



# Application of the Gradient Boosting Algorithm for Classification of Zakat Recipient Groups in Supporting the Digital Transformation of Zakat Management

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## ABSTRACT

**Background:** Accurate distribution of zakat is one of the main challenges in modern zakat management. The manual process of identifying and classifying zakat recipients (mustahik) has the potential to lead to inaccuracy, subjectivity, and inefficiency. In the context of digital transformation, a machine learning-based approach can be a solution to support a more objective and efficient classification process.

**Purpose:** This study aims to develop a classification model for zakat recipients based on eight categories of asnaf (obligatory zakat) using the Gradient Boosting algorithm and compare its performance with the Decision Tree and K-Nearest Neighbor algorithms.

**Methods:** This study uses a quantitative approach using socio-economic data obtained from the Kaggle platform. The variables used include demographic, economic, and social aspects. The research stages include data pre-processing, dividing training and test data, model training, and parameter optimization to improve classification performance. Model evaluation is conducted using accuracy as the main indicator, accompanied by an analysis of the features that most influence the classification results.

**Results:** The research results show that the Gradient Boosting algorithm achieved an accuracy of 81.5% and performed better than Decision Tree and K-Nearest Neighbor. Furthermore, monthly income and employment were identified as the most influential features in determining the classification of zakat recipients.

**Conclusions:** These findings demonstrate that the application of machine learning, specifically Gradient Boosting, has significant potential to improve the accuracy of mustahik classification. This approach can support the digital transformation of zakat management to be more objective, efficient, and data-driven.

**Research Contribution:** This research contributes to the development of digital innovation in zakat management through the application of machine learning-based classification methods. Practically, the research results can serve as a reference for zakat management institutions in improving the quality of zakat fund distribution to ensure more targeted and accountable distribution.

**Keywords:** zakat, mustahik, asnaf, gradient boosting, machine learning, classification, socio-economic data, digital transformation.

## INTRODUCTION

Zakat is one of the five pillars of Islam that must be fulfilled by every Muslim who meets certain requirements, such as nisab and haul. In addition to having a spiritual dimension as a form of obedience to Allah SWT, zakat also plays an important social

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role in society. The payment of zakat is not only intended to purify the wealth of muzakki (zakat payers), but also serves as a mechanism for a more equitable distribution of wealth within society (Yusoff et al., 2023). In this context, zakat functions as an instrument of Islamic social finance that can help reduce social inequality, empower poor and vulnerable groups, and promote more inclusive economic development (Harahap et al., 2024).

The Qur'an explicitly identifies eight categories of zakat recipients (asnaf) in Surah At-Taubah verse 60, namely fakir, miskin, amil, muallaf, riqab, gharimin, fi sabilillah, and ibnu sabil (Qur'an, 9:60). This clear normative basis indicates that zakat distribution must be carried out accurately so that its social and economic objectives can be achieved optimally. Therefore, the identification and classification of mustahik constitute an important part of effective, accountable, and equitable zakat governance.

Although the classification of asnaf has been clearly regulated in Islamic teachings, its implementation in the modern era still faces considerable challenges. One of the main issues lies in the identification and classification of mustahik, which is generally still conducted manually by zakat institutions through surveys, interviews, and field observations (Hudaefi et al., 2022a). This process requires substantial time, cost, and human resources, and is also vulnerable to subjectivity, verification errors, and assessment bias (Hudaefi et al., 2022b).

These challenges become even more complex when dealing with the highly diverse and dynamic socio-economic conditions of society. In large-scale populations, zakat institutions face difficulties in ensuring that zakat funds are distributed to those who are truly eligible to receive them (Harahap et al., 2024). Inaccurate classification of mustahik may reduce the effectiveness of empowerment programs and weaken public trust in zakat institutions (Aziz et al., 2023). Therefore, improving the quality of mustahik classification is relevant not only in terms of sharia compliance, but also from the perspective of institutional efficiency and socio-economic governance.

Advances in information technology, data analytics, and artificial intelligence have created new opportunities to improve the quality of zakat management. In recent years, artificial intelligence (AI) and machine learning approaches have increasingly been used in various sectors to support faster, more objective, and data-driven decision-making (Putri et al., 2023). In the context of zakat, this approach has the potential to facilitate a more systematic mustahik classification process, reduce dependence on manual assessment, and improve the consistency of identification results (Amelia & Aprianti, 2023).

One machine learning algorithm with strong potential for classification tasks is Gradient Boosting. This algorithm is an ensemble learning method that gradually builds predictive models through a combination of decision trees, where each subsequent model is designed to correct the errors of the previous one (Bentéjac et al., 2020). Gradient Boosting is known for its ability to handle complex data, improve prediction accuracy, and provide competitive performance in various classification problems (Pratama & Nasution, 2021).

In zakat management, the application of Gradient Boosting can be directed toward building an automatic classification system that groups potential zakat recipients into asnaf categories based on social, economic, and demographic characteristics. This approach has the potential to improve the effectiveness and efficiency of zakat distribution, minimize errors in the identification of mustahik, and strengthen the transparency and accountability of zakat institutions (Gonzales Martínez & Cooray, 2025). Thus, the use of machine learning in zakat recipient

classification is not only technically relevant, but also has important economic and institutional implications in supporting the digital transformation of zakat management.

Based on this background, this study aims to develop and evaluate a zakat recipient classification model using the Gradient Boosting algorithm. Specifically, this study aims to: (1) develop an automatic classification model to identify mustahik groups based on economic, social, and demographic data; (2) evaluate the performance of the Gradient Boosting algorithm in terms of accuracy, precision, and recall in the mustahik classification process; and (3) compare the performance of Gradient Boosting with other algorithms, namely Decision Tree and K-Nearest Neighbor, to determine their relative advantages.

This study is expected to provide both practical and academic contributions. Practically, the results may provide input for zakat institutions in improving distribution accuracy, reducing the potential for verification errors, and strengthening accountability in zakat management (Anugrah & Parmana, 2025). Academically, this study enriches the discourse on digital innovation in Islamic economic governance, particularly in the development of data-driven decision-support systems for the distribution of religious social funds. Furthermore, this research is also aligned with the broader digital transformation of social services in Indonesia and the development of technology-based public service systems in the era of Industry 4.0 (Maulana et al., 2023).

## **RELATED STUDIES**

Advances in information technology, particularly in the fields of artificial intelligence and machine learning, have had a significant impact on zakat management and distribution. Various studies have shown that these technologies can improve efficiency, accuracy, and transparency in the classification of eligible recipients and in strategic decision-making by zakat institutions.

### **Predicting the Intention to Pay Digital Zakat**

Abdul Samad et al. (2023) examined the factors influencing individuals' intention to use e-zakat services by applying a machine learning approach. The study employed survey data and supervised learning classification algorithms, such as Decision Tree and Naïve Bayes, to predict individuals' tendency to pay zakat digitally. The findings showed that trust in zakat institutions, ease of use of digital platforms, and religious understanding were important variables influencing users' intention to adopt e-zakat services.

### **Sentiment Analysis of Zakat Institutions**

Redjeki and Widyarto (2022) conducted sentiment analysis to identify public perceptions of zakat implementation in Indonesia. They used data from social media and news portals, which were then analyzed using machine learning algorithms such as Naïve Bayes and Random Forest. Their study showed that the majority of public sentiment toward zakat institutions was positive to neutral, and this approach was considered effective in supporting the evaluation of zakat institutions' communication policies.

Similarly, Timur et al. (2023) used a machine learning-based classification approach to analyze public opinion toward zakat institutions in Indonesia. Using social media data, particularly from Twitter, they found that most public opinions were neutral. This finding highlights the importance of developing more interactive

and participatory digital communication strategies in zakat institutions.

### **Data-Driven Mustahik Classification**

Sari et al. (2023) developed a mustahik classification model using the Naïve Bayes algorithm based on data from BAZNAS of Banjar Regency. The study aimed to classify potential zakat recipients objectively into categories such as the poor and the needy. With a classification accuracy of more than 90%, this approach was considered capable of significantly accelerating and improving the verification and validation process for zakat beneficiaries.

### **Expert System for Determining Eligible Recipients**

Setiawan and Lubis (2022) developed an expert system based on the Dempster-Shafer method to support decision-making in determining the eligibility of zakat recipients. This system considered several criteria, such as number of dependents, income, and living conditions. The main advantage of this approach lies in its ability to handle uncertainty in information and provide evidence-based recommendations that can be implemented in mobile applications.

Review of previous studies indicates a strong trend toward the adoption of data-driven technologies to improve the accuracy and efficiency of zakat management. From predicting zakat payment behavior and classifying eligible recipients to analyzing public sentiment toward zakat institutions, machine learning approaches have demonstrated considerable potential in strengthening a more transparent, responsive, and inclusive zakat system.

There is still room to develop more robust classification models based on advanced algorithms such as Gradient Boosting, particularly in the context of Indonesia's complex and dynamic socio-economic data. Therefore, this study aims to develop a Gradient Boosting-based classification model for zakat recipients in order to support more accurate, efficient, and targeted zakat distribution.

## **RESULTS AND DISCUSSION**

### **Result**

The experimental results showed that the Gradient Boosting model performed best in classifying eight categories of asnaf (religious property) based on the socioeconomic data used. This model achieved an accuracy of 81.5% on the test data, indicating a high level of accuracy in automated decision-making for mustahik classification.

Through hyperparameter tuning using Grid Search Cross-Validation, the optimal parameter combination was obtained as follows:

1. learning\_rate: 0.02
2. max\_depth: 3
3. min\_samples\_leaf: 10
4. n\_estimators: 300
5. subsample: 0.8

This parameter combination helps overcome overfitting and maintains the stability of the model's generalization.

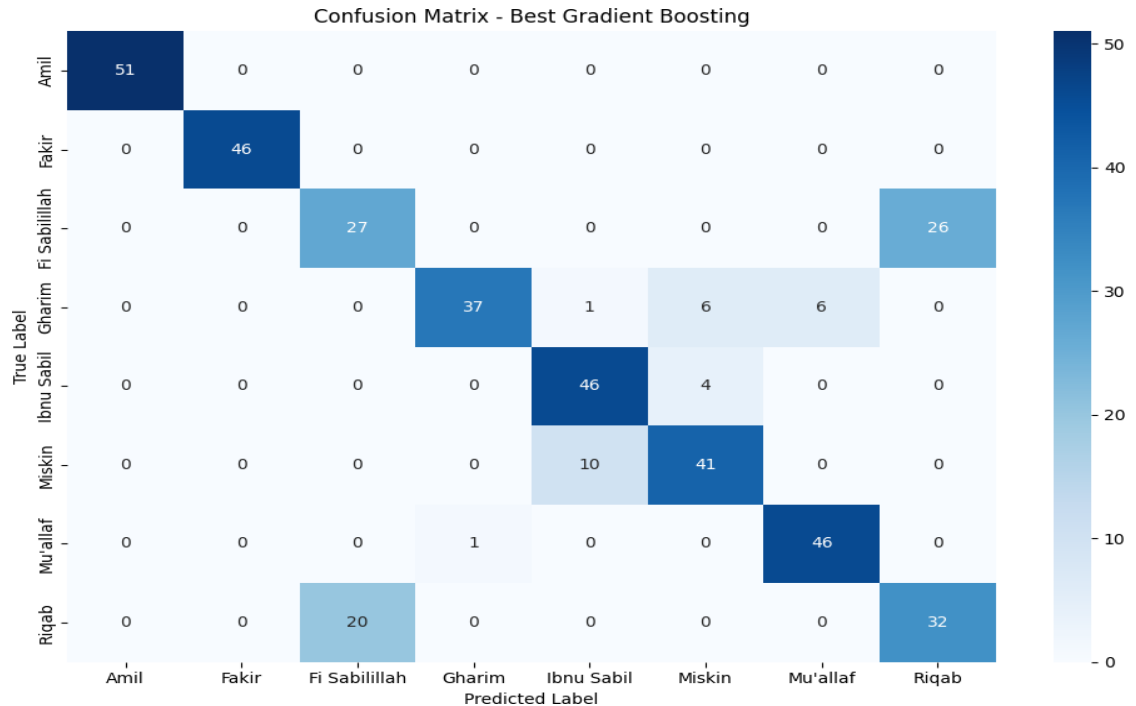
### **Confusion Matrix**

The confusion matrix shows the model's performance in classifying each category. The results show that:

1. The Amil and Fakir categories were perfectly classified (Precision and Recall

= 100%). This indicates that the characteristic features in these categories are highly distinctive and easily distinguished by the model.

- Conversely, the Fi Sabilillah and Riqab categories experienced numerous misclassifications, with some predictions being swapped. This indicates feature similarities or overlapping social characteristics between the two categories.



**Figure 1. Confusion Matrix**

Figure 1 show the high error rates in several classes also highlight the importance of improving data collection, particularly in presenting features capable of more specifically distinguishing between asnaf.

### Classification Report

The following are model evaluation metrics based on precision, recall, and F1-score for each asnaf category.

**Table 1. Classification Report**

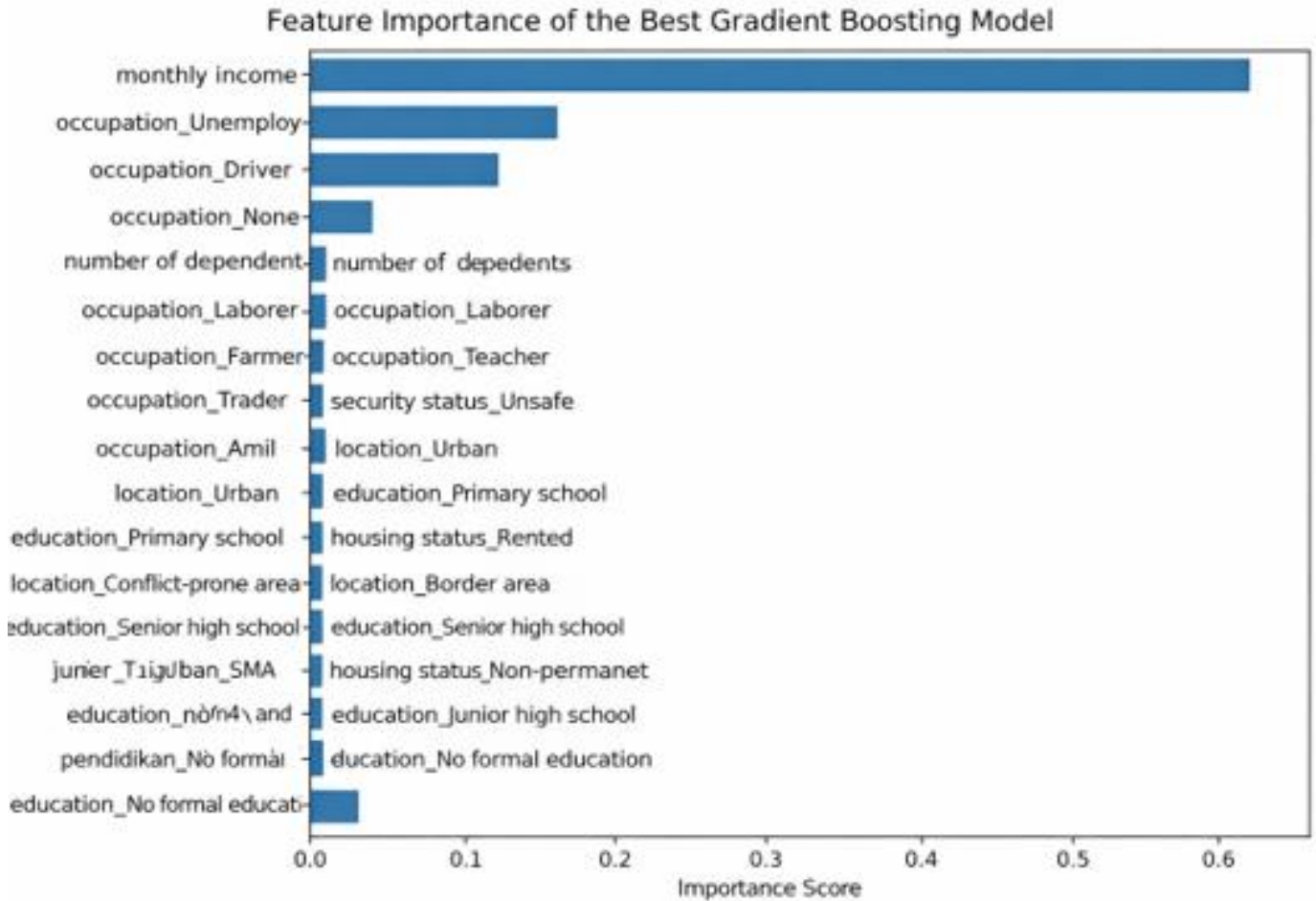
Category	Precision	Recall	F1-Score	Support
Amil	1.00	1.00	1.00	51
Fakir	1.00	1.00	1.00	46
Fi Sabilillah	0.57	0.51	0.54	53
Gharim	0.97	0.74	0.84	50
Ibnu Sabil	0.81	0.92	0.86	50
Miskin	0.80	0.80	0.80	51
Mu'allaf	0.88	0.98	0.93	47
Riqab	0.55	0.62	0.58	52
Rata-rata	0.82	0.82	0.82	400

The model demonstrated very high performance in several classes (Amil, Fakir, Mu'allaf), but its performance declined in the Fi Sabilillah and Riqab categories. The low F1-scores in these two classes indicate a weak balance between precision and recall, which could be caused by:

1. Unbalanced data distribution (uneven amount of data per class),
2. Input attributes that are insufficiently representative to distinguish between classes,

Or the model's limitations in understanding complex social contexts without additional features such as geographic location, aid history, or family status.

**Feature Importance**



**Figure 2. Feature Importance**

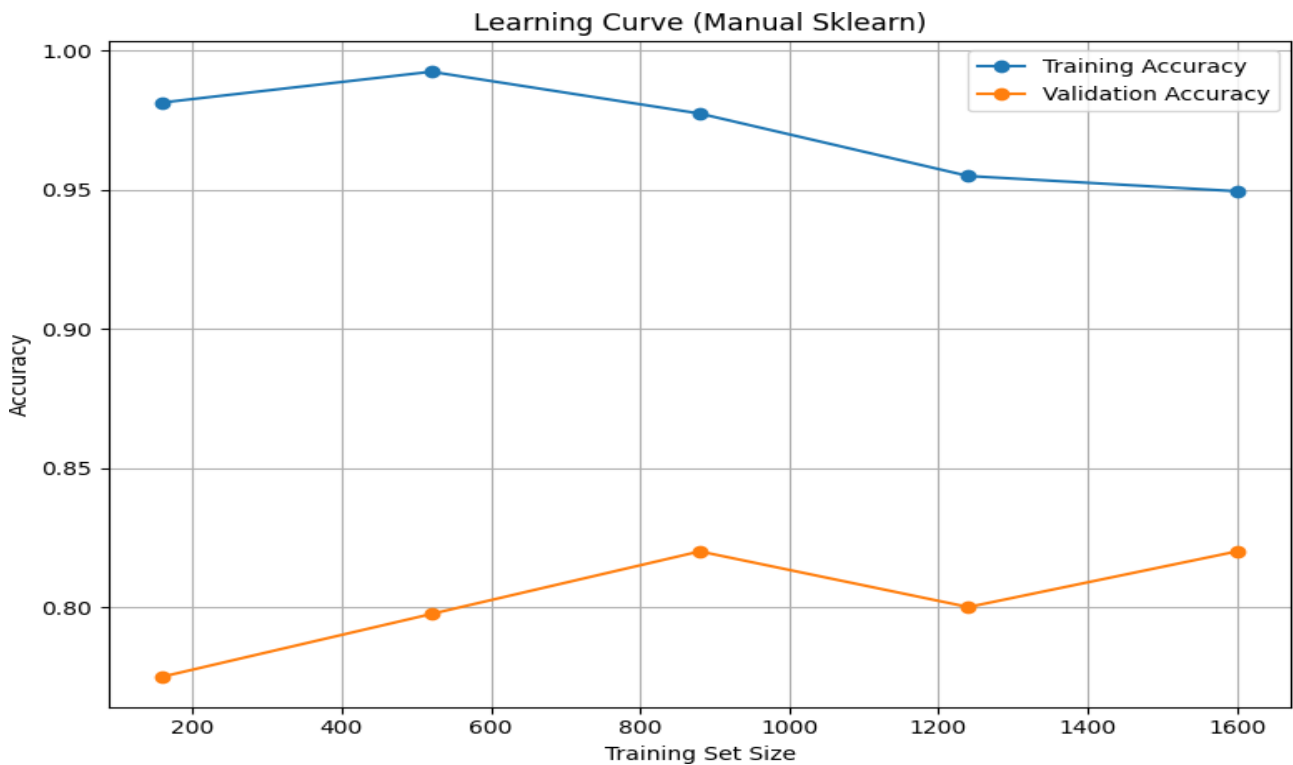
Figure 2 show Feature importance analysis provides insight into the factors that most influence classification results. Based on the results of Gradient Boosting:

1. Monthly income is the most significant feature, indicating that information about economic status is crucial in classifying asnaf.
2. Occupation type, such as "Unemployed," "Driver," or "Trader," is also highly influential, reflecting a strong relationship between occupation and mustahik category.
3. Other features, such as number of dependents, marital status, and education level, also contribute, albeit to a relatively smaller extent.

This insight is crucial for zakat institutions in developing data-driven zakat recipient criteria, replacing traditional, subjective systems.

### Learning Curve

To understand how model performance improves as the amount of training data increases, a learning curve is used as an evaluation tool.



**Figure 3. Learning Curve**

The learning curve shows the relationship between training data size and model performance (both on training and validation data). Figure 3 shows that:

1. There is a consistent gap between training and validation accuracy, indicating slight overfitting of the model.
2. However, the validation trend shows improvement with increasing training data, indicating that increasing the amount of data can further improve accuracy.
3. The curve, which has not yet reached saturation, confirms the possibility that the model still has potential for improvement, either through increasing data volume, data preprocessing, or the addition of other relevant features.

### Discussion

The results of this study indicate that the Gradient Boosting algorithm performed well in classifying eight categories of zakat recipients (asnaf) based on the socioeconomic variables used. The model achieved an accuracy of 81.5%, which suggests that machine learning can function as a reliable decision-support tool for classifying mustahik in a more objective and data-driven manner. This finding is relevant because zakat is not only a religious obligation, but also an Islamic socio-economic instrument with a substantial role in poverty alleviation, welfare improvement, and inclusive development in Indonesia (Arbi et al., 2024; Herianingrum et al., 2024). In this context, improving the accuracy of mustahik classification is important because the effectiveness of zakat distribution depends heavily on whether the funds are directed to the most appropriate beneficiaries.

That broader role of zakat in poverty alleviation and national development is well documented in recent Indonesian studies.

The strong performance of the model is also theoretically consistent with the characteristics of Gradient Boosting itself. Friedman (2001) introduced gradient boosting as a stage-wise additive modeling approach in which each new model is trained to correct the errors of the previous model. This sequential error-correction mechanism makes gradient boosting particularly effective for classification tasks with complex, nonlinear relationships among variables. In the present study, the selected hyperparameter combination—`learning_rate = 0.02`, `max_depth = 3`, `min_samples_leaf = 10`, `n_estimators = 300`, and `subsample = 0.8`—indicates that the model was tuned to balance predictive power and generalization. A relatively small learning rate and moderate tree depth help reduce the risk of overfitting, while the use of subsampling contributes to better stability. Thus, the empirical results are aligned with the methodological strengths of gradient boosting as a robust classification approach (Friedman, 2001).

From the perspective of zakat governance, the result is important because the determination of *mustahik* in practice is often still conducted through interviews, field observation, and administrative review, all of which may be time-consuming and vulnerable to subjective judgment. Akbarizan et al. (2018), in their study on determining zakat recipients in BAZNAS Pekanbaru, explicitly noted that manual assessment of *mustahik* candidates could lead to subjectivity because of the number of applicants and the complexity of the rules involved. Therefore, the relatively high accuracy obtained in this study suggests that an automated classification model can complement conventional assessment by making the selection process faster, more consistent, and more transparent. This does not mean that machine learning should replace institutional judgment entirely, but rather that it can strengthen the quality of evidence used in decision-making.

The confusion matrix and classification report provide a more detailed understanding of model performance across categories. The categories *Amil* and *Fakir* were classified perfectly, with precision and recall values of 1.00. This suggests that the socioeconomic features associated with these categories were sufficiently distinctive for the model to identify them correctly. By contrast, the categories *Fi Sabilillah* and *Riqab* showed noticeably lower precision, recall, and F1-scores, indicating that the model faced more difficulty in distinguishing them. This pattern can be interpreted in at least two ways. First, the available features may not fully capture the conceptual and social complexity of these categories. Second, the characteristics of certain *asnaf* groups may overlap in the dataset, making separation more difficult in statistical terms. This limitation is understandable because zakat eligibility is not solely an economic matter; some categories are also shaped by institutional, social, and normative considerations. For that reason, lower performance in some classes should not be interpreted simply as algorithmic failure, but also as a sign that the available data may still be incomplete for representing the multidimensional nature of *mustahik* classification. This concern is consistent with earlier zakat research emphasizing the need for proper measurement instruments to evaluate the impact and targeting of zakat distribution (Choiriyah et al., 2020; Herianingrum et al., 2024).

The feature importance results strengthen this interpretation. In the present study, monthly income emerged as the most influential feature, followed by occupation type, while variables such as number of dependents, marital status, and education made smaller but still meaningful contributions. This pattern is substantively reasonable because zakat fundamentally operates as a redistribution

mechanism aimed at helping economically vulnerable groups. Studies on zakat in Indonesia consistently emphasize its role in improving welfare, reducing poverty, and supporting *mustahik* empowerment (Arbi et al., 2024; Herianingrum et al., 2024). Therefore, it is logical that economic indicators such as income and occupation dominate the classification process. At the same time, the lower contribution of other variables may indicate that the current dataset still lacks additional contextual information needed to discriminate among more complex ASNAF categories. Variables such as geographic location, prior aid history, housing vulnerability, disability status, or family dependency structure may improve the model's ability to distinguish classes that appear similar in basic economic terms.

Another important point concerns the issue of class imbalance and data quality. In the methodology, SMOTE was included as a possible strategy when class imbalance occurred. This is methodologically justified because Chawla et al. (2002) showed that synthetic minority oversampling can improve classifier performance on imbalanced datasets by generating synthetic minority examples rather than merely replicating existing ones. In a classification problem such as *mustahik* categorization, some *asnaf* categories may naturally have fewer observations than others. If not addressed properly, this imbalance can bias the model toward majority classes and reduce sensitivity to minority categories. The relatively weaker results in categories such as *Fi Sabilillah* and *Riqab* therefore may also reflect limitations in class distribution, not only feature representation. This means that future research should pay greater attention to the balance and representativeness of the training data, especially if the model is intended for real institutional deployment.

The learning curve further supports the interpretation that the model is promising but not yet fully optimized. The gap between training and validation accuracy suggests mild overfitting, meaning that the model performs better on the training data than on unseen data. However, the validation score improves as the amount of training data increases, which indicates that the model still has room for better generalization if more high-quality data are added. In practical terms, this means that the current model should be seen as a strong initial prototype rather than a final solution. For zakat institutions, the implication is important: a machine learning system for *mustahik* classification will become more reliable when it is trained on larger, cleaner, and more institutionally relevant datasets. In this sense, digital transformation in zakat management is not only about adopting algorithms, but also about improving data governance, audit trails, and information systems. Khulataini (2025) similarly argues that digital zakat management requires accountability, transparency, adequate information systems, and digital audit trails in order to strengthen trust and institutional responsibility.

From a broader economic and institutional perspective, the findings of this study support the argument that better classification can contribute to more effective zakat distribution. Choiriyah et al. (2020) found that impactful zakat can reduce poverty indicators, while Arbi et al. (2024) reported that zakat distribution in Indonesia contributed to poverty alleviation during the COVID-19 period. Herianingrum et al. (2024) also emphasize that zakat institutions in Indonesia can support poverty reduction when empowerment programs are aligned with *mustahik* potential and long-term welfare improvement. These findings imply that the success of zakat programs depends not only on the amount of funds collected, but also on the precision of targeting and the quality of institutional management. Therefore, a model such as Gradient Boosting has practical significance beyond technical classification accuracy: it can strengthen the efficiency, objectivity, and accountability of zakat allocation in support of socioeconomic development.

The findings demonstrate that Gradient Boosting is an effective method for classifying zakat recipients based on socioeconomic data. The model's accuracy of 81.5%, combined with the analysis of confusion matrix, classification report, feature importance, and learning curve, suggests that machine learning has strong potential to support digital transformation in zakat governance. Nevertheless, the results also show that classification quality depends heavily on data representativeness, class balance, and feature completeness. For this reason, future development should combine stronger datasets, richer contextual variables, and institutional validation from zakat practitioners. With such improvements, machine learning-based *mustahik* classification could become an important foundation for a more accurate, transparent, and accountable zakat management system, which in turn would strengthen the economic and social impact of zakat distribution in Indonesia (Akbarizan et al., 2018; Khulataini, 2025; Herianingrum et al., 2024).

## **CONCLUSION**

This study concludes that the Gradient Boosting algorithm is effective in building an automatic classification model for zakat recipients based on eight categories of *asnaf* (non-zakatable recipients) with an accuracy rate of 81.5%, and demonstrates better performance than comparison algorithms, namely Decision Tree and K-Nearest Neighbor. These findings confirm that machine learning-based approaches have strong potential to improve objectivity, efficiency, and consistency in the identification and classification process of *mustahik*, which is still largely done manually. The evaluation results also show that the *Amil* and *Fakir* categories can be classified very well, while the *Fi Sabilillah* and *Riqab* categories still face a relatively high level of classification errors, indicating limitations in feature representation or similarities in socio-economic characteristics between categories. Furthermore, feature importance analysis shows that monthly income and type of employment are the most influential variables in determining the classification results, thus emphasizing the importance of economic indicators in determining the eligibility of zakat recipients. The learning curve findings also indicate that model performance still has the potential to be improved by increasing the amount of data, improving data quality, and enriching more relevant variables. Overall, this study shows that the application of Gradient Boosting in the classification of zakat recipients is not only technically relevant, but also provides a practical contribution to strengthening zakat governance that is more targeted, transparent, accountable, and data-based, thus aligning with the digital transformation agenda in the management of social and religious economic services in Indonesia.

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## **CONFLICTS OF INTEREST**

The author declares no conflict of interest.

## **AUTHOR CONTRIBUTIONS**

All authors were involved in the development and design of the study. The processes of material preparation, data collection, data analysis, and manuscript drafting were carried out jointly by all authors. Each author reviewed and approved the final version of the manuscript.

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## DATA AVAILABILITY

Data sharing is not applicable to this article because no new data were created or analyzed in this study.

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