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Improving The Availability Of Automatic Surface Grinding Machines Through A3 Problem Solving, SMED, And Spare Part Control In The Manufacturing Industry

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Abstract

Machine availability is a critical indicator for assessing production asset readiness. This study aims to improve the availability of an automatic surface grinding machine in a tooling area of an electronic component manufacturing company using the A3 problem-solving approach. Machine Operation Data from April-June 2024 showed an initial availability of 34.3%, with an average actual running time of 18,287 minutes against an average planned production time of 53,238 minutes. Breakdown analysis identified two dominant losses: stop waiting operator at 15,135 minutes and stop waiting spare part at 7,680 minutes, contributing 22,815 minutes (93.6%-94.0%) of the total breakdown time. This research employed a descriptive quantitative case study through problem clarification, problem breakdown, target setting, root cause analysis, countermeasure development, implementation, and result monitoring. The main countermeasures included allocating supporting manpower during early-shift setup, reviewing process planning, preparing Single Minute Exchange of Dies (SMED) implementation, coordinating machine component improvement, and establishing a spare part list with minimum stock control. The monitoring result showed that the average availability during September-November 2024 reached 58.7%, an improvement of 24.4 percentage points from the baseline. Stop waiting operator decreased to an average of 4,490 minutes and stop waiting spare part decreased to 0 minutes in the after period. The findings indicate that A3 problem solving combined with changeover and spare part control can significantly improve machine readiness. This study contributes to data-driven continuous improvement practices for enhancing manufacturing equipment performance.

Keywords: ***A3 Problem Solving; Availability; Breakdown Time; SMED; Spare Part; Continuous Improvement.***

INTRODUCTION

The manufacturing industry is increasingly required to maintain production process stability, reduce waiting time, and ensure that every production asset is available when needed. Machine availability is not only related to the technical capability of equipment but is also influenced by operator readiness, supporting material availability, process planning, and maintenance systems. In production environments with high product variation, machines often experience significant downtime due to set-up processes, changeovers, and waiting for personnel or spare parts. This condition results in actual capacity being lower than the planned capacity.

Availability is one of the key indicators in equipment performance management. This indicator represents the proportion of planned production time that is actually utilized by machines for operation. A low availability value indicates time losses in the form of breakdowns, waiting, or other non-productive activities. In the context of lean manufacturing and total productive maintenance, improving availability is a fundamental step toward enhancing Overall Equipment Effectiveness (OEE), as machines cannot produce stable output if operating time is not consistently available.

The problem examined in this study originates from operational data of an automatic surface grinding machine used in the tooling area. This machine plays a strategic role in supporting sharpening and finishing processes of components. Based on Machine Operation Data from April to June 2024, the machine's availability was only 34.3%. This value indicates that a large portion of planned production time has not been successfully converted into actual operating time. This condition impacts area productivity, creates potential process delays, and increases operator workload when production schedules must be recovered.

Preliminary data also indicate that the average planned running time reached 42,652 minutes, while the actual running time was only 18,287 minutes. Thus, there is a significant time gap in the form of breakdown time, totaling 24,365 minutes. Further analysis reveals that breakdown time is not dominated solely by mechanical failures but largely by waiting activities, particularly waiting for operators and spare parts. Stop waiting for operators was recorded at 15,135 minutes, while stop waiting for spare parts reached 7,680 minutes. Combined, these account for 22,815 minutes, or approximately 93.6%–94.0% of the total breakdown time.

These issues indicate that improving availability cannot be achieved solely through isolated technical machine improvements. A structured approach is required to integrate operational data, root cause analysis, countermeasures, implementation, and performance monitoring. A3 problem solving is selected as it guides teams to clearly define problems, break down dominant losses, set measurable targets, analyze root causes, design improvement actions, and continuously monitor outcomes. This approach is suitable for shop floor improvements as it is easy to communicate, fact-based, and promotes cross-functional collaboration.

This study has practical urgency, as many manufacturing companies face similar issues where machines are physically available but not optimally ready for use due to waiting for operators, spare parts, or non-standardized set-up activities. In addition, this study contributes academically by presenting the application of A3 problem solving combined with Single Minute Exchange of Dies (SMED), spare part control, and manpower management in addressing machine availability issues. The focus of this research is not only to measure machine performance but also to demonstrate how loss data can be translated into actionable operational improvements.

Based on this background, the research problem is how to improve the availability of an automatic surface grinding machine by reducing stop waiting for operators and stop waiting for spare parts. The objectives of this study are to analyze the initial availability condition, identify dominant losses and their root causes, develop relevant countermeasures, and evaluate performance changes after implementation. The results of this study are expected to serve as a practical reference for manufacturing companies in developing continuous improvement programs based on A3 reports and Machine Operation Data.

Literature Review

Availability and Equipment Performance

Availability is an indicator that describes a machine's capability to operate during the planned production time. Within the Overall Equipment Effectiveness (OEE) framework, availability is generally influenced by both planned and unplanned downtime. Machines with low availability may lead to decreased actual output, even when product quality and processing speed remain relatively optimal. Therefore, analyzing availability is essential to determine whether productivity issues stem from machine unpreparedness, set-up delays, operator-related interruptions, or limitations in the maintenance system.

In this study, availability is calculated as the ratio between actual running time and planned production time. This formula is used because the available operational data have clearly distinguished total time, planned used time, planned production time, effective production time, planned running time, and actual running time. With this approach, the availability value reflects the extent to which production time is effectively converted into machine operation. The initial availability value of 34.3% indicates a significant gap between planned production and actual machine operation.

Measuring availability is not sufficient if it only produces a percentage value. The figure must be broken down into loss components to enable effective corrective actions. If the dominant loss originates from waiting for operators, then countermeasures should focus on manpower allocation, set-up time reduction, or adjustments in work patterns. If the dominant loss is related to spare parts, then countermeasures should target inventory systems, minimum stock levels, spare part standardization, and maintenance coordination. Thus, availability functions not only as a diagnostic indicator but also as an evaluation metric for improvement efforts.

A3 Problem Solving as an Improvement Framework

A3 problem solving is a structured approach widely used in lean practices. It is referred to as A3 because the analysis is typically summarized on a single A3-sized sheet, allowing the entire problem-solving flow to be viewed comprehensively. An A3 report generally includes background, current conditions, targets, root cause analysis, countermeasures, implementation plans, results, and standardization. The strength of A3 lies in its systematic thinking process rather than the paper size itself.

In manufacturing contexts, A3 helps teams avoid reactive improvement actions. Teams are required to present data before taking action, identify dominant losses, and investigate root causes using tools such as why-why analysis or fishbone diagrams. After implementing countermeasures, the results must be monitored using the same indicators as the initial condition. This approach reinforces the Plan-Do-Check-Act (PDCA) cycle and prevents improvements from stopping at the idea stage.

A3 is particularly relevant to availability issues, as machine downtime often results from a combination of factors, including human, method, machine, material, and environmental aspects. Without a structured framework, teams tend to attribute problems solely to machines or operators. Through A3, causes can be categorized more objectively—for example, whether operators are waiting due to insufficient manpower, excessive changeover processes, inadequate production planning, or declining machine accuracy.

SMED and Changeover Time Reduction

Single Minute Exchange of Dies (SMED) is a method aimed at reducing model change, set-up, or changeover time by distinguishing between internal and external activities. Internal activities are those that can only be performed when the machine is stopped, while external activities can be prepared while the machine is still running. The SMED principle encourages teams to convert as many internal activities as possible into external ones, simplify tasks, prepare supporting tools, and establish standardized work sequences.

In the case of the automatic surface grinding machine, the running time for certain parts is relatively short, and process variation is high. This condition requires operators to frequently perform adjustments, while a single operator may be responsible for multiple machines. If changeover processes are not standardized, machines that have completed operations will wait for operators who are still performing set-ups on other machines. Therefore, SMED not only reduces set-up time but also minimizes operator waiting time caused by workload imbalance.

In this study, SMED implementation is still at the preparation and process evaluation stage. However, its principles have been applied to identify the root causes of high operator waiting time. Reviewing process planning and classifying tasks based on process type and running time are prerequisites for effective changeover management. Through this classification, processes that have the potential to cause waiting can be scheduled more evenly, and set-up activities can be prepared before the machine stops.

Spare Part Control and CMMS

Spare part availability is a critical factor in equipment maintenance. Machines may experience prolonged downtime not due to complex failures, but because spare parts are unavailable and must be ordered. This condition indicates a gap between technical machine requirements and inventory control systems. For critical machines, spare part lists, usage history, procurement lead time, and minimum stock levels must be defined to ensure that procurement decisions are not based solely on assumptions.

Effective spare part control should consider component characteristics, machine age, failure frequency, production impact, and supplier lead time. Older machines generally have a higher risk of accuracy degradation and component wear. Without proper spare part control, minor issues can escalate into significant downtime. Therefore, establishing part lists and minimum stock levels is a crucial initial step before implementing computerized systems such as a Computerized Maintenance Management System (CMMS).

In this study, stop waiting for spare parts represents the second largest loss during the initial period. The root cause is not only the unavailability of spare parts but also the absence of machine-specific spare part lists, lack of minimum stock levels, and the absence of a control system. Countermeasures are directed toward developing spare part lists, establishing minimum stock levels, and planning for computerized control systems. These steps are essential to ensure that technical improvements can be executed without delays caused by unplanned procurement.

RESEARCH METHODS

Research Design

This study employs a descriptive quantitative case study design with a simple action research approach. It is classified as a case study because the research object focuses on a single automatic surface grinding machine in the tooling area of a manufacturing company. It is considered descriptive quantitative because the primary analysis utilizes machine operation time data measured in minutes and availability percentages. The action research element is reflected in the implementation of improvement interventions through countermeasures developed based on root cause analysis.

The data used in this study consist of Machine Operation Data from April to November 2024. The period of April–June 2024 is treated as the initial condition or baseline. July–August 2024 is considered a transition period before stable results are achieved, while September–November 2024 is categorized as the after period, during which several countermeasures have been implemented and their effects can be observed. This period classification is important to ensure that evaluation is not based on a single month, but rather on averaged performance after implementation.

The company identity in this study is intentionally anonymized to maintain industrial data confidentiality. All organizational names, personnel names, and internal document numbers are omitted. The research object is referred to only as a manufacturing company producing electronic components and an automatic surface grinding machine. This approach does not affect the substance of the analysis, as the research focuses on loss patterns, root causes, and the effectiveness of countermeasures rather than organizational identity.

Object, Variables, and Data Sources

The research object is an automatic surface grinding machine used to support tooling processes. This machine was selected due to its low initial availability and its contribution to supporting production flow. The main variables in this study include availability, planned production time, actual running time, planned running time, planned downtime, breakdown time, stop waiting for operators, and stop waiting for spare parts.

The data source is derived from Machine Operation Data records, which categorize machine time into running time, unused time, non-order or no planning, yearly maintenance, external stops, planned downtime, and breakdown time. These data are then summarized to obtain baseline averages. In addition to quantitative data, this study also incorporates brainstorming results from personnel familiar with machine operations to construct fishbone diagrams and why-why analysis. These qualitative insights are used to translate dominant losses into actionable root causes.

Formulas and Analysis Stages

Availability is calculated using the following formula:

$$\text{Availability} = \frac{\text{Actual Running Time}}{\text{Planned Production Time}} \times 100\%$$

At baseline, the average actual running time is 18,287 minutes, while the average planned production time is 53,238 minutes. Thus, availability is calculated as 18,287 / 53,238 × 100% = 34.3%. Breakdown time is calculated as the difference between planned running time and actual running time, which is 42,652 minutes − 18,287 minutes = 24,365 minutes. Planned downtime is calculated as the difference between effective production time and planned running time, which is 53,107 minutes − 42,652 minutes = 10,455 minutes.

The analysis follows the A3 problem-solving framework: (1) clarify the problem to describe the initial availability condition; (2) break down the problem to identify loss components and dominant factors; (3) set targets to determine measurable improvement goals; (4) analyze root causes using fishbone diagrams and why-why analysis; (5) develop countermeasures to design corrective actions; (6) implement countermeasures through an action plan; (7) monitor results and processes to evaluate improvements; and (8) standardize and share success to extend learning to other machines.

The initial improvement target is set by reducing the two dominant losses by 20%. Stop waiting for operators is targeted to decrease from 15,135 minutes to 12,108 minutes, while stop waiting for spare parts is targeted to decrease from 7,680 minutes to 6,144 minutes. If both targets are achieved, total breakdown time is projected to decrease from 24,365 minutes to 19,802 minutes, representing approximately a 19% reduction. This target is considered realistic, as it focuses on gradual improvement rather than eliminating all losses at once.

RESULTS AND DISCUSSION

Initial Condition of Machine Availability

The initial condition indicates a significant gap between planned production time and actual operating time. The average planned production time during April–June 2024 was 53,238 minutes, while the actual running time was only 18,287 minutes. This gap reflects that a substantial portion of available machine time has not been utilized effectively. The availability value of 34.3% indicates that only about one-third of planned production time is converted into actual machine operation.

Table 1 presents a summary of operational data for the initial period. The data show that the average planned running time of 42,652 minutes is still significantly higher than the actual running time. This implies that although machine operation time has been planned, execution on the shop floor is still constrained by downtime and waiting activities. During the same period, the average planned downtime of 10,455 minutes should also be considered; however, improvement efforts are prioritized on breakdown time due to its more significant contribution to low availability.

Table 1. Summary of Machine Operation Data for April–June 2024 (minutes)

Item	Apr 2024	May 2024	Jun 2024	Average
Total time	428.970	399.310	262.535	363.605
Planned used time	418.230	393.335	255.765	355.777
Planned production time	49.785	51.310	58.620	53.238
Potential production time	49.635	51.310	58.620	53.188
Effective production time	49.390	51.310	58.620	53.107
Planned running time	43.110	40.040	44.805	42.652
Actual running time	10.465	21.430	22.965	18.287

Based on Table 1, the availability value is calculated by comparing the average actual running time of 18,287 minutes with the average planned production time of 53,238 minutes. This calculation results in an availability of 34.3%. These data provide a strong baseline for improvement, as the problem has been clearly quantified. Without such measurement, improving availability would be difficult to direct due to the absence of an objective indicator of the performance gap.

Problem Breakdown and Pareto Analysis

The problem breakdown stage is conducted to identify the most dominant loss components. Initial data indicate that the average breakdown time reaches 24,365 minutes. When this breakdown time is further analyzed, the two largest categories are stop waiting for operators and stop waiting for spare parts. Stop waiting for operators accounts for 15,135 minutes or 62.1% of total breakdown time. Meanwhile, stop waiting for spare parts accounts for 7,680 minutes or 31.5%. Cumulatively, these two losses contribute approximately 93.6%–94.0% of total breakdown time.

These findings demonstrate a strong Pareto principle. Most availability issues are not evenly distributed across multiple causes but are concentrated in two primary categories. Therefore, the improvement team does not need to address all losses simultaneously. Focusing on operator waiting and spare part waiting will provide the greatest impact on availability improvement. Table 2 and Figure 1 illustrate the composition of breakdown time during the initial period.

Table 2. Breakdown Time Composition (Initial Period)

Breakdown Category	Time (minutes)	Contribution	Cumulative
Stop waiting operator	15135	62,1%	62,1%
Stop waiting spare part	7680	31,5%	93,6%
Stop waiting adjustment	1220	5,0%	98,6%
Stop waiting work piece	240	1,0%	99,6%
Stop waiting instruction superior	63	0,3%	99,9%
Stop adjustment	20	0,1%	100,0%
Stop waiting inspection by tool maker	7	0,0%	100,0%
Stop inspection after adjustment	0	0,0%	100,0%

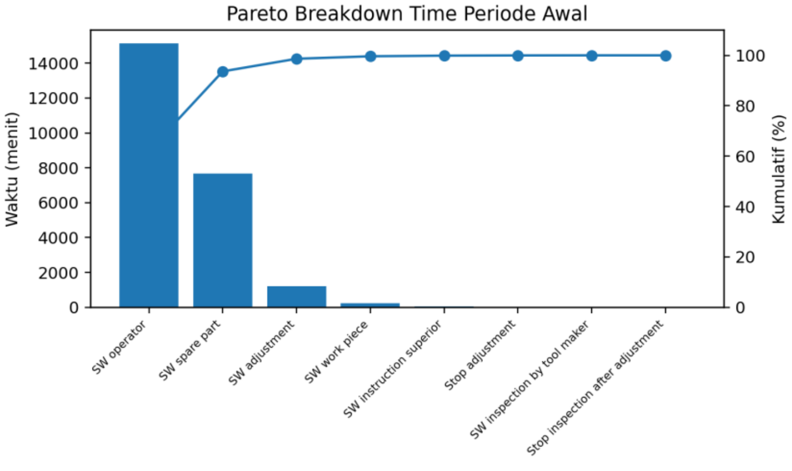

Figure 1. Pareto Diagram of Breakdown Time (Initial Period)

The Pareto diagram reinforces improvement priorities. Stop waiting for operators ranks first and therefore needs to be analyzed from perspectives such as work methods, operator allocation, process variation, and changeover activities. Stop waiting for spare parts ranks second and should be analyzed in terms of spare part control systems, minimum stock levels, and readiness of critical components. By focusing countermeasures on these two losses, the potential improvement in availability becomes significantly greater compared to addressing all losses simultaneously.

Improvement Target Setting

The improvement target is set by reducing the two dominant losses by 20%. This target is chosen as it is realistic for the initial phase and aligned with continuous improvement principles. Targets that are too ambitious may hinder implementation consistency, while targets that are too low may not produce meaningful changes. With a 20% reduction target, stop waiting for operators is expected to decrease from 15,135 minutes to 12,108 minutes, while stop waiting for spare parts is expected to decrease from 7,680 minutes to 6,144 minutes.

If both targets are achieved, total breakdown time is projected to decrease from 24,365 minutes to 19,802 minutes, representing a reduction of 4,563 minutes or approximately 19%. This target also serves as a benchmark to evaluate whether the implemented countermeasures have produced tangible improvements. However, monitoring results in the after period indicate that actual performance has exceeded the initial targets, particularly in reducing both stop waiting for operators and stop waiting for spare parts.

Table 3. Target Reduction of Two Dominant Losses

Dominant Loss	Initial Condition (minutes)	20% Reduction Target (minutes)	Expected Reduction
Stop waiting operator	15,135	12,108	3,027 minutes
Stop waiting spare part	7,680	6,144	1,536 minutes
Total breakdown time	24,365	19,802	4,563 minutes

Root Cause Analysis

Root cause analysis was conducted by combining fishbone diagrams and why-why analysis. For stop waiting operator, the main causes were identified across several aspects. First, tasks at the beginning of the shift were performed sequentially across multiple machines, causing machines that had not yet been served to wait. Second, there were frequent changeover activities due to variations in orders, products, and process types. Third, the running time of several parts was relatively short, causing machines to finish quickly and then wait again for operators who were still performing set-up on other machines. Fourth, there was no classification of work based on process and running time, resulting in scheduling that did not consider the potential for waiting.

Another contributing factor to stop waiting operator was the absence of a specific method to reduce changeover or model change time. This condition is directly related to the need for SMED implementation. In addition, variations in machine capability and accuracy due to component degradation also caused work to accumulate on certain machines. Machines that have been in operation for more than 20 years require special attention, as changes in accuracy can increase adjustment activities and prolong waiting time.

For stop waiting spare part, the main root cause was the unavailability of spare parts when needed, requiring prior ordering. This issue arose because there was no spare part list for each machine, no spare part control system, and no defined minimum stock level. Team discussions also revealed an assumption that spare parts had not previously been a significant issue. This assumption resulted in spare part control not being prioritized until data showed that waiting spare parts contributed 31.5% of total breakdown time.

Table 4 summarizes the relationship between problems, root causes, and the direction of countermeasures. This presentation is important to ensure that improvement actions are not isolated but can be traced back to the loss data and identified causes. Thus, each action plan has a clear rationale and can be evaluated using relevant indicators.

Table 4. Summary of Root Causes and Improvement Directions

Problem	Root Cause	Explanation	Countermeasure
Stop waiting operator	Initial set-up performed sequentially across machines	One operator handles multiple machines; others wait during set-up	Add manpower support from manual grinding area during initial shift set-up
Stop waiting operator	High changeover frequency and process variation	Different orders and processes; short running time; no process classification	Review planning, classify work by process and running time, prepare SMED
Stop waiting operator	Changeover time not reduced systematically	No separation between internal and external set-up	Apply SMED principles for model or process changes
Stop waiting operator	Work accumulates on certain machines	Machine capability and accuracy vary due to component aging	Follow up with vendors for repair or replacement of critical components

Problem	Root Cause	Explanation	Countermeasure
Stop waiting spare part	Spare parts unavailable when needed	No part list per machine and no minimum stock	Develop spare part lists, define minimum stock, implement system-based control

Countermeasure Development

The first countermeasure is the allocation of manpower from the manual grinding area to assist machine set-up at the beginning of the shift. The initial condition shows that one operator can only perform set-up on one machine while others must wait. With additional manpower, set-up can be performed more in parallel, thereby reducing operator waiting. This countermeasure is relatively quick to implement, as it does not require significant investment and directly targets the primary cause.

The second countermeasure is a review of process planning for part production. This review aims to group tasks based on process type, running time, and changeover potential. Parts with short running times need to be scheduled carefully to avoid repeated waiting on other machines. Planning review also helps balance operator workload and minimize situations where multiple machines stop simultaneously for set-up.

The third countermeasure is the preparation for SMED implementation for model or process changes. In the short term, this involves identifying internal and external set-up activities. In the medium term, external activities can be prepared before machine stoppage, tools can be positioned closer to the work area, and work sequences can be standardized. Although full SMED implementation requires time, its preparation can already reduce waiting as teams begin to view changeover as a process that can be redesigned.

The fourth countermeasure is vendor follow-up for machine component repair or replacement. Root cause analysis indicates that some machines experience differences in accuracy and capability due to component degradation. This action is essential to prevent workload concentration on specific machines and to reduce adjustment time. Technical countermeasures such as this must be implemented alongside work management improvements to ensure more stable availability performance.

The fifth countermeasure is the development of spare part lists, determination of minimum stock levels, and planning for computerized spare part control. This step is designed to eliminate waiting caused by spare part unavailability. The part list helps identify critical components for each machine, while minimum stock levels define inventory thresholds. Computerization or the use of a CMMS can be implemented in the next stage to record usage history, lead time, and procurement requirements.

Table 5. Countermeasure Implementation Plan

No.	Action Plan	Target	Timeline	Objective
1	Assign additional manpower during machine setup from manual grinding operators	5 machines	September 2024	Reduce operator waiting time at the beginning of shifts
2	Review process planning based on process flow and running time	5 machines	September 2024	Prevent overlap between setup and changeover requirements
3	Prepare the implementation of SMED for model or process changes	5 machines	September 2024 – March 2025	Reduce changeover time
4	Follow up with vendors for machine component replacement or repair	2 machines	October 2024 – March 2025	Maintain machine accuracy and readiness
5	Develop a spare parts list, minimum stock levels, and systematic control planning	Form sheets and	September 2024 – March 2025	Reduce waiting time for spare parts

No.	Action Plan	Target	Timeline	Objective
		spare parts data		

Monitoring of Improvement Results

Monitoring was conducted by comparing availability and dominant losses from April to November 2024. The data indicate that availability improved after the implementation of countermeasures. During the baseline period (April–June), the average availability was 34.3%. In contrast, during the post-implementation period (September–November), the average availability increased to 58.7%, representing an improvement of 24.4 percentage points. Relatively, the post-implementation availability was approximately 71% higher than the initial condition.

Figure 2 illustrates the monthly changes in availability. Availability was 21% in April, increased to 42% in May, and slightly decreased to 38% in June. The transition period (July–August) showed values of 40% and 50%, respectively. After the countermeasures became more effective, availability reached 60% in September, 55% in October, and 61% in November. Despite some fluctuations, the post-implementation trend shows significantly higher availability compared to the baseline.

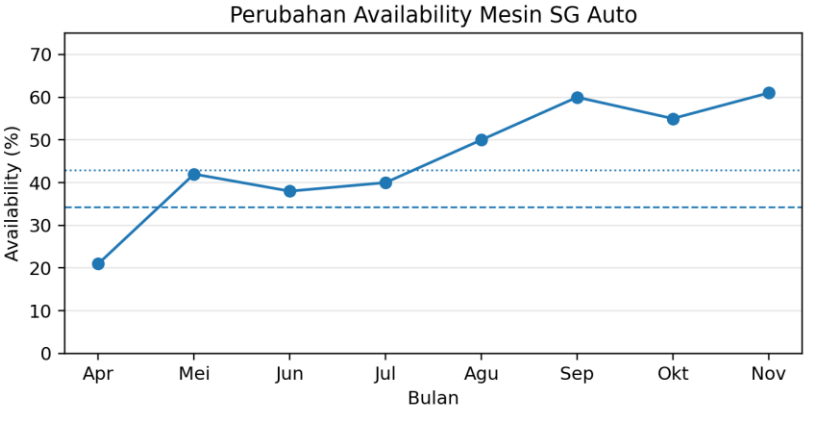

Figure 2. Machine Availability Trend for the Period April–November 2024

The improvement in availability is associated with the reduction of two dominant losses. Operator waiting time, which averaged 15,135 minutes during the baseline period, decreased to an average of 4,490 minutes during September–November. This reduction exceeded the target of 12,108 minutes. Meanwhile, spare part waiting time, which averaged 7,680 minutes during the baseline period, decreased to 0 minutes in the post-implementation period. These results indicate that manpower allocation and spare parts control countermeasures had a direct impact on the dominant downtime losses.

Figure 3 presents a monthly comparison of operator waiting time and spare part waiting time. Operator waiting time was relatively high in June and July but decreased sharply starting in August and continued to decline during September–November. Spare part waiting time was very high in April but almost disappeared in subsequent months, except for a minor value recorded in July. These findings suggest that improvements in spare parts management were reflected more quickly, whereas operator waiting time required more consistent workforce arrangement.

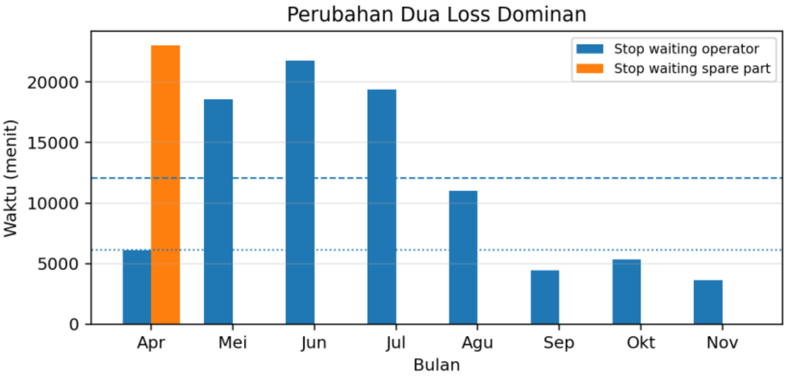

Figure 3. Trend of the Two Dominant Losses for the Period April–November 2024

Table 6. Monthly Performance Monitoring Data (minutes and percentage)

Month	**Availability**	**Running**	**Planned downtime**	**Breakdown time**	**SW operator**	**SW spare part**
Apr	21%	10.345	6.280	32.645	6.125	23.040
May	42%	21.215	11.270	18.610	18.555	0
Jun	38%	22.425	13.170	23.065	21.755	0
Jul	40%	31.875	17.690	31.080	19.385	30
Aug	50%	31.120	16.190	14.795	11.035	0
Sep	60%	30.165	14.210	6.290	4.450	0
Oct	55%	29.715	16.815	7.900	5.365	0
Nov	61%	20.455	8.940	4.105	3.655	0

In addition to the two dominant losses, total breakdown time also experienced a significant reduction. The average breakdown time during the baseline period was 24,365 minutes, whereas during September–November it decreased to 6,098 minutes, representing a reduction of approximately 18,267 minutes or 75.0%. This reduction, which exceeded the initial target, indicates that several countermeasures had a synergistic effect. For example, manpower reallocation not only reduced operator waiting time but also improved setup efficiency, thereby reducing other types of losses.

Figure 4 summarizes the before-and-after comparison. Availability increased from 34.3% to 58.7%, operator waiting time decreased from 15,135 minutes to 4,490 minutes, spare part waiting time decreased from 7,680 minutes to 0 minutes, and breakdown time decreased from 24,365 minutes to 6,098 minutes. These results demonstrate that the implemented countermeasures effectively addressed the key sources of loss

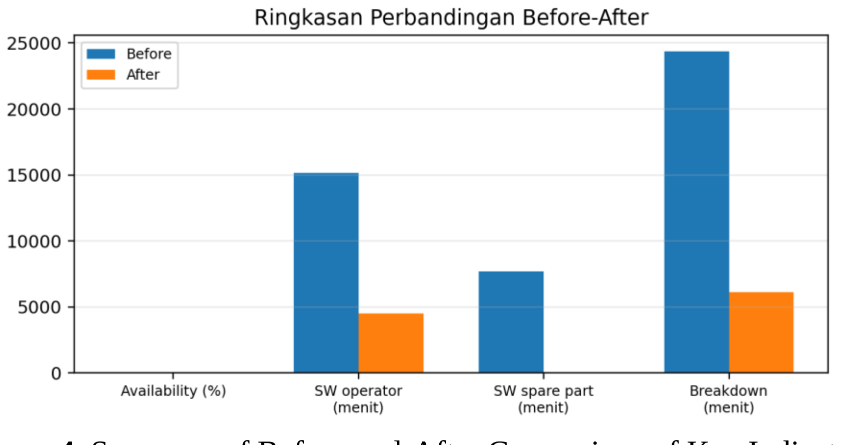

Figure 4. Summary of Before-and-After Comparison of Key Indicators

Discussion on the Effectiveness of Countermeasures

The effectiveness of countermeasures can be explained through the relationship between root causes and the actions implemented. Waiting operator issues occur due to sequential set-up processes across multiple machines, short running times, and high changeover variability. When additional manpower is allocated at the beginning of the shift, several set-up activities can be performed more quickly and are no longer entirely dependent on a single operator. The impact is reflected in the reduction of operator waiting time starting in September.

Planning review also plays a crucial role, as waiting operator issues arise not only from the number of operators but also from work patterns. If parts with short running times or varying processes are scheduled without considering set-up workload, machines may stop simultaneously and wait for operators. Through planning review, job sequences can be arranged to prevent the accumulation of set-up requirements at the same time. This aligns with lean principles that emphasize process flow and the reduction of waiting time.

The preparation of SMED provides a more systematic direction for improving changeover processes. Although this study does not yet present detailed measurements of internal and external activities, the introduction of SMED encourages the team to evaluate set-up practices. Activities previously considered routine are now viewed as processes that can be separated, shortened, and standardized. In the long term, full implementation of SMED will help sustain improvements without relying solely on additional manpower.

The reduction of waiting spare parts to 0 minutes in the after period indicates that spare part control measures are highly effective in this case. However, this result must be interpreted cautiously. A value of 0 over three months does not mean that the risk of spare part shortages has been completely eliminated. Such risks may reappear if spare part lists, minimum stock levels, and usage records are not properly maintained. Therefore, the standardization of part lists and the development of a CMMS are essential to sustain improvements.

Vendor follow-up for machine components serves as both a preventive and corrective countermeasure. Machines that have been in operation for more than 20 years are likely to experience functional degradation in certain components. When machine accuracy varies, operators tend to prefer machines perceived as more stable or requiring fewer adjustments. As a result, workloads may accumulate on specific machines. Component improvements help balance machine capabilities and reduce process variability that triggers waiting.

Overall, the results indicate that improvements in availability do not stem from a single action. Instead, improvements arise from a combination of manpower allocation, process planning, changeover reduction, machine condition improvement, and spare part control. This combination reflects the multidimensional nature of availability issues. A3 data helps the team identify the primary focus first, followed by designing complementary actions.

Managerial Implications

The first managerial implication is the importance of managing availability using detailed loss data. If management only observes low availability without examining breakdown categories, improvement decisions may be misguided. In this case, actions focused solely on machine repair may not directly resolve operator waiting issues. Conversely, increasing the number of operators without improving planning and spare part management may also be unsustainable. Therefore, loss data should form the basis for prioritizing improvements.

The second implication is the need for integration among production, engineering, tooling, and maintenance functions. Waiting operator issues are related to work arrangements and planning, while waiting spare part issues are associated with maintenance and inventory. Aging machines require technical decisions regarding components, but these decisions must be linked to production impact. Thus, availability improvement programs cannot be handled by a single function. The A3 report can serve as a cross-functional communication tool by presenting problems, data, root causes, actions, and results within a unified framework.

The third implication is the importance of standardization after improvements are achieved. Increasing availability to 58.7% is a significant achievement, but it will not remain stable without new work standards. Companies need to establish procedures for manpower assistance during set-up, planning review formats, SMED activity lists, spare part lists per machine, minimum stock levels, and periodic audit mechanisms. Without standardization, results may decline due to operator changes, order variations, or shifts in production load.

Theoretical Implications

From a theoretical perspective, this study demonstrates that A3 problem solving can be used as an integrative framework to combine several lean and maintenance concepts within a single improvement case. Availability, as a performance indicator, serves as the starting point; Pareto analysis is used to determine priorities; fishbone and why-why analysis are used to identify root causes; SMED is applied to address changeover; and spare part control is used to reduce downtime caused by component unavailability. These tools are often studied separately, but this study shows their application within a unified improvement process.

The findings also reinforce the view that availability loss is not always synonymous with machine failure. In this case, the largest losses were due to waiting operator and waiting spare part. This indicates that downtime should be broadly understood as a loss of operating time due to system unpreparedness, including human, method, material, and machine systems. Therefore, research on equipment performance should consider the interaction among these factors, rather than focusing solely on technical conditions.

Standardization and Replication

The standardization phase is necessary to ensure that improvements do not stop at the studied machine. The first standard is the prioritization of machines based on availability and breakdown time data. Machines with the highest losses and greatest production impact should be prioritized. The second standard is the A3 analysis format, which includes baseline data, targets, dominant losses, root causes, action plans, and monitoring results. This format can be applied to other machines to ensure consistency in improvement patterns.

The third standard is the initial shift set-up procedure, which defines when manpower assistance is required, who is responsible, what activities are performed, and how results are recorded. The fourth standard is the planning review procedure, which considers part classification based on process and running time. The fifth standard is the spare part system, which includes part lists per machine, minimum stock levels, responsible personnel, and audit frequency. If these standards are implemented, improvements can be replicated to other machines with a lower risk of failure.

Replication to other machines must still consider the characteristics of each machine. Machines with different dominant losses should not be assigned the same countermeasures. For example, if another machine has dominant losses related to quality adjustment or speed loss, a different approach may be required. However, the A3 framework can still be used to determine the focus of improvement. Thus, what is replicated is not only the action plan but also a data-driven and root-cause-based way of thinking.

CONCLUSIONS

This study shows that the availability of the automatic surface grinding machine in the initial condition was at a low level, namely 34.3%. The low availability was primarily caused by an average breakdown time of 24,365 minutes. Of this breakdown time, two dominant losses were identified: stop waiting operator at 15,135 minutes and stop waiting spare part at 7,680 minutes. These two losses contributed approximately 93.6%–94.0% of the total breakdown time, making them the top priorities for improvement.

Root cause analysis indicates that stop waiting operator was influenced by sequential set-up at the beginning of the shift, one operator handling multiple machines, high changeover variation, short running times, the absence of job classification based on process and running time, and the need for machine component improvements. Meanwhile, stop waiting spare part was caused by the absence of a spare part list per machine, the lack of minimum stock levels, and the absence of a spare part control system.

The implemented countermeasures included allocating manpower from manual grinding to assist with set-up, reviewing process planning, preparing SMED implementation, following up with vendors for machine component improvements, and developing spare part lists along with minimum stock levels. Monitoring results show that availability during the September–November 2024 period increased to an average of 58.7%, representing an improvement of 24.4 percentage points compared to the baseline. Stop waiting operator decreased to an average of 4,490 minutes, while stop waiting spare part was reduced to 0 minutes during the after period.

Thus, A3 problem solving has proven effective as a framework for improving availability, as it is able to link data, loss prioritization, root causes, action plans, and monitoring results. The combination of A3 with SMED principles and spare part control produced significant results in the case studied. To ensure sustainability, the company needs to standardize set-up procedures, planning reviews, spare part control, and periodic availability evaluations.

This study has several limitations. First, it was conducted on a single machine or a single group of automatic surface grinding machines, so generalization to other types of machines should be approached with caution. Second, the after period analyzed was limited to September–November 2024, meaning that long-term evaluation does not yet fully reflect result stability over a full production year. Third, SMED implementation is still in the preparation stage, so the study has not yet quantified reductions in internal and external set-up times in detail.

Suggestions for future research include conducting more detailed measurements of set-up activities using time studies, comparing results before and after full SMED implementation, and integrating spare part data into a CMMS. Future studies may also calculate the financial impact of availability improvements, such as reduced overtime, increased capacity, or decreased downtime costs. In addition, replication on other machines can be conducted to determine whether the dominant loss patterns are similar or different.

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