




# XGBoost-Based Prediction of Innovative Work Behavior Using Organizational Climate and Leadership Variables

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## Article Info

### Article type:

Original Research

### How to cite this article:

Nakamura, T., Sari, D. K., & Papadakis, D. (2026). XGBoost-Based Prediction of Innovative Work Behavior Using Organizational Climate and Leadership Variables. *International Journal of Innovation Management and Organizational Behavior*, 6(3), 1-13.  
<https://doi.org/10.61838/kman.ijimob.5416>



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## ABSTRACT

**Objective:** The present study aimed to develop and evaluate an XGBoost-based machine learning model for predicting innovative work behavior using organizational climate and leadership variables among employees working in Indonesian organizations.

**Methods and Materials:** This study employed a cross-sectional predictive research design involving 1,248 employees from multiple Indonesian organizations representing manufacturing, information technology, telecommunications, financial services, and public administration sectors. Data were collected using standardized measures of innovative work behavior, organizational climate, and leadership. Demographic and occupational variables were also included as supplementary predictors. Data preprocessing procedures included missing-value treatment, standardization, and quality screening. The dataset was divided into training (80%) and testing (20%) subsets. Extreme Gradient Boosting (XGBoost) was utilized to develop the predictive model, while hyperparameter optimization was performed using five-fold cross-validation and grid-search procedures. Model performance was evaluated using the coefficient of determination ( $R^2$ ), root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE). SHapley Additive exPlanations (SHAP) analysis was applied to identify and interpret the relative importance of predictor variables.

**Findings:** Inferential analyses revealed significant positive correlations between innovative work behavior and organizational climate ( $r = .71, p < .01$ ), transformational leadership ( $r = .68, p < .01$ ), transactional leadership ( $r = .41, p < .01$ ), and organizational tenure ( $r = .19, p < .01$ ). The XGBoost model demonstrated strong predictive performance, explaining 88.7% of the variance in innovative work behavior in the training dataset and 84.2% in the testing dataset ( $R^2 = .842$ ). The model achieved low prediction errors, with testing RMSE = 0.287, MAE = 0.223, and MAPE = 7.46%, indicating excellent predictive accuracy and

generalizability. SHAP analysis identified transformational leadership as the most influential predictor, followed by innovation and flexibility climate, supervisory support, autonomy, communication quality, organizational integration, contingent reward leadership, educational level, organizational tenure, and organizational size. The results demonstrated that leadership and organizational climate variables accounted for the majority of predictive power within the model.

**Conclusion:** The findings demonstrate that innovative work behavior can be predicted with high accuracy using organizational climate and leadership variables. Transformational leadership and innovation-supportive organizational climates emerged as the most influential determinants of employee innovation. The study highlights the value of explainable machine learning techniques for organizational research and provides evidence that leadership development and innovation-oriented workplace environments represent critical levers for enhancing innovative work behavior.

**Keywords:** *Innovative Work Behavior, XGBoost, Machine Learning, Organizational Climate, Transformational Leadership, Leadership Variables, Innovation Climate*

## 1 Introduction

Innovative work behavior (IWB) has emerged as one of the most important determinants of organizational competitiveness, adaptability, and long-term sustainability in contemporary business environments. As organizations increasingly operate within rapidly changing technological, economic, and social landscapes, employees are expected not only to perform assigned tasks efficiently but also to continuously generate, promote, and implement novel ideas that contribute to organizational improvement and innovation. Innovative work behavior refers to a set of employee activities involving idea generation, idea promotion, and idea realization aimed at improving products, services, processes, and organizational practices. Unlike creativity, which focuses primarily on the generation of novel ideas, innovative work behavior encompasses the entire innovation process from conception to implementation. Consequently, organizations seeking sustainable competitive advantages increasingly recognize innovative work behavior as a critical organizational resource. Recent literature demonstrates that employees who actively engage in innovation-related activities significantly contribute to organizational effectiveness, knowledge development, productivity enhancement, and strategic adaptability. Systematic reviews have further indicated that innovative work behavior has become a central construct in organizational research due to its direct relationship with organizational innovation outcomes, employee performance, and competitive success in both public and private sectors (Ebrahim et al., 2023; Srirahayu et al., 2023; Veloso et al., 2021). The growing importance of innovation-oriented work behaviors has stimulated extensive scholarly

interest in identifying the organizational and leadership factors that facilitate employees' willingness and capability to engage in innovation-related activities.

Among the various antecedents of innovative work behavior, leadership has consistently emerged as one of the most influential determinants. Leaders play a fundamental role in shaping employee attitudes, motivation, confidence, and behavioral intentions regarding innovation. Leadership behaviors influence the degree to which employees feel empowered, supported, and psychologically safe to experiment with new ideas and challenge established routines. Transformational leadership, in particular, has received substantial attention due to its ability to inspire employees through vision articulation, intellectual stimulation, individualized consideration, and motivational influence. Numerous empirical studies have demonstrated positive associations between transformational leadership and innovative work behavior across different industries and cultural contexts. Recent evidence suggests that transformational leaders encourage employees to explore new opportunities, challenge conventional assumptions, and persist in implementing innovative solutions despite uncertainty and potential risks (Helmy et al., 2023; Junbish et al., 2023; Phairat et al., 2026; Vu et al., 2025). Similarly, studies conducted within healthcare settings have shown that transformational leadership enhances employee happiness, technology acceptance, and innovation-related behaviors, ultimately contributing to organizational innovation capacity (Ağaoğlu et al., 2025). Other leadership perspectives, including servant leadership, authentic leadership, spiritual leadership, inclusive leadership, and responsible leadership, have also demonstrated positive influences on innovative work behavior by fostering trust, empowerment, ethical

conduct, and employee engagement (Bhatnagar & Aggarwal, 2022; Indrayanti & Ulfia, 2022; Musenze et al., 2024; Soukupová & Strítěská, 2024; Usmanova et al., 2021). Furthermore, emerging leadership constructs such as innovational leadership emphasize leaders' direct involvement in creating environments that actively encourage experimentation and innovative thinking among employees (Contreras et al., 2022). Despite these advances, the relative predictive contribution of different leadership dimensions remains incompletely understood, particularly when examined through advanced predictive modeling techniques.

In addition to leadership, organizational climate has been repeatedly identified as a critical contextual factor influencing innovative work behavior. Organizational climate represents employees' shared perceptions regarding organizational policies, practices, procedures, and norms that characterize the work environment. Innovation-supportive climates provide employees with psychological safety, autonomy, collaboration opportunities, communication openness, and access to organizational resources necessary for experimentation and idea implementation. Research indicates that innovation climate directly influences employees' willingness to generate and share new ideas while simultaneously strengthening the effectiveness of leadership behaviors. For example, innovation climate has been found to strengthen the relationship between transformational leadership and innovative work behavior, suggesting that leadership effects are amplified when employees perceive organizational support for innovation (Akinci et al., 2022; Wijaya, 2024). Similarly, studies have demonstrated that diversity climate, humor climate, team climate, learning-oriented culture, and innovation-oriented organizational culture significantly enhance employees' innovative behaviors by fostering supportive social and psychological environments (Baig et al., 2022; Handoko & Anjaningrum, 2024; Listyanti & Hendarman, 2023; Logacheva & Plakhotnik, 2021). Organizational culture and trust in managers have also been shown to mediate important relationships associated with employee innovation outcomes, indicating that innovation-supportive organizational contexts facilitate the translation of leadership influences into actual innovative behaviors (Indrayanti & Ulfia, 2022; Özdaşlı et al., 2023). Collectively, these findings suggest that innovative work behavior is shaped not only by individual leadership experiences but also by broader organizational conditions that either encourage or inhibit innovation-related activities.

Recent theoretical developments have increasingly emphasized the interaction between leadership, organizational climate, and individual psychological mechanisms in explaining innovative work behavior. Studies have identified psychological empowerment, intrinsic motivation, work engagement, psychological safety, creative self-efficacy, and knowledge-sharing behaviors as important mediating mechanisms linking organizational conditions to innovation outcomes. Employees who experience supportive leadership and favorable organizational climates tend to report higher levels of psychological empowerment, stronger intrinsic motivation, greater work engagement, and increased confidence in their ability to contribute innovative ideas. These psychological states subsequently facilitate the generation and implementation of innovative solutions within organizations (Aristana et al., 2024; Junbish et al., 2023; Vu et al., 2025; Xu & Suntrayuth, 2022). Knowledge sharing has also emerged as a particularly important mechanism because innovation frequently depends on employees' willingness to exchange expertise, collaborate across functional boundaries, and integrate diverse perspectives. Research has consistently shown positive relationships between knowledge-sharing practices and innovative work behavior across healthcare, technology, and public-sector organizations (Elsayed et al., 2022; Usmanova et al., 2021; Xu & Suntrayuth, 2022). Furthermore, proactive personality characteristics and innovation-oriented human resource systems have been found to strengthen employees' intrinsic motivation and innovation capabilities, thereby enhancing innovative work behavior (Li et al., 2022; Xu et al., 2023). While these findings have substantially improved theoretical understanding of innovation-related behavior, most existing studies continue to rely on traditional explanatory statistical approaches that prioritize hypothesis testing rather than predictive accuracy.

Although conventional regression-based methodologies have generated valuable insights regarding the determinants of innovative work behavior, they possess several limitations when dealing with complex organizational phenomena. Organizational behavior is inherently multidimensional, nonlinear, and influenced by numerous interacting variables. Traditional statistical models often assume linear relationships, independence among predictors, and relatively simple interaction structures, potentially limiting their ability to capture the complexity of real-world organizational environments. In contrast, machine learning techniques provide powerful analytical capabilities for

identifying hidden patterns, nonlinear associations, and high-order interactions within large datasets. Among these techniques, Extreme Gradient Boosting (XGBoost) has emerged as one of the most accurate and robust predictive algorithms due to its ability to handle complex datasets, minimize prediction error, prevent overfitting, and automatically model nonlinear relationships. XGBoost has demonstrated superior predictive performance across diverse domains including finance, healthcare, marketing, human resource management, and organizational analytics. Despite the growing adoption of machine learning in organizational research, relatively few studies have applied advanced predictive algorithms to investigate innovative work behavior. Existing investigations have predominantly focused on explaining relationships among variables rather than accurately predicting employee innovation outcomes. Consequently, there remains a significant methodological gap regarding the application of explainable machine learning techniques for identifying the most influential predictors of innovative work behavior and quantifying their relative importance within integrated predictive frameworks (Marwan & Alhadar, 2024; Modliba et al., 2024; Muhammad Jahanzeb Khan Saima, 2021).

The need for predictive approaches is particularly relevant in contemporary organizational contexts characterized by rapid digital transformation, increasing technological complexity, and heightened innovation demands. Organizations increasingly require data-driven tools capable of identifying employees who are most likely to engage in innovative activities and determining which organizational interventions are likely to produce the greatest improvements in innovation performance. Public-sector organizations, healthcare institutions, technology firms, and knowledge-intensive industries have all emphasized the strategic importance of fostering innovation-oriented work environments and leadership practices capable of sustaining competitive advantages in dynamic environments (Arham et al., 2024; Husen, 2024). Furthermore, recent evidence suggests that factors such as leader-member exchange quality, team support for innovation, employee participation in decision-making, innovation-oriented human resource systems, and organizational climate characteristics interact in complex ways that may be difficult to capture using traditional statistical approaches (Ezeaku et al., 2024; Modliba et al., 2024; Xu et al., 2023). Explainable artificial intelligence methods, including SHapley Additive exPlanations (SHAP), offer additional advantages by providing transparent

interpretations of machine learning models and identifying the relative contribution of individual predictors. Such approaches enable researchers and practitioners not only to predict innovative work behavior accurately but also to understand the mechanisms underlying those predictions, thereby enhancing the practical utility of organizational analytics.

Given the theoretical significance of innovative work behavior, the established importance of leadership and organizational climate variables, and the growing need for advanced predictive methodologies in organizational research, the present study aimed to develop and evaluate an XGBoost-based predictive model of innovative work behavior using organizational climate and leadership variables among employees in Indonesian organizations.

## 2 Methods and Materials

This study employed a cross-sectional predictive research design using machine learning techniques to examine the extent to which organizational climate and leadership-related variables could predict employees' innovative work behavior. The study was conducted across multiple medium-sized and large organizations operating in the manufacturing, telecommunications, financial services, information technology, and public administration sectors in Indonesia. The research focused on full-time employees who had been employed in their current organizations for a minimum of one year, ensuring that participants possessed sufficient experience and familiarity with their organizational environment and leadership structures.

A total of 1,248 employees participated in the study. Participants were selected using a stratified random sampling approach to ensure representation from different industries and organizational levels. The sample consisted of employees occupying operational, supervisory, middle-management, and senior-management positions. The inclusion criteria required participants to be at least 18 years of age, employed on a full-time basis, and willing to provide informed consent. Employees on temporary contracts, probationary status, or extended leave during the data collection period were excluded from the study. Data collection was conducted electronically through a secure online survey platform, and all participants were informed about the confidentiality and anonymity of their responses. Ethical principles regarding voluntary participation, privacy protection, and informed consent were strictly observed throughout the study.

Innovative work behavior was measured using the Innovative Work Behavior Scale developed by Janssen (2000). The instrument consists of nine items designed to assess employees' generation, promotion, and realization of innovative ideas in the workplace. Participants responded to each item using a five-point Likert scale ranging from strongly disagree to strongly agree. Higher scores reflected greater engagement in innovative work behavior. Previous studies have consistently demonstrated satisfactory construct validity, convergent validity, and internal consistency reliability for the scale across diverse organizational contexts.

Organizational climate was assessed using the Organizational Climate Measure developed by Patterson and colleagues (2005). The instrument evaluates employees' perceptions of key workplace characteristics, including involvement, supervisory support, autonomy, communication, innovation and flexibility, training, integration, and organizational well-being. The questionnaire contains multiple dimensions that collectively capture the psychological atmosphere experienced by employees within their organizations. Responses were recorded on a five-point Likert scale, with higher scores indicating a more favorable organizational climate. The measure has been extensively validated in organizational research and has demonstrated strong psychometric properties, including high internal consistency coefficients and robust factor structures.

Leadership variables were measured using the Multifactor Leadership Questionnaire developed by Bass and Avolio (1995). This instrument assesses transformational leadership, transactional leadership, and passive or avoidant leadership behaviors. The transformational leadership dimension includes idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration, whereas transactional leadership encompasses contingent reward and management-by-exception behaviors. Participants rated the frequency with which their immediate supervisors demonstrated specific leadership behaviors using a five-point response format ranging from not at all to frequently, if not always. Numerous studies have reported strong evidence supporting the validity and reliability of the instrument across different cultural and organizational settings.

In addition to the primary predictor variables, demographic and occupational information was collected, including age, gender, educational level, organizational

tenure, job level, industry sector, and organizational size. These variables were incorporated into the machine learning model as supplementary predictors to improve predictive performance and capture potential contextual influences on innovative work behavior.

Prior to model development, all survey responses were screened for completeness, consistency, and outliers. Missing values were handled using multiple imputation procedures when the proportion of missing data was below established thresholds. Variables were subsequently standardized to ensure comparability across measurement scales and to optimize machine learning performance.

Data analysis was conducted using Python programming language and several machine learning libraries, including Scikit-learn, XGBoost, NumPy, Pandas, and SHAP. Initially, descriptive statistical analyses were performed to summarize participant characteristics and examine the distributional properties of all study variables. Correlation analyses were also conducted to explore preliminary relationships among organizational climate dimensions, leadership variables, and innovative work behavior.

The predictive modeling phase utilized the Extreme Gradient Boosting (XGBoost) algorithm, a highly efficient ensemble learning technique based on gradient-boosted decision trees. XGBoost was selected because of its superior predictive accuracy, ability to model complex nonlinear relationships, resistance to overfitting through regularization mechanisms, and capability to handle high-dimensional organizational datasets. The target variable consisted of innovative work behavior scores, while organizational climate dimensions, leadership factors, and demographic variables served as predictors.

The dataset was randomly divided into training and testing subsets, with 80% of observations allocated to model training and 20% reserved for model evaluation. Hyperparameter optimization was performed using grid search combined with five-fold cross-validation to identify the optimal configuration of model parameters, including learning rate, maximum tree depth, minimum child weight, subsampling ratio, and regularization coefficients. Model performance was evaluated using multiple predictive metrics, including coefficient of determination ( $R^2$ ), root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE).

To enhance model interpretability, Explainable Artificial Intelligence techniques were employed through SHapley Additive exPlanations (SHAP) analysis. SHAP values were calculated to determine the relative importance and

contribution of each predictor variable to innovative work behavior predictions. Feature importance rankings, dependence plots, and summary visualizations were generated to identify the organizational climate dimensions and leadership characteristics exerting the strongest influence on innovative work behavior. This approach enabled both accurate prediction and transparent interpretation of the factors driving employee innovation within Indonesian organizations.

All statistical and machine learning analyses were conducted at a significance level of 0.05, and the robustness of the predictive model was further assessed through repeated cross-validation procedures to ensure generalizability and stability of the findings.

### 3 Findings and Results

A total of 1,248 employees from Indonesian organizations participated in the study. Among the participants, 678 (54.3%) were male and 570 (45.7%) were female. The mean age of the respondents was 36.82 years

(SD = 8.74), with ages ranging from 21 to 59 years. Regarding educational attainment, 18.4% held diploma qualifications, 58.7% possessed bachelor's degrees, 20.1% had master's degrees, and 2.8% held doctoral degrees. In terms of organizational tenure, 23.2% had worked in their organizations for less than five years, 38.9% had between five and ten years of experience, 27.4% had between eleven and fifteen years of experience, and 10.5% had more than fifteen years of service. Participants represented a broad range of organizational sectors, including manufacturing (27.6%), information technology (18.8%), telecommunications (14.3%), financial services (16.7%), public administration (12.5%), and other industries (10.1%). Furthermore, 61.4% of respondents occupied operational or specialist positions, 24.8% held supervisory roles, and 13.8% served in middle or senior management positions. These characteristics indicate that the sample reflected substantial diversity in professional backgrounds, organizational contexts, and leadership experiences, thereby providing a suitable basis for developing a robust machine learning model for predicting innovative work behavior.

**Table 1**

*Descriptive Statistics and Correlation Matrix of Study Variables*

Variable	Mean	SD	1	2	3	4	5
1. Innovative Work Behavior	3.79	0.67	1.00				
2. Organizational Climate	3.85	0.59	0.71**	1.00			
3. Transformational Leadership	3.91	0.63	0.68**	0.74**	1.00		
4. Transactional Leadership	3.54	0.58	0.41**	0.46**	0.52**	1.00	
5. Organizational Tenure	8.72	5.36	0.19**	0.14**	0.11**	0.07*	1.00

Table 1 presents the descriptive statistics and bivariate correlations among the principal study variables. The results indicate that innovative work behavior exhibited a relatively high mean score ( $M = 3.79$ ,  $SD = 0.67$ ), suggesting that employees generally reported moderate to high levels of innovation-related activities in their workplaces. Organizational climate demonstrated the strongest correlation with innovative work behavior ( $r = .71$ ,  $p < .01$ ), followed closely by transformational leadership ( $r = .68$ ,  $p < .01$ ). These findings suggest that employees who perceive a supportive, flexible, and innovation-oriented organizational climate, as well as transformational leadership behaviors from their supervisors, are substantially more likely to engage in innovative work activities. Transactional leadership showed a moderate positive relationship with

innovative work behavior ( $r = .41$ ,  $p < .01$ ), indicating that reward-based leadership practices may also contribute to innovation, although their impact appears weaker than transformational leadership behaviors. Organizational tenure displayed a relatively weak but statistically significant association with innovative work behavior ( $r = .19$ ,  $p < .01$ ), suggesting that longer-serving employees may possess greater organizational knowledge and confidence to generate and implement new ideas. The strong intercorrelations between organizational climate and transformational leadership further indicate the existence of a mutually reinforcing organizational environment in which leadership practices shape employee perceptions of the workplace and subsequently influence innovation-related outcomes.

**Table 2**

*Performance Metrics of the XGBoost Prediction Model*

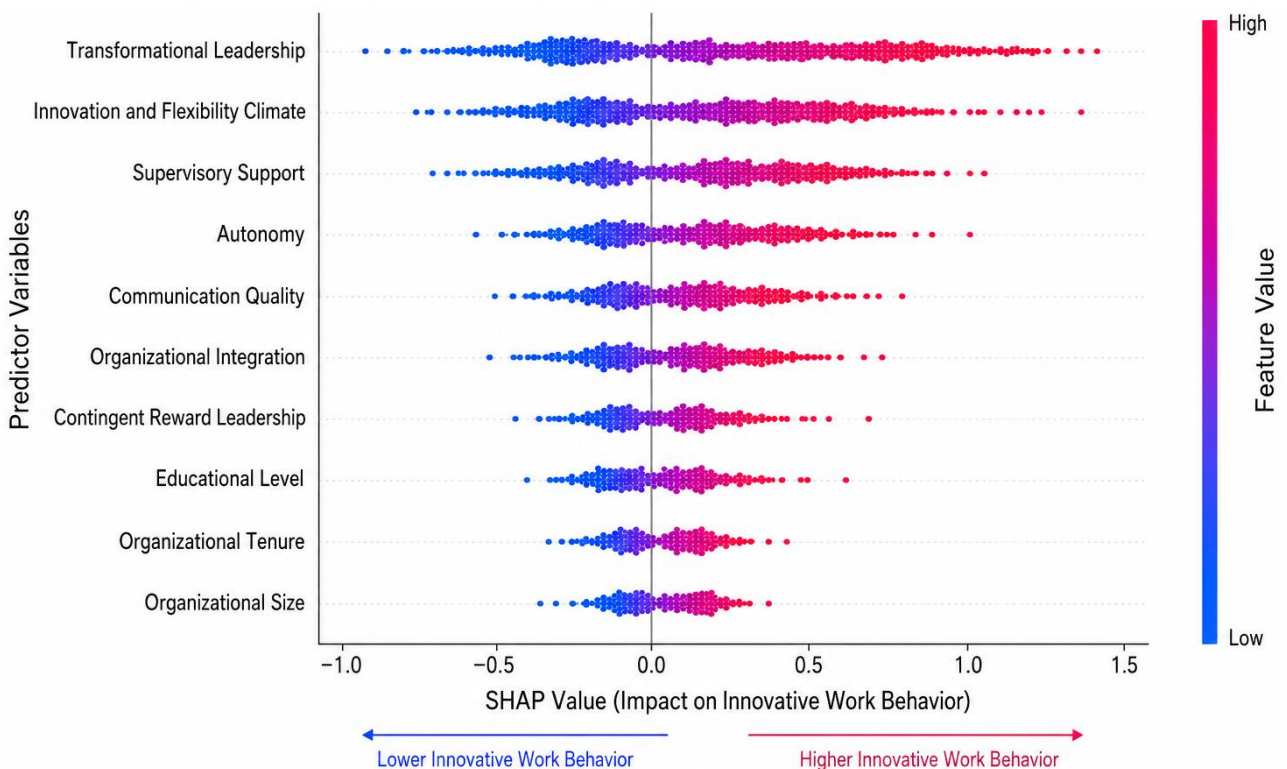
Metric	Training Set	Testing Set
R <sup>2</sup>	0.887	0.842
RMSE	0.214	0.287
MAE	0.167	0.223
MAPE (%)	5.81	7.46

The predictive performance of the XGBoost model is summarized in Table 2. The findings reveal exceptionally strong predictive capability across both training and testing datasets. The model explained 88.7% of the variance in innovative work behavior within the training dataset and maintained an R<sup>2</sup> value of 84.2% when evaluated on previously unseen testing data. The relatively small decrease in predictive performance between training and testing datasets suggests that the model generalized effectively and did not exhibit substantial overfitting. Furthermore, the RMSE value of 0.287 and MAE value of 0.223 on the testing

dataset indicate low prediction errors and high precision in forecasting employee innovative work behavior. The MAPE value of 7.46% further confirms that the model achieved excellent forecasting accuracy, as prediction errors remained well below commonly accepted thresholds in organizational prediction studies. Collectively, these results demonstrate that organizational climate dimensions, leadership variables, and demographic characteristics provide highly informative predictors of innovative work behavior and can be effectively modeled through advanced machine learning techniques such as XGBoost.

**Figure 1**

*SHAP Summary Plot Showing the Relative Importance of Predictor Variables in the XGBoost Model*



The SHAP summary analysis illustrated the contribution of individual predictors to the model's predictions of innovative work behavior. The figure demonstrated that transformational leadership emerged as the most influential

predictor, followed by innovation and flexibility climate, supervisory support, autonomy, communication quality, organizational integration, contingent reward leadership, employee educational level, organizational tenure, and

organizational size. Positive SHAP values indicated that higher levels of these variables increased the probability of higher innovative work behavior scores. Particularly noteworthy was the substantial influence of transformational leadership and innovation-supportive organizational climate, which consistently produced the largest positive contributions across employees. The figure further revealed nonlinear relationships between several predictors and

innovative work behavior, highlighting the advantage of machine learning approaches over conventional linear statistical techniques. For example, moderate-to-high levels of supervisory support generated disproportionately larger increases in innovation-related behaviors compared to low-to-moderate increases, suggesting the presence of threshold effects that may not be captured by traditional regression models.

**Table 3**

*SHAP-Based Feature Importance Ranking*

Rank	Predictor Variable	Mean Absolute SHAP Value
1	Transformational Leadership	0.284
2	Innovation and Flexibility Climate	0.251
3	Supervisory Support	0.218
4	Autonomy	0.194
5	Communication Quality	0.176
6	Organizational Integration	0.163
7	Contingent Reward Leadership	0.147
8	Educational Level	0.114
9	Organizational Tenure	0.098
10	Organizational Size	0.082

The SHAP-based feature importance rankings presented in Table 3 provide a detailed understanding of the variables driving innovative work behavior predictions. Transformational leadership emerged as the strongest predictor, with a mean absolute SHAP value of 0.284, indicating that leadership behaviors characterized by inspiration, intellectual stimulation, and individualized consideration exerted the greatest influence on employee innovation. Innovation and flexibility climate ranked second, emphasizing the importance of organizational environments that encourage experimentation, creativity, and adaptation to change. Supervisory support and employee autonomy also demonstrated substantial predictive influence, suggesting that innovation flourishes when employees receive both managerial encouragement and sufficient discretion in performing their work tasks. Communication quality and organizational integration occupied intermediate positions, highlighting the role of information exchange and collaborative structures in facilitating innovation. Although demographic variables such as educational level, organizational tenure, and organizational size contributed less strongly than organizational and leadership factors, they nevertheless provided meaningful predictive information and enhanced overall model performance. The overall pattern of findings clearly indicates that leadership and organizational climate

variables constitute the dominant drivers of innovative work behavior, accounting for the majority of predictive power within the XGBoost framework.

#### 4 Discussion

The findings of this study demonstrate that organizational climate and leadership variables constitute powerful predictors of innovative work behavior among employees, with the XGBoost model explaining 84.2% of the variance in innovative work behavior within the testing dataset. The high predictive accuracy achieved by the model indicates that innovation-related employee behaviors are strongly influenced by organizational and leadership factors and can be forecasted effectively through advanced machine learning approaches. The descriptive findings further revealed that respondents generally reported relatively high levels of innovative work behavior, organizational climate quality, and transformational leadership. Correlation analyses showed that organizational climate and transformational leadership exhibited the strongest positive relationships with innovative work behavior, while transactional leadership and organizational tenure demonstrated weaker but still significant associations. Moreover, SHAP analysis identified transformational leadership, innovation and flexibility climate, supervisory support, autonomy, communication quality, and

organizational integration as the most influential predictors of innovative work behavior. These findings suggest that innovation is not merely a consequence of individual employee characteristics but emerges through complex interactions between leadership practices and supportive organizational environments.

One of the most important findings of the study was the identification of transformational leadership as the strongest predictor of innovative work behavior. This result is highly consistent with contemporary leadership theories that emphasize the role of inspirational vision, intellectual stimulation, individualized consideration, and motivational influence in encouraging employees to engage in innovation-related activities. Transformational leaders motivate employees to challenge existing assumptions, explore alternative solutions, and embrace organizational change, thereby creating conditions conducive to innovation. The present finding aligns closely with evidence demonstrating that transformational leadership directly enhances innovative work behavior across various organizational settings. Recent studies have reported that transformational leaders stimulate idea generation and implementation by fostering employee confidence, creativity, and commitment to organizational goals (Phairat et al., 2026; Vu et al., 2025). Similar conclusions have been reported in studies involving small and medium-sized enterprises, healthcare organizations, and public institutions, where transformational leadership consistently emerged as a significant determinant of employee innovation (Ağaoğlu et al., 2025; Helmy et al., 2023; Junbish et al., 2023). Furthermore, transformational leadership has been shown to promote psychological empowerment and work engagement, both of which facilitate innovative behavior by increasing employees' willingness to take initiative and contribute novel ideas (Aristana et al., 2024; Vu et al., 2025). The current findings reinforce the argument that transformational leadership represents one of the most effective leadership approaches for cultivating innovation-oriented workplaces.

The results also demonstrated that organizational climate, particularly innovation and flexibility climate, was among the strongest predictors of innovative work behavior. Employees who perceived their organizations as supportive, flexible, collaborative, and innovation-oriented were significantly more likely to engage in innovative activities. This finding supports organizational climate theories suggesting that employees are more willing to experiment, share ideas, and implement innovations when they perceive

psychological safety and organizational support. Previous studies have similarly emphasized the critical role of innovation-supportive climates in facilitating innovative work behavior. Research has shown that innovation climate strengthens the effects of transformational leadership and enhances employees' willingness to participate in innovation processes (Akıncı et al., 2022; Wijaya, 2024). Studies examining diversity climate, humor climate, organizational learning culture, and team climate have also found positive relationships with innovative work behavior, indicating that supportive workplace environments encourage experimentation and reduce fear of failure (Baig et al., 2022; Listyanti & Hendarman, 2023; Logacheva & Plakhotnik, 2021). Furthermore, evidence suggests that organizational culture serves as a foundational mechanism through which innovation-related norms and values become embedded within everyday work practices, ultimately promoting innovation throughout the organization (Handoko & Anjaningrum, 2024; Özdaşlı et al., 2023). The strong predictive influence of organizational climate observed in the present study therefore highlights the importance of creating organizational environments that actively support innovation.

Another notable finding concerns the substantial contribution of supervisory support, autonomy, communication quality, and organizational integration to innovative work behavior predictions. These variables collectively represent the social and structural conditions that enable employees to transform ideas into actionable innovations. Supervisory support may provide employees with emotional encouragement, access to resources, and protection from negative consequences associated with experimentation. Similarly, autonomy allows employees greater discretion in task execution, thereby increasing opportunities for creative problem-solving and innovation. Effective communication facilitates knowledge exchange and collaboration, while organizational integration strengthens cross-functional cooperation and information sharing. These findings are consistent with previous studies emphasizing the importance of leader-member relationships, team support, and collaborative organizational structures in fostering innovation. Research has shown that leader-member exchange quality and team support significantly enhance innovative work behavior by strengthening employees' confidence and willingness to engage in creative activities (Modliba et al., 2024). Likewise, studies examining employee participation, organizational support, and innovation-oriented human resource systems have found

that employees are more innovative when organizations provide opportunities for involvement, communication, and collaboration (Ezeaku et al., 2024; Marwan & Alhadar, 2024; Xu et al., 2023). The present findings therefore suggest that innovation is facilitated not only by leadership style but also by organizational structures that encourage employee participation and interaction.

The importance of knowledge-related processes provides another meaningful interpretation of the study findings. Several highly ranked predictors, including communication quality, organizational integration, and supervisory support, are closely associated with knowledge exchange and learning processes within organizations. Innovation frequently emerges when employees combine existing knowledge in novel ways, access diverse perspectives, and collaborate across organizational boundaries. Previous studies have consistently demonstrated strong associations between knowledge sharing and innovative work behavior. Employees who actively exchange information and expertise are more likely to generate innovative ideas and successfully implement improvements within their organizations (Elsayed et al., 2022; Xu & Suntrayuth, 2022). Furthermore, innovation-oriented organizational systems and learning cultures contribute to innovative work behavior by enhancing intrinsic motivation and facilitating knowledge dissemination (Listyanti & Hendarman, 2023; Xu et al., 2023). The current findings support these perspectives and suggest that organizational interventions aimed at strengthening communication networks and collaborative learning environments may substantially improve innovation outcomes.

The findings additionally support theoretical perspectives emphasizing the importance of psychological mechanisms in the innovation process. Although psychological variables were not directly measured in the present study, several key predictors identified by the XGBoost model have previously been linked to psychological empowerment, creative self-efficacy, intrinsic motivation, and work engagement. Transformational leadership, supervisory support, and innovation climate may enhance innovative work behavior by strengthening employees' confidence in their ability to contribute meaningful ideas and successfully implement innovations. Previous research has demonstrated that psychological empowerment mediates the relationship between leadership and innovative work behavior, while intrinsic motivation serves as an important mechanism linking supportive organizational environments to innovation outcomes (Aristana et al., 2024; Junbish et al.,

2023). Similarly, creative self-efficacy and work engagement have been shown to translate supportive leadership experiences into innovative behavior by increasing employees' confidence and persistence in pursuing innovative activities (Modliba et al., 2024; Vu et al., 2025). These theoretical explanations help clarify why leadership and organizational climate variables exhibited such strong predictive power within the machine learning model.

## 5 Conclusion

An additional contribution of this study lies in its methodological approach. Most previous research on innovative work behavior has relied on conventional regression-based analyses designed primarily to explain relationships among variables. While valuable, such approaches may not adequately capture nonlinear interactions and complex patterns that characterize organizational behavior. By applying XGBoost and SHAP analysis, the present study demonstrated that machine learning techniques can provide both high predictive accuracy and meaningful interpretability. The ability of the model to explain more than 84% of the variance in innovative work behavior suggests that machine learning approaches offer considerable potential for organizational analytics and evidence-based decision-making. This finding supports growing calls for the integration of advanced analytical methods into organizational research and human resource management practice (Contreras et al., 2022; Muhammad Jahanzeb Khan Saima, 2021). The SHAP results further provided transparent insights into the relative importance of predictors, enabling organizations to identify which leadership and climate factors should be prioritized when seeking to enhance employee innovation.

The present study has several limitations that should be acknowledged. First, the cross-sectional design limits the ability to establish causal relationships among the variables. Although the machine learning model demonstrated strong predictive capability, the temporal direction of the observed relationships cannot be definitively determined. Second, all data were collected through self-report questionnaires, creating the possibility of common method variance and response bias. Third, the sample was limited to organizations operating in Indonesia, which may reduce the generalizability of the findings to other cultural and organizational contexts. Fourth, the study focused primarily on leadership and organizational climate variables and did

not incorporate additional individual-level predictors such as personality traits, psychological capital, creativity, or cognitive characteristics that may further enhance predictive performance.

Future research should employ longitudinal and experimental designs to examine the causal mechanisms linking leadership, organizational climate, and innovative work behavior. Researchers may also integrate additional predictor categories, including personality characteristics, psychological resources, digital competencies, and organizational innovation capabilities. Comparative studies across different countries, industries, and organizational structures would provide valuable insights into the contextual factors influencing innovative work behavior. Furthermore, future investigations should explore alternative machine learning algorithms, ensemble models, and deep learning techniques to determine whether predictive performance can be further improved. The integration of objective organizational performance indicators and behavioral data may also enhance the robustness and practical relevance of future predictive models.

From a practical perspective, organizations seeking to increase innovative work behavior should prioritize the development of transformational leadership capabilities at all managerial levels. Leadership development programs should emphasize vision communication, intellectual stimulation, employee empowerment, and individualized support. Organizations should also invest in creating innovation-supportive climates characterized by flexibility, psychological safety, open communication, collaboration, and employee autonomy. Human resource policies should encourage knowledge sharing, cross-functional teamwork, and active employee participation in decision-making processes. Managers should establish systems that recognize innovative contributions, provide resources for experimentation, and reduce barriers to idea implementation. By simultaneously strengthening leadership quality and organizational climate, organizations can create conditions that maximize employee innovation and enhance long-term organizational competitiveness.

### Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

### Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

### Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

### Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

### Declaration of Interest

The authors report no conflict of interest.

### Funding

According to the authors, this article has no financial support.

### Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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