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*Original Article*

# Implementation of Integrated PDCA-Kaizen in the Plastic Converting Machinery Manufacturing Industry

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***Abstract*** *- In this dynamic and ever-evolving world, nothing but change and continuous improvement are the two key drivers for the excellence and success of the business. All industry leaders and market players have one thing in common: they continuously improve the business's current process or product. Continuous improvement in performance parameters gives the cutting edge to the business. Kaizen is the most frequently used methodology in the manufacturing sector and remains an appropriate improvement tool. This study explores integrating the Plan-Do-Check-Act (PDCA) cycle with Kaizen to improve the productivity and quality of products and components of plastic-converting machinery companies. By implementing integrated PDCA–Kaizen, it was found that the productivity of assembly of bearing housing has increased by 41.66%, and the assembly time has reduced to 10.48 min. Also, with the help of integrated PDCA-Kaizen, defects were eliminated for the side sealing (SS-800) machine.*

***Keywords*** *- Kaizen, Lean manufacturing, Plan-Do-Check-Act, Productivity improvement, Why-Why analysis.*

## 1. Introduction

The globalization of economic, political, cultural and financial has increased the business opportunity substantially. But at the same time, the level of the competition has become fierce. The competition has become cutthroat to sustain the business in the market and, not only that, to become the market leader in the segment. To achieve this goal, each industry leader is practicing continuous improvement, innovation, waste reduction and product cost [6]. In the last ten years, the plastic packaging industry has experienced steady growth. Lean techniques have helped industry leaders maintain their market position. Lean techniques or methods are linked to continuous improvement, waste reduction, productivity improvement and reduced lead time in process inventories [7]. When combined with Kaizen, a simple lean technique like Plan-Do-Check-Act (PDCA) can result in enormous benefits to the organization. The Kaizen technique ensures continuous improvement, but the PDCA technique ensures that minor adjustments and modifications made over a period of time will result in great benefits to the company [5]. Laban Gasper has revealed that the PDCA cycle has helped improve the productivity and optimization of processes. Various lean techniques are used in the lead production. For this research study, the objective is to improve productivity, reduce the cost by improving the assembly time and reduce any other kind of waste. For this purpose, Kaizen and Plan-Do-Check-Act techniques (PDCA) are used in this research article. The framework of the integrated PDCA with Kaizen is developed to ensure that the objective is met.

## 2. Kaizen and PDCA

Kaizen is the Japanese word. It combines two words, “KAI” and “Zen”. Kai means change, and “Zen” means for the better. Continuous improvement comes from the Gemba Kaizen. Continuous improvement is the strategy for business excellence and improving the performance of the product and process [11]. Kaizen is the tool which is utilized to eliminate the 3M – MUDA, MURA and MURI. These three words represent the inconvenience, inconsistency and waste [8]. Kaizen means continuous improvement, which means that Kaizen sets the standards and then continually improves the set standards. Kaizen also provides a better view of the improvement and gains to the management and provides guidance, tools and preparation to the staff members to achieve the expectations. Since Kaizen is about continuous improvement, the standard set becomes obsolete as it achieves the set standard, and from there, Kaizen sets another standard for improvement [7]. Below are the five main objectives of the Kaizen

- Waste Management,
- Manufacturing cycle and Quality Assurance
- Standardization of Jobs
- Schedule management of Production
- Improvement in resource productivity

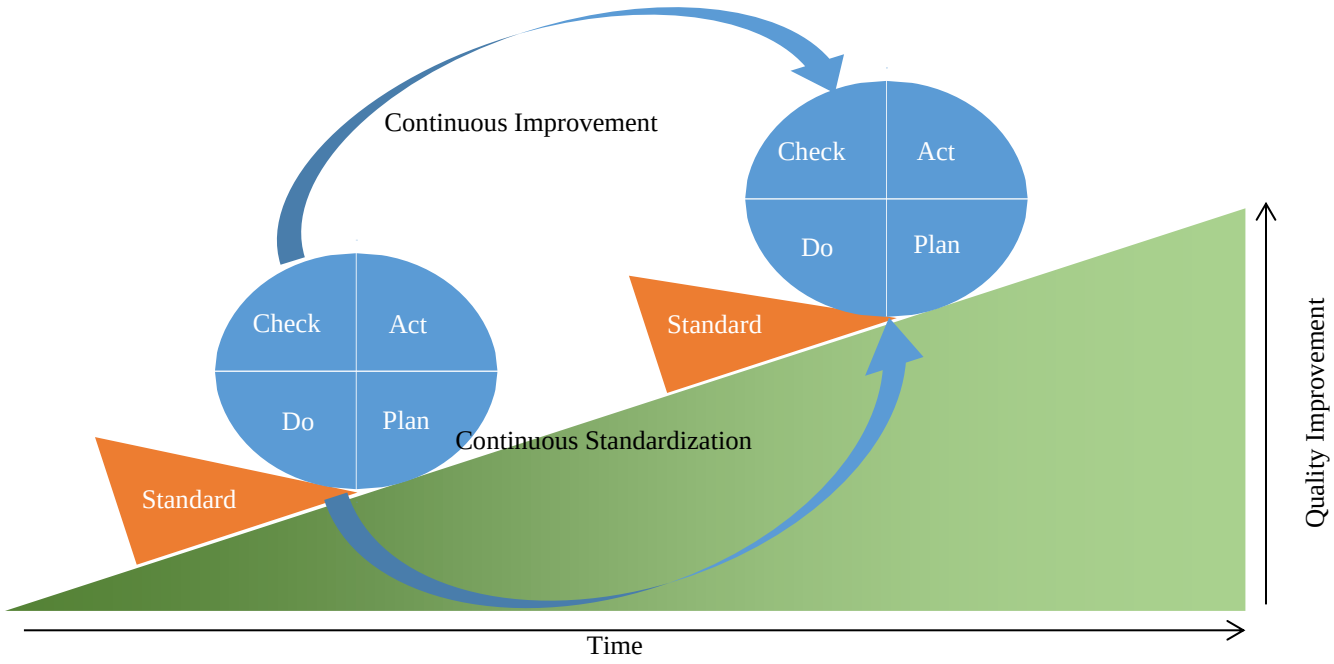



**Fig. 1 PDCA – Continuous improvement [12]**

There is a close relationship between the various methods like root cause analysis, PDCA, 5S, 4M (Man, Material, Machine and Method) and Kaizen. One very good method to keep the Kaizen on track is PDCA – Plan-Do-Check-Act.

Dr. Edwards Demings has developed the PDCA cycle for continuous improvement. It is believed that Dr. Demings is the father of the PDCA cycle. However, he has considered the PDSA – Plan-Do-Study-Act cycle, which was developed by Water Shewhart in 1920 and is also known as the Shewhart Cycle [7]. PDCA has become an integral part of the quality management and quality control. It is used to build process-oriented thinking and control model processes. PDCA offers the cyclic process and, at each stage, is checked thoroughly before moving to the next step. It follows the complete flow chart and allows you to decide at each stage. The figure 1 shows how PDCA drives continuous improvement in order to achieve quality improvement over a period of time. The four stages of the PDCA are described below:

*Plan* : Set objectives and processes required to achieve the desired or target goals

*Do* : Perform operations/processes to achieve the target goals

*Check*: Check the results of the performed operations/ process. Compare the results with the expected outcomes and check for acceptance by identifying the similarities or differences.

*Act* : This phase is also known as Adjust. In this phase, the process or operations performed are being improved by altering the process or operation parameters. This phase basically helps to overcome the non-conformities, issues, problems, and inefficiency.

## 3. Literature Review

A.D. Peterson has investigated creating a collaborative Kaizen scheme with PDCA. They have developed the skeleton of the PDCA, and in the plan, the Kaizen team assessed the required input. The developed framework was tested with OEM, where the target was to improve the workstation's energy consumption and maintenance cost. The author has concluded that with the implementation of this framework, the vendor was able to gain 63.6% of the deal cost, operation cost was reduced, and RM 7532.37 was released to the vendor in 9 months.

Ganesh S. Jadhav and others aimed to implement Kaizen by identifying the effectiveness of Kaizen in electronic manufacturing companies. They have also used the Timed-PDCA concept to improve productivity by motivating workers concurrently. With the implementation of Timed –PDCA Kaizen, the author demonstrated productivity improvement. They were able to produce 5100 pieces instead of 3900 pieces and was able to save 2.66 hours per shift.

Heru Darmawan and others aimed to reduce the important defect rate in the process by implementing 8 steps of the Plan Do Check Act Cycle through the kaizen approach. They showed an improvement in the defect rate, which has changed from 2.47% to 1.52%. Also, because of all the improvements made in the process, there was a 38% reduction in the scrap plate.

Kong Siew Mui and others have studied the Kaizen culture's impact on productivity gains. They have collected the data through a survey. The survey was conducted on 248 E&E

manufacturing companies. The results of surveys were obtained for 127 out of 248. The Author concluded that there is a strong relationship between Kaizen culture and operational performance.

Puneet Sharma and others have shown the Kaizen implementation guided by the PDCA cycle. The author has used various lean techniques like the Pareto diagram, process mapping, and the PDCA cycle. They were able to prove the effectiveness of the Kaizen in non-woven-producing companies. They reduced the sales ordering processing lead by 6.98% and production lead time by 14.93%.

## 4. Research Problem & Objective

The company under study is the leading plastic-converting machinery-producing company. The company produces various machines for plastic bag production. For this study purpose, only the SS-800 machine was the area of interest for implementing the Kaizen and PDCA cycle. It was observed that the SS-800 machine has defects in the production, and it takes more assembly time, particularly for the Sealer roller assembly. The company management decided to investigate the problem, improve productivity, and eliminate the defect. With that regard, this research study was undertaken to improve the defect caused in the Sealer roller unit area and improve the assembly time of the SS-800 machine by implementing Kaizen.

The main objective of this study is to eliminate the defect and improve productivity and quality for the Sealer roller unit of the SS-800 machine by implementing the Kaizen.

## 5. Materials and Methods

To ensure that the implementation of Kaizen is effective and efficient, PDCA was integrated with Kaizen. PDCA cycle has ensured that Kaizen implementation has followed the below process:

### *5.1. Phase 1: Plan*

The current state of the machine was carried out. Primary information was collected through discussion and interviews with the operators, supervisors, Engineers and other staff members to understand the current state of the machine, issues, problems and challenges. After multiple meetings and to develop the culture of Kaizen, Operators, supervisors and other staff members were encouraged to provide ideas for continuous improvement. Kaizen Ideas were collected. After careful review with the management team, engineers, and managers, Ideas were shortlisted, and the most effective and efficient ideas were selected for implementation.

### *5.2. Phase 2: DO*

After carefully studying and selecting Kaizen Ideas, the next step is to perform or implement the idea. Before implementing the idea, minimum acceptance criteria were defined in the planning stage.

### *5.3. Phase 3: Check*

After performing or implementing the idea, the most critical activity is to measure and check whether the objective is achieved against the set target.

### *5.4. Phase 4: Act or Adjust*

At this stage, if the target is achieved, the Kaizen team will set it as a standard document for learning for reference and future prospects. However, if the target is not achieved, the team will start the activity again for the Kaizen idea generation and make the necessary changes or adjust the process to achieve the target.

Figure 2 shows the complete workflow of the Integrated Kaizen with PDCA.

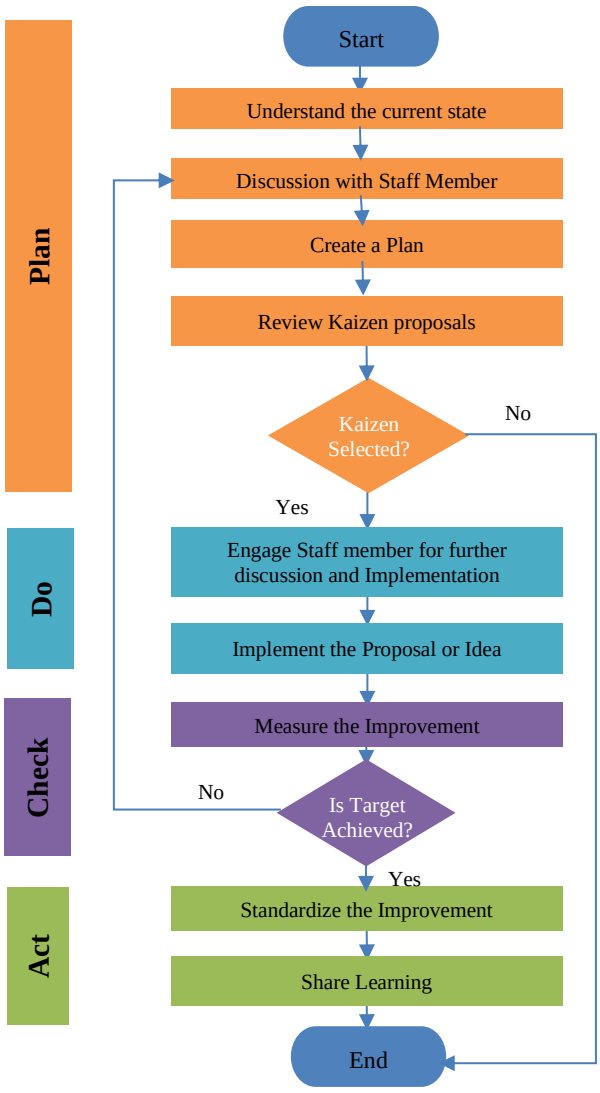



**Fig. 2 Kaizen integrated with PDCA**

## 6. Results and Discussion

This study held a few initial meetings with the top management to understand the opportunity to implement Kaizen. After discussing and interviewing the operators, engineers, and supervisors, two teams decided to identify and report issues, problems or challenges in the SS-800 machine. Reported issues, problems or challenges were assessed based on the impact on the customer satisfaction level, performance parameter and productivity improvement. Below table 1 shows the Kaizen issues reported and assessed in High, medium and low categories based on their impact on the business.

Based on the discussion with engineers and top management of the company, two kaizen ideas were decided for the implementation. For this study, Table 2 below shows the issues considered for improvement.

For Serial No. 2 of Table 2: Rubber sealer shaft attached to the conveyor stacking assembly created a problem with bag production. It was measured that after 300 bags of production, wrinkles in the bag started to appear.

Below, Figure 3a and Figure 3b shows the problem of wrinkles in the bag production.

To understand the cause of the problem, a Why-Why analysis was performed. The table below shows the Why-Why Analysis of the problem.

**Fig. 3(a) Wrinkles in plastic bags - Defect**

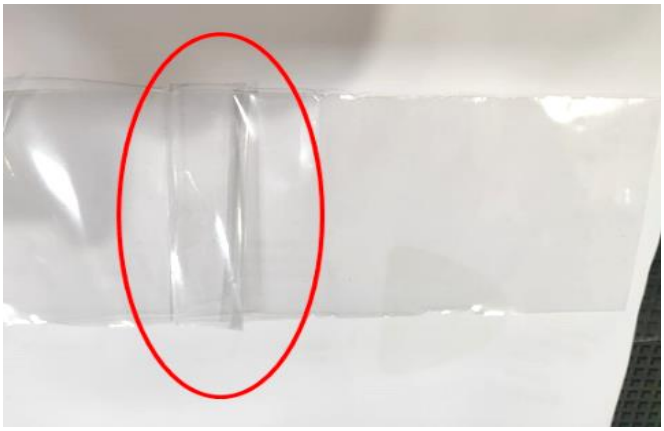


**Fig. 3(b) Wrinkles in plastic bags – Defect**

**Table 1. Issues, Problems or Challenges reported**

| Sr. No. | Team | Problem Description | Impact |
|---|---|---|---|
| 1 | Team A | Shadow Board | Low |
| 2 | Team A | Rubber Sealer shaft - Defect in bag production | High |
| 3 | Team A | Rusting of gears - Maintenance and Storage Problem | Medium |
| 4 | Team A | Process changes in customer service - Call management | Low |
| 5 | Team B | Bearing Housing Block Assembly and Maintenance problem - Productivity impact | High |
| 6 | Team B | Tapping machine modification - For Large Frames, tapping on the plate is difficult. | Low |
| 7 | Team B | Zipper sealing jaw modification - Jaw design needs to be reviewed for assembly. | Low |
| 8 | Team B | Torque machine for tapping | Medium |
| 9 | Team B | Material, Tool store near workshop- Avoid Motion time | Medium |
| 10 | Team B | Table to put bigger job - 5S activity | Low |

**Table 2. Two issues selected for kaizen implementation**

| Sr. No. | Team | Problem Description | Impact |
|---|---|---|---|
| 2 | Team A | Rubber Sealer shaft - Defect in bag production | High |
| 5 | Team B | Bearing Housing Block Assembly and Maintenance problem - Productivity impact | High |

**Table 3. Why-Why analysis for rubber sealer shaft**

| Problem Description | Why -1 | Why -2 | Why -3 | Why -4 | Why -5 |
|---|---|---|---|---|---|
| At the end of the conveyor stacker unit, Plastic bags are getting wrinkles on the surfaces | Roller speed is high | to get the desired output of the number of bags per min | Customer Specification | | |
| | Roller pressure is high | to avoid the slippages of the bag | All bags should be stacked on each other | To pack in the desired quantity of bags | Customer specification |
| | Excessive heat formed at the roller shaft | Friction between Two roller | The sealer shaft material is coated with rubber material | To ensure no damage or cracks on the bag | Quality Requirement |

After careful consideration and discussion with the engineers and team, It was found that speed and pressure were satisfactory. However, due to the rubber coating on the shaft, at a given speed and pressure, it was creating heat and was causing stickiness on the roller shaft, due to which plastic bags were forming wrinkles on the surfaces.

It was decided to replace the rubber sealer shaft with an Aluminum shaft with a Teflon coating, which is lighter in weight. Also, the surface roughness of the Aluminum shaft was kept extremely smooth to avoid any scratch on the surface of the plastic bag. Below table 4 shows the before and after modifying the roller shaft and bag output.

After changing the rubber seal shaft with a Teflon-coated aluminium shaft and changing the corrugated profile from rectangle to round, it was found that the bags were stacking without any wrinkles. By implementing this Kaizen Idea, the bag wrinkle defect was completely eliminated.

For Serial No. 5 of Table 2: It was observed that fitting the bearing assembly and replacing it for maintenance purposes took approximately 37.27 min. The assembly time was considered from taking the bearing housing unit from the store department to the final screw tightening of the bearing assembly. Keeping the motion time constant, the pure assembly time of bearing housing was 25.16 min.

We performed the why-why analysis to understand the causes of the high time for the bearing housing assembly. Below table 5 shows the various causes of the higher assembly time, which impacts productivity.

**Table 4. Before and after the roller shaft**

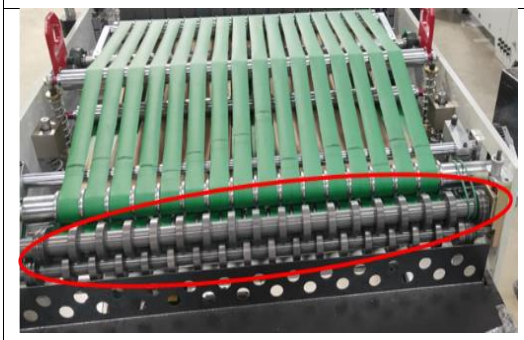
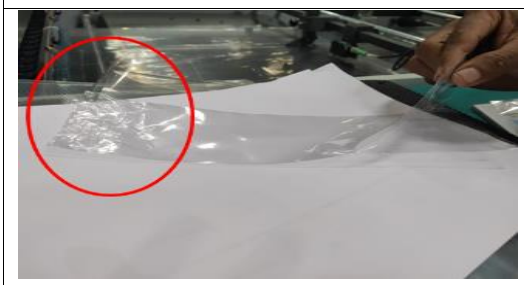
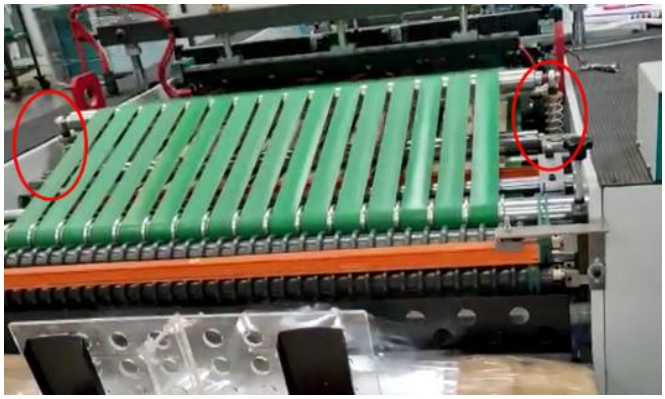
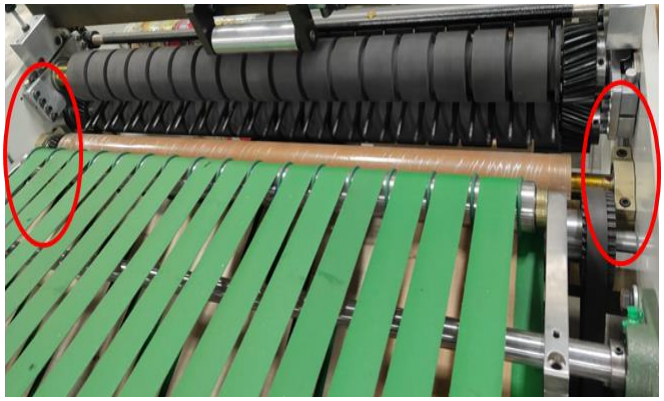
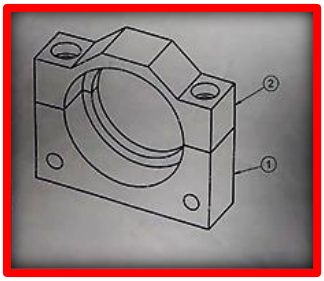
| Before | After |
|---|---|
|  |  |
|  |  |

**Table 5. Why-Why analysis for assembly time of bearing housing**

| Problem Description | Why -1 | Why -2 | Why -3 | Why -4 |
|---|---|---|---|---|
| Assembly time for bearing housing is more | Very narrow accessible space for Bearing housing mounting. | The machine comprises various shaft arrangements and punch and pressing units around the Bearing housing. | It is the process requirement for the plastic-converting machinery. | To meet the machine specification and customer specifications. |
| | Store to the Assembly area travel time is more. | The store location is kept at optimum distance from all required departments. | To increase the efficiency of the operator and reduce time. | |
| | No Tools are available at the time of bearing housing fitting. | Other operators might have used it and have not kept the right location. | No understanding of housekeeping - 5S | |

**Table 6. Before and after of the bearing housing**

| Before | After |
|---|---|
|  |  |
|  |   |

After careful consideration and discussion with the team, it was observed that the Store area is at the optimum distance for easy access to all the departments. Also, dedicated tools are provided at each of the stations. Hence, it was concluded as a discussion that bearing housing needs to be split into two halves to be accessed from the top side of the machine. Below, table 6 shows images of the before and after of the bearing housing. Based on the suggestion from the engineering team and approval from the management team, the bearing housing was replaced with split-type bearing housing, which can be accessed from the top of the machine. This modification has helped to reduce the assembly time from 25.16 min to 10.48 min. The assembly time was measured using the watch clock using the time study method. With the implementation of this kaizen, productivity for the assembly of bearing housing is improved by 41.66%.

## 7. Conclusion

Based on the study in plastic converting machinery manufacturing company, It is observed that when kaizen is integrated with PDCA, it is very effective and useful in identifying, removing defects and improving productivity. After implementing the Kaizen with PDCA, the productivity of assembly of bearing housing has increased by 41.66%, and the assembly time has reduced to 10.48 min.

Also, with the Why-Why analysis, it was easy to identify the right root cause that caused the defects in the production of plastic bags. With the implementation of the kaizen, now SS-800 produces the bags without wrinkles and defect is completely eliminated.

So, by implementing integrated Kaizen with PDCA, the objective of productivity improvement and quality improvement was achieved by eliminating defects. The study reveals that when PDCA is integrated with Kaizen, it helps in the smooth execution of the process and improves the productivity of the process/product.

Various parameters drive the Kaizen; for future work, 5S or 4M (Man, Material, Machine, and Methods) can be integrated for excellence in business operations.

### *7.1. Implication*

This research article includes the implementation of Kaizen to improve productivity and quality by eliminating defects in the plastic-converting machinery industry in India. This study specifically focuses on Gujarat, India's plastic-converting machinery industry. In this study, the authors have considered two dimensions for the study: (1) the nature of the business/industry, i.e. plastic converting machinery industry and (2) the location of the industry, i.e. Gujarat, India, which reflects the current status of the Asian market. This paper also references the plastic-converting machinery industry for improving inventory management by implementing Integrated Kaizen with PDCA.

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