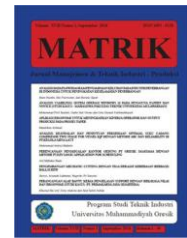




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The Influence of Culture on Operator Flexibility through Work Autonomy: Ergonomics and Leadership Perspectives

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ABSTRACT

This study aims to analyze the influence of lean culture on operator functional flexibility, mediated by work autonomy and moderated by line leadership, within the manufacturing industry. A quantitative approach was employed, utilizing a survey method involving 93 workers in the Kendal Industrial Park (KIK). Data were analyzed using Partial Least Squares-Structural Equation Modeling (PLS-SEM). The results indicate that lean culture has a positive and significant effect on operator flexibility ($\beta = 0.716$; $p < 0.001$) and work autonomy ($\beta = 0.662$; $p < 0.001$). Work autonomy also positively influences operator flexibility ($\beta = 0.476$; $p < 0.001$) and mediates the relationship between lean culture and operator flexibility ($\beta = 0.315$; $p < 0.001$). However, line leadership was not found to moderate this relationship. These findings demonstrate that lean culture can enhance operator flexibility when implemented through the provision of work autonomy. The study underscores that integrating efficiency and flexibility is a crucial strategy for improving the adaptability of manufacturing companies in a dynamic business environment.



1. Introduction

Industrial competition has generally shifted to the level of supply chain competition [1]. Industrial organizations no longer rely solely on internal strengths; instead, they require strategic partnership structures capable of capturing market dynamics and complexities. According to [1] these dynamics constitute a condition known as Volatility, Uncertainty, Complexity, and Ambiguity (VUCA). VUCA reflects the pace of external change, uncertainty, complexity, and ambiguity in the business world [2]. Companies are required to possess agility to adapt to VUCA situations [4]. In this discourse, the concept of agility often stands in diametric opposition to the concept of efficiency. While the VUCA era demands agility, companies are simultaneously required to maintain lean operations. Empirically, the study tests this model using data from manufacturing workers in the Kendal Industrial Park (KIK), thereby providing evidence regarding the relationship between lean culture and operator functional flexibility within the context of Indonesia's manufacturing industry. The findings are expected to clarify whether job autonomy acts as a mechanism bridging lean culture and operator flexibility, and whether line leadership support strengthens or weakens this relationship. Thus, this study not only addresses the conceptual importance of lean and agility but also identifies the socio-organizational mechanisms that explain how operator flexibility is cultivated within manufacturing work environments [3].

The implementation of Lean Manufacturing has become a standard across many manufacturing industries. This concept aims to eliminate waste and continuously enhance value-added activities [4]. Lean culture emphasizes standardized work and process discipline to create a stable and efficient production flow [5]. Amidst uncertainty and intensifying industrial competition, manufacturing industries strive to reduce operational costs through resource optimization, aiming to achieve maximum output with minimal input. However, in the VUCA era, an overly rigid reliance on lean standardization often creates structures that curtail operational

flexibility. When demand fluctuates or material supply disruptions occur, operators accustomed to working within rigid standardization frameworks tend to face cognitive barriers when attempting to switch functions. This mechanism can enhance the functional flexibility of operators. Operators with greater work autonomy have the potential to develop the ability to adjust work methods, manage task priorities, and respond to fluctuations in production loads. Autonomy also fosters experiential learning, as operators do not merely execute instructions but also gain an understanding of the rationale, objectives, and consequences of operational decisions. Thus, work autonomy serves as a mechanism that translates lean cultural values into individual adaptability [6]. The tension between mechanisms for labor standard compliance and the need for agility or flexibility creates a problematic paradox on the manufacturing shop floor. If not managed effectively, this tension can hinder overall organizational resilience and potentially lead to widespread social and ecological impacts. This argument is supported by recent perspectives on the state of Indonesia's manufacturing industry, which faces domestic challenges yet holds the potential to rebound amidst external volatility [6].

According to data from BPS Central Java [7,15]. The economy of Central Java is underpinned by industrial activities situated within Industrial Estates (KI) and Economic Zones (KE). Kendal Regency is home to one such industrial estate, widely known as the Kendal Industrial Park (KIK). Furthermore, empirical evidence indicates that Central Java is rapidly developing into a new manufacturing hub. This is evidenced by industrial development across various areas, including KIK and the Batang Integrated Industrial Estate (KITB) in Batang Regency. This research underscores the potential risk of corporate collapse amidst external disruptions resulting from an overly efficient manufacturing system. Yet, the ability of shop-floor operators to adapt quickly is a key factor in a company's sustainability and resilience. If a "lean" culture is not harmonized with agility, companies risk losing their competitive momentum during disruptions, as

operators may fail to take initiative beyond established standard procedures. In the VUCA era, organizations must integrate lean and agile concepts through strategic leadership.

The integration of lean and agile approaches in manufacturing extends beyond cost efficiency to encompass enhanced flexibility [8], innovation capacity, and market responsiveness. Lean is understood as a tool for continuous learning rather than merely a rigid, static mechanism [1,8]. In this context, [8], notes that lean practices can facilitate organizational agility but does not address how this success is influenced by leadership at the shop-floor level. Yet, critical issues within lean cultures often arise from decision-making dynamics at the shop-floor level [9]. Moreover, research by [1], demonstrates that integrating lean and agile concepts requires organizational leadership to orchestrate dynamic capabilities. However, discourse at the operational level rarely addresses how a lean culture—grounded in standardization—impacts operator functional flexibility, or the extent to which the paradox between efficiency and agility can be mitigated through leadership. Empirical evidence indicates that production activities are shaped not only by work standards and machinery but also by social interactions and worker autonomy. Preliminary field study results reveal that the majority of respondents consider the role of production line leaders to be highly influential in micro-level management decisions[8]. Consequently, this study aims to empirically analyze the impact of lean culture on operator flexibility and to formulate a model integrating operational efficiency and agility at the operator level within the manufacturing industry.

2. Research Methods

This study employs a quantitative, survey-based approach, targeting formal-sector manufacturing workers in the KIK area. KIK is regarded as a key manufacturing hub driving Central Java's economy [8], making it a highly representative subject for this research. A random sample of 93 respondents was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Specifically, the study examines whether lean culture acts as an enabler

or a coercive force regarding operator work flexibility. As a novel contribution, the analysis incorporates frontline leadership (supervisors) as a mediating variable to determine whether the limited autonomy at the operator level can bridge the organizational need for both efficiency and adaptability. The developed model and hypotheses are presented in Figure 1. **Tabel 1.** Definisi Operasional

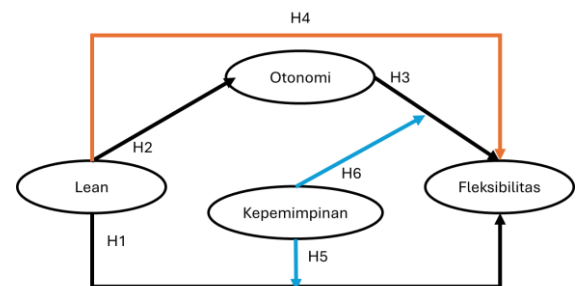


Figure 1. Proposed Lean-Agile Cultural Integration Model through the Role of Strategic Leadership

Hypothesis Development

The direct effect hypotheses include Hypothesis 1 (H1), which posits that lean manufacturing culture has a negative impact on operator functional flexibility. This is based on the view that the overly rigid and repetitive work standardization inherent in lean systems tends to limit the scope for operators to adapt to new tasks that arise spontaneously. [10], highlight the urgency of integrating lean with Industry 4.0 concepts as a solution for industries that have individually failed to successfully implement lean practices. Furthermore, the adoption of lean concepts may encounter resistance if the organizational culture is incompatible, and successful implementation is highly context-dependent [11].

Hypothesis 2 (H2) proposes that lean manufacturing culture has a positive effect on job autonomy. The rationale for this hypothesis is that effective lean implementation—such as Kaizen—should empower operators to oversee quality within their own divisions or work areas; however, this theoretically often conflicts with the lean principle of standardization[1,8].

Hypothesis 3 (H3) states that worker autonomy has a positive effect on operator functional flexibility. This is based on the argument that greater operator control over work methods enhances their ability to quickly adapt to changing workloads. This concept is associated with lean leadership [12].

The mediation hypothesis, Hypothesis 4 (H4), posits that worker autonomy mediates the relationship between lean culture and operator functional flexibility. This hypothesis rests on the argument that the impact of lean systems on operator adaptability is not direct but is instead mediated by the discretion operators have in managing tasks on the production floor [6].

The moderation effect hypotheses comprise Hypothesis 5 (H5) and Hypothesis 6 (H6). H5 states that line leadership support mitigates the negative impact of lean culture on operator flexibility. H5 is based on the argument that line leadership acts as a supportive orchestrator within a lean system, helping operators work flexibly through guidance during disruptions [1].

Meanwhile, H6 proposes that line leadership support positively moderates the relationship between job autonomy and operator functional flexibility. The theoretical rationale is based on the complementary roles of structural empowerment and supervisory support in developing workforce adaptability. Job autonomy enables operators to exercise discretion over task execution, decision-making, and problem-solving, thereby encouraging proactive work behaviors and continuous learning. Nevertheless, the benefits of autonomy may not be fully realized without effective line leadership that provides strategic guidance, performance feedback, coordination, and psychological support. Through these mechanisms, line leaders help ensure that autonomous actions remain aligned with production objectives while fostering confidence, knowledge exchange, and cross-functional collaboration. Therefore, line leadership support amplifies the capacity of autonomous operators to acquire, apply, and integrate diverse competencies, leading to higher levels of operator functional flexibility and improved responsiveness to operational variability [1].

Table 1. Hypotheses for Direct Effects

Hypothes is Number -	Variabel	Arah Pengaruh	Referenc es
H1	Lean Culture → Flexibility	Negative (-)	(Castillo, 2022; Yilmaz et al., 2022)

H2	Lean Culture → Operators Otonomy	Positive (+)	(Amrullah & Yuniar, 2025)
H3	Operators Otonomy → Flexibility	Positive (+)	(Amrullah & Yuniar, 2025; Gatell & Avella, 2024)

3. Results and Discussions

3.1 Outer Model Analysis

- Model evaluation in Partial Least Squares Structural Equation Modeling (PLS-SEM) is conducted through two sequential stages, namely the evaluation of the measurement model (outer model) and the structural model (inner model). The outer model evaluation aims to assess the quality of the measurement instrument by examining the reliability and validity of the latent constructs. Specifically, this stage involves three primary assessment criteria: internal consistency reliability, convergent validity, and discriminant validity. Internal consistency reliability evaluates the degree to which indicators consistently measure the same construct using metrics such as Cronbach's alpha, Composite Reliability (CR), and rho_A. Convergent validity determines whether the indicators adequately represent the intended construct, typically assessed through standardized factor loadings and the Average Variance Extracted (AVE). Furthermore, discriminant validity ensures that each latent construct is empirically distinct from other constructs within the research model, commonly evaluated using the Fornell–Larcker criterion, cross-loadings, and the Heterotrait–Monotrait (HTMT) ratio. Only after the measurement model has demonstrated satisfactory psychometric properties can the structural model be evaluated. The inner model assessment focuses on examining the hypothesized

relationships among latent variables by evaluating path coefficients, the coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2), and the statistical significance of the hypothesized paths through bootstrapping procedures. Consequently, the sequential evaluation of the outer and inner models ensures that the measurement instruments are both reliable and valid, thereby providing robust empirical evidence for testing the proposed research hypotheses and strengthening the explanatory and predictive capabilities of the structural model [1]

b) Internal consistency test

The internal consistency test aims to evaluate the reliability of the indicators for each construct variable. This testing involves assessing criteria such as outer loadings, Cronbach's alpha, and composite reliability [13].

The evaluation of the measurement model was performed using SmartPLS 3.0 software by examining the outer loading values of each indicator, along with Cronbach's alpha and Composite Reliability for each latent construct. Indicators with outer loading values below the recommended threshold were carefully assessed based on their contribution to construct validity and theoretical relevance [3]. Overall, the measurement model is considered reliable when all indicators satisfy the recommended loading criteria and the latent constructs demonstrate acceptable levels of internal consistency reliability. These results provide sufficient evidence that the measurement model is appropriate. Therefore, sample adequacy in this study is not determined solely by rules of thumb but also requires support from a statistical power analysis that considers the significance level, expected effect size, number of predictors for the endogenous construct, and the complexity of the moderation test. If the power analysis indicates that 93 respondents satisfy the requirements for model testing, this result can serve as the basis for

justifying the sample size. Otherwise, the limitation regarding sample size must be explicitly stated, and further research with a larger sample should be recommended. [14]. For subsequent analyses, including convergent validity, discriminant validity, and structural model (inner model) evaluation, are presented in Figure 2 and Table 3.

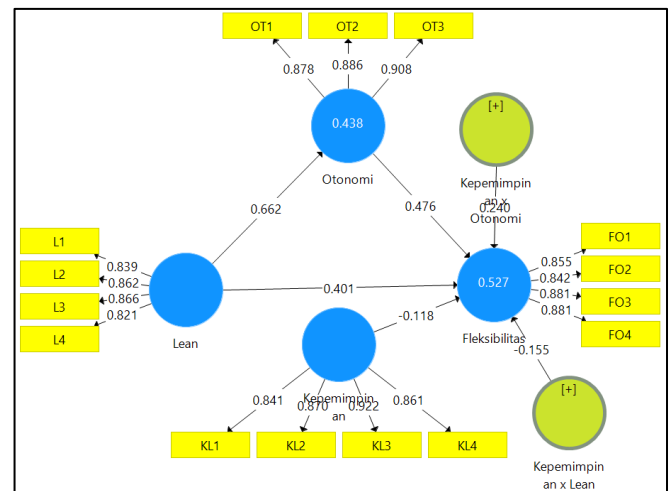


Figure 2. Results of the outer model evaluation analysis.

Table 3. Loading Factor Results

	Fleksibilitas	Kepemimpinan	Lean	Otonomi
FO1	0,855			
FO2	0,842			
FO3	0,881			
FO4	0,881			
KL1		0,841		
KL2		0,870		
KL3		0,922		
KL4		0,861		
L1			0,839	
L2			0,862	
L3			0,866	
L4			0,821	
OT1				0,878
OT2				0,886
OT3				0,908

Based on the loading factor values above, it can be concluded that there are no issues with the construct variable indicators, as the resulting values exceed 0.7. Table 4 presents the data analysis results for model testing based on Cronbach's Alpha and Composite Reliability criteria. The results indicate no issues with the model, as it meets the "rules of thumb" by

exceeding the 0.60 threshold. Consequently, the outer model testing in this study has successfully met the requirements of each measurement criterion, allowing the research to proceed to the inner model testing stage.

Table 4. Results of the Validity and Reliability Test of the Constructs

	Cronbach's Alpha	Composite Reliability
Fleksibilitas	0,888	0,922
Kepemimpinan	0,898	0,928
Lean	0,869	0,911
Otonomi	0,870	0,920

b) Convergent validity test

The criterion used for the convergent validity test is the Average Variance Extracted (AVE) value. Based on the rules of thumb for testing reflective models, the AVE value must exceed 0.50. The results of the AVE data analysis for this study are presented in Table 5. Based on these results, it can be stated that the model proposed in this study meets the AVE criteria, as the AVE value for each construct exceeds 0.50.

	Average Variance Extracted (AVE)
Fleksibilitas	0,748
Kepemimpinan	0,764
Lean	0,718
Otonomi	0,793

c) Discriminant Validity Test

According to [13] discriminant validity refers to the extent to which a construct is truly distinct from other constructs based on empirical standards. This implies that a construct is unique and represents a phenomenon not captured by other constructs within the model. Traditionally, researchers have relied on two measures of discriminant validity: the cross-loading analysis approach and the Fornell-Larcker criterion. However, much of the literature introduces an additional analytical criterion: the Heterotrait-Monotrait Ratio (HTMT). Despite their widespread use, subsequent

methodological research has demonstrated that both the cross-loading approach and the Fornell-Larcker criterion may lack sufficient sensitivity to detect discriminant validity problems, particularly when constructs are conceptually similar or highly correlated. To address these limitations, recent literature recommends incorporating an additional and more rigorous assessment criterion, namely the Heterotrait-Monotrait Ratio of Correlations (HTMT). The HTMT approach estimates the ratio of between-construct correlations to within-construct correlations, providing a more reliable and statistically robust evaluation of discriminant validity. A lower HTMT value indicates greater empirical distinction between constructs, whereas values exceeding the recommended threshold suggest a potential lack of discriminant validity. Consequently, HTMT has become the preferred and recommended method in Partial Least Squares Structural Equation Modeling (PLS-SEM) because empirical studies have consistently shown its superior capability in detecting discriminant validity issues compared with traditional approaches.

Table 5. Cross-Loading Analysis Results

	Fleksibilitas	Kepemimpinan	Lean	Otonomi
FO1	0,855	0,316	0,527	0,502
FO2	0,842	0,299	0,528	0,529
FO3	0,881	0,369	0,534	0,559
FO4	0,881	0,371	0,594	0,544
KL1	0,296	0,841	0,500	0,487
KL2	0,422	0,870	0,730	0,565
KL3	0,309	0,922	0,571	0,508
KL4	0,314	0,861	0,477	0,572
L1	0,511	0,556	0,839	0,639
L2	0,516	0,565	0,862	0,525
L3	0,503	0,642	0,866	0,583
L4	0,611	0,501	0,821	0,487
OT1	0,535	0,589	0,563	0,878
OT2	0,520	0,464	0,529	0,886
OT3	0,589	0,580	0,664	0,908

b. Fornell Larcker Criterion Analysis

The Fornell-Larcker criterion serves as a second approach for assessing discriminant validity. This criterion compares the square root of the Average Variance Extracted (AVE) values with

the correlations between latent variables. Specifically, the square root of the AVE for each construct must exceed its highest correlation with any other construct. An alternative approach to evaluating the Fornell-Larcker criterion results is to determine whether the AVE is greater than the squared correlation with other constructs. The concept underlying the Fornell-Larcker method is the assumption that a construct shares more variance with its associated indicators than with other constructs [13]. The results of the Fornell-Larcker criterion analysis are presented in Table 6.

Table 6. Results of the Fornell-Larcker Criterion Analysis

	Fleksibilitas	Kepemimpinan	Lean	Otonomi
Fleksibilitas	0,865			
Kepemimpinan	0,392	0,874		
Lean	0,632	0,668	0,847	
Otonomi	0,617	0,614	0,662	0,891

c. HTMT (<0.9)

The HTMT criterion requires that the HTMT values for the variables in the model be less than 0.9. Table 7 presents the results of the research model data analysis based on the HTMT criterion. The test results indicate that the research model meets the HTMT criterion, as the values for each variable are below 0.9. This suggests that all research construct variables are distinct from one another [14].

Table 7. HTMT Analysis Results

	Fleksibilitas	Kepemimpinan	Kepemimpinan x Lean	Kepemimpinan x Otonomi	Lean
Fleksibilitas					
Kepemimpinan	0,428				
Kepemimpinan x Lean	0,443	0,543			

Kepemimpinan x Otonomi	0,238	0,525	0,816		
Lean	0,718	0,737	0,772	0,558	
Otonomi	0,699	0,686	0,510	0,510	0,753

B. Inner Model Analysis

Inner model analysis—or structural model analysis—focuses on testing the hypotheses proposed in the study. In this instance, there are three hypotheses concerning direct effects and three concerning indirect effects [8]. The results of the hypothesis testing are presented in Tables 8 and 9. Overall, the research hypotheses regarding direct effects yielded significant and acceptable results; however, the analysis of indirect effects revealed two hypotheses indicating non-significant effects.

- Hypothesis 1 test, H1: Lean manufacturing culture has a negative effect on operator functional flexibility.
- Hypothesis 2 test, H2: Lean manufacturing culture has a positive effect on job autonomy.
- Hypothesis 3 test, H3: Worker autonomy has a positive effect on operator functional flexibility.

Table 8. Bootstrapping Results for Structural Model Analysis (Direct Effect)

Hipotesis	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/S TDE V)	P Values
H1: Lean -> Fleksibilitas	0,716	0,703	0,135	5,298	0,000
H2: Lean -> Otonomi	0,662	0,661	0,068	9,720	0,000
H3: Otonomi -> Fleksibilitas	0,476	0,462	0,103	4,611	0,000

- Hypothesis 4 test, H4: Worker autonomy mediates the relationship between lean culture and operator functional flexibility.

- e) Hypothesis 5 test, H5: Line leadership support weakens the negative influence of lean culture on operator flexibility.
- f) Hypothesis 6 test, H6: Line leadership support strengthens the positive influence of job autonomy on operator functional flexibility.

Table 9. Bootstrapping Results for Structural Model Analysis (Indirect Effect)

Hipotesis	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/S TDEV)	P Values
H4: Lean -> Otonomi -> Fleksibilitas	0,315	0,305	0,073	4,303	0,000
H5: Kepemimpinan x Lean -> Fleksibilitas	-0,155	-0,123	0,149	1,042	0,149
H6: Kepemimpinan x Otonomi -> Fleksibilitas	0,240	0,212	0,153	1,565	0,059

The moderation analysis in this study did not yield a significant effect. The interaction coefficient between line leadership and lean culture regarding operator flexibility was $\beta = -0.155$ ($p = 0.149$), while the interaction between line leadership and work autonomy regarding operator flexibility was $\beta = 0.240$ ($p = 0.059$). These results indicate that line leadership support has not been shown to alter the strength of the relationships between the variables at the 5% significance level. However, these findings cannot be interpreted to mean that line leadership plays no role in a lean system. The lack of a significant moderating effect may be attributed to organizational characteristics, decision-making patterns, variations in supervisor

support, or sample size limitations affecting the detection of interaction effects. Consequently, while line leadership remains theoretically relevant, its moderating influence in this study has not received sufficient empirical support [15].

4. Conclusion and Recommendations

Based on the findings of the article "The Influence of Culture on Operator Flexibility through Work Autonomy: Ergonomics and Leadership Perspectives," it can be concluded that lean culture plays a crucial role in shaping the work flexibility of manufacturing operators. Structural model testing reveals that lean culture has a positive and significant impact on operator flexibility ($\beta = 0.716$; $p < 0.001$) and a positive and significant impact on work autonomy ($\beta = 0.662$; $p < 0.001$). Furthermore, work autonomy is shown to have a positive and significant effect on operator functional flexibility ($\beta = 0.476$; $p < 0.001$) and to mediate the relationship between lean culture and work flexibility ($\beta = 0.315$; $p < 0.001$). These findings indicate that lean culture is not inherently restrictive—despite its reliance on standardization and process control—but can serve as an enabling mechanism when implemented in a way that grants operators autonomy and opportunities for involvement. However, line leadership support was not statistically proven to moderate the relationship between lean culture and operator flexibility, nor the relationship between work autonomy and operator flexibility (with p-values of 0.149 and 0.059, respectively). Thus, this study confirms that enhancing operator flexibility is driven more strongly by the integration of lean culture and the provision of work autonomy than by the direct moderating effect of line leadership within the tested model. Theoretically, this study contributes to the development of the lean-agile perspective by demonstrating that efficiency and flexibility need not be viewed as opposing objectives. Practically, manufacturing companies should cultivate a lean culture that goes beyond emphasizing adherence to standards; it should also foster continuous learning, operator-level decision-

making, and targeted autonomy. In doing so, work systems can become more adaptive to the dynamics of a VUCA environment without compromising the principles of operational efficiency [1,2].

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