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Impact of Automation, Workforce Training, and Lean Manufacturing on Production Efficiency in the Indonesian Automotive Industry

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ABSTRACT

This study will explain how automation, workforce training, and lean manufacturing influence production efficiency within the Indonesian automotive industry. Data were collected from 76 respondents and analyzed using SPSS version 26, applying a quantitative research approach. It was observed that all three factors enhance production efficiency significantly, in the order of workforce training, automation, and lean manufacturing. These results highlight how integrating technology, human resource development, and process optimization will provide sustainable efficiency improvements. These findings suggest some actionable steps that industry players may take in their efforts to improve competitiveness within the turbulent market environment.

Keywords: *Automation, Workforce Training, Lean Manufacturing, Production Efficiency, Indonesian Automotive Industry.*

1. INTRODUCTION

The automotive industry is among the high-priority sectors in Indonesia's economy, and thus it urgently requires the development of an innovative strategy by introducing automation, workforce training, and lean manufacturing to improve efficiency and competitiveness. Automation, including robotics, has a positive impact on manufacturing performance, boosting productivity and supporting the adoption of Industry 4.0 principles to improve energy efficiency and operational effectiveness [1], [2]. Lean manufacturing focuses on waste reduction and efficiency improvement, though its implementation in Indonesian SMEs remains limited, underscoring the potential for enhanced competitiveness in this critical sector [3], [4]. Furthermore, the shift toward Industry 5.0 highlights the importance of workforce training to equip employees with the skills needed to manage and integrate advanced technologies effectively [5]. Together, these strategies are essential for fostering sustainable growth and maintaining the industry's global relevance.

The integration of automation in manufacturing has revolutionized the industry, improving efficiency and productivity while emphasizing the need for a skilled workforce to operate and maintain advanced systems. Workforce training is critical for equipping employees with the necessary skills to manage complex machinery and robotics, ensuring adaptability to technological advancements [6], [7]. Other technologies, such as deep learning, are being used in automation, allowing predictive maintenance and requiring skillful personnel to make sense of such data to ensure equipment does not fail. A properly trained workforce also maximizes the benefits from automation. For instance, production is efficient and less error-prone [8]. Automation can be a potential source of disruptions, impacting job availability and economic insecurity among workers.

To address this, companies must invest in reskilling initiatives, helping employees transition to new roles created by automation and maintaining workforce balance [6], [9], [10].

Lean manufacturing is a waste reduction and process optimization methodology that has gained considerable momentum in Indonesia's automotive industry. Lean practices help much in enhancing production efficiency with quality standards by getting rid of redundancies in operations. The integration of automation, workforce training, and lean manufacturing is expected to comprehensively address the industry's challenges toward sustainable growth. Despite the recognized importance of these factors, there is very limited empirical research into their combined impact on production efficiency within the Indonesian context. This paper hence seeks to bridge this gap by examining how automation, workforce training, and lean manufacturing affect production efficiency in Indonesia's automotive sector.

2. LITERATURE REVIEW

2.1 Automation in Manufacturing

Automation has been a transforming force in the manufacturing sector, particularly in the automotive industry, as it greatly enhances production efficiency and reduces operational costs. Advanced technologies like AI, robotics, and machine learning minimize human intervention in such production processes, thereby reducing errors and increasing consistency in production. On the other hand, as mentioned by [11] and [8], success with automation implementation heavily depends on the skilled workforce and also on the supporting systems. Automation offers key benefits, including a productivity increase of up to 30% and a reduction in manual errors by 25% [12]. It also streamlines operations to lower costs and improve data accuracy [13] while enhancing quality control through better resource management and assurance systems [8]. Despite these benefits, challenges remain, such as high initial investment costs, as reported by Yahya et al. (2024) and [12] skill gaps within the workforce that hinder effective adoption, as reported by [12], and complexities in integrating new technologies with existing systems, which require thorough strategic planning.

2.2 Workforce Training

Training is crucial in integrating the workforce with new, advanced manufacturing technologies and also automation. In other words, proper training would develop the employee's technical proficiency level to cope with new technologies to produce better outcomes on productivity while minimizing the incidences of breakdown. In the context of Indonesian manufacturing firms, training significantly enhanced the efficiency of production [14], [15]. Skill development contributes to higher productivity, job satisfaction, and employee retention, creating a positive feedback loop for organizations [16]. Additionally, the role of technology in training has become increasingly significant, with AI reshaping workforce development by necessitating new strategies for skill enhancement [17]. Advances in robotics also require workers to be trained in operating and maintaining these systems, underscoring the need for continuous education in the manufacturing sector [18]. However, gaps remain in understanding the optimal training approaches for maximizing the benefits of automation and lean manufacturing in Indonesia.

2.3 *Lean Manufacturing*

Lean manufacturing, pioneered by the Toyota Production System, was designed to reduce waste and enhance quality and efficiency. Application of lean techniques includes just-in-time, kaizen, and value stream mapping that aim to simplify processes and remove any form of inefficiency. Evidence has been seen empirically, and lean practices in the automotive industry are more effective, yielding productivity gains and cost reductions. JIT reduces inventory cost because it aligns production to demand, thus reducing overproduction waste [19], [20]. Kaizen continuous improvement with small changes thus improves efficiency and quality [21]. Value stream mapping identifies wastes by analyzing the flow of material and information. Lean practices improve operational efficiency through short production cycles and enhancement of product quality. Companies using lean methods see notable improvements in productivity and customer satisfaction [22]. However, implementing lean practices in developing economies like Indonesia can be challenging due to cultural and organizational barriers. Research by [20], [23] highlights the importance of aligning lean practices with local industry contexts to achieve optimal results.

2.4 *Production Efficiency*

The integration of automation, workforce training, and lean manufacturing will significantly enhance production efficiency in Indonesia's automotive industry. Studies have proven that a combination of these elements results in higher output with minimum input and without compromising quality. Automation, particularly with deep learning, helps solve some of the manufacturing problems, such as defects and equipment failure, since predictive maintenance reduces downtime and improves the accuracy of defect detection [10]. The synergy between automation and deep learning allows for real-time monitoring and streamlines processes [10]. Lean manufacturing, which focuses on waste reduction and efficiency, uses techniques like Value Stream Mapping (VSM) and Overall Equipment Efficiency (OEE) to optimize production [24]. Implementing lean tools before automation increases productivity in automated lines, suggesting a strategic integration of both approaches [25]. Combining lean practices with automation creates a "leagile" production environment, boosting productivity and efficiency, especially for large-scale manufacturing in Indonesia’s automotive sector [26]. Similarly, workforce training was identified as a mediating factor that enhances the impact of automation and lean manufacturing on efficiency. This study seeks to build upon these findings by providing a comprehensive analysis of how these factors interact in the Indonesian automotive sector.

2.5 *Research Gap*

Although there is literature on the individual benefits of automation, workforce training, and lean manufacturing, not much research has been done on how these practices collectively affect production efficiency in developing economies. Most of the studies also focused on developed countries, which leaves a gap in understanding how these practices apply to the Indonesian automotive industry with its own particular set of challenges and opportunities. This study addresses these gaps by analyzing the relationships of these factors and their influence on production efficiency in the Indonesian context.

3. METHODS

3.1 Research Design and Sample

This study has adopted a quantitative research design to establish the relationships that exist between the independent variables (automation, workforce training, and lean manufacturing) and the dependent variable, which is production efficiency. The data collection was done through a cross-sectional survey method that allowed for the establishment of relationships and causality analysis between the variables [27].

The target population for this study is professionals, managers, and technicians working in automotive manufacturing firms in Indonesia. This study targets them because they are direct implementers of automation, workforce training programs, and lean manufacturing practices. A purposive sampling method was used to ensure that the respondents had relevant knowledge and experience. The sample size was 76 respondents from different automotive firms, which was considered sufficient to conduct regression analysis and ensure statistical validity.

3.2 Data Collection

Data collection was done through a structured questionnaire, both online and face-to-face. The questionnaire has been designed in such a way that it measures the perceptions of respondents with regard to automation, workforce training, lean manufacturing, and production efficiency. Before full-scale distribution, the questionnaire was checked for clarity and reliability by carrying out a pilot test with 10 respondents.

3.3 Data Analysis

Statistical data were analyzed using the SPSS version 26, implementing various statistical tests such as descriptive statistics sum-up information on demographic characters in respect to the respondents and each variable's summative score; reliability analysis employing Cronbach's alpha was considered to establish a gauge of the reliability of the instruments' internal structure [28]. Classically, the normality of residuals was considered using the Kolmogorov-Smirnov test and also by visual check of the P-P plot and histogram, while heteroskedasticity was tested using the Glejser test [28]. VIF values and tolerance were considered to test the multicollinearity. Lastly, multiple linear regression was conducted to examine the single and combined effects of automation, workforce training, and lean manufacturing on the efficiency of production at hand.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Descriptive statistics give an overview of respondents' demographic characteristics and their perception of the variables under study, namely automation, workforce training, lean manufacturing, and production efficiency. Demographics summarized in Figure 1 include respondents' roles, years of experience, and the size of organizations they represent.

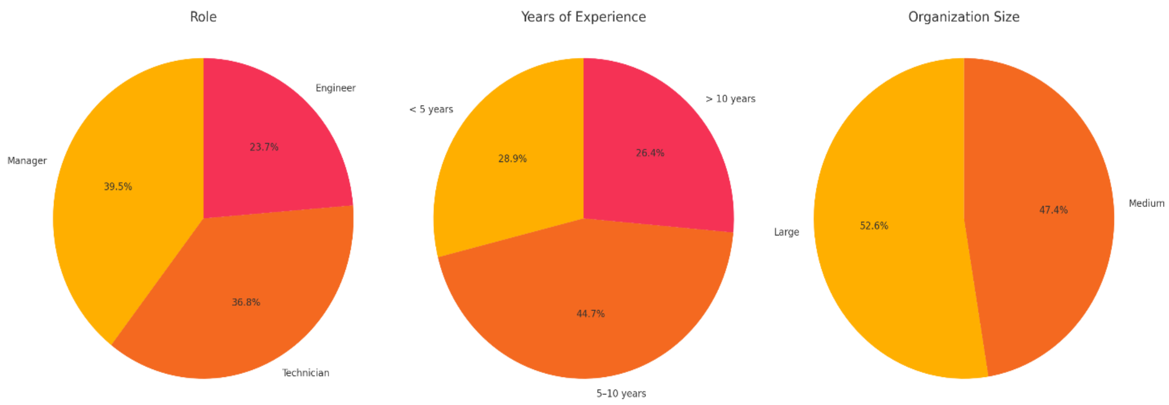

Figure 1. Demographic Sample

Table 1 shows descriptive statistics for study variables: automation, workforce training, lean manufacturing, and production efficiency. For all the above-mentioned variables, respondents were asked to grade on a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 1. Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
Automation	4.15	0.58	3.00	5.00
Workforce Training	4.01	0.63	2.80	5.00
Lean Manufacturing	4.09	0.61	3.10	5.00
Production Efficiency	4.21	0.55	3.20	5.00

The respondents reported a very high level of automation adoption, with a mean score of 4.15, indicating that advanced technologies have been widely integrated into the production process. Workforce training received a slightly lower mean score of 4.01, indicating a need for enhanced training programs to take full advantage of automation. Lean manufacturing practices were moderately implemented, as reflected in the mean score of 4.09, thus highlighting opportunities for further optimization. The mean score for production efficiency was the highest, at 4.21, showing that most respondents feel that their organizations are efficient in using resources and observing quality standards. These statistics thus provide a basis on which the study of the relationship between the variables is founded and further analyzed in subsequent analyses.

4.2 Reliability Analysis

The internal consistencies of the measurement instruments for automation, workforce training, lean manufacturing, and production efficiency were analyzed using Cronbach's alpha (α) as the reliability coefficient, which is considered to be reliable with a value of more than 0.70. Automation was measured with five items, with a Cronbach's alpha of 0.792, reflecting good internal consistency for automation-related practices. Workforce training was assessed with four items and showed high reliability with an α of 0.824. Lean manufacturing was measured with five items and showed a reliability of 0.817, showing that the items measuring lean manufacturing were reliable. Production efficiency, assessed using four items, obtained the highest reliability score of 0.854. This shows the internal consistency of efficiency measures. These findings confirm the robustness of the measurement instruments across all variables.

4.3 Classical Assumptions

Tests for classical assumptions were conducted to ensure the validity and reliability of the regression model. The tests included normality, heteroskedasticity, and multicollinearity, which are essential prerequisites for multiple linear regression analysis.

1. Normality Test

Residual normality was investigated using both the Kolmogorov-Smirnov test and by visual inspections of the histogram and normal probability plot (P-P plot). The result from the Kolmogorov-Smirnov test gave a statistic of 0.087 with a p-value of 0.200, greater than the commonly used significance level of 0.05. Thus, residuals are normally distributed. Furthermore, there were no indications from the histogram and P-P plot regarding important deviations from normality; the assumption of residual normality can therefore be supported.

2. Heteroskedasticity Test

Heteroskedasticity has been checked with the Glejser test by regressing the absolute values of residuals against the regressors. The p-values greater than 0.05 show no heteroskedasticity.

Table 2. Glejser Test

Independent Variable	t-value	Sig. (p-value)
Automation	0.745	0.458
Workforce Training	1.102	0.274
Lean Manufacturing	0.873	0.386

Since, for all independent variables, the p-values are above 0.05, no heteroskedasticity is indicated; hence, the variance of the residuals is constant across observations.

3. Multicollinearity Test

The multicollinearity between independent factors was checked by the VIF and tolerance value. If the VIF value is less than 10 and the tolerance is above 0.1, there is no multicollinearity.

Table 3. VIF and Tolerance Outcomes

Independent Variable	VIF	Tolerance
Automation	1.432	0.698
Workforce Training	1.568	0.638
Lean Manufacturing	1.394	0.717

All VIF values are less than 10, and tolerance values are greater than 0.1, which indicates no multicollinearity among the independent variables.

4.4 Multiple Linear Regression

The multiple linear regression test shall, therefore, be conducted to analyze the independent and combined influence which automation, manpower training, and lean manufacturing practices have on production efficiency within the Indonesian automotive industry. The results of significance show that the set of predictors is relevant towards improving the efficiency outcome variables.

The R value from the summary of the regression model was 0.762, while the R^2 was 0.581; thus, 58.1% of the variation in production efficiency is explained by independent variables. The adjusted R^2 accounted for the number of predictors to give 0.568 as the reliability of the model. The model is statistically significant since it has a standard error of 0.361, F-statistic of 34.12, and p-value less than 0.001, thus it confirms that there is a strong relationship between automation, workforce training, lean manufacturing, and production efficiency.

Table 4. Hypothesis Testing

Predictor	Unstandardized Coefficient (B)	Standard Error (SE)	Standardized Coefficient (Beta)	t-value	Sig
Automation	0.342	0.088	0.340	3.896	0.000
Workforce Training	0.381	0.093	0.370	4.127	0.000

Lean Manufacturing	0.305	0.088	0.300	3.472	0.000

In support, all three predictors significantly and positively predict production efficiency. The β-value for automation is 0.340, significant at $p < 0.001$, hence revealing that efficiency was higher due to increased technological assimilation. Workforce training comes out to be the most influential variable: β = 0.370, p-value less than 0.001, thus showing skilled manpower to be the vital driver of productivity. Lean manufacturing also contributes to production efficiency: β = 0.300, $p < 0.001$, which evidences the role of waste reduction and process optimization in improving performance.

Discussion

1. **The role of automation**

Automation showed a significant positive impact on the efficiency of production. This confirms earlier works of [12], [13] showing that automation reduces human errors, improves accuracy, and accelerates the pace of production. For Indonesia, in view of gradual implementation of Industry 4.0 technologies in the automotive industry, such findings highlight investment opportunities in state-of-the-art machinery and robotics for the country to be more competitive in a global context.

However, the application of automation to developing economies like Indonesia has challenges: huge initial costs and unavailability or inadequate supporting infrastructure. Such challenges have to be met with strategic investments in projects and government policies that provide an enabling environment for investment in automation technologies across various sectors.

2. **Workforce Training as Key Driver**

Workforce training became the strongest driver of change, underlining that employee skill development is a crucial factor in enhancing production efficiency. This finding is in agreement with the works of [14], [18], [29], who indicated that a well-trained workforce is indispensable for the successful implementation of advanced technologies.

These results therefore suggest that specific training programs are urgently needed in Indonesia, where a large proportion of the workforce does not have access to higher technical education. In this way, an organization will ensure full utilization of advantages created by technological investments through employee skills to operate and maintain automated systems. The involvement of industry stakeholders with educational institutions can thus help resolve the skills shortage and provide a consistent supply of qualified professionals.

3. **Lean Manufacturing Practices**

Lean manufacturing also had a positive and significant effect on production efficiency. These results are consistent with the studies of [22], [30], [31], which evidence that lean practices, such as waste reduction and process rationalization, improve operational performance. Thus, there is apparently ample opportunity for the implementation of lean methodologies within the Indonesian automotive sector due to increasing competition and limited resources.

However, the cultural and organizational levels of developing economies present various challenges in implementing lean practices. As noted by [20], [23] an organization should contextualize lean principles to the local context and try to obtain employee buy-in. This can be accomplished through incremental implementation and continuous improvement initiatives relevant to the needs of the organization.

4. Combined Effects

The study showed that automation, workforce training, and lean manufacturing together explained 58.1% of the variance in production efficiency, with $R^2 = 0.581$. This shows how well technology, human capital, and process optimization can go hand in hand. Those organizations that have been able to integrate these factors into their operational strategies are in a better position to achieve sustainable efficiency improvements.

These findings also give credence to the RBV theory, as it was realized that tangible resources need to combine with intangible resources to result in a competitive advantage. In other words, through applying automation technologies, human resource development, and lean practices, Indonesian automotive manufacturers may improve their productive efficiency and global competitiveness.

5. Practical Implications

A number of practical implications are drawn from the results for stakeholders in the Indonesian automotive industry:

a. The need is to invest in those automation technologies which the enterprise requirements for immediate production needs and for strategic goals of long-term focus.
b. Specific training should be imparted for the workmen to manage use and maintenance of automated systems.
c. Lean manufacturing must be tried by avoiding unnecessary wastes and processes. Again, it has a requirement for local contextualizing the practices.

6. Future Research

Although this study provides great insight, there are some limitations that need to be considered. Longitudinal effects are not reflected in the cross-sectional design; the sample size is 76 respondents, and generalizability may be an issue. Future research could consider these limitations by using a greater sample size, longitudinal designs, and exploring other factors that may influence perceptions, such as government policies, industry regulations, and external market dynamics.

CONCLUSION

This study underlines the importance of automation, workforce training, and lean manufacturing in enhancing the production efficiency of the Indonesian automotive industry. Workforce training is found to be the most influencing variable, showing that employees need to be trained to operate and maintain the advanced technologies. Automation and lean manufacturing also play an important role in efficiency by demonstrating the worth of technological advancement and waste reduction practices in optimizing the production processes. All put together, findings stress that these would highlight a holistic approach in matching technological adaption to human resource development and process optimization; an approach to such areas more surely helps achieve sustainable growth and competitiveness of the organization within the global context.

Practically, investing in the needed automation technologies and in developing a program which, besides lean, applies contextualized needs. This again could be encouraged through the use of enabling regulations, financial incentives by policymakers, and partnership building with educational institutions in order to meet the workforce challenges. Other studies can also further this work by incorporating other factors, such as government policies, external market conditions, and long-term implications of adopting such practices. The paper gives a basic insight into the drivers of production efficiency and gives actionable insights for the advancement of sustainability and competitiveness in the automotive industry

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