable racks. Movable racks would allow for the stockroom employees to move material shelves around more easily than the standard racks that are currently in the stockroom.

With racks that can be moved around, the location of materials can change based on demand. If a material is farther away from the processing station, employees can physically move that material's shelf closer to the processing station with a movable rack. This act of moving material closer to the processing station would reduce travel times of the employee. With the reduction in travel time, the overall lead time of the order will be reduced and thus the overall cost to produce the product is reduced.

Another related option is movable bin labels. Similar to the movable racks, individual materials can be relocated based on usage. While this option could also benefit the company by reducing lead times for products, this option would require a more robust materials management software in order to keep track of where material is located within the stockroom.

VII. CONCLUSION

During the team's first meeting with Elcon Precision in the winter of 2018, the Elcon Precision employees were in agreement that the stockroom needed change. The current layout was set in a way that made it difficult to communicate with other employees, manage material, and walk around to pull items. During the first week, the team worked with Elcon Precision to define a scope and develop three main objectives for the project:

1. Increase visibility
2. Improve material management
3. Reduce travel distances and improve ergonomics

The team started the project by analyzing the current state of the stockroom. This involved measuring the dimensions of the shelves and equipment in the stockroom, observing the shelf utilization, analyzing material's last date accessed, recording employee movements, noting the ergonomic conditions and inspect the overall safety. Using tools such as a spaghetti diagram, Excel, Sketchup, Visio, and surveys, the team analyzed the data collected and developed a series of recommendations that satisfy the objectives of the project. The team produced a list of key conclusions that would result in implementation of the project recommendations.

- Implementation of Alternative Layout 1 will yield a 42% reduction in travel distances
- Estimated Cost of Implementation is $4,140
- Potential savings of $11,996.25 per year on rental space
- Consolidated inventory of Raw Material, Finished Goods, and Customer Supplied Material
- Based off employee evaluations, visibility and communication would increase

The team had to make several assumptions that if wrong, could have an influence on the recommendations. Key assumptions are listed below:

- Employees travel to and within the main stockroom areas equally
- Labor pay rate was estimated based on standard wages of a stockroom employee
- Elcon Precision's property rent is based off of average rent / sq. ft in San Jose area
- Based off the results from the Raw Material inventory, approximately 50% of Finished Goods and Customer Supplied Material can be regarded as stale inventory

Working with Elcon Precision was overall an excellent experience as the team maintained strong communication on a weekly basis. Elcon Precision employees were very cooperative and were available to speak by phone on request.

However, with the facility in San Jose, the team wasn't able to easily conduct experiments and collect data. Easier access to the facility would have been beneficial in getting more accurate data, taking more observations, and doing more for the project.

The societal impacts of the stockroom redesign project are the stockroom employees' reception of the project team's recommendations and ideas. Being that none of the members in the project team are employed by Elcon, it is difficult for the team to deeply understand the business activities in Elcon. A potential ethical impact is that the employees will not want to implement the project team's new designs because they do not think that the designs are created from a credible viewpoint. In essence the project is a group of students that are working part-time and without pay to redesign the layout of a full-time employee's workspace. The full time employees might not receive the project team's ideas and designs well and not take the project seriously because the changes are not coming from within the company.

Throughout the stockroom project, the Cal Poly team discusses improvements to the layout that will increase both short term and long-term safety of the employees. An example of this is making the workstations more ergonomic by implementing anti-fatigue mats and sit-stand desks to alleviate the impact of the work on the worker and to reduce the risk of musculoskeletal disorders. With this, the workers at Elcon will be happier and healthier, which will ultimately allow them to be more productive during the workday.

Although many inefficiencies have been discovered and recommendations have been given to Elcon for implementation, there is still more work that can be done. In the future, the project team recommends focusing on other key areas of opportunity within the Elcon Precision stockroom including their ERP reliability, implementing the improved layout, and improving efficiencies throughout other department areas. The ERP system's reliability was closely related to the overall efficiency of the stockroom. Elcon reported issues related to a lack of accurate data in the ERP system, which can hinder the ability for Elcon to make a sale. Improving this function of Elcon could greatly benefit their business. Likewise, although recommendations for implementations were made, the layout still has yet to be fully implemented. Figuring out how to dispose of waste along with contracting necessary members to move, buy, or place furniture within the stockroom will take a considerable amount of time. The project team believes that a Cal Poly senior project team would be able to accomplish these tasks if given time to work on them.

Overall, the project team strongly recommends that future teams work with Elcon Precision. As previously stated, Elcon Precision has been an exceptional company to work with based on their level of communication and project involvement with the project team.

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IX. APPENDIX

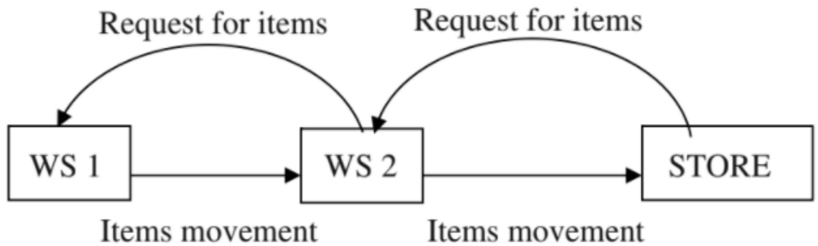


Figure 1 - Kanban Card System (Kumar, 394)

$$K \geq \frac{DL(1+\alpha)}{C}$$

where,
K is the number of kanbans,
D is the demand per unit time,
L is the lead-time,
α is the safety factor and
C is the container capacity

Figure 2 - Number of Kanban Cards Calculation, (Kumar, 397)

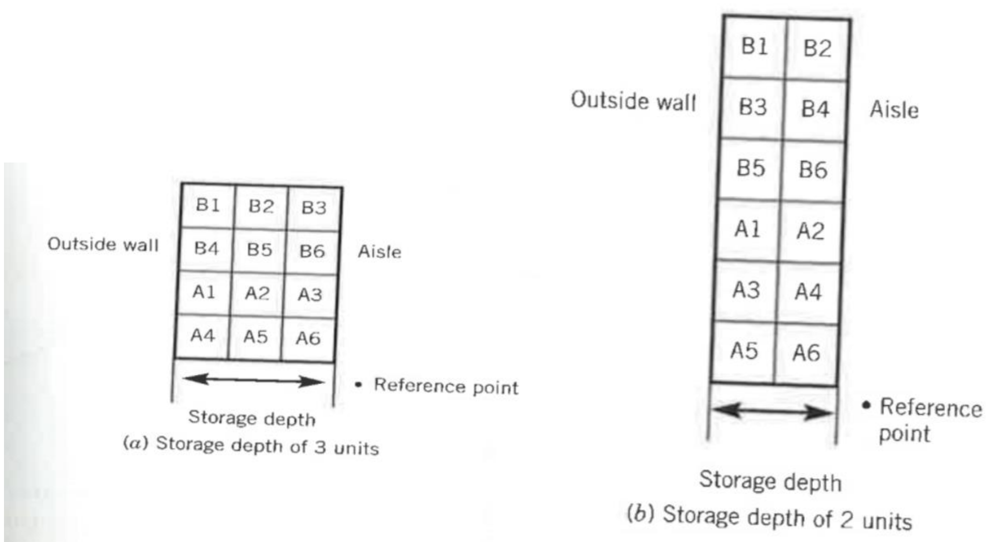


Figure 3 - Inventory Sorting Method, (Tompkins)

1.	Initial Data Required
2.	Use of Charts
3.	Use of Graphs and Diagrams
4.	Future Expansion Consideration
5.	Constraints considered
6.	Procedure implementation
7.	Material Handling Equipment Selection Consideration

Table 3 - Factors for evaluation of procedural approaches

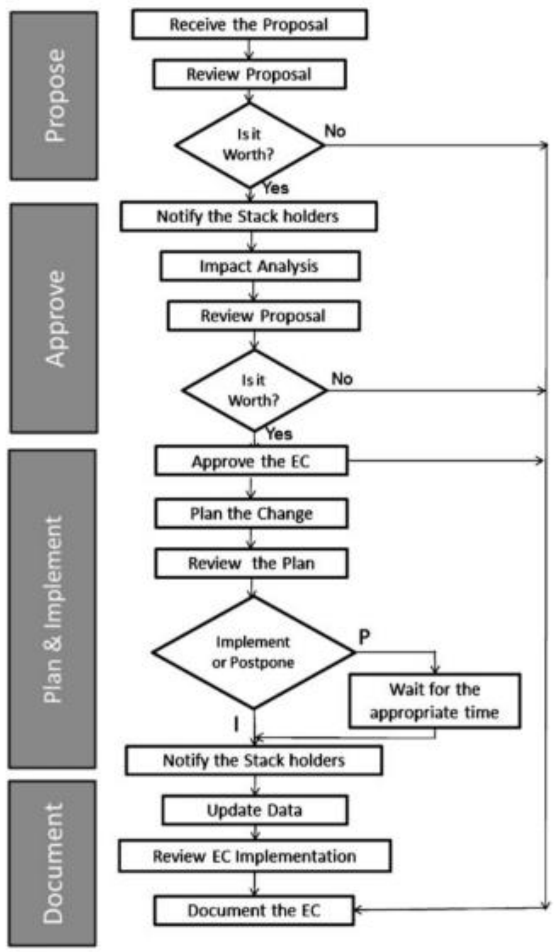


Figure 4 - Change Management Process Map (Reddi, 1226)

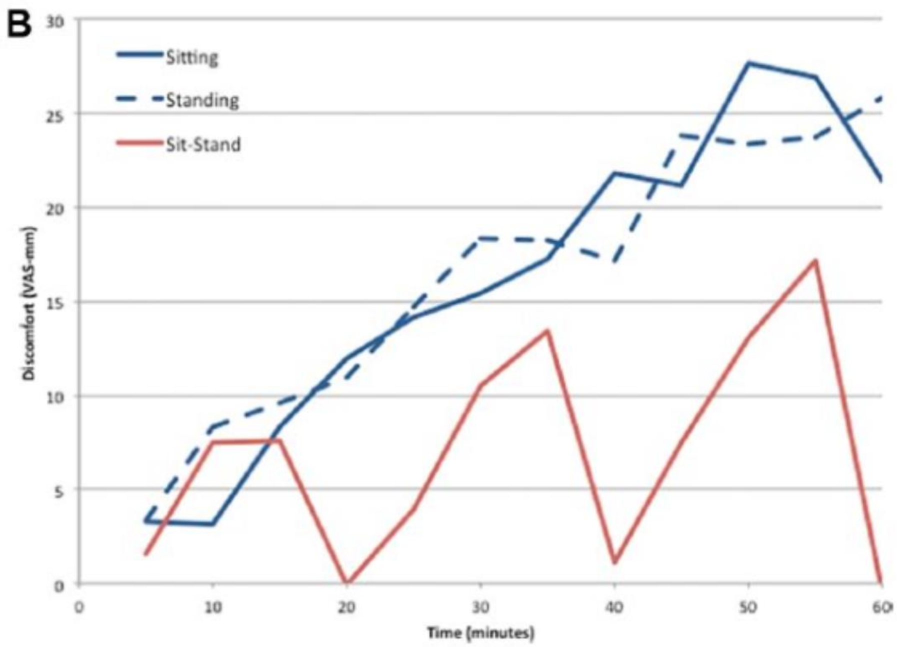


Figure 5: Discomfort vs. Time (Callaghan, 22.)

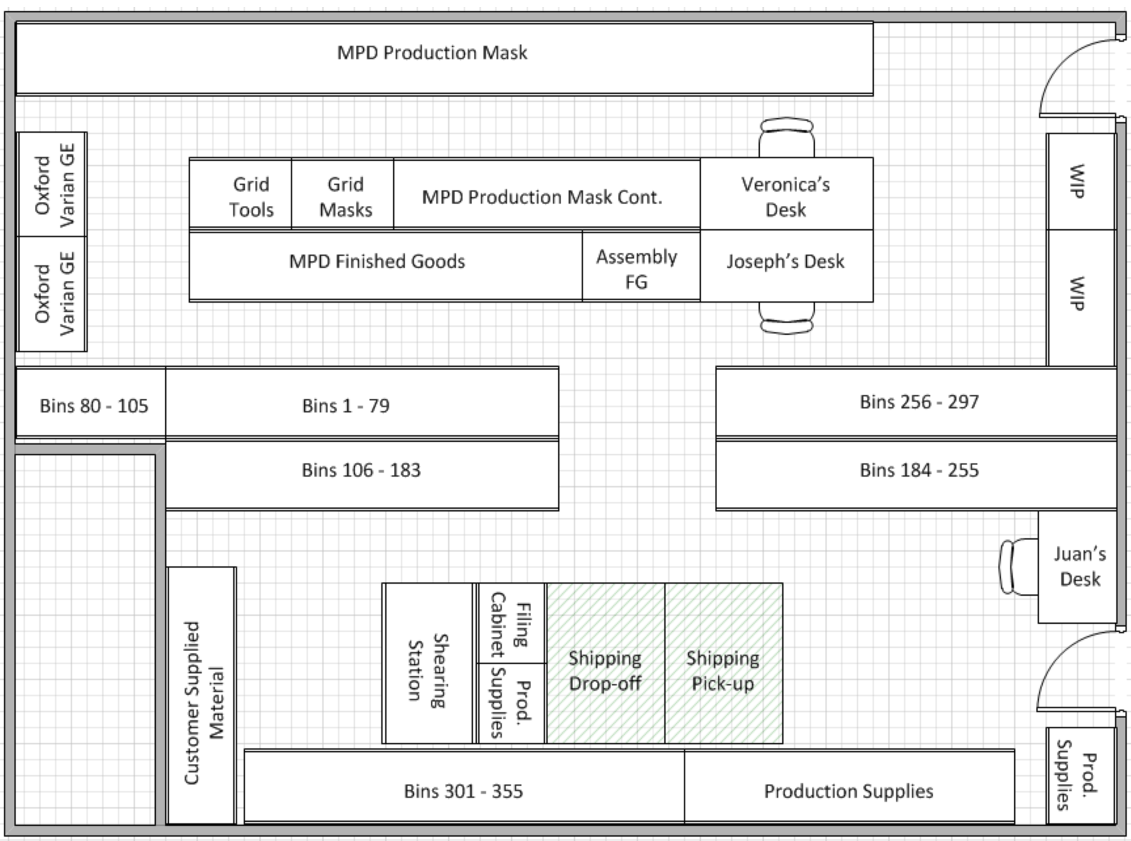


Figure 6 –Elcon Precision Stockroom – Current Layout (Mastromattei)

Figure 7 & 8: Designated Areas of Pick up and Drop Off (Matsumoto)

Figure 9: Current Shelf Capacity – Raw Materials (Mastromattei)

	BIN 209 - 255 INVENTORY CAPACITY ANALYSIS				
Bin Number	Percent Capacity (%)	Bin Number	Percent Capacity (%)	Bin Number	Percent Capacity (%)
255	50	239	50	182	90
254	40	238	40	183	90
253	80	237	20	184	40
252	30	236	60	185	30
251	30	235	50	186	20
250	30	234	40	187	20
249	40	233	50	188	30
248	10	232	70	189	20
247	10	231	20	190	50
246	80	230	0	191	50
245	40	229	50	192	60
244	10	228	50	193	60
243	5	227	50	194	40
242	30	226	60	195	30
241	50	225	50	196	50
240	50	224	30	197	70
		223	30	198	40
		222	20	199	40
		221	20	200	40
		220	40	201	60
		219	10	202	30
		218	20	203	20
		217	30	204	20
		216	40	205	10
		215	20	206	10
		214	20	207	30
		213	40	208	20
		212	30	209	0
		211	100		
		210	100		

Figure 10: BIN 209 – 255 Inventory Capacity Analysis, (Mastromattei)

	BIN 265 - 300 INVENTORY CAPACITY ANALYSIS				
Bin Number	Percent Capacity (%)	Bin Number	Percent Capacity (%)	Bin Number	Percent Capacity (%)
300	20	285	40	270	40
299	10	284	20	269	20
298	40	283	20	268	20
297	70	282	10	267	40
296	0	281	30	266	30
295	50	280	5	265	50
294	20	279	40	264	100
293	10	278	60	263	50
292	20	277	30	262	40
291	20	276	20	261	20
290	10	275	60	260	20
289	10	274	60	259	20
288	5	273	50	258	10
287	10	272	10	257	10
286	10	271	20	256	30

Figure 11: BIN 256 – 300 Inventory Capacity Analysis, (Mastromattei)

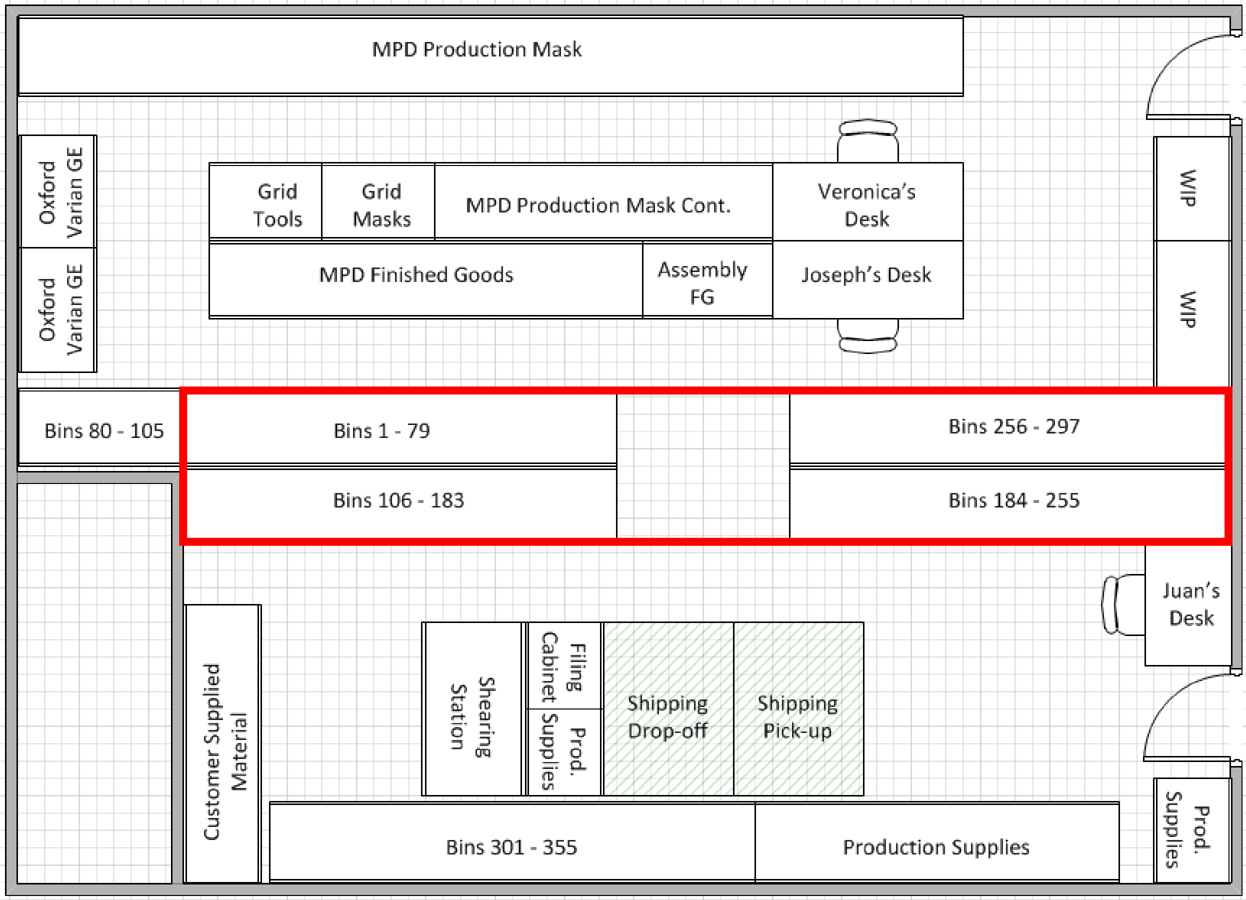


Figure 12: Metal Raw Material Location (Mastromattei)

Last Year Accessed	Percentage of Total
2011	0.36%
2014	7.50%
2015	42.86%
2016	7.50%
2017	23.93%
2018	17.86%

Table 2: Percent Breakdown by Year Last Accessed, (Matsumoto)

Figure 14: Pick-up and Drop-off Safety Hazards(Matsumoto)

Figure 15: Employee Sitting at Workstation (Mastromattei)

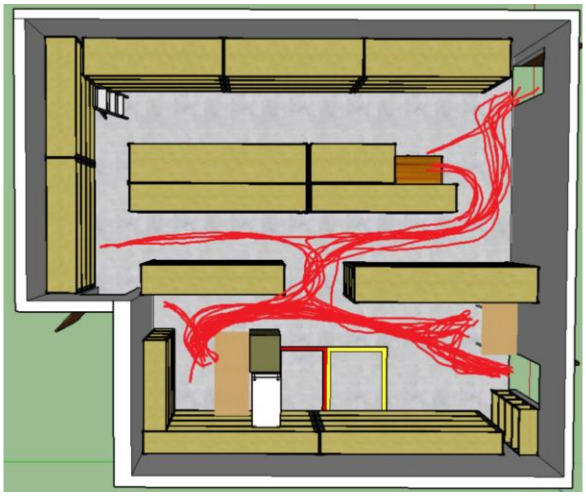


Figure 16 Employee 1(Matsumoto)

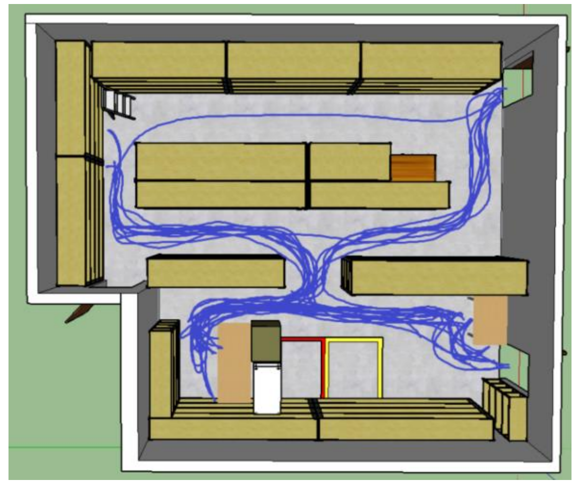


Figure 17: Employee 2 (Matsumoto)

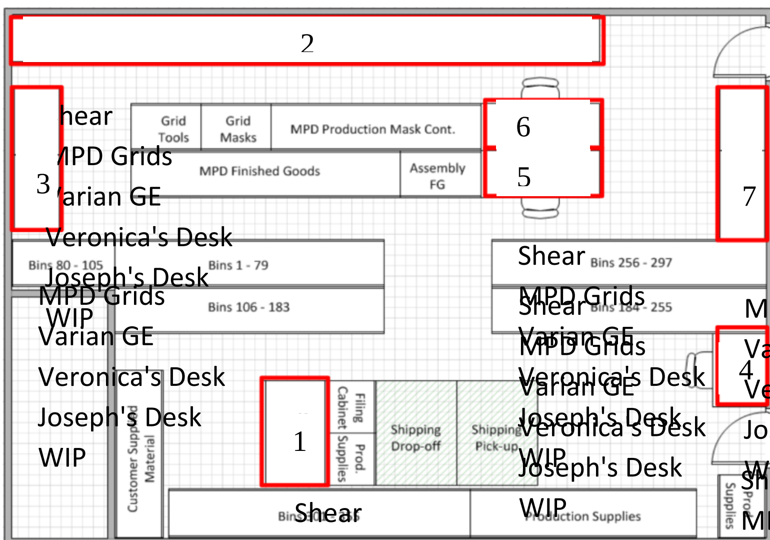


Figure 18: Key Stockroom Areas

Number	Location
1	Shear Station
2	MPD Grids
3	Varian GE
4	Employee 1 Desk
5	Employee 2 Desk
6	Employee 3 Desk
7	Work-in-Process

Table 3: Key Stockroom Areas

From	To	Distance (ft.)	In
Employee 1 Desk	Shear	24	7
Employee 1 Desk	MPD Grids	47	5
Employee 1 Desk	Varian GE	35	1
Employee 1 Desk	Veronica's Desk	21	3
Employee 1 Desk	Joseph's Desk	38	3
Employee 1 Desk	WIP	37	4
	AVG	34	3

Table 4: Employee 1 From-To Chart

From	To	Distance (ft.)	In
Employee 2 Desk	Shear	22	1
Employee 2 Desk	MPD Grids	33	5
Employee 2 Desk	Varian GE	22	11
Employee 2 Desk	Veronica's Desk	16	10
Employee 2 Desk	Juan's Desk	38	3
Employee 2 Desk	WIP	7	6
	AVG	23	6

Table 5: Employee 2 From-To Chart

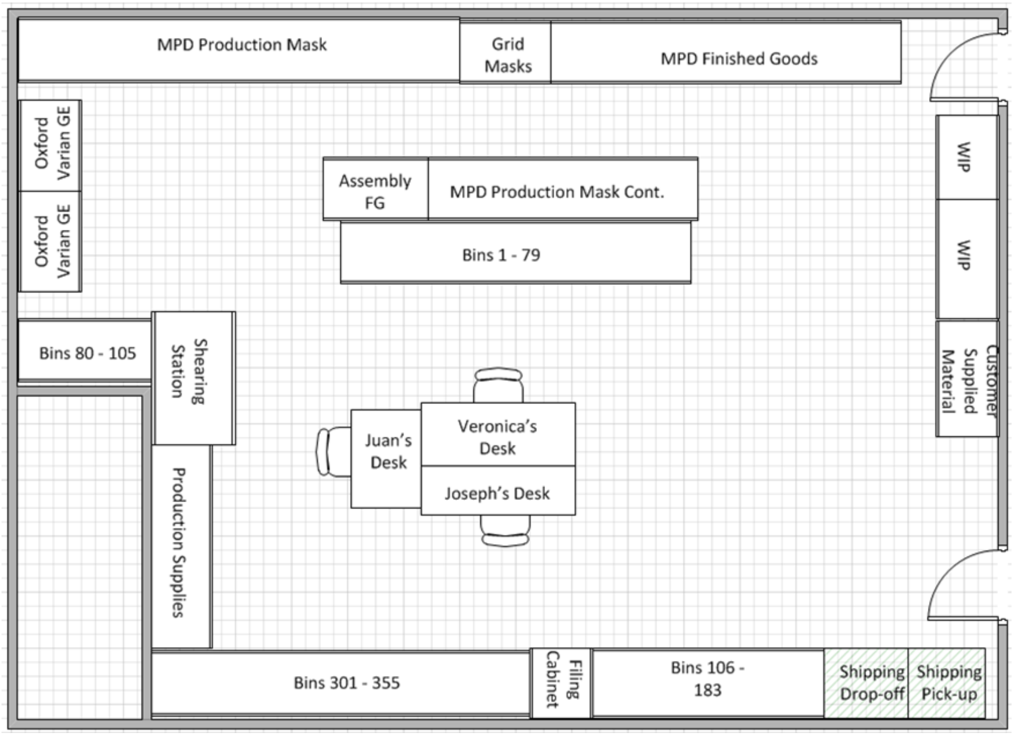


Figure 19: Alternative Layout 1

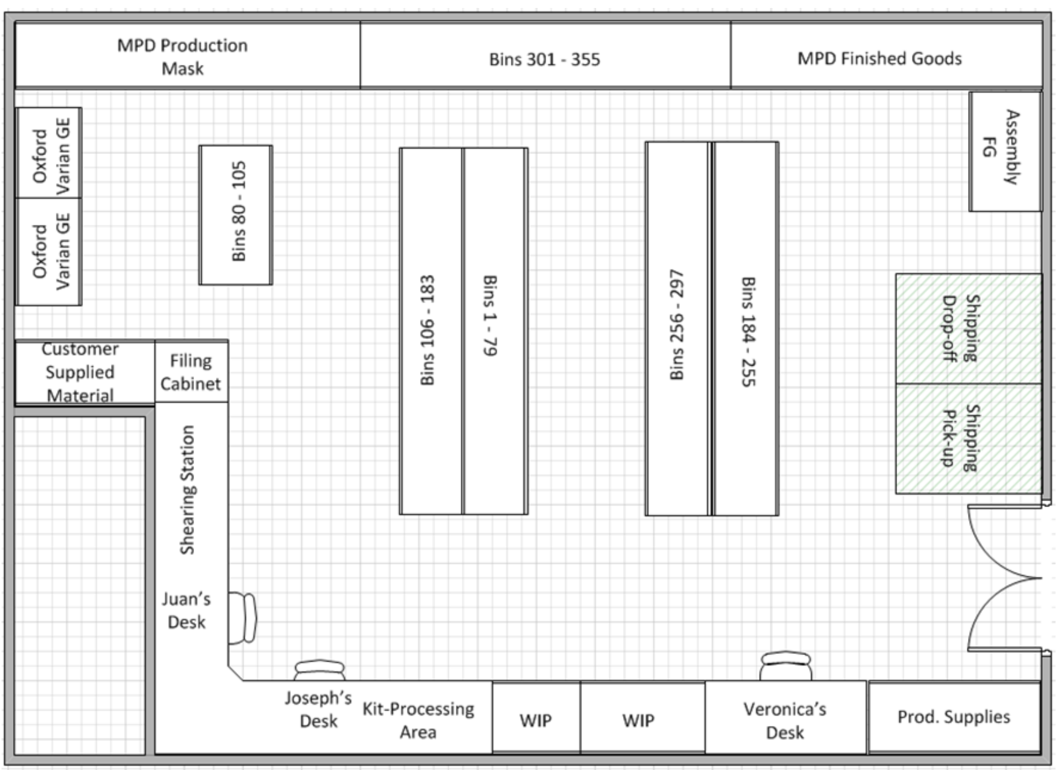


Figure 20: Alternative Layout 2

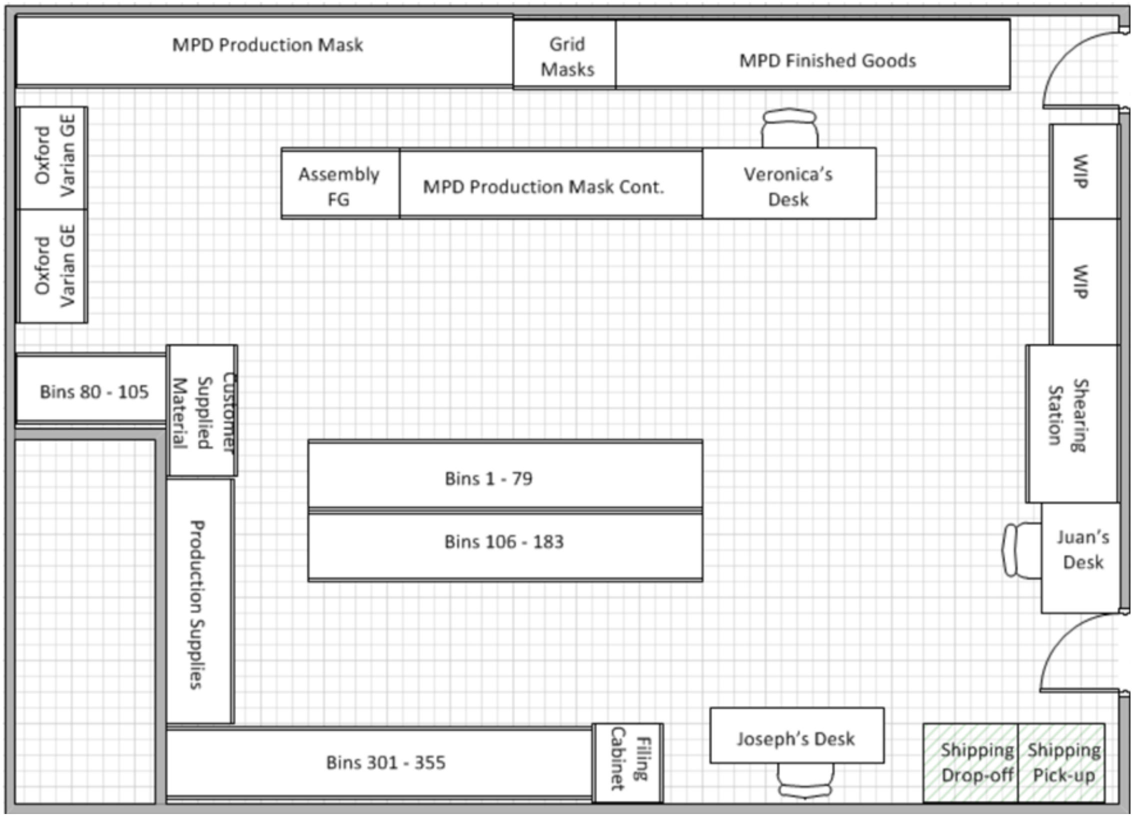


Figure 21: Alternative Layout 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility		
Communication between employees		
Walking Space		
Flow		
Entrances		
Shear Location		
Kit-processing area		
Feasibility of Implementation		

Figure 22: Alternative Layout Evaluation Metrics

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**3**	Shelves may be blocking
Communication between employees	**5**	3 should be closer to each other
Walking Space	**6**	Because of the extra items, it is not great because of the big ladder
Flow	**4**	Not great
Entrances	**9**	Ok for now
Shear Location	**6**	Not as close to shear as possible
Kit-processing area	**3**	Very minimal
Feasibility of Implementation	**10**	Already done

Figure 23: Employee 1 Current Layout Evaluation

Evaluation 2

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**3**	
Communication between employees	**3**	Have to walk through shelves
Walking Space	**2**	Too many hurtles
Flow	**2**	NO Flow
Entrances	**4**	
Shear Location	**3**	Transportation of parts to shear
Kit-processing area	**3**	My desk is processing area
Feasibility of Implementation	**10**	

Figure 24: Employee 2 Current Layout Evaluation

Evaluation 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**8**	
Communication between employees	**6**	
Walking Space	**10**	
Flow	**7**	
Entrances	**10**	
Shear Location	**10**	
Kit-processing area	**3**	
Feasibility of Implementation	**6**	

Figure 25: Employee 3 Current Layout Evaluation

Employee 1

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**7**	Not open space
Communication between employees	**10**	Very close - good
Walking Space	**8**	Avoid back corridor
Flow	**6**	Shear away from materials and kitting materials far from each other
Entrances	**9**	Good as is
Shear Location	**7**	Shear not close to all material
Kit-processing area	**6**	WIP scattered
Feasibility of Implementation	**9**	Easy to do but not best flow

Figure 26: Employee 1 Alternative 1 Layout Evaluation

Employee 2

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**4**	Material too far apart
Communication between employees	**4**	Would be too difficult being together
Walking Space	**4**	Nice but not functional
Flow	**3**	Would be crossing paths picking up material
Entrances	**3**	Same
Shear Location	**3**	Too far from material
Kit-processing area	**3**	Too far from material
Feasibility of Implementation	**2**	Negative

Figure 27: Employee 2 Alternative 1 Layout Evaluation

Employee 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**10**	
Communication between employees	**10**	
Walking Space	**10**	
Flow	**10**	
Entrances	**10**	
Shear Location	**10**	
Kit-processing area	**0**	None in layout
Feasibility of Implementation	**3**	

Figure 28: Employee 3 Alternative 1 Layout Evaluation

Employee 1

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**4**	Not clearly visibly space
Communication between employees	**7**	Better than now
Walking Space	**7**	Seems ok
Flow	**0**	
Entrances	**0**	Must have 2 doors
Shear Location	**3**	Far from bins
Kit-processing area	**3**	WIP/kitting not close together
Feasibility of Implementation	**9**	Easy to do it but not best flow

Figure 29: Employee 1 Alternative 2 Layout Evaluation

Employee 2

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**8**	I like the double doors open
Communication between employees	**9**	We can see each other, and I think communicate better
Walking Space	**9**	Nice Open flow
Flow	**8**	Need a couple of carts for transportation of raw and finished material
Entrances	**7**	Need both doors, but I like double doors open
Shear Location	**8**	Where is should be, next to the operator
Kit-processing area	**8**	nice
Feasibility of Implementation	**9**	This is what I envision the stockroom will look like

Figure 30: Employee 2 Alternative 2 Layout Evaluation

Employee 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**3**	
Communication between employees	**6**	
Walking Space	**10**	
Flow	**7**	
Entrances	**0**	Block entrance
Shear Location	**5**	
Kit-processing area	**10**	
Feasibility of Implementation	**5**	

Figure 31: Employee 3 Alternative 2 Layout Evaluation

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	**7**	Some areas not visible
Communication between employees	**7**	Spread too far
Walking Space	**7**	Back area corridor
Flow	**3**	MPD & CPD all scattered
Entrances	**9**	2 doors good
Shear Location	**7**	Material far from shear
Kit-processing area	**6**	Some WIP far from each other
Feasibility of Implementation	**9**	It can be moved but not best flow

Figure 32: Employee 1 Alternative 3 Layout Evaluation

Employee 2

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	4	
Communication between employees	4	
Walking Space	3	
Flow	4	
Entrances	3	
Shear Location	3	
Kit-processing area	2	
Feasibility of Implementation	2	Too close to current layout

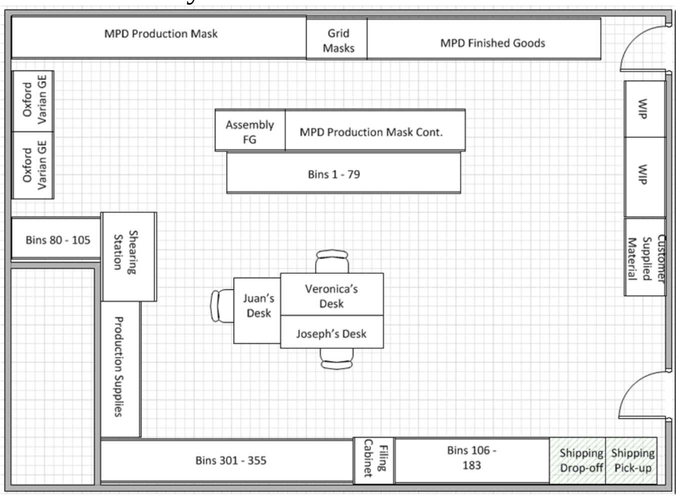
Figure 33: Employee 2 Alternative 3 Layout Evaluation

Employee 3

Metric	Score (0 = Low, 10 =High)	Reasoning
Visibility	5	Mask too far
Communication between employees	3	Too far away from each other, Veronica and Joseph should be closer
Walking Space	10	
Flow	3	
Entrances	10	Same
Shear Location	3	Too far from material
Kit-processing area	0	Not on layout
Feasibility of Implementation	3	Do not like layout

Figure 34: Employee 3 Alternative 3 Layout Evaluation

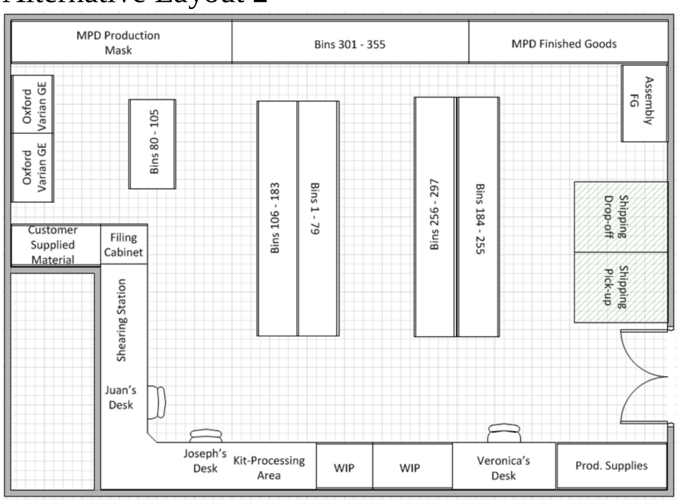
Alternative Layout 1



Alternative Layout 1			
From	To	Distance (ft.)	In
Juan's Desk	Shear	6	6
Juan's Desk	MPD Grids	28	10
Juan's Desk	Varian GE	20	9
Juan's Desk	Veronica's Desk	6	6
Juan's Desk	Joseph's Desk	6	6
Juan's Desk	WIP	24	1
	AVG	15	5
Joseph's Desk	Shear	11	6
Joseph's Desk	MPD Grids	33	10
Joseph's Desk	Varian GE	29	11
Joseph's Desk	Veronica's Desk	6	6
Joseph's Desk	Juans's Desk	6	6
Joseph's Desk	WIP	22	0
	AVG	18	6
Total AVG Distance		16	5

Figure 35: Alternative Layout 1 Travel Distances

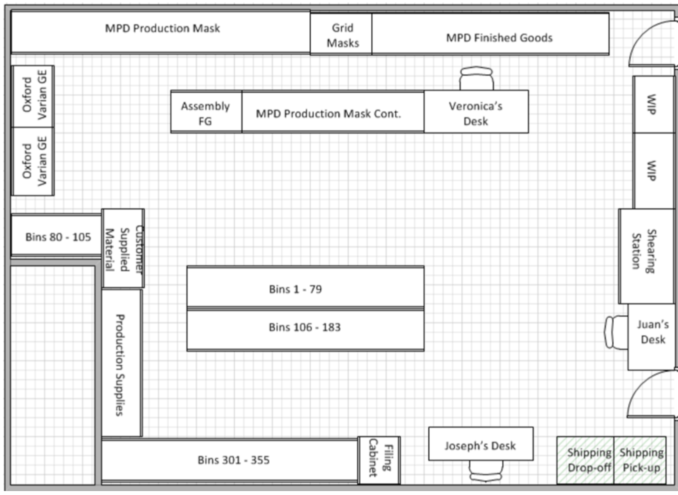
Alternative Layout 2



Alternative Layout 2			
From	To	Distance (ft.)	In
Juan's Desk	Shear	4	9
Juan's Desk	MPD Grids	24	9
Juan's Desk	Varian GE	18	4
Juan's Desk	Veronica's Desk	19	2
Juan's Desk	Joseph's Desk	5	8
Juan's Desk	WIP	9	7
	AVG	13	5
Joseph's Desk	Shear	8	1
Joseph's Desk	MPD Grids	27	4
Joseph's Desk	Varian GE	21	6
Joseph's Desk	Veronica's Desk	14	10
Joseph's Desk	Juans's Desk	5	8
Joseph's Desk	WIP	7	6
	AVG	14	6
Total AVG Distance		13	5

Figure 36: Alternative Layout 2 Travel Distances

Alternative Layout 3



Alternative Layout 3			
From	To	Distance (ft.)	In
Juan's Desk	Shear	6	0
Juan's Desk	MPD Grids	32	2
Juan's Desk	Varian GE	25	2
Juan's Desk	Veronica's Desk	21	3
Juan's Desk	Joseph's Desk	10	0
Juan's Desk	WIP	10	3
	AVG	17	2
Joseph's Desk	Shear	12	3
Joseph's Desk	MPD Grids	40	8
Joseph's Desk	Varian GE	34	1
Joseph's Desk	Veronica's Desk	25	6
Joseph's Desk	Juans's Desk	10	0
Joseph's Desk	WIP	21	2
	AVG	24	3
Total AVG Distance		21	2

Figure 37: Alternative Layout 1 Travel Distances

	Average Travel Distance	Average Evaluation Score
Current Layout	28 ft. 4 in.	56
Alternative Layout 1	16 ft. 5 in.	68.33
Alternative Layout 2	13 ft. 5 in.	66
Alternative Layout 3	21 ft. 2 in.	61

Table 6: Summarized Data

Cost of Implementation	
Standard Stockroom Employee Rate Per Hour	$ 23.00
Number of Employees	3
Implementation Time (Hours)	60
Total Cost	**$4,140.00**

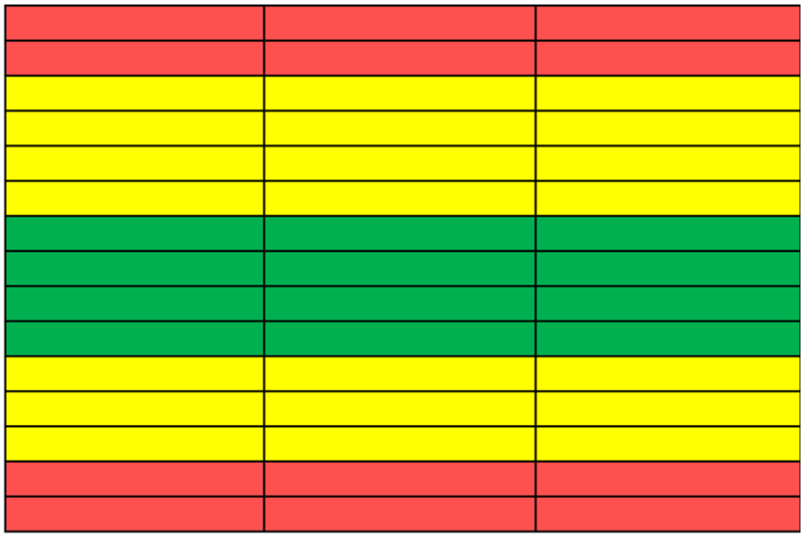
Table 7: Estimated Cost of Implementation

Location - Silicon Valley	
Average Cost to Rent Per Square Foot (2017)	$4.57
Elcon Stockroom Square Footage	875
Yearly Cost (Opportunity Cost)	**$47,985.00**

Table 8: Estimated Yearly Cost of Rent (Opportunity Cost)

Space Reduction	15%	20%	25%	30%
Monthly Savings	$599.81	$799.75	$999.69	$1,199.63
Yearly Savings	$7,197.75	$9,597.00	$11,996.25	$14,395.50

Table 9: Yearly Savings for Space Reduction



Last Date Accessed	Percent of Total Inventory
2016	15.22%
2017	48.55%
2018	36.23%

Figure 38: Ergonomic Material Organization