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Kaizen for Footprint Reduction and Process Flow Improvement at Great Plains Industries

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Abstract: Continuous improvement has always been a vital practice in most companies since it was introduced by Masaaki Imai as Kaizen. It is known to bring many benefits to management and manufacturing processes. In this paper, it will be demonstrated how Kaizen was implemented at Great Plains Industries, with the primary goals of reducing workstation footprint and improve overall process flow. Achieving these goals will consequently help the company with profit generation per square foot. Moreover, as Great Plains Industries introduce new products to the market, this Kaizen event will help create space within the existing floorplan, instead of having to purchase a new facility. Several Industrial Engineering tools were utilized to analyze the problem, perform root cause analysis, as well as develop solutions. At the end of the paper, an improved cellular layout of a reduced footprint, which will increase overall process efficiency and eliminate Lean wastes, will be introduced. Plan for implementation and long-term impacts will also be discussed further in the paper.

Keywords: Continuous Improvement, Kaizen, Footprint Reduction, Process Flow, Lean Wastes.

1. Introduction

Great Plains Industries, or GPI, was established in 1972 and is located in Wichita, Kansas. GPI manufactures agricultural fuel transfer pumps and meter systems that are easy to install, operate and maintain. The company is looking to consolidate its current assembly lines of four hand pump models: HP-90, HP-100, RP-10 and DP-20. Each model is produced on a separate assembly line, and only one line is run at a time. The frequency of use of each workstation depends on weekly demand. The workstations are set up in a traditional assembly line, and the material handling creates an unnecessary amount of wasted space. Additionally, inventory storage and equipment placement are not optimal and could be improved. The team first obtained data and then applied methods such as the Ishikawa Fish Bone diagram and data analytics techniques to investigate the root cause of the concerns. Online tools, such as Visio, were used to demonstrate a tangible workshop rearrangement. Time studies have also been done and will be used to analyze the difference between the pre and post implementation. After developing the various solution approaches, the team presented them to GPI staff and project sponsors for feedback and approval. As the course concludes, the team will be leaving GPI with several solution approaches to optimize their floor layout while still maintaining the production rate.

2. Problem Definition

At Great Plains Industries, the revenue per square foot of utilized floor space is comparatively low for the HP-90, HP-100, RP-10 and DP-20 hand pumps. The four workshops use a total of 2,142 square feet on the shop floor, but only an average of 500 square feet is generating profit during each shift. For the overall GPI assembly operation, space has become a significant constraint. Each separate assembly line takes up about one fourth of the total area, but only operates a fraction of the time. If two, three, or all of the assembly lines can be combined, valuable floor space can be gained. However, since the tools required to assemble each pump are completely different, the team had a discussion with the sponsors to redesign the assigned floor layout instead of combining all four workshops together. This changed the original objective yet maintained the goal of producing larger profit margin per square foot and maximizing the available space for new products.

Other important factors that could not be compromised were keeping model-to-model changeover time at a minimum, cycle time the same, and labor cost the same. Another important factor was the flow and presentation of component parts, as well as completed hand pump units. Ergonomic concerns were considered and further addressed to assist workers physically during work hours.

3. Methodology

As the team dove deeper into the scope of the project, many methods and approaches from previous and ongoing Industrial Engineering courses were used, such as System Simulations, Industrial Ergonomics, Production Systems, Work Systems, Lean Manufacturing and Facilities Planning.

Data collection was a significant source of information in the progression of the project. The team was able to calibrate numerical values from the worktables and equipment that would later aid in the cultivation of time studies and measurements charts. Along with the data, Industrial Engineering tools such as the fishbone diagram and CTQ (Critical-to-Quality) chart were applied in the initial stage to identify the root causes. There were six distinct categories in the fishbone diagram: Machine, Method, Material, Man, Environment, and Measurements. Three observations were listed under each category as a hindrance that needed to be changed. The team discovered that the root cause of GPI's concern is ultimately the work cell configuration and old tooling. Other causes that were identified such as variating materials and tools for each hand pump model, did not impact the problem on the large scale, so the team decided to tackle the main root causes. In order to create an attainable goal, with reference to SMART (Specific, Measurable, Achievable, Relevant and Time-Bound) goals, the team decided to narrow the scope down to improving the layout within the given 4 months of the project.

The team created a Critical to Quality chart to clarify the company's needs. The big milestone was broken down into subsets and from there, branching out with specific tasks and measurable methods to make the process more manageable. A Work Breakdown Schedule, or WBS, that detailed a chronological procedure of the project was also constructed. As recommended by the instructor, the team also used a Responsibility Assignment Matrix (RAM), also referred to as a RACI matrix, to delegate responsibilities and accountability accordingly to the role of each member. To ensure that the team stayed within the boundaries of the project, an In-Scope and Out-of-Scope chart was established. This method acted as a reminder to keep the team members focus on tasks that steered toward the end goal and not divert effort and time to other unnecessary resources.

Even though official reports on ergonomic issues were not filed, the team members were given a chance to learn about physical discomfort while working on the assembly line. One operator noted that the employees who were on the taller or shorter side of an average stature may suffer slight discomfort that could cause injury in the long term. This observation led the team to scrutinize the dimensions of worktables and product placements to alleviate these work-related risks. For the visual layout design, the team resorted to Visio, a simple and user-friendly Computer-Aided Design (CAD) software, instead of Simio. The team then revised the given layout using three main Lean-based approaches: U-shaped cells, outward-facing inventory replenishment, and relocation of tape machines.

4. Data

Data was divided into two categories: quantitative, which included charts, tables, numerical and statistical measurements; and qualitive, which was expressed through observations and interpretations. During the stages of data collection, all safety protocols were strictly adhered to ensure the well-being of participants involved.

The team decided to conduct a time study for the workstations prior to implementation of the solution and will be conducting another time study after implementation has taken place to compare the difference in efficiency. With the approval of the company, the team was able to record videos and take photos of the assembly line to better understand the order of task sequences. Measurements for the time studies were administered in a way that would be easy to replicate and validate with the redesign. To further elaborate, numbers of equipment for each workstation and which steps the specific equipment being used for were also documented, besides the time it took to complete each task.

A notable mishap occurred during the first data-gathering sessions, considering one of the operators for the DP-20 assembly line was new and still in the process of learning the assembly procedures. Those measurements were recorded as outliers for the purpose of comparing the efficiency between a standard worker and an inexperienced worker, but not calculated into the official tables. The time study data also provided a good analysis on the current state. As shown in Figure 1, it can be observed that the cycle time to produce DP-20 and RP-10 is larger than the expected takt time. The takt time in this case is calculated based on the demand of 13 pumps an hour, where $\frac{60 \text{ minutes}}{13 \text{ pumps}} = 4.62 \text{ minutes}$, which is denoted as the orange line in the chart. By using the takt time as a baseline, the current performance can be easily analyzed and compared to after the new layout is implemented. Therefore, another goal of the new layout is to bring the numbers down so that customer's demand can be met, while optimizing floorspace within the facility. Interviews with the operators, shop floor supervisor and the on-site Lean Team were also logged for a more detailed inside view. From the staff, the team gathered that there were certain specific guidelines regarding workspace clearance that need to be followed, such as three feet for operators to walk within a workstation, eight feet for both wave and operators to access inventory and materials, and at least one safety exit.

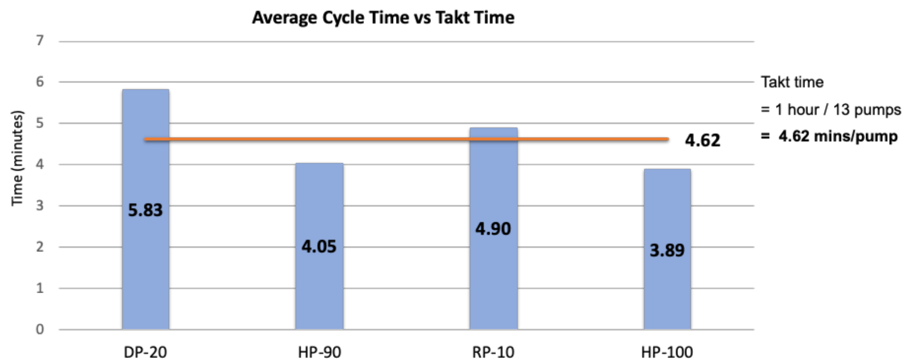

Figure 1. Time Study Analysis

5. Solution Approach

After extensive data collection and root cause analysis, the scope was narrowed down to focus on the root cause of each problem identified. This helped the team identify the key areas of the layout to tackle during the Kaizen event. The approach the team took did not only focus on reducing wasted space but took potential ergonomic risk into account. With the current state documentation shown in Figure 2 that was provided by GPI, the team was able to understand the process flow for each hand pump and identify potential improvements. Therefore, the team members revisited a few key concepts and attempted to incorporate them into process improvement at GPI.

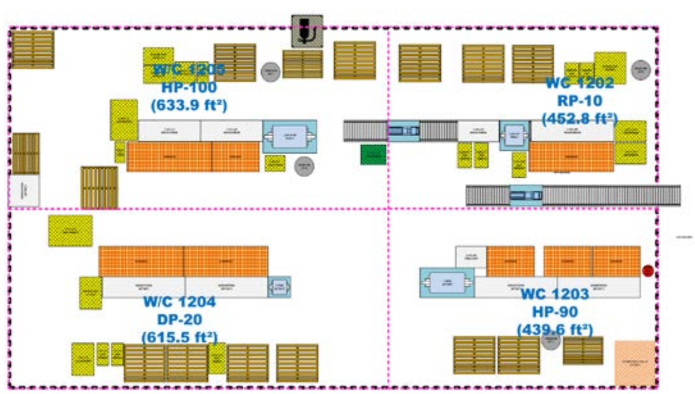

Figure 2. Current state of hand pump workstations at GPI

The team developed three different alternatives for the overall layout and an additional three alternatives for assistive devices within the work cells. The layout was specifically modeled on Visio to ensure feasibility and better illustrate the proposed layout. The two targeted waste identified from the Eight Wastes of Lean were transportation and motion. Each of the solution approaches took on the key areas that were identified during the root cause analysis. Therefore, the proposed solution is feasible after considering different approaches. The integrated proposal will reduce the footprint of the workstation area and

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improve overall process efficiency. Also, since professional and experienced stakeholders have reviewed the solution, the solution is concluded as being more than feasible.

6. Solution Concept

The first proposed solution was to have materials replenished from the outside of the work cells. In the current layout at GPI, there is approximately 15x8 feet of wasted space within the work area. This is to accommodate for water striders on work assist vehicles (WAV) to enter the replenishment area. A water strider (also known as a water spider or "mizushumashi" in Lean terms) is a person who carries out the replenishment of materials that the primary operator needs on the assembly line. This allows the operator to stay focused on the job and not worry about acquiring materials themselves.

The second solution approach is to implement the well-known Lean concept of U-shaped cells. This approach is known as "shojinka", meaning to optimize the work center layout that can support a variating number of operators performing tasks in the layout. One of the known advantages of U-shaped cells is the flexibility for line balancing. Despite the fluctuating demand of hand pumps at GPI, line balancing is implemented, and with this suggestive configuration, operators can move from one station to the other with minimal effort at a shorter distance. It was understood that the work contents within a U-shaped cell is supposed to flow from left to right, while the suggested layout has two of the assembly lines flowing right to left.

The third solution approach is to change the location of hose assembly cell to feed all four workstations at minimal distance and time. With the hose assembly workstation being located in the middle, operators will not need to travel long distance to replenish hoses within the work cells. This will greatly reduce the waste of motion and transportation, which were previously mentioned as part of the Eight Wastes of Lean.

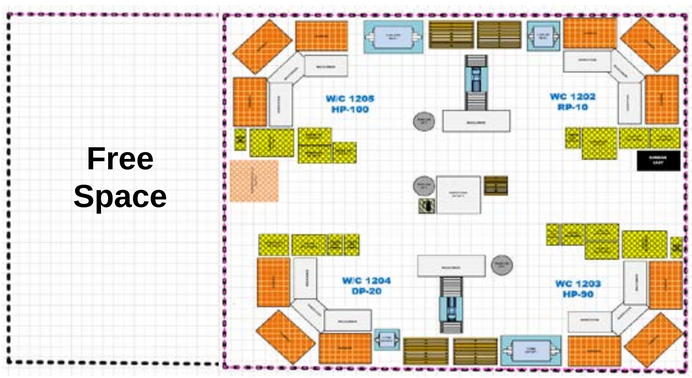

Figure 3. Integration of all three alternatives in overall proposed layout.

According to the simulated layout, there is a potential reduction of fifteen feet in length and 32.5 feet in width of space, which is a substantial contribution to the shop floor. That totals up to approximately 400 square feet in footprint reduction. This equates to about a savings of $9000 per year in rent per square foot and electricity usage. Besides that, this extra space also allows GPI to bring in new product assembly to the shopfloor for a more significant profit generation.

Apart from that, the team discovered that the other workstations on the shop floor utilize customized Lean tables as shown in Figure 4. This would help reduce footprint, motion and travelling distance for operators when assembling the hand pumps. It has also been proven around the shop floor that these customizable lean tables can alleviate many ergonomic risks. The flexibility of customizing the worktable makes it easier to accommodate for different processes and work contents.

Moreover, the current placement of packaging cardboard boxes takes up a significant amount of space in the work cells. With the unfolded cardboards placed flat on the ground, approximately twelve square feet are reserved for the boxes within each hand pump assembly line. That adds up to a total of forty-eight square feet solely for storing packaging boxes on the floor. Therefore, the team developed a suggestion that has been implemented within GPI – Lean pipe cardboard racks. Cardboard can then be stored vertically on the racks, which will take up a substantially smaller amount of space in the workstation. Operators will also not need to reach to the ground when cardboards are being used up, which mitigates ergonomic risks.

The final suggestion was to utilize mobile racks to store hoses. Currently, GPI stores the hoses in boxes which can be hard to reach the bottom for operators. The hoses also take up a lot of space within the workstation when placed flat on the ground. With the hose racks, operators could easily reach for the hose and pull it downwards to take it off the rack for packaging purposes. These racks also have caster wheels installed so operators can move them around as needed to cater to the assembly line and overall demand.

While the team makes major changes to the overall layout, safety aspects are not neglected. The team consulted the Safety Manager at GPI and gathered additional information to ensure workers' safety within the workplace. It is required to have at least one safety exit, but the proposed solution has multiple. Apart from that, there should be three feet of clearance for operators to walk around and transport materials. The team incorporated all these safety requirements into the new layout. The proposed solution also took into account of placing the fire extinguisher by the hose assembly station, which is located in the center point of all four hand pump stations. This allows easy access to the extinguisher in case of a fire emergency.

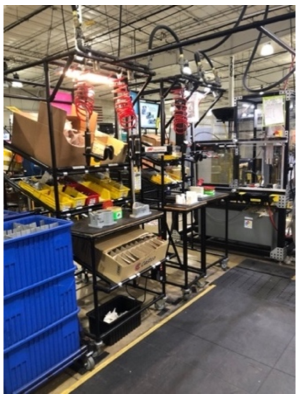

Figure 4. Customized lean tables

Figure 5. Cardboard carts

Figure 6. Hose rack

7. Results

The team presented the proposed layout halfway through the semester to the company sponsors and other stakeholders of the company, including the Value Stream Leaders, Lean Team, Production Manager, and Process Engineers. This allowed ample time to gather feedback and make changes to the solution. The company made sure to include every stakeholder in the progress report meeting so that there was communication and shared information across every level of the organization. This practice is reflected as a Lean concept known as "Yokoten".

In regard to the suggestion about using racks to store hoses, one individual from GPI pointed out that it may cause more inconvenience than good. This is due to the fluctuating demand of each hand pump as well as the different configuration and types of hoses needed. There may be more wasted space with all the hose racks laying around in the work cell that is not being used by the operators. The team agreed with the feedback and decided to recall the suggestion. The current hose system worked well for the company, and the team did not want to affect the current state negatively.

The stakeholders were in favor of the proposed layout, but several concerns were mentioned. Since this is a significant Kaizen event that will entirely transform the workstations, a cost of implementation was required. This figure will help the management decide if the layout will generate profit and whether it will serve as a reliable long-term solution. The cost of implementation encompasses labor cost, changeover cost, material cost for new Lean tables, and possible downtime cost. One of the stakeholders also pointed out that the scaling of the Visio layout was not correlated to the actual dimensions. These concerns turned into a delay of implementation, as the team was fairly new to this part of the process.

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Table 6. Cost breakdown of proposed Kaizen event

Item	Unit Cost	Min. Quantity	Min. Cost	Max. Quantity	Max. Cost
Casters Set	$ 70.00	11	$ 770.00	12	$ 840.00
Power Supply	$ 50.00	11	$ 550.00	11	$ 550.00
Kanban Shelf System	$ 10.00	11	$ 110.00	11	$ 110.00
Additional Kanban Shelf	$ 50.00	11	$ 550.00	12	$ 600.00
Cardboard Carts	$ 100.00	4	$ 400.00	6	$ 600.00
Monitor & Mounting Hardware	$ 250.00	7	$ 1,750.00	11	$ 2,750.00
Lighting	$ 50.00	11	$ 550.00	12	$ 600.00
Wood/Plastic Surface	$ 50.00	11	$ 550.00	12	$ 600.00
Pipes	$ 35.00	12	$ 420.00	14	$ 490.00
Labor	$ 20.00	48	$ 2,240.00	48	$ 2,560.00
TOTAL ESTIMATE			**$ 7,890.00**		**$ 9,700.00**

The team then had to gather more measurements of the equipment, work area, and Kanban bins and suggest optimal dimensions for the new worktable. The team also worked very closely with the Lean Team on obtaining a scaled model of the layout and generating the cost of implementation. After consulting the Lean team at GPI, a cost of implementation is generated. This gives a promising idea of how much GPI would need to spend if the Kaizen event is deemed worthy and beneficial to the company. Most of the items are ultimately for the build of worktables but labor for both the build and implementation are considered as well. The team provided a minimum and maximum value of cost to the company sponsors. The minimum cost was the least amount of budget that GPI would need to allocate to this project if they do decide to proceed with the Kaizen event proposed. The maximum cost takes into account of any unforeseen issues, such as a delay in material, additional material, labor and equipment or any unpredictable problems. With this, the team proposed a cost in the range of $7,890 to $9,700 to Great Plains Industries for the entire Kaizen Event. The cost breakdown is shown in Table 6. That being said, the team is estimating a yearly savings of $9,000 when this solution is implemented.

8. Feasibility

The problem solution proposed by the team was reviewed by all stakeholders of the company and has gone through a few changes according to the feedback received. The team took into consideration all problems that were brought up when the project was assigned – maintaining or improving cycle time, changeover time and overall process flow. But with the additional knowledge that the team members have, ergonomic aspects were also taken into account when developing the solutions. The manufacturability of the project was highly based on GPI's lean team and their capabilities. After discussing the possibilities and reviewing other structures at GPI, the team decided to build all tables and replenishment carts in-house. Many of the structures at GPI are built in house using lean pipe and plywood, so the team decided that would be appropriate for the hand pump project as well. Table sizes were determined by measuring the equipment needed for each assembly line and dividing the equipment into either two or three worktables, depending on the line. Scaled Visio models of the worktables and carts were then produced for GPI's reference. After taking into account of the other required items that need to be built with the worktable, the overall look of worktable for the hand pump stations was created.

9. Conclusion

The team believes the hand pump consolidation project was a success. After identifying the problem and brainstorming solutions, the team came to a conclusion that met the needs of GPI and incorporated the ideas of each team member into the proposed layout. Kaizen events are known to take place for around two to six months, with daily efforts toward continuous improvement. Due to time constraints, the team decided not to rush the solution implementation and provided as much information as GPI needed to continue the solution implementation. This included the dimensions of the worktables, cost of implementation, and a detailed Visio model of the proposed layout as well as the Kanban bin placements. Since one of the team members will be working at GPI after the semester ends, she will take over the implementation and the rest of the Kaizen event.

Utilizing methods from previous and current Industrial Engineering courses, the team was able to develop an improved layout that will save a significant amount of space along with increasing overall process efficiency. The team was able meet the voice of customer and then exceed customers' expectations - not only did the team solve the problem by introducing an improved layout, several other problems such as the material flow, ergonomics and waste of motion were all tackled and mitigated, even though it was not part of the initial scope.

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