

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

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Abstract: Introduced by Masaaki Imai as Kaizen, continuous improvement has always been a vital practice in most companies. It is known to bring many benefits to management and manufacturing processes. This paper demonstrates how Kaizen was implemented at Great Plains Industries, with the primary goals of reducing workstation footprint and improving overall process flow. Achieving these goals will consequently help the company with profit generation per square foot. Moreover, as Great Plains Industries introduces 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 (IE) 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 reduced footprint, which would increase overall process efficiency and eliminate Lean wastes, will be introduced. Plan for implementation and long-term impacts will also be discussed 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 was looking to consolidate its current assembly lines of four hand pump models: HP-90, HP-100, RP-10, and DP-20. Each model was produced on a separate assembly line, and only one line was run at a time. The frequency of use of each workstation depended on weekly demand. The workstations were set up in a traditional assembly line, and the material handling created an unnecessary amount of wasted space. From initial observation, inventory storage and equipment placement were not optimal and could be improved (Whalen, 2002). 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 were also performed and would 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 concluded, the team would deliver to GPI 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 was comparatively low for the HP-90, HP-100, RP-10 and DP-20 hand pumps. The four workshops used a total of 2,142 square feet on the shop floor, but only an average of 500 square feet was generating profit during each shift. For the overall GPI assembly operation, space had become a significant constraint. Each separate assembly line consumed approximately one fourth of the total area, but only operated a fraction of the time. If two, three, or all of the assembly lines were to be combined, sizeable floor space could be gained. However, since the tools required to assemble each pump were 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 a larger profit margin per square foot and maximizing the available space for new products.

One important factor that could not be compromised was to keep model-to-model changeover time at a minimum, cycle time the same, and labor cost the same. Another significant factor to be kept constant 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 IE courses, such as System Simulations, Industrial Ergonomics, Production Systems, Work Systems, Lean Manufacturing and Facilities Planning, were used.

3.1 Data Collection

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, IE 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 hindrances that needed to be fixed. 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 varying 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.

3.2 Roles and Responsibilities

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 four 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 Structure, or WBS, that detailed a chronological procedure of the project was also constructed. As recommended by the instructor, the team subsequently 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 without diverting effort and time to other unnecessary resources.

3.3 Ergonomics Considerations

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 (Pattanaik, 2009): U-shaped cells, outward-facing inventory replenishment (Gnanavel, 2015), and relocation of tape machines.

4. Data

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

4.1 Techniques

The team decided to conduct a time study for the workstations prior to implementation of the solution and would be conducting another time study after implementation had 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.

4.2 Outliers

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.

4.3 Analysis

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 was larger than the expected takt time. The takt time in this case was quantified based on the demand of 13 pumps an hour, where $\frac{60 \text{ minutes}}{13 \text{ pumps}} = 4.62$ minutes, which was 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 was 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 needed to be followed, such as a three-foot distance for operators to walk within a workstation, an eight-foot distance for both transportation and operators to access inventory and materials, and at least one safety exit.

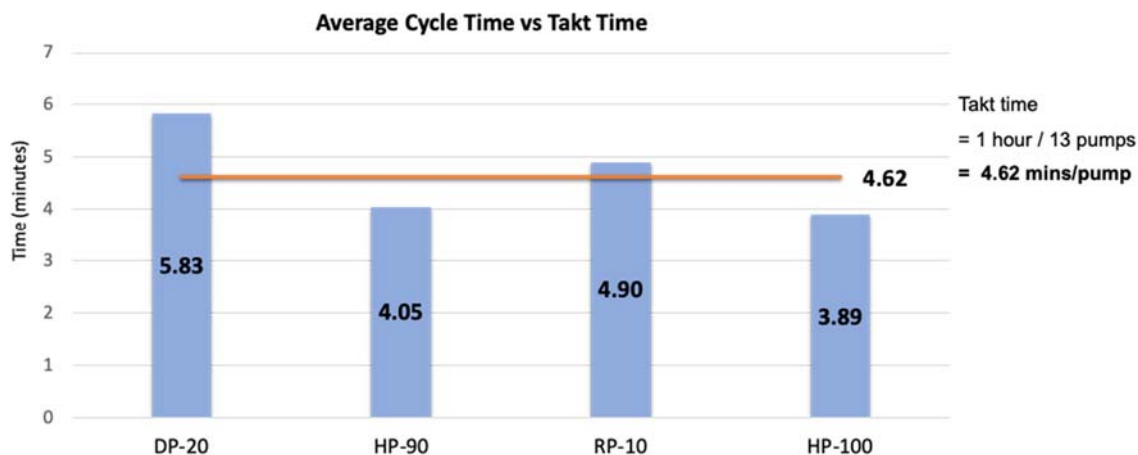


Figure 1. Time Study Analysis

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 also took potential ergonomic risks 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. From here, the team members revisited a few key concepts and attempted to incorporate them into the process improvement at GPI.

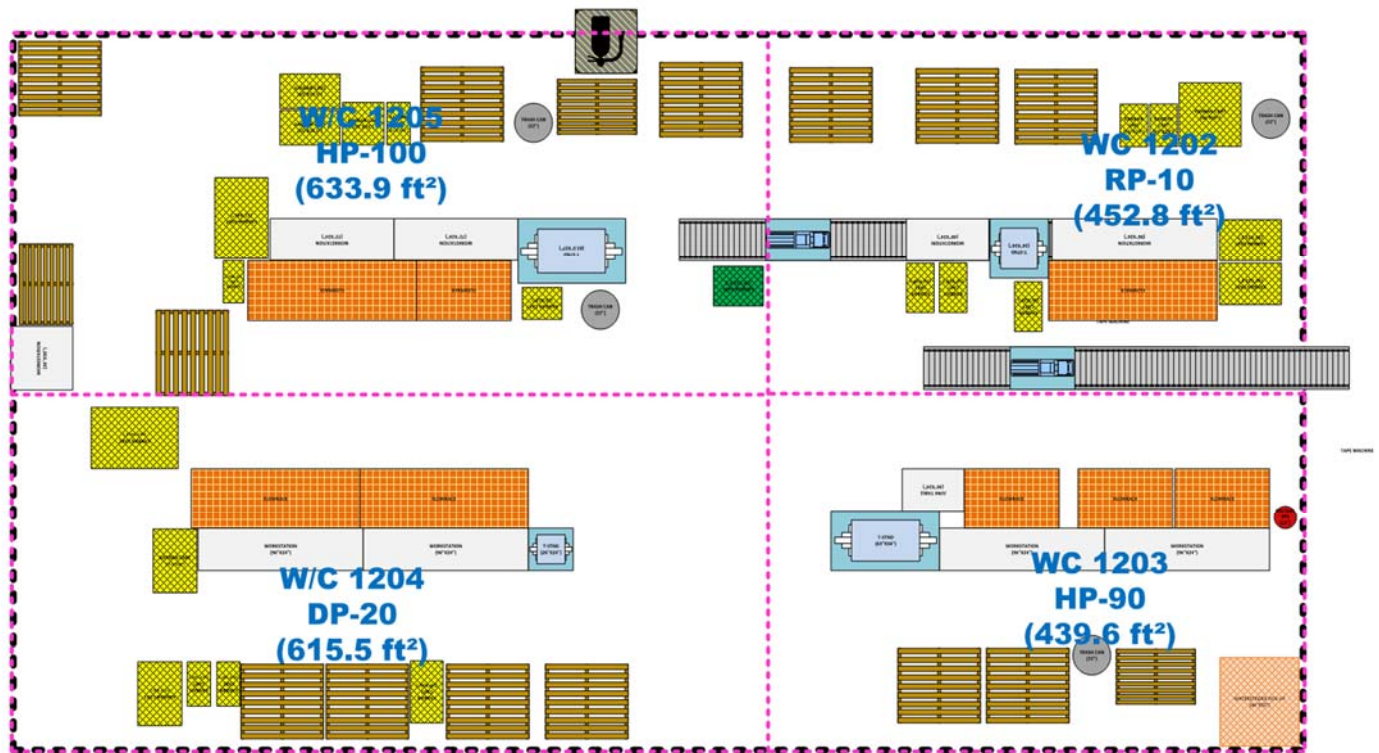


Figure 2. Current state of hand pump workstations at GPI

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 embraced key areas that were identified during the root cause analysis. Therefore, the proposed solution was feasible after considering different approaches. The integrated proposal would reduce the footprint of the workstation area and improve overall process efficiency. Also, since professional and experienced stakeholders had reviewed the solution, the solutions were 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 was 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 was 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 varying 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 was 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 was supposed to flow from left to right, while the suggested layout had two of the assembly lines flowing right to left (Rekiek, 2002).

The third solution approach was to change the location of hose assembly cell to feed all four workstations at minimal distance and time. With the hose assembly workstation located in the middle, operators would not need to travel long distance to replenish hoses within the work cells. This would 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 was a potential reduction of 15 feet in length and 32.5 feet in width of space, which was a substantial contribution to the shop floor. That totaled up to approximately 400 square feet in footprint reduction. This equated to about a savings of \$9,000 per year in rent per square foot and electricity usage. Besides that, this extra space also allowed 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 result in less footprint, travelling distance, and motion for operators when assembling the hand pumps. It had also been proven around the shop floor that these customizable lean tables can alleviate many ergonomic risks. The flexibility of customizing the worktable made it easier to accommodate for different processes and work contents.

Moreover, the current placement of packaging cardboard boxes took up a significant amount of space in the work cells. With the unfolded cardboards placed flat on the ground, approximately twelve square feet were reserved for the boxes within each hand pump assembly line. That added up to a total of forty-eight square feet solely for storing packaging boxes on the floor. Therefore, the team developed a suggestion that was late implemented within GPI – Lean pipe cardboard racks. Cardboards could then be stored vertically on the racks, which would utilize a considerably smaller amount of space in the workstation. In addition, the operators would not need to reach to the ground when cardboards were being used up; hence, the ergonomic risks in this case were mitigated.

The final suggestion was to utilize mobile racks to store hoses. Currently, GPI stored the hoses in boxes which can be hard to reach the bottom for operators. The hoses also dominated 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 had caster wheels installed so operators can move them around as needed to cater to the assembly line and overall demand.

While the team contributed major changes to the overall layout, safety aspects were not neglected. The team consulted the Safety Manager at GPI and gathered additional information to ensure workers' safety within the workplace. The requirement was to have at least one safety exit, but the proposed solution contained 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 solutions also took into account of placing the fire extinguisher by the hose assembly station, which was located in the center point of all four hand pump stations. This allowed easy access to the extinguisher in case of a fire emergency.

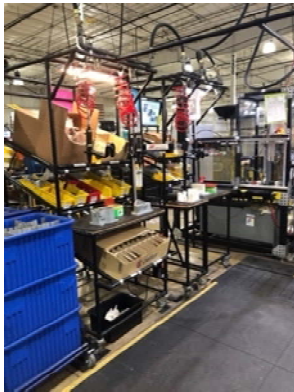


Figure 4. Customized lean tables



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 action granted ample time to gather feedback and revise the solutions. The company made sure to include every stakeholder in the progress report meeting so that there was sufficient communication and shared information across every level of the organization. This practice is reflected as a Lean concept known as “Yokoten”.

7.1 Constructive Feedback

In regard to the suggestion about using racks to store hoses, one employee from GPI pointed out that it may cause more inconvenience than good. This was 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 was 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 was a significant Kaizen event that would entirely transform the workstations, a cost analysis was required. The calculated figures would assist the management in deciding if the layout would generate profit and whether it would serve as a reliable long-term solution. The cost of implementation encompassed labor cost, changeover cost, material cost for new Lean tables, and possible downtime cost. One of the stakeholders also mentioned that the scaling of the Visio layout was not correlated to the actual dimensions. These concerns evoked a delay on the implementation, as the team was fairly new to this part of the process.

7.2 Revisions

Team members then calibrated more measurements of the equipment, work area, and Kanban bins (Apreutesei, 2010) and suggested 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 was generated. This gave a promising idea of how much GPI would need to spend if the Kaizen event was deemed worthy and beneficial to the company. The majority of costs listed were for the construction of worktables but labor cost for the implementation was 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 did decide to proceed with the Kaizen event proposed. The maximum cost included unforeseen issues, such as a delay in material, additional material, labor and equipment or any unpredictable problems. With this, the team proposed a cost ranging from \$7,890 to \$9,700 to Great Plains Industries for the entire Kaizen Event. The cost breakdown is shown in Table 7. That being said, the team estimated a yearly savings of \$9,000 when the solution proposals were implemented.

Table 7. 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

8. Feasibility

The proposed solutions were reviewed by all stakeholders of the company and went through a few revisions 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 supplemental knowledge of team members, ergonomic aspects were also deliberated 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 were built in house using lean pipe and plywood, so the team established 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 needed to be built with the worktable, the overall look of worktable for the hand pump stations was created.

9. Conclusion

The team presumed that 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 necessitated to continue the solution implementation. This encompassed the dimensions of the worktables, cost of implementation, and a detailed Visio model of the proposed layout as well as the Kanban bin placements.

Utilizing methods from previous and current Industrial Engineering courses, the team was able to develop an improved layout that would 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.

10. References

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