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Comparative Analysis of Classification Models for Competencies Certification: A Data Mining Approach

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Abstrak

Penelitian ini mengelaborasi penerapan berbagai model algoritma machine learning (ML) untuk mengidentifikasi klasifikasi kompetensi pegawai yang mengikuti sertifikasi kompetensi yang dibutuhkan untuk menunjang pekerjaan. Tujuannya adalah memilih model ML terbaik untuk meningkatkan akurasi, skalabilitas, dan kewajaran. Algoritma yang akan diuji adalah Regresi Logistik, SVM, KNN, dan Naive Bayes sebagai algoritma tradisional dengan Random Forest sebagai algoritma ensembe atau kombinasi. Penelitian ini mengambil data dari 13.830 pegawai yang telah diajukan untuk mengikuti kegiatan sertifikasi kompetensi pada tahun 2024 di PT PLN (Persero). Semua model diukur melalui validasi silang pada parameter seperti akurasi, presisi, recall, dan F-1 score menggunakan bahasa pemrograman Python pada Jupyter Notebook. Model kinerja terbaik pada parameter F-1 score adalah Regresi Logistik yang mencapai skor tertinggi sebesar 0.9559. Sementara Random Forest merupakan model terbaik pada parameter Precision yang sangat penting digunakan untuk mengidentifikasi pegawai yang benar-benar belum kompeten untuk menghindari kerugian perusahaan akibat human error. Berdasarkan penelitian ini, Regresi Logistik dan Random Forest dapat diprioritaskan untuk meningkatkan akurasi status kompetensi pegawai agar dihasilkan pegawai yang benar-benar kompeten untuk memperkuat kinerja operasional dan meningkatkan pendapatan perusahaan.

Kata kunci : Analisa Perbandingan, Sertifikasi Kompetensi, Machine Learning

Abstract

This study elaborates the application of various machine learning (ML) algorithm models to identify the classification of employee competency to take the competency certification needed to support the work. The goal is to choose the best ML model to improve accuracy, scalability, and fairness. The algorithms to be tested in this study are Logistic Regression, SVM, KNN, and Naive Bayes as traditional algorithms with Random Forest as an ensemble algorithm. This study took data from 13,830 employees who had been submitted in competency certification activities in 2024 at PT PLN (Persero). All models were measured through cross-validation on parameters such as accuracy, precision, recall, and F-1 score using the Python programming language on Jupyter Notebook. The best performing model on the F-1 score parameter was Logistic Regression which achieved the highest score of 0.9559. Meanwhile, Random Forest is the best model on the Precision parameter which is very important to identify employees who are truly incompetent to avoid losses due to human error. Based on this research, Logistic Regression and Random Forest can be prioritized to improve the accuracy of employee competency status in order to produce truly competent employees to strengthen operational performance and increase company revenue.

***Keywords**: Comparative Analysis, Competency Certification, Machine Learning*

INTRODUCTION

The complexity of the labor market requires individuals and organizations to understand the trends and needs of the work environment (Nawawi et al., 2024). Recently, one of the challenges and needs of the work environment is the availability of workers who have the competencies according to the needs of the company in the current digital era. Competence refers to the abilities and skills that a person has in carrying out their duties and work (Aruna et al., 2022). In addition, competence is a basic characteristic related to the effectiveness of individual performance in completing work according to what the organization expects

in achieving its goals (Spencer & Spencer, 1993).

Employee competence is a crucial aspect in ensuring the quality of service and productivity of an organization, especially in the government and industrial sectors. Therefore, accuracy and consistency in conducting competency assessments are very important (Kamper et al., 2023).

Competency certification is one of the instruments to ensure that employees have the abilities, skills and knowledge according to the established standards. Every year, various agencies conduct an assessment process to determine the competency status of employees, which are categorized into two main labels, namely Competent (K) and Not Yet Competent (BK).

The assessment of this competency is usually carried out by assessors by referring to certain work standards, such as the Indonesian National Work Competency Standards (SKKNI). However, this process is highly dependent on the subjectivity of the assessor and other non-technical variables, such as the psychological conditions of the participants and assessors. Therefore, there is a need to develop a more objective and data-based approach to support the competency assessment process.

Along with the development of digital technology, the use of data mining and machine learning (ML) techniques has become a promising alternative to project assessment results based on historical data. Supervised learning techniques, especially binary classification, allow the system to learn from labeled data and make predictions on new data.

In 2024, there will be 13,830 realization data of certification implementation with K and BK labels that can be used as training data in building a competency status prediction model. The data includes various features that can affect the assessment results, such as sub-fields of work, types of work, job scheme positions, employee unit of origin and other relevant data.

The use of the Python programming language in this study is an ideal choice because it has a complete library for data analysis and application of machine learning algorithms, such as Scikit-learn, Pandas, Matplotlib, and so on. In addition, Python supports the data visualization process which is important in explaining patterns and relationships between variables.

The purpose of this study is to build a supervised learning-based predictive model that can classify employee competency status into categories K and BK. This model is expected to be a decision-making tool in designing competency improvement strategies and the effectiveness of certification implementation.

By integrating machine learning technology in the competency assessment process, it is expected that there will be an increase in objectivity, efficiency, and accuracy in determining employee competency status. The results of this study also have the potential to provide scientific contributions in the field of human resource development and competency management information systems.

LITERATURE REVIEW

The current business environment demands creativity in ensuring human resource restructuring (Sharma et al., 2024). A company's most valuable asset is its workforce, or human resources (Krishna et al., 2024). A key challenge in human resource management is employee competency management. Competence is a fundamental characteristic related to the effectiveness of individual performance in completing work as expected by the organization and achieving its goals (Spencer & Spencer, 1993). According to Spencer & Spencer's (1993) core competency theory, there are five competency characteristics that support individual performance effectiveness:

knowledge, skills, attitudes, motives, and self-concept.

In Indonesia, competency assessments or certification must refer to the Indonesian National Work Competency Standards (BNSP, 2013). Through the implementation of these standards, it is hoped that a competent and qualified Indonesian workforce will be available through professional certification recognition appropriate to the position and work assigned.

In today's era, the approach to managing human resources in companies is shifting from traditional HR management practices to more modern practices based on technology and data. For example, many companies use employee data records to identify employee churn rates. Companies use predictive analytics through machine learning to predict the chances of employees leaving the company. Organizations effectively use HR predictive analytics to increase revenue and reduce turnover (Bongale et al., 2023). In addition, machine learning is also used to increase or improve employee job satisfaction and attrition rates based on data (Patil et al., 2023).

Based on this, machine learning has been widely used in the world of work to classify various phenomena, including in the fields of competency certification and HR. Therefore, the optimization approach in machine learning is very important for training models to achieve high performance in various HR management cases (Bian & Priyadarshi, 2024).

In the study of Manoharan et al (2024), it was shown that supervised learning is a part of machine learning that has extraordinary potential. Supervised learning algorithms such as decision trees, logistic regression and SVM are used to predict employee performance in order to optimize productivity and efficiency in workforce management. Supervised learning has the potential to significantly improve the decision-making and prediction capabilities of employee performance management systems.

Tools and programming languages such as Python are the backbone of many machine learning studies due to their easy syntax and the availability of data analysis libraries (McKinney, 2017). Libraries such as Scikit-learn allow for rapid implementation of various algorithms, including validation processes and model performance evaluation (Geron, 2019).

In Indonesia, the use of machine learning in HR management is still relatively limited. Consequently, research adopting machine learning for competency assessment is still relatively limited, particularly regarding employee competency assessment in Indonesian companies to improve individual employee performance and achieve company goals. However, interest in technology integration in certification systems is growing, in line with the digital transformation agenda in the public sector. Both business and academics agree on the significant impact of digitalization on the business world (Blanka et al., 2022). The rapid adoption of digital technology is transforming the way organizations manage their human resources (Stone et al., 2015).

Based on research by Kamper et al., (2023), a competency assessment was conducted on the final assignment reports of students at a university in South Africa by comparing the assessment results between humans and machine learning. The results of the assessment conducted with a machine learning approach showed higher accuracy than the assessment conducted by humans. In addition, in the study of Dubey & Kumar (2015), it was shown that objective speech quality assessment was carried out to replace subjective speech listening assessment because it is time-consuming and difficult to assess the quality of speech processed by various processing algorithms. The two studies above have the same approach to competency assessment studies, namely using a machine learning approach, but the focus of the study is different: the first study focused on the final assignment report or

written test, while the second study focused on the oral test.

Considering the existing literature, this study aims to fill the research gap in the implementation of machine learning related to comprehensive employee competency assessments, including written, oral, and practical tests, based on real data using employee competency assessment data sources from PT PLN (Persero) in 2024. PT PLN (Persero) is a state-owned company focused on the electricity business in Indonesia. Furthermore, this study is expected to provide empirical contributions in the adoption of machine learning technology in competency management systems in Indonesia to support individual performance improvement that has an impact on improving company performance.

RESEARCH METHODS

This study uses a quantitative approach with a supervised learning method in binary classification to predict employee competency status based on the realization data of the 2024 certification implementation. This approach was chosen because the main focus of the study is to build a predictive model that is able to classify data into two labels, namely Competent (K) and Not Yet Competent (BK). In this context, the machine learning model is expected to be able to learn patterns from historical data and provide predictions of competency status on new data objectively and consistently.

The data source used comes from the internal certification information system that records employee certification results throughout 2024. There are 13,832 individual data that have taken part in the certification process, complete with the final label K or BK. Each data has a number of features that reflect individual characteristics, including age, gender, education level, position, work unit, length of work experience, and training history and previous assessment results. This data provides a comprehensive picture of the profile of certification participants which is then used to train the classification model.

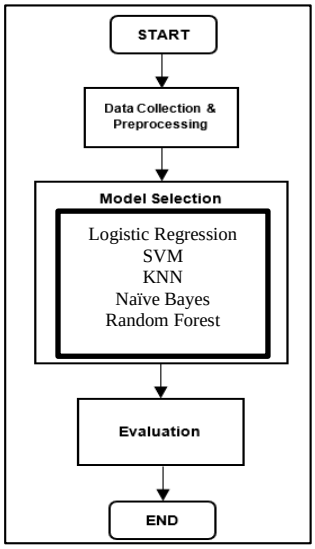

Figure 1 - Flowchart of Research Methods

Before the data is further analyzed, a pre-processing stage is carried out to ensure optimal data quality. This stage includes cleaning the data from duplication, removing or imputing missing values, and transforming categorical variables into numeric form so that they can be processed by machine learning algorithms. In addition, numeric features are standardized to have a uniform scale. After this process is complete, the data is then divided into two parts: 80% is used as training data (training set), and 20% as testing data (testing set) to measure model performance on data that has never been seen before.

This study implements several supervised learning algorithms as candidate predictive models, including Logistic Regression, Naïve Bayes, Support Vector Machine (SVM), and K-Nearest Neighbors (KNN) and Random Forest. The selection of algorithms was carried out to see the comparison of classification performance between methods and to choose the best model that is most accurate in predicting labels K or BK. These algorithms were chosen because they have been proven to be widely used in binary classification and are

fully available in the Python machine learning library.

Model performance evaluation was carried out using various classification evaluation metrics, namely accuracy, precision, recall, F1-score, confusion matrix, and ROC-AUC score. These metrics provide a comprehensive picture of how well the model can distinguish between labels K and BK, including in class imbalance conditions.

All stages of data processing and modeling are carried out using the Python programming language because it provides a complete and efficient library ecosystem for data analysis and machine learning purposes. The libraries used include Pandas for data manipulation, NumPy for numerical computation, Matplotlib and Seaborn for data visualization, Scikit-learn for implementing machine learning algorithms, and Imbalanced-learn if an imbalance in the label distribution is found. The analysis process is carried out in the Jupyter Notebook environment to facilitate documentation and replication of the process.

In general, the methodological flow in this study starts from data acquisition, data exploration (EDA), data pre-processing, modeling with various machine learning algorithms, model performance evaluation, selection of the best model, and ends with interpretation of results and preparation of recommendations. With this methodology, the study is expected to produce an accurate and useful classification model as a predictive tool in the assessment process and employee competency management.

RESULTS & DISCUSSION

This study aims to develop a predictive model of employee competency status based on the Realization of Certification Implementation data at PLN Group in 2024, using a supervised learning approach. Five machine learning algorithms have been tested, namely Logistic Regression, Naive Bayes, Support Vector Machine (SVM), Random Forest, and K-Nearest Neighbors (KNN). Model performance evaluation is carried out by comparing the values of accuracy, precision, recall, and F1-score, with the main focus on the F1-score as an indicator of the balance between precision and sensitivity of classification.

```
Logistic Regression
Accuracy: 0.9335019877123238
Precision: 0.9180855959502991
Recall: 0.9970014992503748
F1 Score: 0.9559175850503114
ROC AUC: 0.9313473158981866
Confusion Matrix:
 [[ 588  178]
 [   6 1995]]
              precision    recall  f1-score   support

           0       0.99      0.77      0.86       766
           1       0.92      1.00      0.96      2001

    accuracy                           0.93      2767
   macro avg       0.95      0.88      0.91      2767
weighted avg       0.94      0.93      0.93      2767
```

Figure 2 –
Classification Report of Logistic Regression

The Logistic Regression model showed the best performance with an F1-score of 0.9559. This indicates that this model is able to provide a very balanced prediction between the ability to capture "Competent" cases (recall = 0.9970) and accuracy in avoiding wrong classification of "Not Yet Competent" (precision = 0.9181). Another advantage of this model is its simplicity and interpretability, which makes it very relevant to be applied in the context of managerial decision making in the human resources sector.

```
Random Forest
Accuracy: 0.9324177809902421
Precision: 0.9323164918970448
Recall: 0.9775112443778111
F1 Score: 0.9543791168577702
ROC AUC: 0.9667936919268824
Confusion Matrix:
 [[ 624  142]
 [  45 1956]]
              precision    recall  f1-score   support

           0       0.93      0.81      0.87       766
           1       0.93      0.98      0.95      2001

    accuracy                           0.93      2767
   macro avg       0.93      0.90      0.91      2767
weighted avg       0.93      0.93      0.93      2767
```

Figure 3 –
Classification Report of Naïve Bayes

The Naive Bayes model ranks second with an F1-score of 0.9551 and the highest recall among all models (0.9990). This value indicates that almost all truly competent employees are successfully classified correctly by this model. Although this model works based on a fairly strict assumption of

independence between features, the evaluation results prove that the distribution of the certification data used matches the probabilistic approach applied by Naive Bayes.

Support Vector Machine
Accuracy: 0.9320563787495483
Precision: 0.9156350298028427
Recall: 0.9980009995002499
F1 Score: 0.9550454328072693
ROC AUC: 0.9446207053131398
Confusion Matrix:
[[582 184]
[4 1997]]

	precision	recall	f1-score	support
0	0.99	0.76	0.86	766
1	0.92	1.00	0.96	2001
accuracy			0.93	2767
macro avg	0.95	0.88	0.91	2767
weighted avg	0.94	0.93	0.93	2767

Figure 4 – Classification Report of SVM

Support Vector Machine (SVM) also recorded a very competitive performance with an F1-score of 0.9550, precision of 0.9156, and recall of 0.9980. This algorithm works optimally when the data has a clear dividing margin, and is able to handle high-dimensional data quite well. Thus, SVM is a promising alternative if the main focus is to avoid misclassification of competent employees.

Naive Bayes
Accuracy: 0.9320563787495483
Precision: 0.9148741418764302
Recall: 0.999000499750125
F1 Score: 0.9550883898709985
ROC AUC: 0.926134517597598
Confusion Matrix:
[[580 186]
[2 1999]]

	precision	recall	f1-score	support
0	1.00	0.76	0.86	766
1	0.91	1.00	0.96	2001
accuracy			0.93	2767
macro avg	0.96	0.88	0.91	2767
weighted avg	0.94	0.93	0.93	2767

Figure 5 –
Classification Report of Random Forest

Meanwhile, the Random Forest model recorded the highest accuracy (0.9400) and the highest precision among all models (0.9293), although its recall value was slightly lower (0.9760), which caused the F1-score to be slightly below the other models (0.9535). The unique characteristics of Random Forest which is able to handle nonlinear data and interactions between features still make it a reliable model, especially in the context of certification data which has many categorical variables.

K-Nearest Neighbors
Accuracy: 0.9306107697867727
Precision: 0.9284699194694458
Recall: 0.9795102448775612
F1 Score: 0.953307392996109
ROC AUC: 0.9519072056660965
Confusion Matrix:
[[615 151]
[41 1960]]

	precision	recall	f1-score	support
0	0.94	0.80	0.86	766
1	0.93	0.98	0.95	2001
accuracy			0.93	2767
macro avg	0.93	0.89	0.91	2767
weighted avg	0.93	0.93	0.93	2767

Figure 6 –
Classification Report of KNN

Meanwhile, the K-Nearest Neighbors (KNN) model has an F1-score of 0.9533 and a precision of 0.9285, with a recall of 0.9795. This performance shows that although the KNN model is quite conservative in classifying "Competent", overall it still provides strong and competitive results. KNN's sensitivity to the local structure of the data also allows this model to capture patterns that other models may not capture.

Overall, the five algorithms tested showed very high classification performance, with all F1-score values above 0.95. This finding indicates that the supervised learning approach can be used effectively to build a predictive system for employee competency status.

Table 1 Comparison of Model Results

Model	Accu.	Prec.	Recall	F1 Score
Logistic Regression	**0.9335**	0.9180	0.9970	**0.9559**
SVM	0.9320	0.9156	0.9980	0.9550
KNN	0.9306	0.9284	0.9795	0.9533
Naïve Bayes	0.9320	0.9148	**0.9990**	0.9550
Random Forest	0.9309	**0.9293**	0.9790	0.9535

Based on the comparison table of the evaluation of the algorithm model metrics above, it can be identified that the logistic regression model is very strong in the F-1 score metric with a value of 0.9559 so that it can balance the ability to capture "Competent" cases and avoid wrong classification of "Not Yet Competent". This

model can be considered for use as the best algorithm model to predict the classification of employee competency status that is truly competent and not yet competent in new data in the future.

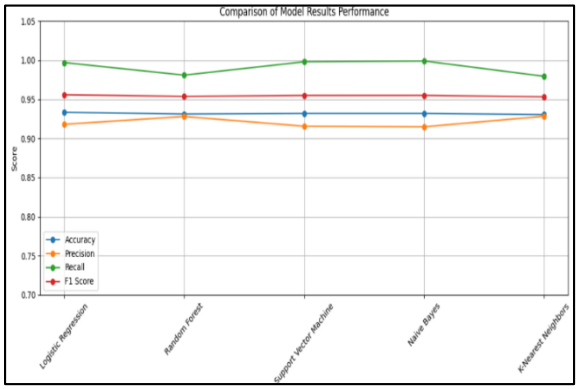

Figure 7 – Comparison of Model Results Performance

In addition, this study also aims to minimize the potential for losses to the Company caused by work errors due to human error because the company is unable to identify employees who are not yet competent in carrying out their work. Failure to identify employees who are not yet competent in working can have fatal consequences if a work accident occurs, resulting in a decline in the Company's operational performance. This must be avoided by choosing an algorithm model that is able to identify employees who are truly not yet competent, namely an algorithm model with the lowest false positive value or the highest precision value.

Based on the comparison table of model results, it is known that the model with the highest precision value is Random Forest. The model can identify very well by minimizing false positive cases to avoid prediction errors on employees who should not be competent but are predicted to be competent by the model.

Based on the Confusion Matrix Figure 8, it is known that the Random Forest model has the smallest "false positive" value of 141 (can also be seen in Figure 5) compared to the Logistic Regression, Naïve Bayes, SVM, and KNN models which each have values of 178, 186, 184, and 151 (can be seen in Figures 2, 3, 4, and 6).

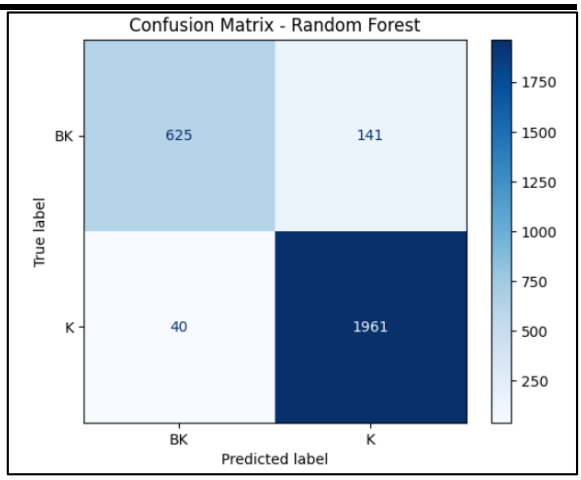

Figure 8 –
Confusion Matrix of Random Forest

A low "false positive" value can help the company avoid mistakes in identifying employees who are truly not competent in working so that employee competency development can be carried out first. One of them is through training for employees to improve their knowledge and skills until they are declared graduated and ready to work.

CONCLUSION

This study aims to develop a supervised learning-based predictive model to project employee competency status based on the realization data of certification implementation in 2024. By using five classification algorithms, namely Logistic Regression, Naive Bayes, Support Vector Machine (SVM), Random Forest, and K-Nearest Neighbors (KNN), the training and evaluation process is carried out on data that has been cleaned and prepared through preprocessing techniques. Performance evaluation is carried out using accuracy, precision, recall, and F1-score metrics.

The evaluation results show that all five models have excellent classification performance, with F1-score values above 0.95. However, the Logistic Regression model shows the highest overall performance, with an F1-score of 0.9559 and a recall of 0.9970, indicating that this model is very reliable in identifying competent employees.

In addition, the confusion matrix analysis confirms the power of the Random Forest model in detecting a number of false positives that are useful for avoiding misclassification of incompetent employees. This shows that although the model is very efficient in capturing qualified employees, mitigation is still needed against potential misclassification of incompetent classes. This finding needs to be considered in the implementation of the model so that the prediction results are not used as the sole basis for decision making.

Based on these results, it is recommended that the logistic regression and random forest models can be selected as the best algorithm models in this study. The logistic regression model is very good at identifying employees who are truly competent so that they are worthy and ready to work. While the random forest model is very good at identifying employees who are truly not yet competent so that it can avoid prediction errors that have the potential to harm the Company. To improve the accuracy of implementation in the field, it is recommended that this model be equipped with an additional verification system or used in conjunction with the assessor assessment. In addition, further analysis of important features that influence classification also needs to be carried out to support data-based policy making.

In further research, it can be directed at developing a model that can be integrated with a digital technology-based HR management system. With the right implementation strategy, this model can make a real contribution to the development of competent and superior human resources in supporting the Company to improve operational performance and revenue in the future.

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