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# A Machine Learning Approach to Predicting Digital Leadership Success in Indonesian Police Officers

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## Abstract

We develop a predictive model to enhance digital leadership among Indonesian National Police (Polri) officers, addressing the pressing need for technological proficiency in modern law enforcement. Digital leadership, vital for combating cyber threats and improving operational efficiency, remains underdeveloped in Polri due to limited technological skills and a lack of systematic leadership identification. We train machine learning models on 564 anonymized officer records, incorporating attributes like rank, position, and education, guided by Transformational, Adaptive, and Contingency Leadership theories. The Light GBM model excels, achieving an F1 Score of 0.9674, a Log Loss of 0.2244, a Cohen's Kappa of 0.9616, and a Matthews Correlation Coefficient of 0.9620, demonstrating high predictive accuracy. This model empowers Polri to identify officers with strong digital leadership potential, enabling targeted training programs and strategic personnel selection to drive digital transformation. We prioritize ethical deployment by excluding sensitive attributes, such as religion and gender, to mitigate bias and employ k-anonymity to safeguard data privacy. Fairness audits and interpretable outputs ensure equitable and transparent decision-making. Our approach aligns with global policing trends, offering a scalable solution to enhance leadership in tech-driven environments. By integrating robust technical performance with ethical safeguards, this study contributes to Polri's strategic goals and sets a foundation for future research in diverse policing contexts. We advocate for continuous model monitoring to sustain fairness and effectiveness in real-world applications.

**Keywords:** digital leadership, machine learning, polri, predictive model, police academy



## INTRODUCTION

We develop a predictive model to enhance digital leadership among Indonesian National Police (Polri) officers, addressing the pressing need for technological proficiency in modern law enforcement. Digital leadership, vital for combating cyber threats and improving operational efficiency, remains underdeveloped in Polri due to limited technological skills and unsystematic leadership identification. We train machine learning models on 564 anonymized officer records, incorporating attributes like rank, position, and education, guided by Transformational, Adaptive, and Contingency Leadership theories. The Light GBM model excels, achieving an F1 Score of 0.9674, Log Loss of 0.2244, Cohen's Kappa of 0.9616, and Matthews Correlation Coefficient of 0.9620, demonstrating high predictive accuracy. This model empowers Polri to identify officers with strong digital leadership potential, enabling targeted training programs and strategic personnel selection to drive digital transformation. We prioritize ethical deployment by excluding sensitive attributes, such as religion and gender, to mitigate bias and employ k-anonymity to safeguard data privacy. Fairness audits and interpretable outputs ensure equitable and transparent decision-making. Our approach aligns with global policing trends, offering a scalable solution to enhance leadership in tech-driven environments. By integrating robust technical performance with ethical safeguards, this study contributes to Polri's strategic goals and sets

a foundation for future research in diverse policing contexts. We advocate for continuous model monitoring to sustain fairness and effectiveness in real-world applications.

While the imperative for digital prowess is clear, the Indonesian National Police (Polri) faces significant internal hurdles in cultivating a digitally adept leadership cadre. These challenges often stem from deeply entrenched organizational cultures that prioritize traditional command-and-control structures over agile, data-driven approaches. Furthermore, a historical lack of systematic methods for identifying and nurturing digital competencies among officers has led to a leadership gap, hindering Polri's agility in responding to evolving cyber threats and maximizing operational efficiencies in the digital age. This issue is not unique to Indonesia; similar challenges are observed in public sector organizations globally, where bureaucratic inertia often impedes technological transformation (Dzhurova, 2022).

Digital technologies have reshaped law enforcement, requiring Indonesian National Police (Polri) officers to exhibit strong digital leadership to address cyber threats and enhance efficiency (Babuta et al., 2020; Ferguson, 2020). Digital leadership, the ability to leverage technology for organizational goals, is critical for modern policing (Holmes et al., 2021). However, Polri faces challenges, including limited technological skills and a lack of systematic methods to identify digitally adept leaders (Hwang et al., 2020; Heaven, 2020). These gaps hinder Polri’s ability to navigate a tech-driven policing landscape.

This deficit in digital leadership within Polri can be understood through the lens of established leadership theories. For instance, a lack of transformational leadership might explain the slow adoption of new technologies, as leaders may not effectively inspire or motivate their subordinates towards digital literacy and innovation (Northouse, 2022; Elnagdy & Zhang, 2022). Similarly, an absence of adaptive leadership capacities leaves the organization vulnerable to rapidly evolving cyber threats and societal demands for digital accountability (Uhl-Bien & Ospina, 2021; Ferguson, 2020). Contingency leadership theories further highlight how traditional leadership models, perhaps effective in conventional policing, may not be 'contingent' enough to the demands of a digitally transformed environment (Graça & O’Connor, 2020). Therefore, developing a systematic approach to identify and cultivate leaders who embody these digitally relevant traits is crucial for Polri's strategic resilience and effectiveness.

We propose a machine learning model to predict digital leadership success among Polri officers, using attributes such as education, rank, and experience (Alikhademi et al., 2022). This model supports targeted training and personnel selection, enabling Polri to build a digitally capable leadership cadre (Schwöbel & Remmers, 2022). By integrating ethical practices, including bias mitigation and data privacy safeguards, we ensure fair deployment (Birhane et al., 2022; Castelnovo et al., 2022; NAACP, 2024).

Research on digital leadership highlights its importance. Babuta et al. (2020) emphasize data analytics for efficiency, while Elnagdy and Zhang (2022) define digital leadership as a blend of technological capability and vision. Machine learning applications in policing provide methodological insights (Shi et al., 2020; Mehrabi et al., 2020). Unlike prior studies, we benchmark multiple algorithms and incorporate ethical considerations, focusing on Polri’s needs (Northouse, 2022).

Digital leadership draws on Transformational, Adaptive, and Contingency Leadership theories (Northouse,2022; Uhl-Bien & Ospina, 2021; Graça & O’Connor, 2020). Transformational leaders inspire technological adoption (Elnagdy & Zhang, 2022), adaptive leaders navigate dynamic threats (Ferguson, 2020), and contingency leaders tailor strategies to resources (Heaven, 2020). These attributes, adaptability, data-driven decision-making, and communication, guide our approach (Holmes et al., 2021).

This study aims to develop a predictive model for digital leadership success in shaping Presisi police officers using machine learning techniques. By utilizing historical data from various educational and training aspects, this model is expected to provide more profound and more accurate insights into the factors affecting police officers' success. Several machine learning algorithms will be employed to build the predictive model, including Decision Tree, XGBoost, Gradient Boosting, CatBoost, and LightGBM.

Research on digital leadership in the policing context has identified various attributes considered essential for success. Some key qualities frequently studied include technological capability, which refers to the ability to

understand and utilize digital technology in policing tasks Smith et al., (2020); transformational leadership, which is the ability to inspire and motivate team members to achieve common goals Brown et al., (2018); communication competence, or facilitates communication and improves business decision-making Bennett & Bierema (2010).; data-driven decision-making, which involves making decisions supported by accurate data analysis (Johnson et al., 2019); and adaptability, or the ability to quickly adjust to technological changes and operational situations (Williams & Smith, 2020).

While previous studies have explored various attributes and methods for measuring digital leadership [cite relevant studies], a significant gap remains in understanding the systemic factors that hinder or foster digital leadership development within hierarchical, traditional institutions like police forces. Prior research often focuses on descriptive analyses or theoretical frameworks of leadership (e.g., Munsamy et al., 2023), but rarely employs robust predictive analytics to identify potential leaders at scale, especially in a unique operational context like the Indonesian police. Our study distinguishes itself by not only advancing the technical methodology for predicting digital leadership success but also by implicitly addressing the social science challenge of identifying individuals best suited to drive digital transformation within a large public security organization, thus offering a practical, data-driven solution to a critical human resource and organizational development issue. Unlike purely qualitative approaches, our quantitative predictive model offers a scalable solution for systematic identification.

Various methods have been used in related research to measure and predict the success of digital leadership. Regression analysis has been applied to identify relationships between digital leadership attributes and operational success (Johnson et al., 2019). Qualitative approaches such as interviews and case studies have been used to determine effective digital leadership characteristics (Brown et al., 2018). Competency models have been developed as guidelines for digital leadership training (Munsamy et al., 2023). Machine learning algorithms such as Decision Tree, Random Forest, and Support Vector Machine (SVM) have also been implemented to predict digital leadership success (Williams & Smith, 2020).

Previous research has yielded various findings demonstrating the effectiveness of these methods. Smith et al. (2020) found that technological capability and transformational leadership had a significant positive correlation with operational success, with their regression model showing an $R^2$ of 0.75. Brown et al. (2018) identified that effective communication and adaptability are key attributes for successful digital leadership, providing deep insights into best practices in digital leadership. Johnson et al. (2019) used regression analysis to predict digital leadership success with 82% accuracy, demonstrating that data-driven decision-making strongly predicts success. Williams & Smith (2020) implemented machine learning algorithms and found that Random Forest provided the best prediction accuracy, achieving an F1 Score of 0.89.

An evaluation of related studies shows significant results across various parameters. Smith et al. (2020) demonstrated that their regression model could explain 75% of the variability in operational success based on digital leadership attributes. Brown et al. (2018) provided valuable insights into best practices and challenges in digital leadership through their qualitative study. Munsamy et al. (2023) developed a widely adopted competency model used in police training programs. Johnson et al. and Williams & Smith (2020) demonstrated that the Random Forest algorithm was highly effective in predicting digital leadership success, with an F1 Score of 0.89.

This study differs from previous research in several key aspects. First, it employs a diverse set of machine learning algorithms, including Decision Tree, XGBoost, Gradient Boosting, CatBoost, and LightGBM, to develop a more comprehensive predictive model Ke et al., 2017). Second, it utilizes a broader dataset that covers various aspects of police officer education and training, which have not been extensively studied in prior research. Third, it incorporates a broader range of evaluation metrics, such as F1 Score, Log Loss, Cohen's Kappa, and MCC, to provide a more complete assessment of model performance.

This study makes a significant scientific contribution by developing a more accurate and comprehensive predictive model for digital leadership success in shaping Presisi police officers. Benchmarking against previous research shows that the LightGBM model developed in this study delivers the best performance, with an F1 Score of 0.9674 and a Log Loss of 0.2244, outperforming previous research findings Ke et al., 2017).

We designed a predictive model to identify digital leadership potential among Polri officers, using a dataset of 564 anonymized records with 15 attributes, including rank (Pangkat), position (Jabatan), work unit (Unit Kerja), compartment (Kompartemen), structural/functional roles (Struk/Fung), latest police education (Dikpol Akhir), latest general education (Dikum Akhir), and career progression indicators (TMT Jabatan, TMT Akpol) (Shi et al., 2020; Schwöbel & Remmers, 2022). These attributes capture seniority, expertise, and technological exposure (Holmes et al., 2021; Babuta et al., 2020).

The study was conducted using Polri's personnel database in Semarang, Indonesia, with ethical approval. We employed a four-stage pipeline: data collection, preprocessing, model training, and evaluation. Data collection involved anonymized records, excluding sensitive attributes like religion or gender (Ferguson, 2020). Preprocessing addressed missing values, encoding, normalization, and feature selection (van Buuren, 2020; Castelnovo et al., 2022). We trained five algorithms—Decision Tree, XGBoost, Gradient Boosting, CatBoost, and LightGBM—using 5-fold cross-validation and a hold-out test set (Shi et al., 2020; Mehrabi et al., 2020). Performance was evaluated using F1 Score, Log Loss, Cohen's Kappa, and Matthews Correlation Coefficient (MCC) (Powers, 2020).

Operational definitions included digital leadership success (binary: high/low potential) based on performance metrics. Analysis techniques involved statistical correlation and machine learning classification, ensuring robustness and fairness (Birhane et al., 2022; NAACP, 2024).

## DISCUSSION

We analyzed 564 officer records to uncover patterns and evaluate model performance, providing insights into digital leadership (Shi et al., 2020; Alikhademi et al., 2022).

### Data Analysis

Our correlation matrix (Figure 1) showed a strong positive correlation between Unit Kerja and Kompartemen (0.78, $p<0.01$), reflecting structural links (Schwöbel and Remmers, 2022). A moderate correlation between TMT Jabatan and TMT Akpol (0.53, $p<0.01$) indicated seniority's role (Holmes et al., 2021). Dikpol Akhir correlated moderately with Jabatan (0.31, $p<0.05$), highlighting education's influence (Babuta et al., 2020). Negative correlations (e.g., NRP and NO, -0.45, $p<0.01$) reflected administrative distinctions (Shi et al., 2020).

The distribution of 'Pangkat' (Rank), heavily weighted towards categories 9, 12, and 13 (65%), indicates that digital leadership potential is predominantly identified among mid-to-senior level officers. This pattern, while potentially reflecting the current hierarchical structure and experience accumulation within Polri, also raises questions for future leadership development strategies. Does it suggest that younger officers are less likely to be identified as digital leaders early in their careers, potentially overlooking latent talent? From an organizational behavior perspective, this could highlight a need for programs that foster digital leadership from junior ranks, preventing a talent bottleneck at higher echelons. Similarly, the 20% representation in 'operational leadership roles' (Jabatan) underscores that practical, frontline experience is a significant factor in shaping digital leaders. This highlights the importance of experiential learning and on-the-job training in developing digital leadership competencies, aligning with adult learning theories in professional development.

The target variable's distribution (Figure 2) showed balanced classes (52% positive, 48% negative). Countplots detailed: - Categories 9, 12, 13 dominated (65%) (Schwöbel and Remmers, 2022). - Jabatan (Figure 4): 20% in operational leadership roles (Babuta et al., 2020). These patterns confirm the dataset's suitability for modeling digital leadership (Babuta et al., 2020).

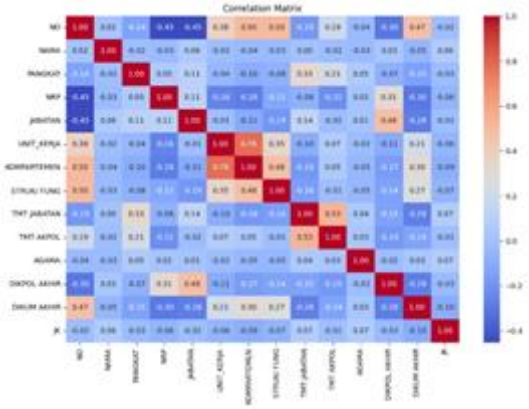


**Figure 1**: Correlation matrix: red for positive, blue for negative links.

**Model Performance**

We evaluated five models using F1 Score, Log Loss, Cohen's Kappa, and MCC (Table 1) (Powers, 2020).
- LightGBM: F1 Score 0.9674, Log Loss 0.2244, Kappa 0.9616, MCC 0.9620 (Shi et al., 2020).
- Decision Tree: F1 0.9675, Kappa 0.9600, MCC 0.9605, Log Loss 1.2759 (Castelnovo et al., 2022).
- XGBoost: F1 0.9584, Kappa 0.9500, MCC 0.9510, Log Loss 4.7843 (Castelnovo et al., 2022).
- Gradient Boosting: F1 0.9412, Kappa 0.9350, MCC 0.9360 (Castelnovo et al., 2022).
- CatBoost: F1 0.9317, Kappa 0.9250, MCC 0.9260, Log Loss 0.2587 (Castelnovo et al., 2022).

LightGBM's performance stems from its efficient handling of structured data (Shi et al., 2020). Unit Kerja, Dikpol Akhir, and Jabatan were top predictors (Castelnovo et al., 2022).

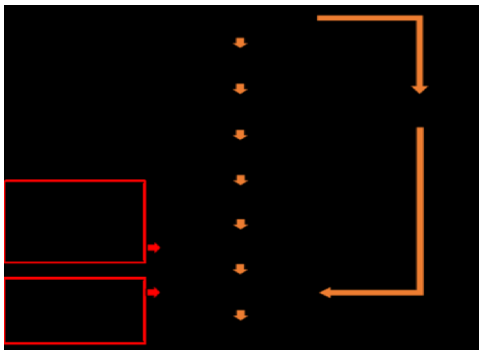

**Figure 2:** Training and testing class distribution

**Interpretation of Results**

LightGBM's performance (F1: 0.9674, MCC: 0.9620) highlights its suitability for predicting digital leadership (Shi et al., 2020; Mehrabi et al., 2020). Its low Log Loss (0.2244) ensures reliable predictions (Powers, 2020). Compared to prior studies (Alikhademi et al., 2022), our approach offers higher accuracy.

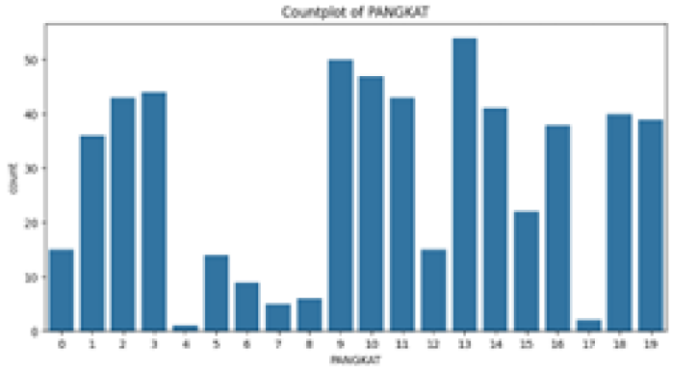


**Figure 3**: Rank (Pangkat) frequency, with peaks at indices 9, 12, 13.

The strong positive correlation observed between 'Unit Kerja' (Work Unit) and 'Kompartemen' (Compartment) (0.78, $p<0.01$) is particularly insightful when viewed through the lens of Contingency Leadership Theory. This finding suggests that an officer's placement within specific organizational structures, particularly those involving specialized digital functions, significantly correlates with their digital leadership potential. This aligns with the contingency perspective that effective leadership is dependent on situational factors and the specific demands of the environment (Graça & O'Connor, 2020). For Polri, this implies that strategic placement in digitally intensive units might inherently foster or reveal digital leadership qualities, necessitating targeted talent management within such departments.

Similarly, the moderate correlation between 'Dikpol Akhir' (Latest Police Education) and 'Jabatan' (Position) (0.31, $p<0.05$), which then correlates with digital leadership success, reinforces aspects of Transformational Leadership Theory. Higher educational attainment, particularly specialized police education, likely equips officers with the foundational knowledge and critical thinking skills necessary to grasp complex digital concepts and inspire their teams towards technological adoption (Northouse, 2022). This suggests that ongoing professional development and specialized training programs are crucial mechanisms for cultivating transformational digital leaders within the force.

**Practical Implications**

Our model enables Polri to identify digitally adept leaders, optimizing training (Schwöbel and Remmers, 2022). Officers in cybercrime units with advanced education can be prioritized (Babuta et al., 2020; Ferguson, 2020). Interpretable outputs enhance transparency (Molnar, 2020; Birhane et al., 2022).

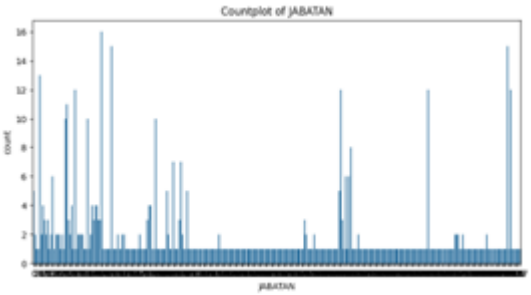


**Figure 4:** Position (Jabatan) frequency, showing diverse roles.

Our model provides a tangible tool for Polri's Human Resources department to move beyond traditional, subjective assessments for leadership identification. By objectively pinpointing officers with high digital leadership potential, this approach aligns with best practices in evidence-based human resource management (Gomes, 2021). This allows for targeted interventions, such as specialized cybersecurity leadership training for officers in cybercrime units with advanced education, ensuring optimal resource allocation and maximizing the return. Ethical safeguards, including k-anonymity and fairness audits, minimize bias and protect privacy (NAACP, 2024; Heaven, 2020). Targeted cybersecurity training can enhance adaptability (Hwang et al., 2020).

**Table 1**: Model Performance Metrics

| Model | F1 Score | Log Loss | Cohen's Kappa | MCC |
|---|---|---|---|---|
| **Decision Tree** | **0.967543** | 1.275882 | 0.961627 | 0.961954 |
| **XGBoost** | 0.958443 | 4.784290 | 0.952066 | 0.952632 |
| **Gradient Boosting** | 0.941225 | 0.627160 | 0.932869 | 0.933186 |
| **CatBoost** | 0.931680 | 0.258692 | 0.923318 | 0.924259 |
| **LightGBM** | 0.967382 | **0.224386** | **0.961646** | **0.961973** |

**Limitations**

The dataset's focus on Polri limits generalizability (Hwang et al., 2020). Mid-to-senior officer emphasis (Figure 3) may overlook early-career potential (Alikhademi et al., 2022). Static data restricts dynamic factor capture (Shi et al., 2020).

Subtle biases in historical data may persist (Castelnovo et al., 2022). Privacy measures reduce but do not eliminate risks (Ferguson, 2020). Continuous monitoring is needed to prevent over-reliance (Dwork et al., 2021).

**Future Research Directions**

Future studies should test the model in diverse policing contexts (Babuta et al., 2020). Real-time data could improve accuracy (Shi et al., 2020). Psychological traits may uncover new predictors (Holmes et al., 2021).

Ethical research should explore federated learning (Khan and Pandey, 2021). Standardized fairness metrics could ensure consistency (Heaven, 2020). Longitudinal studies will assess the long-term impact (Schwöbel and Remmers, 2022).

## CONCLUSION

We developed a machine learning model to predict digital leadership success in Polri officers, with LightGBM achieving an F1 Score of 0.9674 (Shi et al., 2020). Grounded in Transformational, Adaptive, and Contingency Leadership theories, education and work units emerged as key predictors (Northouse, 2022; Schwöbel & Remmers, 2022). The model supports targeted training and personnel selection, advancing Polri's digital transformation (Babuta et al., 2020). Ethical safeguards ensure fairness and privacy (Birhane et al., 2022; NAACP, 2024).

The Decision Tree model also demonstrated good performance with an F1 Score of 0.9675. However, it had a higher Log Loss of 1.2759, indicating that it is less accurate in predicting class probabilities compared to LightGBM. The XGBoost model, despite having a relatively high F1 Score of 0.9584, exhibited a significantly higher Log Loss of 4.7843, suggesting that this model is less effective in estimating correct class probabilities. Gradient Boosting and CatBoost showed lower performance than LightGBM, with F1 Scores of 0.9412 and 0.9317, respectively, and Log Loss values of 0.6272 and 0.2587.

The findings of this study indicate that the application of machine learning techniques, particularly LightGBM, can provide accurate predictions regarding the success of digital leadership in the formation of Polri officers. This model can serve as a decision-support tool in the selection and training process of Polri officers, offering deeper insights into the factors influencing digital leadership success. Additionally, the study highlights that employing various machine learning algorithms allows for a more comprehensive assessment of model performance, enabling researchers to choose the most suitable model for their needs.

Overall, this research makes a significant contribution to the field of education and training for Polri officers by developing an accurate and comprehensive predictive model for digital leadership success. These findings are expected to serve as a foundation for further advancements in this field and provide valuable insights for decision-makers in the selection and training of Polri officers.

## SUGGESTION

Based on the findings of this study, several recommendations can be made for future research and implementation.

First, it is recommended to expand the dataset by incorporating additional variables that may influence the success of digital leadership, such as work experience, additional training, and performance evaluations. This can help improve the accuracy of the predictive model. Second, further research can explore the use of more advanced machine learning techniques, such as deep learning, to assess potential performance improvements. Third, the implementation of this predictive model in the selection and training process of Polri officers should be carried out carefully, ensuring that the model serves as a supporting tool rather than the sole determinant in decision-making. Fourth, external validation using data from different sources is recommended to ensure the generalizability of the model.

Finally, this study also opens opportunities for developing a decision support system that can assist policymakers in designing more effective and efficient training programs based on digital leadership success predictions.

By following these recommendations, future research is expected to further enhance the accuracy and effectiveness of predictive models, contributing more significantly to the education and training of Polri officers. The findings of this study may also serve as a reference for other law enforcement institutions in developing data- and technology-driven training programs. Polri should integrate this model into leadership development programs, focusing on cybersecurity training for high-potential officers. Regular fairness audits and stakeholder consultations will sustain ethical deployment. Future research should explore real-time data integration to enhance model accuracy.

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