Jurnal Teknologi dan Manajemen Industri Terapan (JTMIT) Vol. 5, No. 3, September 2026 pp. 1119 - 1128
P-ISSN: 2829-0232 E-ISSN: 2829-0038

Activity-Level Waste-Time Diagnosis in Corrective Maintenance Using WAM-T: Evidence from 40 Repair Events in Manufacturing Lines

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ABSTRACT

Corrective maintenance plays an important role in maintaining machine availability and the stability of the production process. However, maintenance performance measurement still relies heavily on macro indicators such as Overall Equipment Effectiveness (OEE), Mean Time Between Failures (MTBF), and Mean Time To Repair (MTTR). These indicators are useful for evaluating system performance, but they are not sufficient to identify which activities cause time waste during the repair process. This study aims to diagnose waste time in corrective maintenance activities using Waste Analysis Mapping–Time (WAM-T). The research data came from 40 repair events on manufacturing production lines collected through field observations, Computerized Maintenance Management System (CMMS) data, and technician interviews. Each repair activity is mapped, timed, and classified into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA). The results showed that, out of a total of 7,055 repair minutes, VA activity accounted for 2,340 minutes (33.17%), NNVA for 4,054 minutes (57.46%), and NVA for 661 minutes (9.37%). The largest types of waste come from the Skill/Knowledge Gap (260 minutes) and the Inventory (197 minutes). These findings show that WAM-T provides more detailed visibility into the repair-time structure and the points at which waste time occurs. Thus, WAM-T can be used as a practical diagnostic tool to help maintenance management determine improvement priorities based on actual data in the field.

Keywords: *Corrective maintenance; WAM-T; waste-time; VA-NNVA-NVA; maintenance efficiency*

Introduction

Maintenance is an important function in manufacturing because it is directly related to asset reliability, machine availability, process stability, and the achievement of production targets. When a machine breaks down, the impact is not only downtime, but also reduced production output, higher labor and energy costs, delivery delays, and decreased customer satisfaction. Therefore, corrective maintenance must be managed not only to restore machine operation quickly, but also to ensure that repair time is used efficiently. In industrial practice, maintenance performance is commonly measured using macro indicators such as Overall Equipment Effectiveness (OEE), Mean Time Between Failures (MTBF), and Mean Time To Repair (MTTR). OEE reflects equipment effectiveness through availability, performance, and quality [1], while MTBF and MTTR indicate failure frequency and recovery speed after breakdowns [2]. Although important, these indicators remain aggregate because they show performance outcomes but do not clearly identify which repair activities cause time inefficiency. Performance indicators are also often selected based on data availability rather than their ability to explain operational efficiency in detail [3], and measurement systems can become ineffective when indicators do not accurately represent actual process conditions [4].

These limitations are increasingly evident in corrective maintenance because, unlike stable, repetitive production processes, it is event-based, job-based, and dynamic. Repair sequences can vary depending on the type of failure, machine condition, technician capability, spare part availability, tool readiness, and diagnosis speed, so long repair time may arise not only from core repair activities but also from waiting, searching for parts or tools, opening machine access, repeated trials, or unavailable technical information. Lean maintenance examines these activities by distinguishing between value-added and non-value-added work, focusing on waste reduction, such as waiting, motion, rework, and other activities that do not directly support repair [5]. Lean maintenance has also been used to improve maintenance efficiency and reduce waste in machine maintenance activities [6], support downtime reduction in industrial maintenance practices [7], and improve productivity and asset performance through lean, TPM, 5S, and kaizen approaches [8]. However, common lean tools such as Value Stream Mapping (VSM) are more effective in high-volume, low-variation, and relatively linear production processes [9], whereas corrective maintenance requires a more adaptive mapping approach due to its dynamic flow [10]. Time-motion studies and work element analysis can measure work duration and activity elements, but they do not directly show whether activities are value-added, necessary non-value-added, or non-value-added in maintenance contexts [11]. Similar limitations also appear in maintenance activity classification studies, which still require clearer integration of activity duration with value classification [12]. Based on these problems, this study uses Waste Analysis Mapping–Time (WAM-T) to map actual repair activities, record activity duration, and classify them into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA), so that waste-time in 40 repair events can be diagnosed and improvement priorities can be determined based on actual field data.

The research gap addressed in this study lies in the limited ability of conventional maintenance indicators to diagnose waste at the repair-activity level. Previous studies have mainly used macro indicators such as OEE, MTTR, and MTBF, or lean-based process mapping tools, but these approaches do not fully explain where time waste occurs within actual corrective maintenance activities. WAM-T contributes by integrating actual activity mapping, time measurement, VA–NNVA–NVA classification, and waste identification into one micro-operational diagnostic approach. In practice, this method helps maintenance management prioritize improvements based on actual waste occurrence rather than relying solely on total repair duration or aggregate maintenance KPIs.

Maintenance Efficiency and Limitations of Macro Indicators

Maintenance plays an important role in ensuring machine reliability, availability, process stability, and achievement of production targets by supporting productivity and customer demand fulfillment in manufacturing. Inefficient maintenance can increase downtime, reduce production output, and raise labor, material, energy, and delay-related costs; therefore, maintenance efficiency reflects the maintenance system's ability to maintain asset reliability and productivity through optimal resource use [13]. In industrial practice, maintenance efficiency is commonly measured using macro indicators such as Overall Equipment Effectiveness (OEE), Mean Time Between Failures (MTBF), and Mean Time To Repair (MTTR). OEE describes equipment effectiveness in terms of availability, performance, and quality [1], while MTBF and MTTR assess system resilience to failure and the speed of recovery after breakdowns [2]. Although useful, these indicators remain aggregate because they show performance outcomes but do not directly reveal which activities cause repair-time inefficiency. Similar limitations appear in broader maintenance measurement approaches, where scorecards assess performance from managerial perspectives but are less able to expose waste at the repair-activity level [14], KPI- and KRI-based studies align indicators with organizational objectives but do not directly explain operational time losses in corrective maintenance [15], conceptual maintenance indicators are often not connected to actual field activity structures [16], and diagnostic frameworks generally focus on broader process performance rather than classifying repair activities into VA, NNVA, and NVA time [17]. This need becomes more important in corrective maintenance because repair activities are event-based, job-based, and dynamic, so total repair time alone is insufficient to explain process efficiency. Long repair duration may come not only from core repair work, but also from waiting, searching for spare parts or tools, opening machine access, repeated trials, or unavailable technical information. Therefore, maintenance analysis needs to move beyond macro indicators and examine actual repair activities more closely, especially because modern maintenance increasingly requires detailed operational data to support reliability and maintainability decisions [18].

Lean Maintenance and Activity Classification

Lean maintenance is the application of lean principles to identify and reduce waste in maintenance activities, especially non-value-added activities such as waiting, motion, rework, and unnecessary processes [5]. In practice, lean maintenance is often associated with Total Productive Maintenance (TPM), 5S, and kaizen to reduce downtime and improve asset productivity [7], while lean tools have also been shown to support productivity improvement in industrial settings [8]. In corrective maintenance, this perspective is important because not all repair time is spent directly restoring machine function; some time is spent on core technical activities, some on necessary supporting activities, and some on wasteful activities. Therefore, this study classifies corrective maintenance activities into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA). VA activities directly repair or restore machine function, such as replacing damaged components, repairing wiring, making adjustments, cleaning abnormalities, or performing technical setup. NNVA activities do not directly repair the machine but remain necessary for safe and correct work, such as safety confirmation, diagnosis, preparation, opening machine access, trials, and verification. Meanwhile, NVA activities do not add value and should be reduced, such as waiting for spare parts, searching for tools, taking parts from unprepared locations, or repeating work due to unclear technical information. This classification provides a sharper reading than total repair duration alone because two repair events may have the same duration but different activity compositions, making activity classification an important basis for identifying non-value-added activities, tracing their root causes, and determining more precise improvement priorities [19].

VSM, Time-Based Analysis, and Activity Level Diagnosis Needs

Value Stream Mapping (VSM) is a lean tool used to map the flow of value-added and non-value-added processes, information, and activities, making it useful for identifying waste, shortening lead times, and improving process flow [20]. However, VSM is generally more suitable for relatively stable, repetitive, and clearly structured processes, especially production systems with high volume, low variation, and linear material and information flows [9]. These characteristics are not fully aligned with corrective maintenance because repair jobs are often dynamic, job-based, and do not always follow the same sequence. The activities in one repair event may differ from those in another depending on the type of failure, machine condition, and actual field conditions, so dynamic processes require a more adaptive mapping approach than static process mapping [10]. Time-motion study and work element analysis are also relevant because they can measure activity duration and break work into activity elements, but duration measurement alone does not explain whether an activity is value-added, necessary non-value-added, or wasteful [11]. Therefore, time-based analysis needs to be combined with activity value classification, because measuring actual activity time helps organizations read process efficiency and identify waste more objectively [21]. A time-study perspective is also useful for linking operational time measurement with performance and sustainability analysis [22]. Thus, corrective maintenance analysis requires an approach that integrates actual activities, actual time, and activity-value classification into in single diagnostic framework.

Waste Analysis Mapping–Time (WAM-T)

Waste Analysis Mapping–Time (WAM-T) is a diagnostic method used to identify waste time at the maintenance activity level by integrating actual repair activity mapping, activity duration measurement, and classification into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA) categories. This approach is consistent with the activity-based view, which places actual activities as the main unit of analysis for understanding organizational processes and capabilities [23]. Unlike methods that only measure total repair duration or final performance outcomes, WAM-T records the actual sequence of repair activities, calculates their duration, and classifies their contribution to the repair process. This allows WAM-T to show not only how long a repair takes, but also how repair time is used and which activities are wasteful. In this study, WAM-T is positioned as a diagnostic tool that identifies points of waste occurrence and supports management in setting repair priorities, including improving troubleshooting skills, spare part readiness, tool availability, technical information, and repair activity recording. Thus, WAM-T complements macro KPIs such as OEE and MTTR by providing a more detailed micro-operational diagnosis of the structure of corrective maintenance time.

Table 1. Summary of Literature and Research Position

Area Literature	Main References	Relevant Limitations	Position of this article
Macro maintenance KPIs	[1], [2], [13]	Measure maintenance and equipment performance in aggregate, but do not directly show the source of waste at the repair-activity level.	Analyze repair time down to the activity level.
Maintenance measurement system	[14], [15], [16], [17]	Tend to be managerial, KPI/KRI-oriented, scorecard-based, or broader diagnostic frameworks rather than activity-level waste-time classification tools.	Focus on micro-operational diagnosis.
Lean maintenance	[5], [6], [7], [8], [19]	Discuss waste reduction, downtime reduction, and productivity improvement, but do not always read waste-time at the corrective repair activity level.	Use the VA–NNVA–NVA classification on repair events.
VSM and process analysis	[9], [10], [20]	Stronger in relatively stable, repetitive, and process-centric flows, while corrective maintenance is more dynamic and job-based.	Use an activity-centric approach to corrective maintenance.

Time and activity-based analysis	[11], [12], [18], [21], [22], [23]	Time measurement and activity-based perspectives need to be linked to activity value classification to determine whether an activity is VA, NNVA, or NVA.	WAM-T combines activities, time, and value classification.

Based on the literature review, the main gap in this study is the lack of a robust diagnostic tool capable of identifying waste in corrective maintenance time at the activity level. Previous research has mostly discussed macro KPIs, strategic measurement systems, lean maintenance, VSM, and activity time measurement. However, there is still a need for an approach that is able to integrate actual activities, actual time, and classification of activity values in one simple and practical diagnostic tool. This article places WAM-T as an approach to answer these needs.

Research Methods

Design and Research Objects

This study uses a descriptive quantitative case study approach. This approach was chosen because the purpose of the study is to diagnose time waste in corrective maintenance activities using actual data in the field data, rather than to test the cause-and-effect relationship between variables. The research focuses on corrective maintenance activities on the manufacturing production line. The unit of analysis in this study is the repair event and the activities that occur in each repair event. A repair event is understood as an event of machine repair, from the initial information about the problem received to the machine being declared ready for reuse. This research focuses on corrective maintenance because repair work is dynamic and job-based and does not always follow the same sequence. This character is in accordance with the purpose of WAM-T, which is to read the waste of time at the actual activity level, not just look at the total repair time in aggregate.

Data and Data Collection Techniques

The research data come from 40 repair events at two manufacturing plants, namely Karawang and Sunter, covering two main production lines: Casting and Machining. The two lines were chosen because they have different characteristics in process and maintenance activities, providing a broader picture of the use of WAM-T in corrective maintenance work. Data collection was carried out through three main sources, namely field observations, Computerized Maintenance Management System (CMMS) data, and technician interviews. Field observations are used to record actual activities and the duration of repair work. CMMS data is used to complete repair event information, such as machine identity, time of occurrence, and type of problem. Technician interviews are used to clarify the chronology of work and the reasons for the emergence of certain activities that are not always visible in the system data. The combination of these three data sources is necessary because not all repair activities are recorded in full in the CMMS. Some activities such as waiting for parts, looking for tools, opening machine access, repeated trials, or technical confirmations can often only be understood through direct observation and explanation of technicians.

WAM-T Analysis Instruments and Procedures

The main instrument used in this study is the WAM-T sheet, which records repair activity sequences, durations, categories, and waste types. Each activity is classified into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA), where VA directly restores machine function, NNVA supports safe and proper repair work, and NVA represents activities that do not add value and should be reduced. To improve classification consistency, the VA, NNVA, and NVA categories were defined using operational guidance prior to data classification. The classification was supported by field observation, CMMS records, and technician confirmation to reduce interpretation bias. When an activity was unclear, the classification was assessed based on its contribution to restoring machine function, its necessity for safe and proper repair, and its potential as pure waste. This classification is relevant because lean-based maintenance studies emphasize the need to identify non-value-added processes and link them with actual activity time to reduce maintenance waste and cost [24]. For NVA activities, waste types are grouped into the W–T–M–O–R–I–D–S category: waiting, transportation, motion, over-maintenance, rework, inventory, data/information waste, and skill/knowledge gap. This grouping allows waste to be understood not only by the amount of time lost but also by its source, in line with lean studies that identify waiting, inventory, movement, and other non-value-added activities as major causes of productivity and efficiency losses [25].

In general, the stages of WAM-T analysis in this study are as follows:

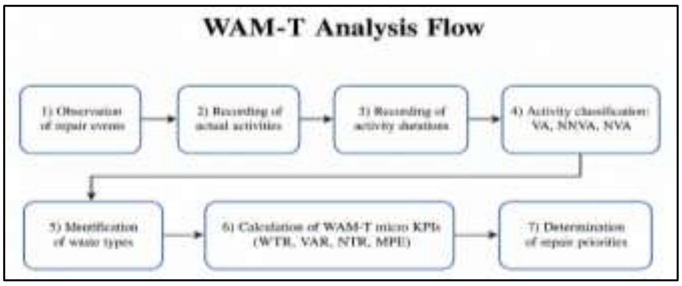


Figure 1. WAM-T Analysis Flow

Figure 1 summarizes the integration of real-time measurement, activity classification, waste identification, and micro-KPI calculation in the WAM-T analysis process.

WAM-T Micro Indicators

Quantitative analysis was conducted by calculating four WAM-T microindicators: Waste-Time Ratio (WTR), Value-Added Ratio (VAR), Necessary Time Ratio (NTR), and Maintenance Process Efficiency (MPE). WTR is used to measure the proportion of wasted time to total repair time. VAR is used to see the proportion of time that actually adds value. NTR is used to see the proportion of supporting activity time that is still required. Meanwhile, MPE is used to see the efficiency of the repair process by comparing the VA time to the total activity time that is still needed, namely VA and NNVA.

The formula used is as follows:

WTR = NVA Time / Total Repair Time × 100%
VAR = VA Time / Total Repair Time × 100%
NTR = NNVA Time / Total Repair Time × 100%
MPE = VA Time / (VA Time + NNVA Time) × 100%

The results of the calculation were analyzed descriptively to see the time distribution of VA, NNVA, and NVA in 40 repair events. The analysis was also carried out based on plant, line, sub-line, event repair with the highest NVA contribution, and the most dominant type of waste. The final results are used to identify the point of waste occurrence and determine the priority of repairs in the corrective maintenance process.

Method Limitations

This research has several limitations. First, the research only focuses on corrective maintenance, so the results do not directly represent preventive maintenance, predictive maintenance, procurement spare parts, or administrative maintenance activities. Second, the research data comes from two plants in one context of a manufacturing company, with the scope of the Casting and Machining line, so generalizations to other industries need to be done carefully. Third, the results of the activity classification depend on the observer's understanding of the VA, NNVA, and NVA guidance. Therefore, operational definitions and observer training are still needed to ensure more consistent implementation of WAM-T.

Results and Discussion

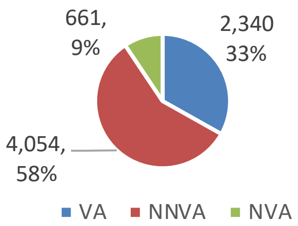
Corrective Maintenance Data Overview

This study analyzed 40 repair events on the manufacturing production line. Each event is mapped to actual activities that occur in the field, from initial information about the problem, diagnosis, and work preparation, through repair actions and trials, to the machine being declared ready for reuse. The total duration of the entire event was 7,055 minutes. Through WAM-T, total time is not only the duration of repair but is also broken down into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA) categories. In this way, the structure of corrective maintenance time can be examined in greater detail, enabling management to determine whether repair time is allocated more to core repair activities, supporting activities, or wasteful activities.

VA, NNVA, and NVA Time Distribution

The results of measuring 40 repair events showed that the longest time was in the NNVA category, at 4,054 minutes (57.46%). Meanwhile, VA time totaled 2,340 minutes (33.17%), and NVA totaled 661 minutes (9.37%).

Table 2. Time Distribution of VA, NNVA, and NVA at 40 Repair Events



Activity Categories	Total Time (minutes)	Percentage
VA	2.340	33,17%
NNVA	4.054	57,46%
NVA	661	9,37%
Total	7.055	100%

The dominance of NNVA indicates that most repair time is spent on supporting activities, such as diagnosis, safety confirmation, preparation, opening machine access, trials, and verification. These activities do not directly repair the machine but are still necessary for the work to run safely and correctly. The VA portion of 33.17% indicates that about one-third of the repair time is spent on activities that directly restore machine function. Meanwhile, NVA of 9.37% indicates a waste of time that needs to be reduced. Although the percentage is lower than the NNVA, the 661 minutes still matter because they come from activities that do not add value to the repair process. These findings show that opportunities for improvement exist in two areas. First, reduce NVA activities that are pure waste. Second, simplifying NNVA activities so that supporting processes such as diagnosis, preparation, and trials can run faster.

This finding indicates that corrective maintenance efficiency should not be improved only by accelerating technical repair actions. A large portion of repair time is consumed by supporting activities; therefore, improvements should also focus on simplifying the diagnosis, preparation, access, trial, and verification processes.

Plant and Line-Based Analysis

Analysis of plants shows that Sunter has a longer total repair time than Karawang. Sunter recorded 25 events with a total time of 4,760 minutes, while Karawang recorded 15 events with a total time of 2,295 minutes. In terms of waste time, Sunter also has a higher WTR, at 10.32%, compared to Karawang's 7.41%.

Table 3. Time Distribution and WAM-T KPIs by Plant

Plant	Number of Events	Classification			Total Time	KPI			
		VA	NNVA	NVA		WTR	VAR	NTR	MPE
Karawang	15	855	1.270	170	2.295	7,41%	37,25%	55,34%	40,24%
Sunter	25	1.485	2.784	491	4.760	10,32%	31,20%	58,49%	34,79%
Total	40	2.340	4.054	661	7.055	9,37%	33,17%	57,46%	36,60%

Figure 2. Comparison of Maintenance Time Classification and WAM-T Micro KPIs between Karawang and Sunter Plant

These results show that Sunter needs more attention because it has a higher total repair time and a higher waste-time proportion. However, these differences cannot be directly interpreted as differences in performance alone, as they may be influenced by the machine's complexity, the type of problem, the equipment's age, and the condition of spare parts. Analysis based on the line shows sharper findings. Casting has a total repair time of 3,623 minutes, while Machining is 3,432 minutes. If you only look at the total time, the two look relatively balanced. However, the WTR Machining is much higher at 15.62% compared to the casting at 3.45%.

Table 4. Time Distribution and WAM-T KPI Based on Line

Line	Number of Events	VA	NNVA	NVA	Total Time	WTR	VAR	NTR	MPE
Casting	17	1.323	2.175	125	3.623	3,45%	36,52%	60,03%	37,82%
Machining	23	1.017	1.879	536	3.432	15,62%	29,63%	54,75%	35,12%
Total	**40**	**2.340**	**4.054**	**661**	**7.055**	**9,37%**	**33,17%**	**57,46%**	**36,60%**

Figure 3. Comparison of Time Composition and WAM-T Micro KPIs between Casting and Machining Lines

These findings show that the total repair duration alone is insufficient to determine the priority of improvement. Casting has a longer total time, but the waste proportion is lower. In contrast, Machining has a slightly shorter total time, but the NVA is much higher. Thus, the priority of improvement is more strongly directed to the machining line.

The higher WTR in Sunter and Machining suggests that waste time may be influenced by machine complexity, problem characteristics, spare-part readiness, and technical support conditions. Therefore, plant and line comparisons should be used as diagnostic signals rather than direct performance rankings.

Sub-Lines and Dominant Types of Waste

To see the priority areas more specifically, the analysis continues at the sub-line level. The results show that the waste time in machining is concentrated on certain sub-lines, especially the Crank Shaft and Cylinder Head.

Table 5. Sub-Line with the Highest NVA Contribution

Line	Sub-Line	Number of Events	VA	NNVA	NVA	Total Time	WTR
Machining	Crank Shaft	7	211	687	294	1.192	24,66%
Machining	Cylinder Head	8	151	402	127	680	18,68%
Machining	Cam Shaft	3	320	235	95	650	14,62%
Casting	Sand Preparation	5	170	230	60	460	13,04%
Casting	Molding	5	379	1.085	38	1.502	2,53%

The Crank Shaft has an NVA of 294 minutes with a WTR of 24.66%, while the Cylinder Head has an NVA of 127 minutes with a WTR of 18.68%. This shows that improvements do not need to be directed directly to all areas, but can be focused first on the sub-lines that contribute the most waste. From a managerial perspective, this result suggests that improvement should start from high-waste sub-lines rather than applying the same improvement effort equally across all areas.

Furthermore, NVA activities are classified based on the type of waste. The results showed that the largest waste came from the Skill/Knowledge Gap of 260 minutes or 39% of the total NVA, followed by the Inventory of 197 minutes or 30%.

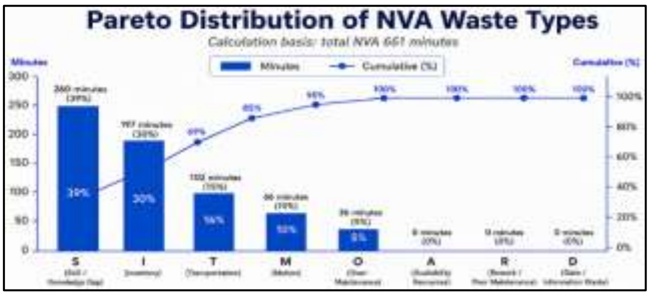


Figure 4. Pareto Analysis of Non-Value-Added Waste Types Based on WAM-T Classification

The two largest wastes, namely Skill/Knowledge Gap and Inventory, accounted for 457 minutes or around 69% of the total NVA. This means that improvement priorities should focus on enhancing technicians' troubleshooting capabilities and spare parts readiness. Waste transportation and motion also need to be considered, but their contribution is smaller than the two main wastes.

These two dominant waste types indicate that the main direction for improvement is not only faster execution but also stronger diagnostic capability and better readiness for repair support. Training based on actual repair cases and improvement of critical spare part management can directly address these two waste sources.

Summary of WAM-T Micro KPIs

Based on the time distribution of VA, NNVA, and NVA, WAM-T micro KPIs are calculated to see the efficiency of the repair process in a more operational manner.

Table 6. Summary of WAM-T Micro KPIs on 40 Repair Events

KPI	Ratio Formula	Results
WTR	661 / 7.055	9,37%
VAR	2.340 / 7.055	33,17%
NTR	4.054 / 7.055	57,46%
MPE	2.340 / (2.340 + 4.054)	36,60%

The WTR value of 9.37% indicates that 661 minutes were pure waste out of a total of 7,055 minutes. The VAR value of 33.17% indicates that one-third of the repair time is used for activities that actually repair the machine. The NTR value of 57.46% indicates that supporting activities dominate the repair process. Meanwhile, the MPE of 36.60% indicates that the share of VA activities remains relatively low compared to the necessary supporting activities. In practical terms, these results show that improving corrective maintenance is not enough to achieve NVA reduction. Companies also need to simplify NNVA, especially in diagnosis, preparation, trial, and verification, to make the repair process more efficient.

Managerial Discussion and Implications

The results of the study show that WAM-T can read corrective maintenance in greater detail than macro indicators such as MTTR or OEE. Macro indicators are still important to see how the system is performing, but they are not enough to explain which activities make the repair process lengthy. Through WAM-T, repair time can be broken down into VA, NNVA, and NVA activities, so management can see the repair-time structure more clearly.

The main finding of this study is the dominance of NNVA activities of 57.46%. This shows that the corrective maintenance process not only contains technical activities that directly repair the machine, but is also heavily influenced by supporting activities such as diagnosis, safety confirmation, preparation, opening machine access, trial, and verification. These activities cannot be completely eliminated because they are still necessary to ensure repair work is safe and correct. However, the duration of supporting activities still needs to be controlled to prevent delays in the repair process.

The next finding was NVA activity of 9.37% or 661 minutes. Even though the portion is smaller than the NNVA, this activity is still important because it is pure waste that does not add value to the repair process. In other words, NVA is the most obvious area to reduce, while NNVA is an area that needs to be simplified or made more efficient.

Analysis of waste types shows that the largest waste comes from Skill/Knowledge Gap and Inventory. This finding indicates that some of the wasted time stems not only from the technician's work speed but also from the readiness of the repair support system. An inaccurate diagnosis, technical information that is not easy to use, or suboptimal spare-parts availability can extend the repair time, even though the core repair activities are not too long.

The results of the analysis also show that waste-time is not evenly distributed. Line Machining, especially the Crank Shaft and Cylinder Head sub-line, has a higher NVA contribution. This finding is important managerially because improvement does not need to be done too extensively from the beginning. Management can start with the areas that contribute the most to waste, then expand improvements once the problem pattern is clearer.

Thus, the main implication of this study is the need to change how we approach data repair. Repair time is not sufficient to be treated as a single number; it needs to be read as the composition of the activity. WAM-T helps management see whether repair time is absorbed in activities that actually repair the machine, in support activities that are still needed, or in wasteful activities. This information makes the improvement decision-making process more objective and grounded in actual field data.

In practice, WAM-T can be used as a review tool for certain repair events, especially long-duration breakdowns, recurring problems, critical machines, or events with high waste indicators. With this approach, WAM-T does not add excessively to the administrative burden, yet still provides information sharp enough to determine the priority of corrective maintenance improvements.

Conclusion

This study shows that Waste Analysis Mapping–Time (WAM-T) can serve as a detailed diagnostic tool for identifying waste time in corrective maintenance activities. Unlike conventional analysis, which only observes total repair duration, WAM-T breaks down the repair process into actual activities, records the duration of each activity, and classifies them into value-added (VA), necessary non-value-added (NNVA), and non-value-added (NVA). Based on 40 repair events, the total repair duration reached 7,055 minutes, consisting of 2,340 minutes of VA activities, 4,054 minutes of NNVA activities, and 661 minutes of NVA activities. The WAM-T micro KPIs show a Waste-Time Ratio (WTR) of 9.37%, a Value-Added Ratio (VAR) of 33.17%, a Necessary Time Ratio (NTR) of 57.46%, and a Maintenance Process Efficiency (MPE) of 36.60%. These results indicate that corrective maintenance time is dominated by NNVA activities, such as safety checks, diagnosis, preparation, machine access, trials, and verification. Although these activities do not directly restore machine function, they remain necessary to ensure that repair work is safe, accurate, and procedurally correct.

The findings also show that wasted time is not evenly distributed across all repair areas. The largest waste contribution was found in the Machining line, particularly in the crankshaft and Cylinder Head sub-lines, while the dominant waste types were Skill/Knowledge Gap and Inventory. This indicates that improvement priorities should focus on strengthening technician troubleshooting capability and improving spare parts readiness. Overall, WAM-T provides managerial value by integrating time measurement, activity classification, waste identification, micro-KPI calculation, and waste-occurrence points into a single practical diagnostic approach. However, this study is limited to corrective maintenance activities and has not yet measured the impact of WAM-T-based improvements on MTTR, OEE, availability, or maintenance cost reduction. Therefore, future studies should test WAM-T in other maintenance contexts, such as preventive and predictive maintenance, spare parts procurement, and maintenance administration, and evaluate its effectiveness after implementation of improvement actions. Future research should also evaluate whether WAM-T-based improvement actions can significantly reduce MTTR, increase equipment availability, improve OEE, or reduce maintenance costs after the identified waste sources have been addressed

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