

A Kaizen Based Approach for Cellular Manufacturing System Design: A Case Study

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Organizations are currently encountering a necessity to respond to rapidly changing consumer needs, desires, and tastes. To compete in this continuously changing environment, these organizations must seek out new methods allowing them to remain competitive and flexible simultaneously, enabling their companies to respond rapidly to new demands. The contemporary industrial world is in a new era termed the "third industrial revolution" (Black, 1991). The effect of this new era is dramatic to most businesses because they have been forced into the global economy by emerging global competition. In order for companies to remain competitive, retain their market share in this global economy, and satisfy both external and internal customers, continuous improvement of manufacturing system processes has become necessary (Kokuo, 1992; Shingeo, 1988; Yaruhiro, 1993). The method used to design a flexible, unique, controllable, and efficient cellular manufacturing system has become a topic that modern industrial operations are eager to learn and implement. The Kaizen technique has been proven as an effective tool for process improvement (Yung, 1996), process reengineering (Lyu, 1996), and even for organizational designs (Berger, 1997). Kaizen now is further implemented in industries for designing cellular manufacturing system to reduce cost and working space.

As an example of the successful implementation of Kaizen, take the case of a U.S. wood window company in the state of Iowa. This company has been using Kaizen since 1991 to redesign their shop floor, replacing expensive, nonflexible automation with low cost, highly flexible cellular applications. This company uses Kaizen to respond rapidly to consumer needs and to resolve problems in their manufacturing processes. Kaizen is used extensively in Product, Process, and Production (PPP) development. The major strategy of this development is to design a new product while considering the functions of products, the production processes used, and efficient production practices on the shop floor. This approach is similar to concurrent engineering; however, the

distinction between concurrent engineering and Kaizen is that the latter calls for the creation of a team that includes cross-functional employees, such as engineers, shop managers, and operators, working together on targeted areas. With a set of goals and a series of brainstorming processes, this team is expected to obtain a solution for resolving the problem within a week's time. During this week, the team concentrates on nothing but the project at-hand. This wood window company has successfully undertaken hundreds of projects over the past eight years. Achieving success in this way, the company has become a model for many local industries.

The Kaizen process is successful because it employs the lean thinking approach of designing a flexible, controllable, efficient, and unique manufacturing process (Womack & Jones, 1996). This article describes an example of Kaizen's success in a pull cellular manufacturing system and addresses this success in terms of cost, space, and improved worker satisfaction.

What Is Kaizen?

Kaizen is a Japanese word that has become common in many Western companies; the word indicates a process of continuous, incremental improvement of the "standard" way of work. This kind of creative improvement is something that every employee is capable of contributing to. The front-line employee is, in fact, most familiar with the actual work; there may be no one person to ask for improvement ideas.

Kaizen thrives by being adopted into the organizational culture. Successful implementation results in a cooperative atmosphere where everyone is aware of the key goals and measures of success. In this type of environment, implementation of new concepts is readily achieved with a high degree of success. Kaizen can be applied to any area in need of improvement. Kaizen is more than just a means of improvement because it represents the daily struggles occurring in the workplace and the manner in which those struggles are overcome (Kaizen Teian 1, 1992; Kaizen Teian 2, 1992). The flexibility inherent in this

approach makes it applicable to myriad corporate situations with only a few basic requirements necessary before full implementation can be realized.

The Kaizen approach requires that all employees participate; therefore, everyone in the company is encouraged to play a role in Kaizen activities. Kaizen has three major components:

1. **Perceptiveness:** All Kaizen projects are based on identified problems. If no problem has been identified, there is no use for Kaizen.
2. **Idea development:** This stage requires more than one person to provide better innovative ideas; therefore, forming a Kaizen focus team for the identified problem is very important. In this team-assembly process, one key is putting employees who work in the problem area together in order to interact in this innovative team.
3. **Decision, implementation, and effect:** Kaizen is only valuable if and when it is implemented. In the decision-making process, the team identifies what appears

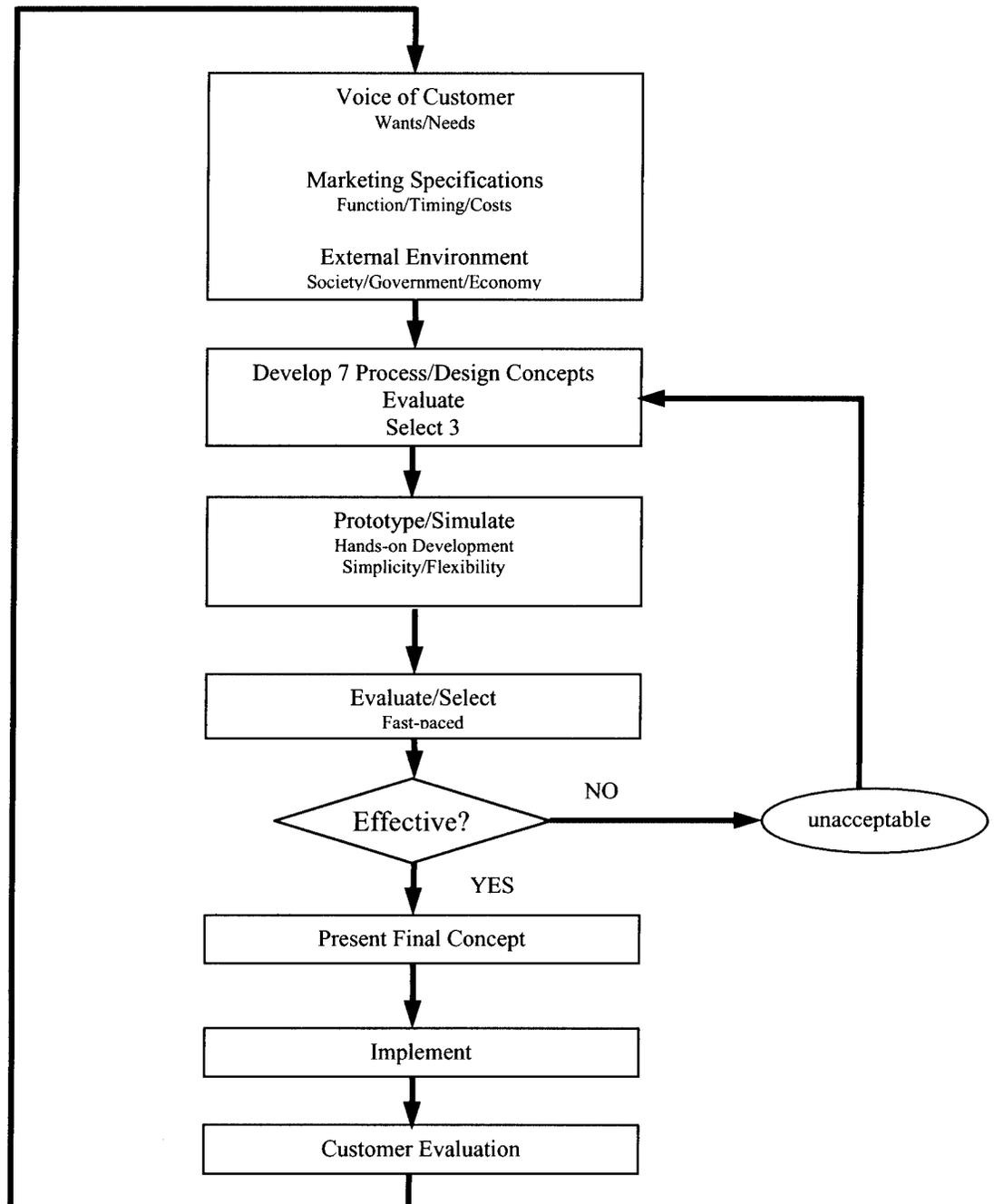


Figure 1. The Kaizen Process Overview.

to be the best solution to the problem being dealt with, and then begins the implementation process. Following implementation, the team is also responsible for evaluating the effect of the Kaizen process once it has been implemented in the shop flow of a factory.

Transferring these three stages into a systematic approach, Figure 1 shows the flow chart of the Kaizen process employed in this case study. The following section of this article introduces, step-by-step, how a Kaizen approach has been used to implement a pull cell design. The steps of this approach are summarized as follows:

1. Identify a problem.
2. Form a team.
3. Gather information from internal and external customers, and determine goals for the project.
4. Review the current situation or process.
5. Brainstorm and consider seven possible alternatives.
6. Decide the three best alternatives of the seven.
7. Simulate and evaluate these alternatives before implementation.
8. Present the idea and suggestions to managers.
9. Physically implement the Kaizen results and take account of the effects.

The following case study demonstrates the Kaizen practice.

Case Study

The focus of this project is the virtual manufacture of meat tenderizers. The full design of a meat tenderizer is shown in Figure 2. The problem identified in this virtual situation is that the product is currently too expensive to produce. After the cellular manufacturing system was introduced, a Kaizen team was formed to design a cellular manufacturing system to reduce production costs and improve the quality of every product. In order to address this system design problem, a design engineer, a manufacturing engineer, a quality engineer, and two machining operators were invited to be team members in this Kaizen project. [JCD1]

After identifying the problem, forming the team, and discussing the problem with all the employees in that production area, the team met to discuss the goal of this project. A brainstorming process was used to explore the team's goals. For this particular project, there were three goals: (a) reduce 25% of the unit cost, (b) design a cellular manufacturing system, and (c) reduce floor space by 15%. With setting these goals, the team could begin to review the current process of the product.

Review of Current Situation/Process

Meat tenderizer production consists of machining four basic components followed by a final assembly process (Figure 2). The facility is organized as a job shop with a separate assembly line. Flow of material follows a push

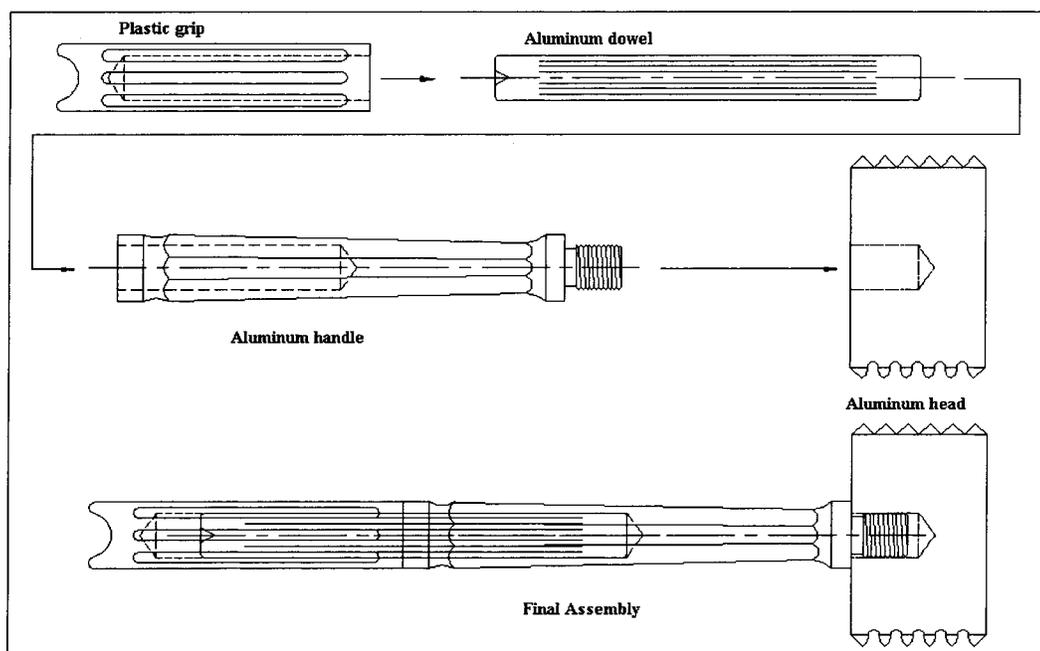


Figure 2. A Final Assembly Drawing for the Meat Tenderizer.

model: the up-stream operation pushes the work-in-progress (WIP) to the down-stream operation and requests information from the down-stream operator. The current process needs to be determined and developed into a *Process at a Glance* (Figure 3), displaying the current method in a step-by-step flow.

The sequence of the manufacturing process begins with the cutting of raw stock. The operator is given a cut sheet and a cut quantity for each part. Some setup time is necessary between the production of each part and is considered as internal setup time. Referring to Figure 2, the first cutting operation produces the aluminum handle, the second produces the aluminum dowel, the third produces the plastic grip, and the fourth produces the aluminum head. After a specified quantity of aluminum is cut for the handle, it is delivered to the lathe operator, where the drilling and reaming operation is performed, allowing the handle to accept the dowel insert. Then, the relief cut, diameter reduction, and threading operations are performed. The proper length for the handle is established at this time. This process is repeated until the batch quantity delivered from the cutting operation is completed. The operator then performs the necessary setup required for the next operation.

The next part of the meat tenderizer to arrive at the lathe is the dowel. Both ends are faced, with one end center-drilled to facilitate a milling operation later in the manufacturing process. Straight knurling is also applied at this time.[j2] Once the batch quantity is completed, the setup for production of the plastic grip is done. At the lathe, the plastic grip is faced on one end, drilled, and reamed[j3]. The grip is also rotated to the opposite end to prepare it for a later machining operation. This operation is repeated until the required batch size is produced. At this time, the operator returns to the first operation for turning the aluminum handle.

Once the lathe operations on the aluminum handle and the dowel have been completed, the parts go to a press operation in the assembly area. At the press, the aluminum dowel is inserted into the handle to a specified depth of 2.375 inches. This operation is repeated until the predetermined batch size has been produced. From this point, the handle and dowel move to the milling operation, where the nine flutes are applied. When the complete batch is finished, the parts are moved to a polishing center where the handles receive a final finish. These finished parts are then inventoried until delivered to the assembly area.

The next component to move through the

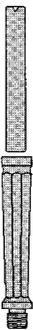
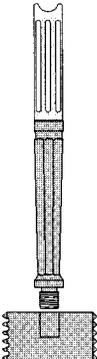
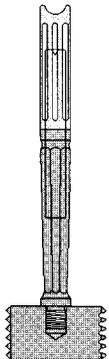
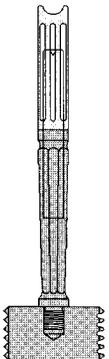
Process Number	10	20	30	40	50
Process Description	Press 0.5" dowel into aluminum handle	Press plastic grip onto 0.5" dowel	Thread handle assembly and tenderized head together	Clean, polish and prepare for packaging	Package completed product and ready for shipment to retailer
Process Sketch					
Tool	Arbor Press	Arbor Press	None	None	Shrink Wrap

Figure 3. The *Process at a Glance* of Production of the Meat Tenderizer.

process is the plastic grip (Figure 2). After being prepared by the lathe operation, the grip is delivered to a milling process where 10 flutes are machined. Once this process has been done on the batch quantity, the plastic grips are taken back to the lathe to go through the final ball end-milling operation. From this point, the grips are cleaned and de-burred. Once this de-burring procedure is complete, the parts are passed to an inventory location, awaiting final assembly.

The meat tenderizer head (Figure 2) is produced concurrently with other parts of the product. Once the cutting operation is complete, the batch quantity is delivered to the milling operation where the block is faced on all sides and a pattern is cut on each end. Once the milling operation has been performed, the head is transferred to the drilling and tapping process, where the hole is drilled and tapped. After this operation is finished, the meat tenderizer head is delivered to a de-burring and polishing station, and then to inventory to await final assembly.

The assembly process operates around an assembly station consisting of four workstations for each of the meat tenderizer's four components (aluminum handles, dowels, plastic grips, and the tenderizer head) with one worker at each station. First, the aluminum handle is threaded into a fixture to protect the threads and align the part. The dowel is then pressed into the handle and the assembly is removed from the fixture. This process is

repeated until the lot size is complete. Next, the assembly is delivered to the milling operation where the nine flutes are milled onto the handle. After the handle is milled and polished, it is returned to the assembly area for final assembly. The aluminum handle is threaded into the fixture as before, in order to protect the threads. To ensure proper alignment, the plastic grip is pressed onto the handle. The assembly is then removed from the fixture and the tenderizer head is threaded onto the handle assembly. The completed product is cleaned, packaged, and prepared for shipment to a retail outlet.

Brainstorming and Consideration of Possible Alternatives

Once everyone on the team understands the current method, a brainstorming phase begins in order to accumulate ideas determining seven new processes to be evaluated. No ideas are too bizarre, ranging from doing nothing at all to viewing various ways to completely redesign the process. The number of new processes changes depending on the project, but seven is the number typically used because it creates a high degree of stimulation during the limited time allotted for the brainstorming phase.

The seven proposed methods should be displayed in a chart that allows everyone to view them quickly and easily. The information provided also needs to be clear and concise, including a process sketch, a brief explanation

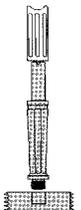
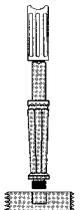
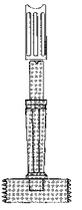
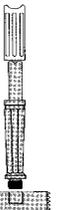
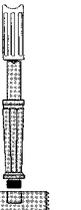
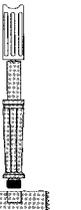
Process Number	1	2	3	4	5	6	7
Process Sketch							
Operation	Press dowel Press plastic grip Thread Head	Injection mold plastic grip Press dowel Thread Head	Press plastic grip Die cast head and handle all one piece	Press plastic grip Produce handle all one piece Press head (no threads)	Press plastic grip Produce handle all one piece (no flutes) Press head (no threads)	Use adhesive bond on plastic grip to handle assembly and on handle to head	Die cast entire part no assembly
Measuring Gauge	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tool	Arbor Press	Injection mold	Die Cast	Arbor Press	Arbor Press	None	Die Cast
Fixture	Use Existing			Use Existing	Use Existing	None	

Figure 4. The Seven Alternative Methods after Kaizen Brainstroming Process.

of the operation, a measuring gauge, a list of necessary tools, and required fixtures. The seven methods for this project are summarized in Figure 4. Once these methods are developed, an evaluation of these proposed processes must be undertaken.

Evaluation and Selection of Process

A group approach was implemented based on the three goals of this project to develop evaluation criteria. The decision was made to evaluate this project based on the following criteria: (a) *flexibility*: with two subcriteria: simplicity and ease of repetition; (b) *cost*: with five subcriteria: capital investment, labor costs, tooling costs, known technology, and required maintenance costs; and (c) *safety*: with seven subcriteria: safe, clean, ergonomic, of desired quality, required skills, defects per shift, and meets customer specifications. The first column in Table 1 shows the criteria for evaluating the seven alternatives. In addition, the weight of each criterion and the value of the subcriteria are also determined and shown in the second and third columns of Table 1.

The evaluation sheet determines how the seven proposed methods will be assessed. This sheet should consist of categories that are appropriate for the project. Once the

evaluation sheet is prepared, each member of the team independently rates the seven proposed methods on a scale from 1 to 5, with 1 indicating strongly disagree and 5 indicating strongly agree. A value of X can be entered if the team member feels that one of the proposed methods is not an acceptable solution. After each member has voted, the results are tallied and entered into a chart as shown in the last seven columns of Table 1. From this chart, the three best methods can be selected for simulation. The top three methods selected in this study were Methods 5, 4, and 1. At this point, one method was chosen for simulation to determine how effective it might be when implemented.

Prototype and Simulation

Alternative number 5 shown in Figure 4 was chosen for prototyping and simulation because it had the highest score in the decision matrix (Table 2). The design of the cell was developed and carefully laid out using measurements from actual machines involved. Tables, chairs, cardboard boxes, or any other readily available material can be used to simulate the cell design. Members of the team used stop watches to simulate the cycle time of each station in the cell. The workers in the cell could not move to the next assignment in

Table 1. The Evaluation Criteria, Weights, Values, and Overall Scores for the Seven Alternatives.

Evaluation	Weight	Value	Category	Proposed Process						
				1	2	3	4	5	6	7
Flexible	25	5	1) Simplicity	4	1	1	3	5	4	4
			2) Easily Repeatable	2	2	1	2	5	3	4
		10	3) Inexpensive	2	2	1	3	5	4	1
			SUBTOTAL	50	35	20	55	100	75	50
Cost	25	10	1) Capital Investment	4	2	x	5	5	4	1
			2) Labor	4	4	2	4	5	4	4
		5	3) Tooling	3	2	1	4	4	3	1
			4) Known Technology	3	3	1	5	4	4	2
			5) Maintenance Required	3	2	2	4	5	2	3
SUBTOTAL	105	75	#####	135	140	105	60			
Safety	25	10	1) Safe	4	3	1	4	4	4	2
			2) Clean	4	3	1	4	5	3	1
		5	3) Ergonomic	3	3	1	4	4	1	3
			SUBTOTAL	75	60	20	80	85	60	40
Quality	25	5	1) Skill required	3	2	2	4	5	3	2
			2) Defects per Shift	2	3	1	4	5	4	5
		10	3) Meets Customer Specs.	1	4	3	4	5	4	5
			SUBTOTAL	45	80	50	100	125	95	110
TOTAL			227	217	#####	317	355	263	214	

the process until signaled by the timekeeper. By following this example, the cycle time of the cell was predicted very accurately relative to real-time values.

Another important key to success under the Kaizen methodology is to generate a written description of worker responsibilities. This key must be provided in order for everyone involved to be acutely aware of what is going on in the process. A pictorial representation of the cell design can be seen in Figure 5. Before worker responsibilities can be addressed, a few explanations of the cell are necessary.

Cell Design

The cell is a U-shaped pull design with a one-piece flow. A de-coupler is used between the workers to break the dependency of the process and relax the need for precise line balancing (Black, 1991). It holds one part with a specific input and output, and is not a storage area or buffer. Every part of the cell, in each machine and in each de-coupler, is ready to be advanced. Work begins at the last process, and no part can advance through the cell until the part is removed from the de-coupler. This signals the other worker to begin. In other words, the work is "pulled" through the cell. The assignment of the work is as follows.

Worker Responsibilities

WORKER 1

Starts at Station 4, and pulls the cleaned part from the de-coupler, signaling Worker 2 to begin the process at Station 3. Worker 1 places the clean part in Station 4 and packages it, then walks to Station 1 and waits until the de-coupler is empty to begin work. When Worker 2 pulls the part from the de-coupler, Worker 1 places the finished part that was in Station 1 into the de-coupler and begins this process. When the operation at Station 1 has been completed, the worker walks back to Station 4 and pulls the cleaned part from the de-coupler. The process is then repeated.

WORKER 2

Begins at Station 3 when Worker 1 pulls the part from the de-coupler. Worker 2 will move the already cleaned part to the de-coupler and will then move the part from Station 2 to Station 3 and clean it. After it is cleaned, Worker 2 will move to Station 2 and pull the part from the de-coupler, signaling Worker 1 to begin work at Station 1. Worker 2 will perform the process at Station 2 and then move back to Station 3. When the de-coupler is emptied, Worker 2 repeats this procedure.

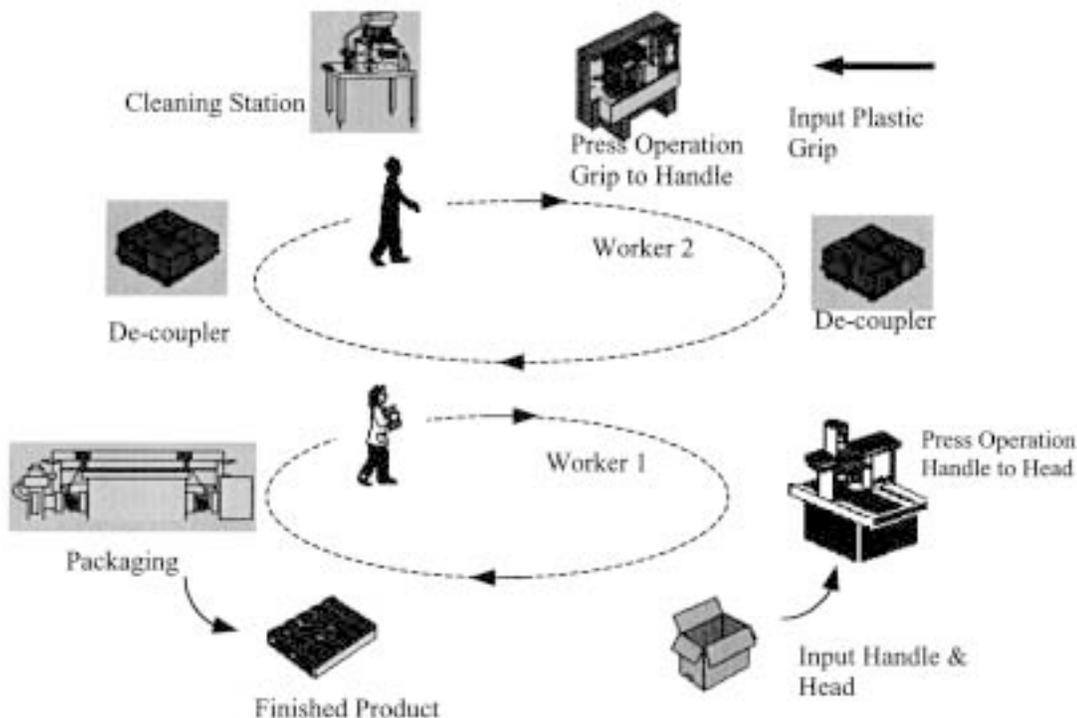


Figure 5. The Proposed Two-Worker Cell Layout.

After physical simulation with this cell implementation, a cycle time of 27 to 29 seconds was obtained through measurement. These results exceeded the goal of the team, allowing them to plan for the presentation of this new alternative to upper management for approval before this approach could be fully adopted on the shop floor.

Presentation and Implementation

Presentation to upper management is crucial for Kaizen to succeed because it allows upper management to observe the impact Kaizen is having on the success of the organization while keeping them in the information loop. Additionally, it provides an excellent method to train the entire organization on Kaizen implementation. The presentation can also be used to provide feedback to improve the implementation of the Kaizen methodology, resulting in the continuous improvement the name *Kaizen* implies. This increase in visibility between upper management and the workforce establishes a high level of communication, creating trust and understanding, eventually resulting in improved employee relations and morale.

Results

The existing cycle time per assembly was 62 seconds. The new cycle time was about 28 seconds, which constitutes an approximate 44% reduction in cycle time. The existing assembly area consisting of workstations occupied 192 square feet. The proposed assembly area requires two cells, which use a space of 160 square feet. The new plan reduces the workspace by 37%. Quality to the consumer is 100% because the "make one check one pass one on" method provides 100% inspection, ensuring that no inferior-quality products are passed on to the consumer. Scrap and re-work are minimized because quality problems become visible immediately and can be addressed before additional defects may be produced. Employee morale is improved because the cellular design makes it possible for workers to fill multiple jobs. With Kaizen, workers rotate the tasks they undertake, raising satisfaction and morale. Higher worker satisfaction and morale decrease boredom, resulting in increased productivity and higher quality workmanship.

Conclusion

The Kaizen process acknowledges the information at all levels of an organization through the incorporation of a special type of intense teamwork. In addition, process steps that require seven alternatives force teams to think "outside the box," which often results in major innovations. Finally, the general guidelines are fundamentally sound manufacturing practices, such as "one piece flow" and the elimination of non-value added practices.

When implementing the Kaizen approach, much of the responsibility lies with upper management. Pitfalls include the tendency of upper management to micromanage the teams and a lack of initial training in teamwork effectiveness.

The ability of an organization to respond to the rapidly changing global marketplace will eventually determine the ultimate success of that organization. The implementation of Kaizen addresses many of the needs that modern organizations face. While Kaizen brings continuous improvement, it also develops a communications network throughout the organization that intrinsically supports a method of checks and balances within daily operations. The daily trials and tribulations that upper management once confronted on their own are now solved by the workforce, increasing morale and allowing upper management to concentrate efforts on strategic planning.

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