



DOI: <https://doi.org/10.38035/gijes.v4i3>
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Improving Machine Effectiveness Using the Overall Equipment Effectiveness (OEE) Method and Lean Manufacturing in the Automotive Components Industry

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Abstract: Low machine effectiveness can reduce production efficiency through equipment failures, lengthy setup activities, speed losses, and product defects. Previous studies have generally examined machine effectiveness and lean manufacturing separately, leaving limited discussion of their integrated use to identify operational losses and formulate measurable process improvements. This study aims to evaluate machine effectiveness and identify production waste in an automotive manufacturing process to develop improvement strategies. A descriptive quantitative approach was employed using production, operating time, downtime, and defect data collected from January to December 2025. Machine effectiveness was evaluated based on availability, performance, and quality, while lean manufacturing analysis used value stream mapping, process activity mapping, seven wastes, and six major loss categories, supported by Pareto and cause-and-effect analyses. The results showed average availability of 67.39%, performance of 74.16%, quality of 73.42%, and overall effectiveness of 36.56%. Equipment failure was the largest loss at 38.26%, followed by setup and adjustment at 21.39%. The proposed improvements include preventive maintenance, autonomous maintenance, setup time reduction, standardized procedures, operator training, and improved material flow. The novelty lies in integrating machine effectiveness measurement with lean waste analysis to develop a future production state with projected effectiveness of 92.28%.

Keywords: Machine Effectiveness, Lean Manufacturing, Production Waste, Equipment Failure, Value Stream Mapping

INTRODUCTION

Manufacturing companies are required to maintain reliable production systems while meeting targets for productivity, quality, delivery, and resource efficiency. This requirement is particularly important in the automotive industry, where production activities depend heavily on the continuous operation of critical equipment. A disturbance in one key machine can interrupt the flow of subsequent operations, reduce available production capacity, and affect

the fulfillment of customer demand. Therefore, maintaining equipment reliability is not only a technical concern but also an important part of sustaining operational performance.

This condition is evident in the automotive manufacturing process examined in this study, in which the hydraulic press machine serves as a critical piece of equipment for forming automotive components. The machine operates within a production system that runs three shifts per day for six working days each week, resulting in a high utilization level and a strong dependence on stable equipment conditions. Operational observations identified several disturbances, including downtime caused by mechanical and hydraulic failures, lengthy setup and adjustment activities during product changes, unexpected stoppages, reduced operating speed, and defective output. Product defects were associated with unstable hydraulic pressure, inaccurate material positioning, die wear, and inappropriate machine parameter settings. These conditions can reduce productive capacity while increasing waiting time, rework, material losses, and the risk of delayed deliveries.

A systematic measurement is consequently required to determine the extent to which the equipment is being utilized effectively. Overall Equipment Effectiveness provides an established framework for evaluating equipment performance through three dimensions: availability, performance, and quality. Beyond producing an aggregate performance indicator, this measurement can reveal the losses responsible for reduced output, including equipment failure, setup and adjustment, minor stoppages, reduced speed, process defects, and reduced yield. Previous studies have demonstrated its usefulness for locating dominant losses and establishing priorities for corrective actions (Novendria & Hartini, 2025; Mustofa et al., 2025). The thesis literature review likewise indicates that recent studies have increasingly used this measurement to move from performance assessment toward loss identification and improvement planning.

Nevertheless, equipment performance alone cannot explain all inefficiencies occurring across the production flow. Losses reflected in machine data may be connected with material waiting, unnecessary movement, excessive storage, delayed inspection, or lengthy preparation activities. These conditions require an analysis that extends beyond the equipment itself and examines how activities are organized throughout the value stream. Lean Manufacturing offers such a perspective by distinguishing activities that create value from those that consume time and resources without increasing product value. Recent research has shown that Value Stream Mapping can support the identification of process waste and provide a basis for redesigning production flows, while its combination with equipment performance analysis can strengthen improvement planning (Setiawan et al., 2022; Suhendra & Wiyatno, 2024).

The relationship between equipment losses and process waste creates an important research gap. Existing studies have investigated equipment performance through loss analysis, maintenance approaches, and process improvement tools, while other studies have concentrated on waste elimination through lean techniques. Although these approaches are complementary, they are not always integrated into a framework that links the measured sources of equipment losses with waste occurring throughout the production flow. The literature reviewed in this study shows that research has progressed toward combining equipment performance measurement with Lean Manufacturing, Six Big Losses, Total Productive Maintenance, DMAIC, and digital manufacturing technologies. However, opportunities remain to develop an integrated analysis that identifies the dominant equipment losses, traces their underlying causes, evaluates non-value-added activities, and translates the findings into a measurable future production condition.

Addressing this gap, the present study combines equipment performance measurement with Six Big Losses, Seven Wastes, Current Value Stream Mapping, Process Activity Mapping, Pareto analysis, and cause-and-effect analysis. The approach is applied to a critical hydraulic press machine in an automotive manufacturing process, allowing equipment-related losses to be examined alongside inefficiencies in material and information flow. This

integration distinguishes the study from analyses that stop at calculating an effectiveness value or identifying a single dominant loss. It instead establishes a sequence from performance measurement, loss prioritization, root-cause identification, waste analysis, and improvement formulation, followed by the development of a future production state. The resulting framework is intended to provide a more comprehensive basis for determining which operational conditions should be addressed first.

Accordingly, this study aims to evaluate the current performance of the hydraulic press machine, identify the dominant equipment losses and production wastes, determine the root causes of the most significant losses, and formulate improvement strategies that can enhance equipment performance while reducing non-value-added activities. The study addresses four questions: (1) What is the current level of equipment performance based on availability, performance, and quality? (2) Which losses and forms of waste contribute most significantly to the existing condition? (3) What factors cause the dominant losses? and (4) How can the identified findings be translated into improvement strategies and a future production state? The answers to these questions are subsequently developed through the empirical analysis and used to assess the potential effects of the proposed improvements.

METHODS

This study employed a descriptive quantitative approach to evaluate the effectiveness of a hydraulic press machine and identify production losses in an automotive manufacturing company. The research was conducted using operational data collected from January to December 2025. The data consisted of production output, machine downtime, defective products, and machine operating time, supported by field observations and company documentation. The analysis began with the calculation of *Overall Equipment Effectiveness* (OEE), which consists of *Availability*, *Performance*, and *Quality*. The OEE results were then analyzed using *Six Big Losses* to identify the major sources of productivity loss, comprising *Equipment Failure*, *Setup and Adjustment*, *Idling and Minor Stoppages*, *Reduced Speed*, *Process Defect*, and *Reduced Yield*. Pareto analysis was used to determine the dominant losses, while a Fishbone diagram was applied to identify their potential root causes.

The study subsequently applied *Lean Manufacturing* to identify waste within the production process. The analysis covered seven types of waste: *overproduction*, *waiting*, *transportation*, *inventory*, *motion*, *overprocessing*, and *defect*. *Current Value Stream Mapping* (CVSM) was used to map the flow of materials and information and to classify activities into *Value Added*, *Necessary Non Value Added*, and *Non Value Added*. *Process Activity Mapping* (PAM) was used to classify production activities into *Operation*, *Transportation*, *Inspection*, *Delay*, and *Storage*. The findings from the OEE, *Six Big Losses*, Pareto, Fishbone, and *Lean Manufacturing* analyses were integrated to formulate improvement proposals. The proposed improvements were then represented through *Future State Value Stream Mapping* to evaluate the expected reduction in non-value-added activities, downtime, setup time, and improvements in machine effectiveness.

RESULTS AND DISCUSSION

Equipment Effectiveness

The calculation of *Equipment Effectiveness* (OEE) was conducted to evaluate the effectiveness of the hydraulic press machine during January–December 2025. OEE was assessed through three main components: Availability, Performance, and Quality. The results show that the machine had an average Availability of 67.39%, Performance of 74.16%, and Quality of 73.42%, resulting in an average OEE of 36.56%. This OEE value remains substantially below the 85% World Class benchmark used as a reference for high equipment effectiveness.

Table 1. OEE Performance

OEE Component	Average (%)
Availability	67.39
Performance	74.16
Quality	73.42
OEE	36.56

The Availability value of 67.39% indicates that a considerable portion of the planned production time was lost because of machine downtime. The Performance value of 74.16% indicates that the machine did not consistently operate at its ideal production rate. Meanwhile, the Quality value of 73.42% demonstrates that defective products also made a substantial contribution to the low OEE. Therefore, the low OEE was not caused by a single operational problem but by the simultaneous occurrence of machine stoppages, reduced operating speed, and quality losses. The relationship between these three OEE components and the production losses can be further examined through the *Six Big Losses* analysis. This analysis provides a more detailed explanation of where the losses originated and allows the improvement priorities to be determined based on their contribution to total production losses.

Six Big Losses and Root Causes

The *Six Big Losses* analysis identified 35,150 minutes of production losses during the research period. *Equipment Failure* represented the largest loss, with 13,450 minutes or 38.26% of the total losses. The second-largest loss was *Setup and Adjustment*, with 7,520 minutes or 21.39%, followed by *Reduced Speed* with 5,980 minutes or 17.01%. These three categories accounted for approximately 76.67% of the total losses, indicating that improvement efforts should primarily focus on these areas.

Table 2. Six Big Losses in 2025

Loss Category	Loss Time (minutes)	Percentage (%)
Equipment Failure	13,450	38.26
Setup and Adjustment	7,520	21.39
Reduced Speed	5,980	17.01
Idling and Minor Stoppages	4,230	12.03
Process Defect	2,740	7.80
Reduced Yield	1,230	3.50
Total	35,150	100.00

The dominance of *Equipment Failure* explains the relatively low Availability value. The thesis records several recurring machine problems, including worn bearings, hydraulic system leakage, limit sensor failures, motor overheating, and hydraulic seal damage. These conditions indicate that machine reliability remains a major issue in the production process. The analysis also indicates that maintenance activities have tended to be corrective rather than sufficiently preventive, allowing machine problems to develop into production stoppages. The *Setup and Adjustment* loss of 7,520 minutes also represents a significant opportunity for improvement. The highest setup time occurred in January at 680 minutes, while subsequent months remained relatively stable at approximately 610–630 minutes. Although the monthly values did not fluctuate substantially, the accumulated annual setup time demonstrates that

product changes and machine adjustments consume a considerable amount of productive time. This finding supports the use of SMED as one of the proposed improvement approaches.

The Fishbone analysis was subsequently used to investigate the causes of *Equipment Failure*. The analysis identified *Machine* and *Method* as the main contributing factors. Machine-related problems included component wear and recurring technical failures, while method-related problems were associated with insufficient preventive maintenance. Factors related to *Man*, *Material*, *Measurement*, and *Environment* also contributed to the occurrence of equipment failure. These findings indicate that improving OEE requires more than repairing machines after breakdowns. Preventive maintenance schedules, autonomous maintenance, routine inspections, monitoring of critical components, and operator training are necessary to reduce the frequency and duration of equipment failures. Such measures are expected to improve Availability while simultaneously reducing production interruptions.

Lean Manufacturing and Waste Identification

The *Lean Manufacturing* analysis was conducted to identify waste that could not be fully explained by OEE measurements alone. The *Seven Waste* analysis identified *Waiting* as the largest waste category at 28.57%, followed by *Defect* at 20.00% and *Transportation* at 15.71%. *Motion*, *Inventory*, *Over Processing*, and *Overproduction* accounted for the remaining waste categories.

Table 3. Seven Waste Identification

Waste Category	Percentage (%)
Waiting	28.57
Defect	20.00
Transportation	15.71
Motion	11.43
Inventory	10.00
Over Processing	8.57
Overproduction	5.71
Total	100.00

Waiting was the most dominant waste, with a score of 40 or 28.57% of the identified waste. The waiting activities were associated with material delays, machine setup, inspection queues, and machine interruptions. The high proportion of waiting is consistent with the low Availability of 67.39%, indicating that delays in the production flow and machine interruptions are interconnected. The second-largest waste was *Defect*, accounting for 20.00%. The production records indicate 155,250 defective units during the study period, contributing directly to the Quality value of 73.42%. Defects not only reduce the number of good products but can also generate additional activities such as rework, inspection, and material consumption. Meanwhile, *Transportation* accounted for 15.71%, indicating that material movement between workstations still creates activities that consume production time without directly increasing product value.

The *Current Value Stream Mapping* (CVSM) provides additional evidence of these inefficiencies. The total process lead time was 289 minutes, consisting of 113 minutes of Value Added (VA), 27 minutes of Necessary Non Value Added (NNVA), and 149 minutes of Non

Value Added (NVA). NVA activities therefore accounted for 51.56% of the total lead time, which is higher than the proportion of value-adding activities.

Table 4. Current Value Stream Mapping

Activity Classification	Time (minutes)	Percentage (%)
Value Added (VA)	113	39.10
Necessary Non Value Added (NNVA)	27	9.34
Non Value Added (NVA)	149	51.56
Total Lead Time	289	100.00

The NVA activities mainly consisted of waiting for materials, machine setup, transportation between workstations, waiting for inspection, and finished-goods storage. This finding strengthens the results of the Seven Waste analysis because waiting and unnecessary movement are visible not only as waste categories but also as measurable time losses within the production flow.

Integration of OEE and Lean Manufacturing Findings

The combination of OEE and Lean Manufacturing provides a more detailed explanation of the production problems. OEE identifies the extent of machine effectiveness loss, while Lean Manufacturing identifies waste occurring throughout the production flow. The results demonstrate that the two approaches are interconnected. *Equipment Failure* was the largest *Six Big Loss*, while *Waiting* was the largest Lean waste. Both findings point to interruptions and delays as major sources of production inefficiency. Similarly, *Process Defect* and the *Defect* waste category are related to the low Quality component of OEE. *Reduced Speed* contributes to the low Performance value, while long setup activities affect machine availability and create waiting within the production flow. Thus, the losses identified through OEE can be traced to specific forms of waste within the production process.

This relationship demonstrates why OEE measurement alone is insufficient for determining the appropriate improvement action. An OEE value can indicate that equipment effectiveness is low, but the integration with Six Big Losses, Pareto, Fishbone, Seven Waste, and VSM allows the causes and locations of inefficiency to be examined in greater detail. The resulting analysis provides a basis for prioritizing improvements rather than treating all production problems with the same corrective action.

Improvement Proposal and Future State

Based on the identified losses and waste, several improvement actions were proposed. The main actions include preventive maintenance, autonomous maintenance, routine inspection of critical machine components, SMED for reducing setup time, standardization of work procedures and machine parameters, operator training, daily inspection checklists, 5S implementation, and optimization of material flow. These proposals were formulated based on the dominant causes identified through the Six Big Losses, Fishbone, Seven Waste, and VSM analyses.

The proposed improvements were translated into a *Future State Value Stream Mapping*. The projected lead time decreases from 28,500 to 24,100 minutes, while Non Value Added Time decreases from 9,750 to 5,350 minutes, representing a 45.13% reduction. Downtime is projected to decrease from 13,450 to 8,500 minutes, while setup time decreases from 7,520 to 4,800 minutes.

Table 5. Current and Future State Performance

Indicator	Current State	Future State
Lead Time (minutes)	28,500	24,100
Value Added Time (minutes)	18,750	18,750
Non Value Added Time (minutes)	9,750	5,350
Downtime (minutes)	13,450	8,500
Setup Time (minutes)	7,520	4,800
Availability (%)	67.39	95.20
Performance (%)	74.16	97.80
Quality (%)	73.42	99.10
OEE (%)	36.56	92.28

The projected results indicate substantial improvements in all three OEE components. Availability is projected to increase from 67.39% to 95.20% as a result of reduced downtime and improved maintenance. Performance is projected to increase from 74.16% to 97.80% through improved operating stability and reduced speed losses. Quality is projected to increase from 73.42% to 99.10% through better process control and standardization. As a result, the projected OEE increases from 36.56% to 92.28%. The Future State therefore indicates that the proposed improvements have the potential to move machine effectiveness above the 85% World Class benchmark.

The research finding and novelty of this study lie in the **integration of machine-effectiveness measurement and production-flow analysis into a single improvement framework**. OEE identifies the magnitude and type of equipment losses, while Lean Manufacturing connects these losses with specific waste and process activities. The integration of Six Big Losses, Fishbone, Seven Waste, CVSM, and Future State VSM enables the dominant problems to be prioritized and translated into measurable improvement targets. In this case, *Equipment Failure*, *Setup and Adjustment*, *Reduced Speed*, and *Waiting* emerged as the key improvement priorities. The proposed Future State projects a 45.13% reduction in Non Value Added Time and an increase in OEE from 36.56% to 92.28%. This demonstrates that improving machine effectiveness requires simultaneous attention to equipment reliability and production-flow waste rather than treating them as separate problems.

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

This study shows that the hydraulic press machine had low equipment effectiveness, with an OEE value of 36.56%. The main losses were Equipment Failure, Setup and Adjustment, and Reduced Speed, while Waiting was the dominant waste in the production flow. The integration of OEE and Lean Manufacturing identified the main sources of inefficiency and provided improvement priorities. The proposed Future State is projected to increase OEE to 92.28% and reduce Non Value Added Time by 45.13%. These findings contribute to industrial engineering practice by providing an integrated approach for linking equipment losses with production-flow waste to support more targeted improvement.

Limitations

This study was limited to one hydraulic press machine and a specific observation period from January to December 2025. Therefore, the findings may not be directly generalized to

other machines, companies, or industrial sectors. The analysis also focused on selected operational and production factors and did not examine long-term implementation results.

Recommendations

1. Future research should apply the proposed improvement actions in actual production conditions and evaluate their effectiveness over a longer observation period.
2. Future studies should examine different machines or production lines to assess whether the proposed approach can be applied under different operating conditions.
3. Research can also be extended to other industrial sectors to evaluate the broader applicability of the OEE and Lean Manufacturing approach.

Author Contributions

The author was responsible for the conceptualization, data collection, analysis, interpretation of findings, and preparation and revision of the manuscript.

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