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Improve Productivity and Quality Using Lean Six Sigma: A Case Study

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Abstract

Continuous improvement activities are widely deployed, applying the DMAIC cycle in the Lean Six Sigma method combined with 5s activities and industrial engineering tools such as Man-Machine chart statistics tools in DFSS (Design For Six Sigma). The results of the improvement activity must be approved and operated by the machine operator, measuring the loyalty of operators, users and system maintainers after kaizen against satisfaction criteria, technicality, usefulness and convenience are needed. This study proposes a model that combines the PLS - SEM method to measure user loyalty and implement a training program for users on incorrect performance results to improve CDIO standards. The result is a reduction of workers at the processing line from 4 people on two shifts to 2 people, and the amount of money brought in is 10,224 USD per year. Defect of negative outside diameter decreased from 31.2% to 4.5% based on the amount of waste reduction of USD 980 per year. In terms of productivity increased from 15 units per hour per person to 30 units.

1. Introduction

The Kaizen word comes from Japan and means improvement. Initially, the Kaizen term was only used within Japanese companies gradually. Kaizen is disseminated globally and exported to continuous improvement standards In ISO 9001: 2015 (Yuliia) . Continuous improvement activities are active that mechanical production companies always love the top. Combining the DMAIC cycle in the Lean 6 Sigma method into improvement has been applied with tea (Minh) ; a company calls this improvement from Quality Control Story Action or calling by Quality Control Cycle. The results of improvement activities provide a competitive advantage for competitors in the joint trading market and improve product quality with continuously improving to grow together with standards of new techniques. The results of improvement activities provide a competitive advantage for competitors in the joint trading market and improve product quality with constantly improving to grow together with standards new technical accompanying .

Along with the development of technology 4.0 and extensive data, the improvement of production activities must also follow technology development. Techniques or improvement methods must also have inevitable progress, especially algorithms (Mast) . Removing activities that do not bring value-added, improving productivity, waste type (Chiu) and improving customer satisfaction are common factors that employees improve as well as the entire participating staff Production activities in organizations always think (Sin) . Precision Mechanical Manufacturing Company Implementing the improvement of the company's powerful production tools (Lizarelli) and operating tools on processing machines and automation machines Machining (Castro) . Perform a stage assessment and application of system analysis tools and analytics tools from Lean Six Sigma or DMAIC cycle combined with Industrial Engineering tools for improvement (Soliman) . However, re-evaluate loyal users to use all improvement activities and create an unexpected improvement in improved operations. However, there has not been any study implementing this investigation.

In this study, we apply the DMAIC cycle in Lean Six Sigma combined with tools in Industrial Engineering and 5S operations for investigation. Mechanical product process analysis Implement improvements to remove actions that do not bring added value, the stage generates wasteful. To analyze the satisfaction of operators' loyalty to the effectiveness of automation to automate the stone surface polish at the stage Grinding by the PLS – SEM model analyzes the correlation between usefulness, convenience, and technical calculation of arguing activities on user loyalty by Smart PLS 3.0 software. Create training guidelines for user-linked users with professional improvement activities according to CDIO standards. The study structure includes parts organized as follows: Related studies are shown in the Literature Review section, introducing the theoretical basis and research methods to show Raw Material and Methodology, the proposed research model app in case Study; Finally, the research results.

2. Literature Review

Along with the continuous development of the current business environment, as well as the level of competition in the market also increased, organizations that implement continuous quality improvement activities are a urgent operation to bring the company's competitive advantage before rival companies, tools like Total Quality Management, ISO Certification, Agile & Lean manufacturing expensive support in quality improvement activities (Pugna) , application of Lean Six Sigma tool in implementing quality improvement activities in the process of processing products to improve the quality of product removal products and improve productivity (Telma) , as well as improve competitive advantage for business Production by methods such as applying the DMAIC cycle (D – Define, M – Measure, A – Analysis, I – Improve, C – Control) to the stage, the current process is in need of improvement and cycle DMADV (D – Define, M – Measure, A – Analysis, D – Design, V – Verify) into the product design process (Monika) , 6 sigma cycle into the environment of Industrial Foundation 4.0 performed on information technology and communication technology to the Lean Six Sigma connection in the DMAIC cycle to improve the processing process (Rohin) , Mechanical outsourcing companies are focused on product quality improvement activities and quality processing processes to provide results on Fastest Rate of Improvement in Customer Satisfaction, Cost, Quality, Process Speed and Invested Capital by applying Lean Manufacturing (Nikhil) , Cycle DMAIC (Define – Measure – Analyze – Improve - Control) & RCA (Root Cause Analysis) Tools into Lean Manufacturing into the quality of product processing processes to optimize processing processes, type quitting activities that do not bring value-added as well as implementation of measurement, inspection, confirmation of gay factors that generate incidental products without reaching and implementing processing and assembly processes (Priya) , Using combinations of tools like The Critical To Quality (CTQ), The Voice of the Customer (VOC) and Pareto Chart along with Six Sigma's DMAIC on the process of controlling processing products and removal Factors do not bring added value along with improving product quality (Srinivasan et al.) , Operating in the process of processing products depends heavily on human skills and operations, in the process of operating if the processing parameters are incurred, the risk of waste (Ranade et al.) , DMAIC cycle in Six Sigma into process quality improvement and product quality (Costa, Lopes, and Brito) , the goal of the Lean Six Sigma application is to improve the process of mechanical production machining as well as improvement from semi-automatic machines into automatic machines to improve productivity and reduction of waste (Klochkov, Gazizulina, and Muralidharan) .

The PLS – SEM model uses a correlation analysis between elements of satisfaction and loyalty , building a led and structural model from the user survey datasheet and then using Smart-PLS 3.0 software to analyse (Kregel et al.) . To identify and evaluate how the indicators affect a user's behaviors using the hypothesis and determining the correlation from the value of P-value according to the conductive model (Cao et al.) . User loyalty evaluation on an object or one object that users are interested in (Tagod, Adeleke, and Moshood) by using the survey questionnaire and determining the interaction of the characteristics of the medium object user (Ali) .

3. Raw material and Methodology

5S Action material

The production environment in a gas processing plant with automatic processing machines jig equipment is used at each stage for various products of different sizes. Practicing 5S at each processing line is necessary, as shown in Tab 1. Workspace is free items or objects in the aisle, shortening travel time in the work area.

TABLE 1. Structure of operating environment 5S

5S word	Operation	Result
Seiri	Eliminate toolsless & unnecessary	Need it immediately
Seiton	Clearly label tools-tools	Visual management environment
Seiso	Convenient to clean	A clean environment
Seiketsu	Standardization 3S	Culture of practice 5S
Shitsuke	Set up 5S process	Create rule 5S

Kaizen action material

The machining environment is convenient in the precision mechanical factory. It is necessary to evaluate and identify activities that do not add value or hinder machining activities from proposing improvement according to standards. Standard Poka-yoke action. Results in creating continuous improvement practices, meeting KPI criteria in the organization's business operations, monitoring and controlling KPIs to create an organization's business advantage over other business environments the same, similar. Kaizen activities are performed in the sequence of 7 steps shown in Tab. 2.

TABLE 2. 7 steps in Kaizen operation

No.	Name	Operation
Step 1	Identify the problem	Collect and analyze
Step 2	Investigate the current situation	Evaluate the site and analyze the results
Step 3	Goal setting	SMART goals
Step 4	Investigate the cause	Analyze the cause of the problem
Step 5	Set up countermeasures	Suggest ideas for improvement
Step 6	Implement the countermeasures	Implement improvement ideas
Step 7	Verification & Evaluation	Result Analysis & Discussion

Lean action material

Every activity in a mechanical processing plant somewhere happens; some activities do not add value, also known as activities that cause waste. Something needs to be maintained in activities that cause waste because somewhere, there is a connection for value-added activities (Ruano) . However, it is necessary to analyze the current state of activities in detail with a human-machine interaction flowchart to identify the type of waste that needs to be eliminated. Camera manipulator video capture and man-machine activity analysis is powerful tool that delivers powerful results. Eliminating the factors that cause waste to make the product flow in the processing line more efficient, reducing production lead time, there are eight types of waste that improvement operations managers need to know and eliminate. To apply is shown in Tab. 3.

Six sigma action material

However, improvement activities that eliminate machining operations or processes that do not add value to the machining environment of a precision machine shop should consider process stability; minimizing process variations is a factor to be studied. The Six Sigma tool called the DMAIC (Define - Measure - Analysis - Improvement - Control) cycle helps improve the process (and) . Statistical tools such as Pareto charts, flowcharts, fishbone diagrams and other types of charts are applied to control fluctuations in the machining process at each stage. The content of DMAIC cycle execution is shown in Tab. 4.

DfSS (Design for six sigma) action material

Managing the process by linear regression, looking for new ways to manage the process to improve

TABLE 3. 8 wastes in Lean operation

Name	Content 8 wastes
Over production	Production output exceeds the planned target
Waiting	The choking stage, the flow is interrupted
Inventory Waste	Happened dead stock or damaged goods
Defect Waste	Happened damaged goods in processing
Operation Waste	Activities that do not bring added value
Processing Waste	The process is difficult to implement, easy to generate wrong operations
Conveyone Waste	Unreasonable layout
Knowledge waste	Irrational resource allocation

TABLE 4. DMAIC cycle in Six Sigma

DMAIC	Operation of DMAIC
Define	Collect & process historical data
Measure	Validate & measure past data
Analysis	Analysis of the current situation
Improve	Design & implement innovative ideas
Control	Verify & track results

the organization's competitiveness. The DMADV (Define – Measure – Analyze – Design – Verify) cycle or IDOV (Identify - Design - Optimize - Verify) cycle is performed to find new design solutions into the operation of the manufacturing process (Mariusz) shown at Tab.5 & Tab.6. Change management or perform Kaizen work, find, or design a new process to replace the old process, improve machining capacity, improvement productivity and profit.

Improvement activities eliminate waste, increase added value in the organization. Improve productivity, reduce waste and increase loyalty using post improvement results and Creating environment, training standards and operating results

TABLE 5. DMADV Cycle in DfSS

DMADV	Operation of DMAIC
Define	Identify needs & Generate Ideas
Measure	Collect value from Define phase
Analyze	Analyse the value just collected
Design	Design ideas that fit the data you just analysed
Verify	Verify & revise the idea you just designed

TABLE 6. IDOV Cycle in DfSS

IDOV	Operation of IDOV
Identify	Define design ideas
Design	Implement the design according to the idea
Optimize	Optimizing ideas just designed
Verify	Verify & revise the idea you just designed

after Kaizen according to CDIO standards is shown in Fig. 1.

CDIO standards material

Deploying user training or instruction on how to translate new ideas into a manufacturing environment at a machining plant is essential. Criteria to evaluate the results of user training based on the CDIO (Conceiving – Designing – Implementing – Operating) cycle to improve awareness of usage efficiency. Put the design ideas into criteria are shown in Table 7. Implement the operating instructions by the operation sequence tables, the operating instructions according to CDIO standards.

TABLE 7. Criterion of CDIO standards

Criterion	Contents of the criteria
Criterion 1	Novelty and originality of the idea (idea, prototype, or product)
Criterion 2	Logical structure of Kaizen ideas
Criterion 3	Effectiveness of Kaizen conceptual design
Criterion 4	Applicability to practical operations of the product

PLS-SEM method material

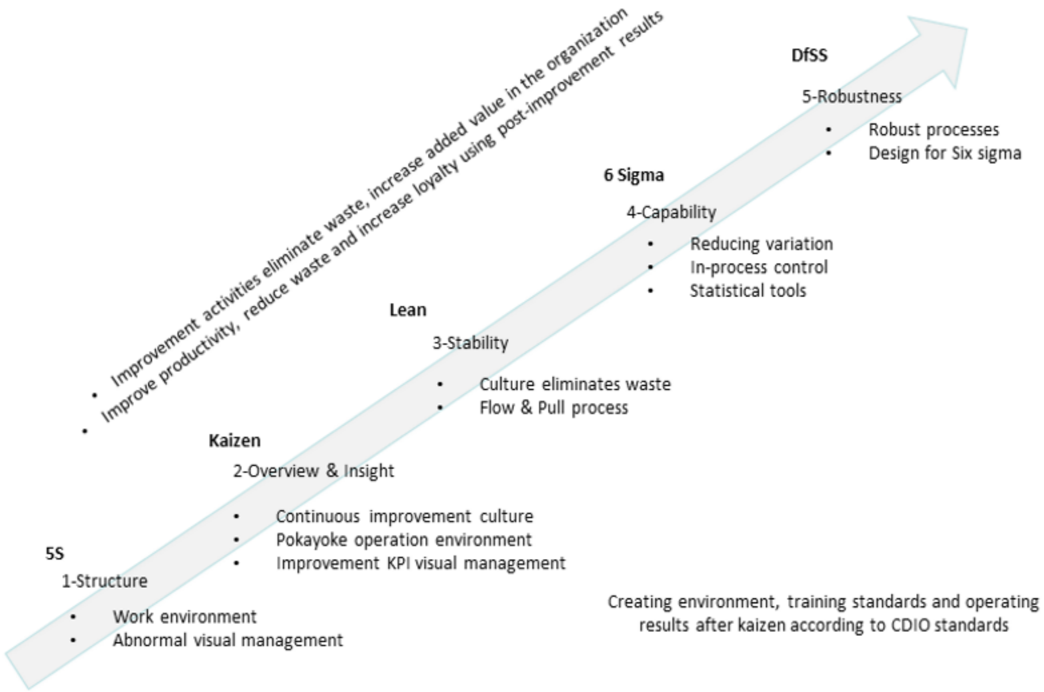

FIGURE 1. **Tools in Kaizen activities**

Determining and measuring operator loyalty about using and operating designs in Kaizen activities by factors of user satisfaction in terms of technology, convenience and usefulness of the new design. Conduct a survey to collect opinions of users, maintainers, outsourcing managers, factory managers using a 5-level Likert scale survey, using a PLS – SEM linear structural model to analyze The analysis determines the relationship of factors affecting the user's loyalty to the results of Kaizen activities. The PLS – SEM model performs measurement through multivariate analysis, including five factors: (1) composite variable, (2) measure (3) scale, (4) coding, and (5) Data distribution and path model. There are four basic elements: (1) the research concept (construct), (2) the measurement variable, (3) the relationship (relationship), and (4) the error term.

Proposing research methodology

Kaizen activities, design improvement ideas to eliminate waste or non-value-added activities by incorporating 5S activities into the DMAIC cycle of Lean Six Sigma method used by authors around the world. Using statistical methods in six sigma to evaluate the performance improvement after the time of putting into operation at processing lines. There has been no research on evaluating loyalty through user satisfaction, improvement results, and no research results to establish criteria for training implementation, establishing user training process on instructions. Operate Kaizen results according to CDIO standards.

This study proposes a model that combines the PLS – SEM model to measure user loyalty through the variables of satisfaction, technical innovation, usefulness and convenience of Kaizen performance results. deploy the training program to operate Kaizen results for users according to the CDIO evaluation criteria set into the 5S, Lean Six Sigma and DFSS operational model combined with the method shown in Fig. 2.

The research model proposed to carry out the research through the following five steps:

Step 1: Use 7 quality management tools to collect historical data, analyze data and select research subjects.

Step 2: Apply industrial engineering tools such as a Man – Machine chart, Value stream map, analyze the status of research objects.

Step 3: Apply tools in DFSS to generate ideas, design new models, remove models that do not bring added value in the processing line according to the IDOV model.

Step 4: Measure user loyalty about the results

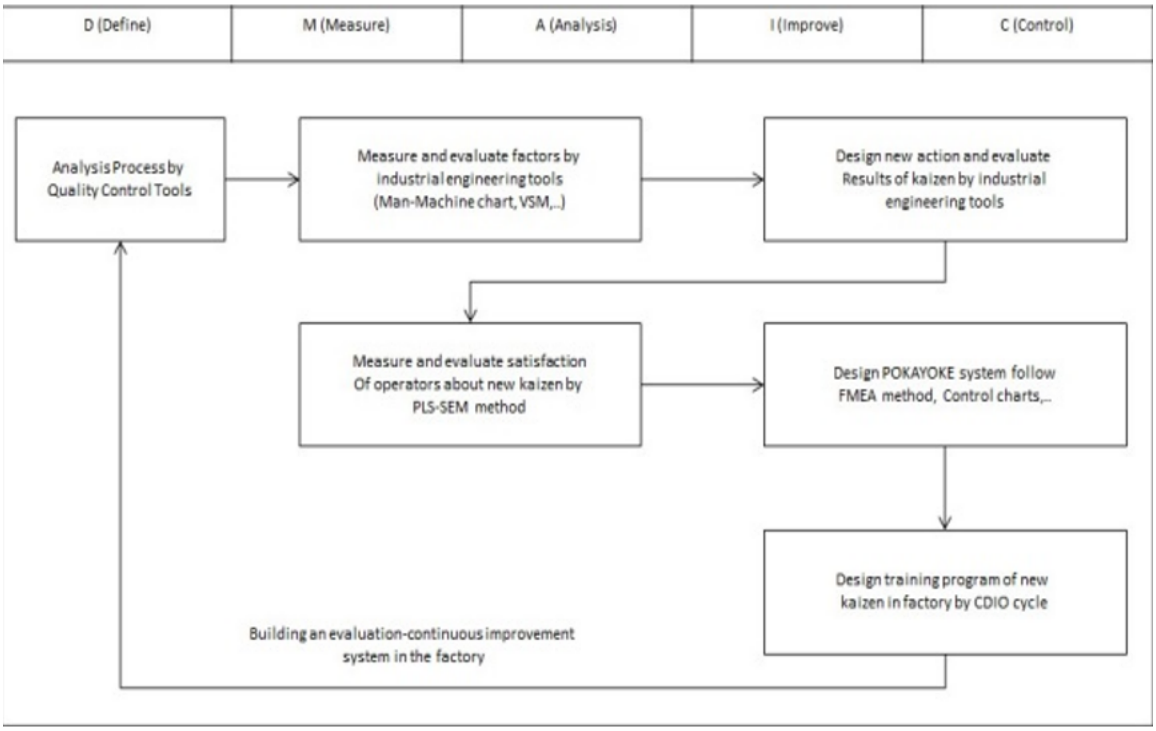

FIGURE 2. **Propose a model of research method**

of using actual improvement ideas at the machining line by measuring variables of satisfaction, technology, usefulness, and convenience. using the PLS – SEM model to analyze and determine the impact of factors on loyalty.

Step 5: Build an automatic control system for Kaizen ideas that are deployed and operated according to Poka-yoke operating criteria. Deploy user training programs according to CDIO standards for periodic training programs according to operating manual files. Step 1: Choose a research problem. At the precision mechanical factory. XYZ product category is made up of 5 mechanical parts: (1) Flange, (2) Sleeve, (3) Retainer, (4) Balls and (5) Seal as shown in Fig. 3.

The sleeve detail has an outside diameter according to the tolerance of 0/-0.013 and is ground on an automatic machine with a surface roughness of Ra0.8. Collecting the results of processing Sleeve products from April 2019 to March 2020 shows that the generated waste rate is 3,522 products, with an output of 1,802,000 products, accounting for 0.21% of waste products. When analyzing waste products according to each measurement size, the waste products in terms of outer diameter size (tolerance 0/-0.013) are negative, accounting for 41.6% (1464 products), detailing the percentage of defective products in Fig. 4.

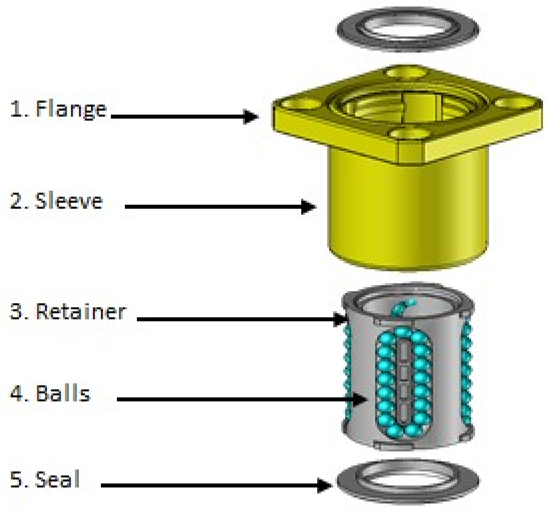

FIGURE 3. **Structure and types of products XYZ**

Step 2: Choose a research problem. The structure of the Centerless Outside Diameter Grinding machine includes a rotating guide stone (Feed wheel) that guides Workpiece interacts with the Grinding wheel for grinding outside diameter, shown in Fig. 5. Take a video of the machining of 100 products and use the Man-Machine diagram analyzed according to Table 8, and the results show that for every 12 products, the stone surface must be sanded once. Using histogram in Minitab 18.0 software to analyze the distribution domain and capacity

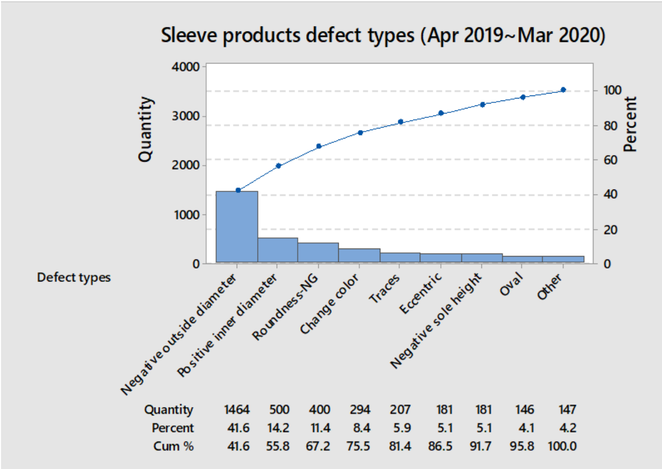

FIGURE 4. Sleeve product defect types of chart

index Cp, Cpk of the product outer diameter size, the result is that Cpk0.62 is smaller than Cpk1.33.

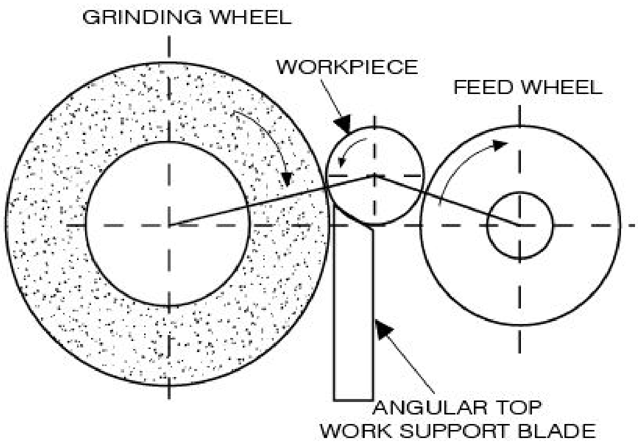

FIGURE 5. Structure of the Centerless Out side Diameter Grinding machine

Performed a grinding cycle to the 100th product and found that at the 13th product that an outside diameter size was generated that was out of specification and had to be re-sanded grinding wheel.

Check the outside diameter size data variation using the I-MR Chart, found that between the 13th products after sanding the rock surface is the trend of the data going out of the dimensional tolerance, shown in Fig. 7

The time spent for one time grinding the grinding wheel surface is 120 seconds. Failure to ensure the correct frequency of rock scraping will result in waste products. The roof operator must count and remember the quantity of each product. Depending on the human skill, the error of forgetting to count, wrong counting leads to the generation of

TABLE 8. Man – Machine chart

Step	Operations	Time (s)
1	Press the Start button	1
2	Perform grinding surface sanding	120
3	Grinding the 1st product	60
4	Take out the 1st product	5
5	Check outside diameter size	30
6	Grinding the 2nd product	60
7	Take out the 2nd product	5
8	Check outside diameter size	30
9	Grinding the 3rd product	60
10	Take out the 3rd product	5
11	Check outside diameter size	30
....	....	
35	Grinding the 13th product	60
36	Take out the 13th item	5
37	Check outside diameter size (Failed result)	30
38	Perform grinding surface sanding	120
....	Next grinding cycle	-

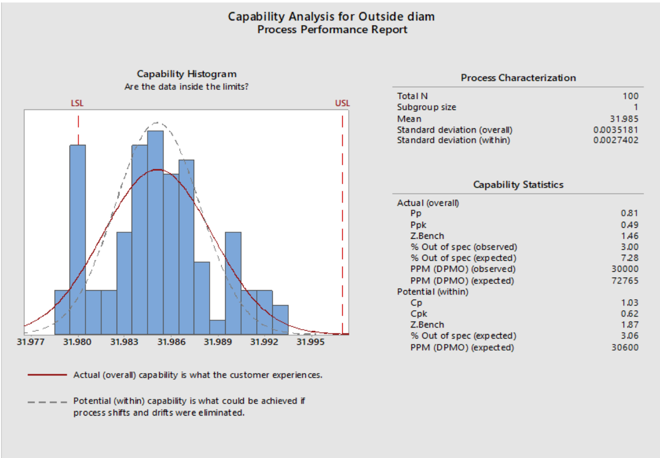

FIGURE 6. Histogramchart of Outside diameter dimension

waste products. The question is: (1) Automation of stone surface sanding will increase productivity, eliminating the need for manual sanding. (2) Eliminate human dependence on product counting when processing by personal memory.

Step 3: Design and implement the automatic model of surface sanding. Digital Numerical Control (DNC) applying the IDOV cycle in the DFSS method to determine the current state of stone sanding at the grinding machine, conceptualizing the design of an automation system operating by PLC

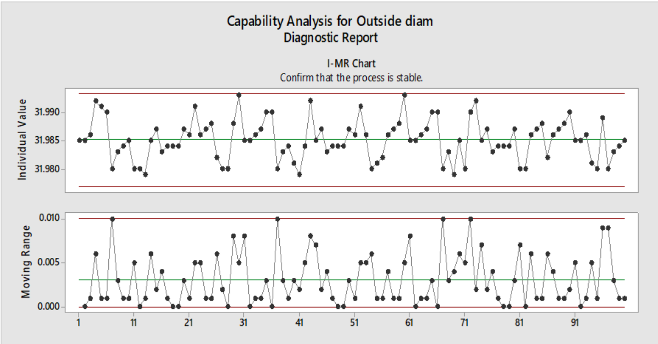

FIGURE 7. I-MR chart of Outside diameter dimension

program connecting the position sensor system to adjust the position in and out between the stone surface with the stone face sander. PLC program algorithm for automation system. Develop the idea of designing the system hardware, using PLC software to remember the number of times the grinding wheel moves to calculate the equivalent for each product surface grinding, shown at the number 1 mark; the position sensor will determine the distance between the grinding wheel surface and the product surface is shown at position 3, the servo motor replaces manual operation in the process of adjusting the travel distance between the grinding wheel and the product surface, showing at position 2, all shown in Fig. 9.

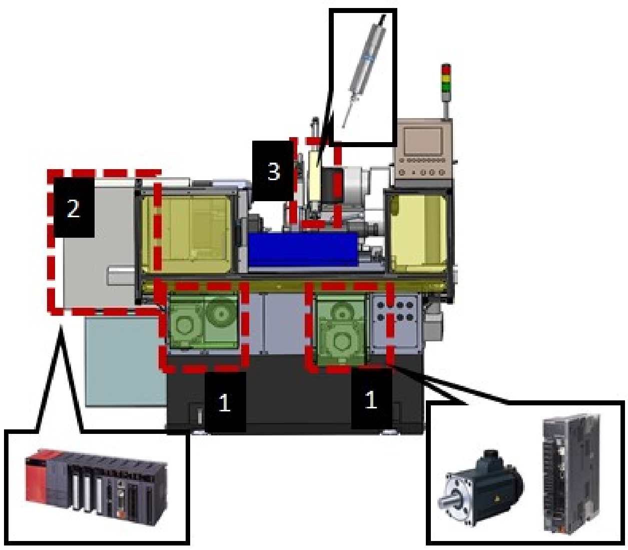

FIGURE 8. Improved structure of automatic stone sander

The automation system was implemented in 6 months with the number of employees 4. The tasks are divided by each member shown in Tab. 9. Finish the hardware, software and related parts and assemble them into the grinding machine and put it into operation at the machining line. Use video to record the operation between man and machine and use Man - Machine diagram to analyze and evaluate the operation of the new design board, the test results of the system after improvement show the stability of the system, the time for grinding wheel surface sanding cycle is reduced from 120 seconds per time to 60 seconds per time, equivalent to the cycle time of grinding stage reduced from 104.23 seconds to 99.62 seconds. The operation and product quality are improved, the variation in dimension values is low, stage capacity index is improved and reaches Cpk1.68, was shown in Fig. 9.

Step 4: Measuring operator loyalty using PLS – SEM algorithm. Make a vote and conduct a user survey with improved results on automation of grinding wheel sanding by combining motion and controlling by servo motor through PLC program. Sending 105 questionnaires to the group of machine operators in the line, maintenance technicians, technicians repairing machine tools and processing line managers, the results got 100 samples. The rate of monitoring reached 95.24%, shown in Tab. 10. The path model of the PLS – SEM algorithm is analyzed by smartPLS 3.0 software shown in Fig. 10.

TABLE 9. Jobs of Kaizen team

Employees	Operations	Software
1	Project Leader	-
2	Mechanical part design	Auto cad software
3	Electrical part design	PLC Program
4	Processing and manufacturing	CNC Machine

TABLE 10. Sample for surveying at processing line

Dept	Gender	Quantity	Percent (%)
Operators	Man	69	69
	Women	20	20
Maintenance	Man	4	4
Technique	Man	4	4
Supervisors	Man	3	3

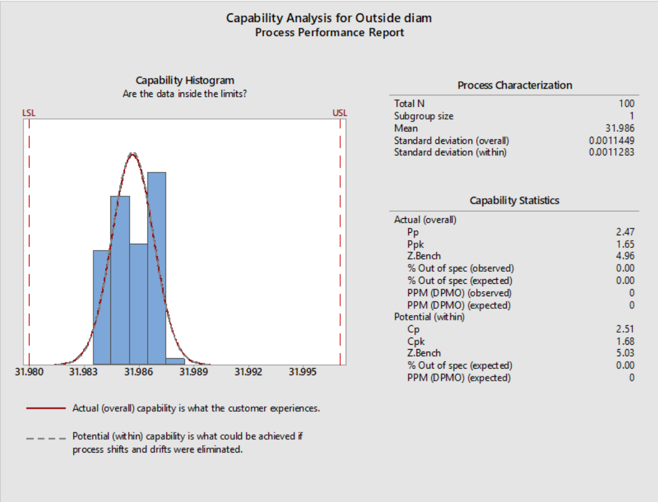

FIGURE 9. Histogram chart of Outside diameter dimension

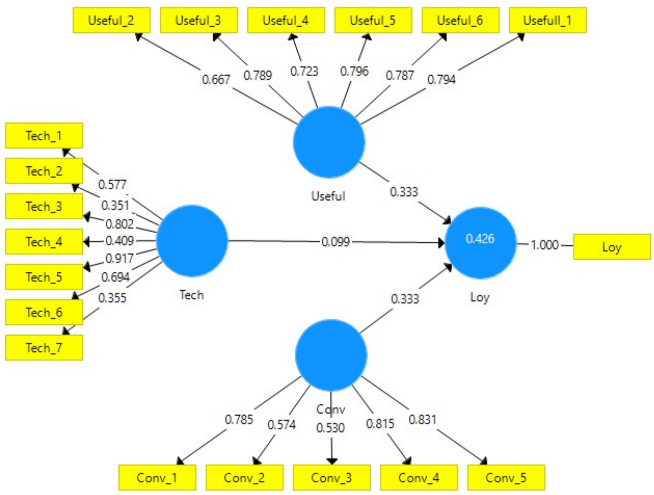

FIGURE 10. Path modelof the PLS - SEM algorithm

Hypothesis testing on the impact of factors in the indicators for the index of loyalty using the improved star device on users.. H1: Considering the impact of user satisfaction factors on improvement activities, survey six factors related to improvement activities, analyze the correlation between satisfaction and loyalty. with improvement activity. H2: Evaluation and validation of technical criteria of automatic improvement of automatic stone checking table through 7 factors, performing analysis of the correlation between technical requirements and loyalty using improved results. Advances related to placing technical properties. H3: Correlation of results of improvement activities in terms of convenience in use as well as ease of operation for users in terms of automation of grinding wheel cleaning versus user loyalty Using the results of improvement activities by five criteria.

Post-improvement product user evaluation is one of the new activities in the continuous improvement environment. This is a new point to promote and also a point to be replicated for other improvement activities and especially for employees of the improvement department. Increase awareness of improvement results and get user feedback on improvement. Then use smartPLS 3.0 software to analyze survey results; the results show that the improvement factor affecting loyalty (H1) has a strong correlation with the P value of 0.01, the factor of convenience. The advantage in using improved results of stone surface sanding table has a strong impact on loyalty (H2) using highly improved results with a P-value of 0.00. However, in terms of technical factors, the interaction on loyalty is unsatisfactory (H3) with a P-value of 0.54. This shows that from a technical point of view, the improvement team needs to re-evaluate and consider improving the improvement activities in technical terms for the next improvement activities; the content of the analysis is shown in Tab.11.

Step 5: Develop training program to operate the system after Kaizen according to CDIO training standards. Conceiving: Team Kaizen assessed the scene at the grinding machine stage and used the Man-Machine correlation chart to analyze the interaction relationship between the operator and the grinding machine operation, determining the problem that needs improvement. Design automation system for stone screening table. Designing: The innovation must meet the criteria of convenience, ease of use, safety and cheapness. Kaizen team designed the ideas and brainstormed each other's ideas to choose the best design idea to meet user requirements, improve user satisfaction in terms of convenience, technical design table optimization, convenience and portability. Implementing: In order for the design to be put into practice, the Kaizen team conducted a survey to collect opinions from operators at similar grinding machines in the factory, technical units and managers to collect ideas and perfect the design. Operating: Finally, the team completes the final improved concept design that fully meets the criteria from 1 to 4 in Table 4 and puts the idea into practice at the machining line.

TABLE 11. Path coefficient, T – value and P – value of PLS estimation

Path	Path coefficient	T-value	P-value
Useful -> loyalty	0.33	2.54	0.01
Convenience -> Loyalty	0.33	2.92	0.00
Technology -> Loyalty	0.10	0.61	0.54

CDIO (Conceiving - Designing - Implementing – Operating): In order for the Kaizen system to operate according to the operator's requirements, Team Kaizen has built a training program for system users after Kaizen showed in Tab.12, to help users understand the purpose of Kaizen. Beneficial to the company and simple to operate for the operator. Training users on the automation of the grating table as well as the operation of the grinding machine system according to CDIO standards. The post-Kaizen system operation training course for machining machine operators, machining line managers, workshop managers, and system maintenance personnel consists of 6 hours of theory and 24 hours of practice at machining machines.

TABLE 12. Kaizen training syllabus

Sources Content	Theory class hours	Practice class hour
Kaizen overview	1	0
Lean Six Sigma overview	1	0
Pokayoke theory	1	0
Work design overview	1	0
Basic electronic overview	1	0
Kaizen system overview	1	0
Kaizen system operation and practice maintenance	0	24

4. Result and Discussion

Evaluation of efficiency verification from improved automation of grinding wheel sanding in 2 months after Kaizen, which brings efficiency by reducing waste on the stage, improving productivity as shown in Tab. 13 and increase operator loyalty to the machine. with Kaizen activities in the organization of mechanical processing factories.

TABLE 13. Result after Kaizen action

Contents	Reduces ratios	Reduce ($)/years
Person	-2	+10,224
Defect	- 85.6%	+960
Productivity(pcs/h/man)	Before: 15 After: 30	

Automating the stone scanning operation at the grinding machine, the operator has spare time and enough time to operate the remaining machine at the machining area. After analyzing the time according to the Man-Machine diagram and calculating that the staff has enough time to operate the 2 machines, the type according to the current layout. The results show that before Kaizen, 2 people operate 3 machines, after Kaizen, 1 person operates 3 machines, see Fig. 11 and profit is 10,224$ per year in terms of labor costs. Product quality is stable and reduced from 31.2% to 4.5%, 85.6% reduction in profit is $960 per year and machining productivity at post-Kaizen grinder increases from 15 to 30 pcs per hour per person, see Tab. 9.

The grinding machine after Kaizen from semi-automatic is completed by connecting the servo motor and the PLC program, the system has been put into operation, as shown in Fig. 12.

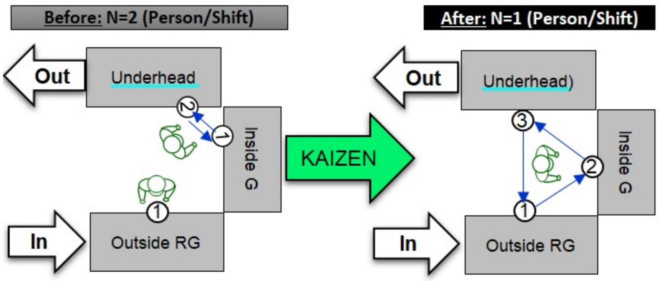

FIGURE 11. Layout before-after Kaizen

5. Conclusion

Kaizen activity delivers visible results with real-world improvements on automated machining machines, such as this case study on improved operations in a precision machining plant. Innovation brings the change from semi-automatic to automatic operation, eliminating wasteful operations such as stopping the grinder and sanding the stone surface that takes up to 120 seconds at a time. However, when automation is improved, the time is reduced

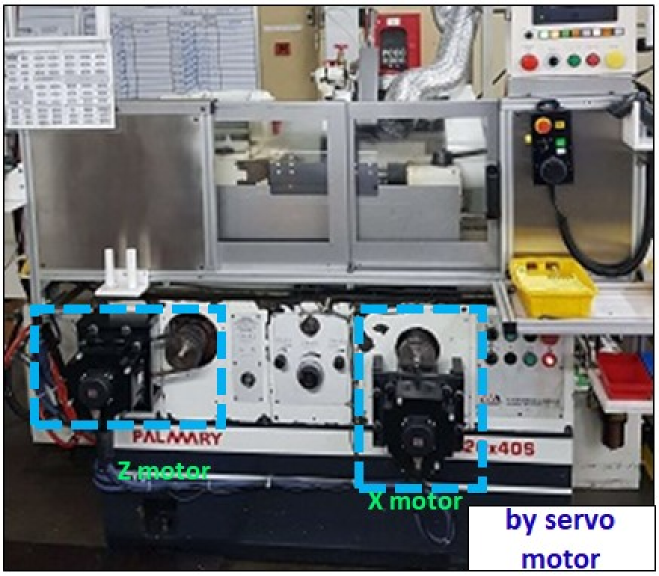

FIGURE 12. **Actual automatic machine after Kaizen**

by 50% compared to before the improvement, and the machine works continuously and non-stop; the operator has more time to operate an additional processing machine next to it. Earnings from reduced labours costs are $10,244 per year from improvement activities. In addition, the application of the PLS – SEM method to investigate the operator's satisfaction with improvement activities and perfect the training methods to meet CDIO standards contributes to improving customer satisfaction and satisfaction. The loyalty of machine operators at the machining plant is high and reduces job abandonment.

However, scrap products still arise at the rate of 4.5%, and there is no product quality control system at the processing line, no system to check for defects in the appearance of surface roughness of the products after processing according to the standards max Ra0.8, at the same time, the control of WIP goods at the stage is still open. From the limitations of the study, we propose future research directions in 3 directions about data, target and IOT connection (Internet of things), as shown in Fig. 13.

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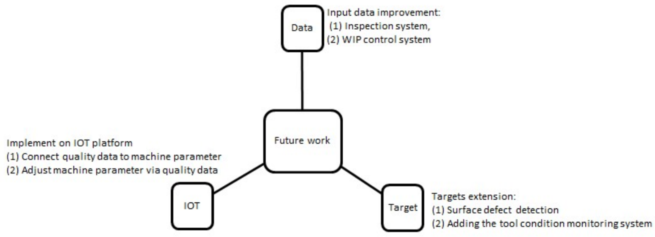

FIGURE 13. **Future work**

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