



Digitalization of gold pawn services: Customer satisfaction and innovation challenges analyzed using Indonesian bidirectional encoder representations from transformers

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ABSTRACT

Background: The rapid digitalization of financial services has transformed customer interaction patterns, making user reviews a critical source for evaluating service quality. In digital gold pawn services, understanding customer sentiment is essential for sustainable digital transformation. While deep learning models often outperform conventional methods, their application in the Indonesian gold pawn sector remains limited. This study analyzes user sentiment toward the Tring! by Pegadaian application and evaluates a transformer-based model's effectiveness in capturing customer satisfaction and complaints. **Methods:** This research employed a quantitative experimental approach using 21,413 Google Play Store reviews. Classification was performed using a pre-trained IndoBERT (indobert-base-p1) model, fine-tuned over three epochs with class weighting to address severe data imbalance. Performance was evaluated using accuracy, precision, recall, F1-score, and confusion matrix analysis. **Findings:** The results demonstrate that the model achieved an accuracy of 86.36% and a weighted F1-score of 0.8840. A recall of 79.46% for the negative sentiment class confirms the model's capability to effectively detect customer complaints. Analysis revealed a dominance of positive sentiment related to ease of use and transaction speed, while negative sentiment highlighted issues regarding system stability and cost transparency. These findings show that transformer architectures effectively capture semantic nuances in informal Indonesian text. **Conclusion:** IndoBERT-based sentiment analysis provides a reliable framework for evaluating digital gold pawn services. By achieving high accuracy and recall, the model effectively transforms unstructured feedback into actionable insights, supporting data-driven decision-making for service optimization in financial institutions. **Novelty/Originality of this article:** This research applies a class-weighted IndoBERT model to a large-scale Indonesian gold pawn dataset, addressing severe class imbalance inherent in financial apps. It positions sentiment analysis as a real-time early warning system (EWS) for state-owned enterprises to monitor digital transformation challenges and maintain competitive advantages in the fintech landscape.

KEYWORDS: customer satisfaction; digital entrepreneurship; fintech; IndoBERT; sentiment analysis.

1. Introduction

Digital transformation has become a central strategic agenda in the development of the financial services sector in Indonesia. Rapid advances in digital technology have

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fundamentally reshaped how financial institutions design, deliver, and evaluate their services. Grewal et al. (2020) emphasize that technological innovation has transformed financial institutions from transaction-oriented entities into customer-centric organizations that actively invest in digital platforms to establish deeper, more personalized connections with users. This shift has been further intensified by the post-pandemic recovery phase, which established a low-touch economy as the new operational standard. For traditional state-owned enterprises, this era demands a departure from conventional brick-and-mortar reliance toward a seamless, mobile-first approach to maintain market relevance. In Southeast Asia, the acceleration of the digital economy over the past decade has been particularly significant, positioning the region as one of the fastest-growing digital markets globally. Within this regional context, Indonesia occupies a pivotal role, driven by demographic advantages and widespread mobile adoption. As demonstrated in Figure 1, Indonesia's digital economy reached a significant milestone in 2025, nearing the USD 100 billion mark with a 14% year-over-year growth in gross merchandise value (GMV). With projections estimating the market to reach at least USD 180 billion by 2030, this trajectory reinforces Indonesia's position as a primary driver of digital expansion in the region.

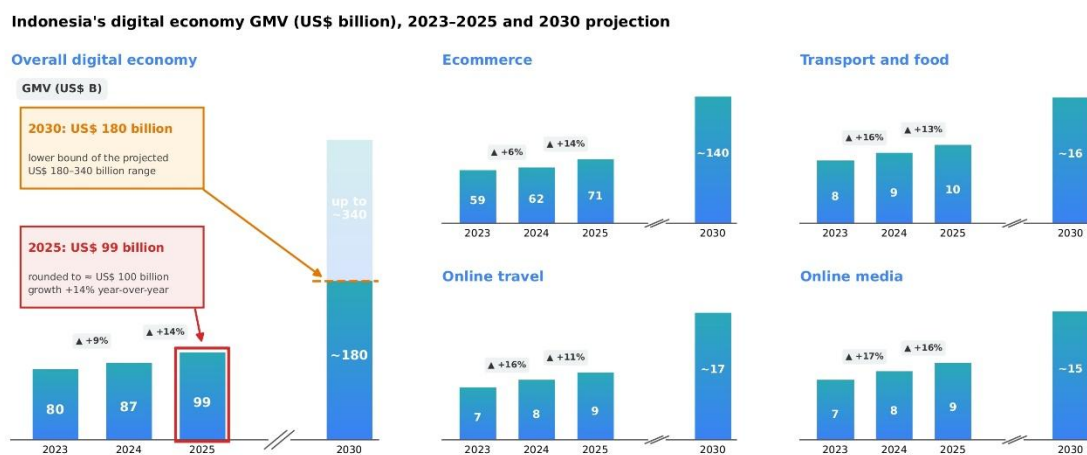


Fig. 1. Indonesia's digital economy GMV: USD 100 billion (2025) and USD 180 billion projection (2030)
(Google et al., 2025)

The growth of digital financial services in Indonesia has been propelled not only by technological availability but also by shifting user expectations. Andrian et al. (2022) argue that customers increasingly demand financial services that are fast, flexible, transparent, and seamlessly integrated into their daily digital ecosystems. This shift has led to a gradual but decisive transition from conventional, face-to-face financial transactions toward mobile-based and application-driven services. Consequently, financial institutions are compelled to continuously innovate in order to remain relevant, competitive, and responsive to evolving customer needs. This decisive transition toward application-driven services creates a massive digital footprint in the form of user-generated content (UGC). According to Shafa et al. (2025), these digital reviews possess a higher degree of credibility compared to traditional customer satisfaction surveys. While conventional surveys often suffer from social desirability bias, where respondents provide answers they believe the institution wants to hear, digital reviews are unsolicited, spontaneous, and reflective of real-time user experiences. This raw data provides an unfiltered window into systemic issues, such as cost transparency and platform stability, which are often missed by structured questionnaires.

In line with this national digital transformation trend, Limited Liability Company/*Perseeroan Terbatas* (PT) Pegadaian, one of Indonesia's leading state-owned financial institutions, has articulated an ambitious strategic direction to strengthen its digital ecosystem. This commitment is explicitly outlined in the 2024 Annual Report of PT

Pegadaian, which adopts the theme “Going Beyond: Innovate to Develop Business Capabilities”. The report underscores the organization’s intention to position Information Technology not merely as a supporting function but as a primary accelerator of business growth through continuous process improvement (PT Pegadaian, 2025). This strategic vision has been operationalized through the development of multiple digital service platforms, including a digital gold pawn application designed to provide secure, transparent, and easily accessible financial services to a broad segment of the population.

Despite the extensive implementation of digital innovations, a fundamental challenge persists regarding the extent to which these platforms successfully meet increasingly complex user expectations. Digital transformation does not automatically guarantee positive user experiences or customer satisfaction. In many cases, the introduction of new technologies may generate usability issues, technical disruptions, or misalignments between system design and user needs. In this context, customer feedback becomes a critical indicator of service quality and organizational performance.

User reviews published on application distribution platforms such as Google Play Store represent a direct and unfiltered expression of customer perceptions. These reviews reflect real-world user experiences and provide insights into satisfaction levels, technical issues, service deficiencies, and unmet expectations. However, the large volume and unstructured nature of such data render manual evaluation impractical. As a result, advanced computational approaches are required to systematically extract meaningful insights from large-scale textual data.

The relevance of digital financial services in Indonesia is further reinforced by the country’s exceptionally high level of mobile device penetration. Kemp (2025) reports that active mobile connections in Indonesia have reached approximately 125 percent of the total population, indicating a strong technological foundation for digital expansion. This momentum is clearly reflected in the rapid advancement of the nation’s financial infrastructure. As illustrated in Figure 2, Indonesia is currently experiencing an accelerating digital finance revolution, characterized by significant breakthroughs in digital banking and the explosive growth of the national quick response code Indonesian standard (QRIS) payment system. However, high technological penetration does not automatically ensure comprehensive financial inclusion. According to the World Bank (2025), approximately 48 percent of Indonesia’s adult population remains underbanked, with limited utilization of formal financial products, particularly credit services.

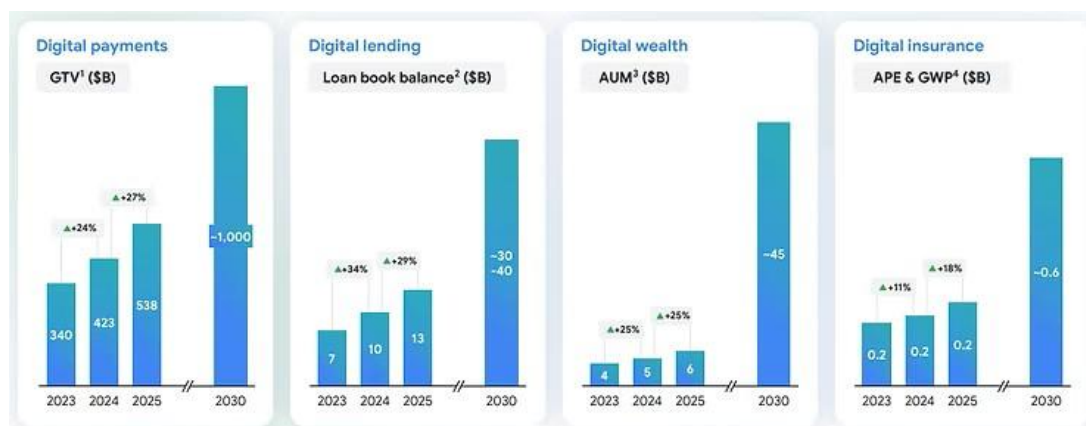


Fig. 2. Indonesia’s digital finance and payment infrastructure growth 2025
(Google et al., 2025)

This discrepancy highlights a critical challenge: digital financial services have not yet been fully leveraged to address structural gaps in financial inclusion. Consequently, it is essential to evaluate whether digital platforms, such as the Tring! by Pegadaian application, effectively serve user needs and contribute meaningfully to inclusive financial development. Such evaluation requires an evidence-based approach grounded in real user experiences rather than solely relying on institutional performance indicators.

From a regulatory perspective, the Financial Services Authority of Indonesia/*Otoritas Jasa Keuangan* (OJK) emphasizes that digitalization is a cornerstone of building an inclusive, efficient, and sustainable financial system (OJK, 2025). Digital transformation is viewed not only as a mechanism for operational efficiency but also as a strategic instrument to broaden access to financial services for underserved communities. Accordingly, financial institutions are increasingly expected to develop analytical capabilities that enable them to process large-scale user data in order to better understand customer preferences, perceptions, and sentiments (Pendyala & Lakkamraju, 2024).

As a state-owned enterprise, PT Pegadaian plays a strategic role in supporting national financial inclusion objectives. The organization has consistently pursued continuous business capability development, emphasizing information technology as a growth accelerator through systematic process improvement. This strategic orientation aligns with broader organizational adaptation requirements in response to digital market dynamics, which often necessitate fundamental structural and operational changes (Plekhanov et al., 2023). One of the most prominent manifestations of this strategy is the development of the *Tring!* by Pegadaian application as an integrated digital service channel.

The pawn industry in Indonesia has undergone a substantial transformation from traditional counter-based operations to an integrated digital ecosystem. Under conventional models, gold pawn transactions required physical presence for valuation, administrative processing, and fund disbursement. Digitalization has altered this paradigm by enabling online submission of pawn requests, real-time transaction monitoring, and digital repayment mechanisms. This transformation has enhanced operational efficiency and organizational responsiveness to market changes (Suwanda, 2023), while redefining value creation logic and business structures (Verhoef et al., 2021). Furthermore, as illustrated in Figure 3, this evolution is increasingly driven by highly engaging digital platforms, such as video commerce, which has seen a 75% year-over-year surge in sellers. For PT Pegadaian, the emergence of such a powerful growth engine highlights the necessity of integrating interactive digital features into its ecosystem to maintain brand relevance and capture new opportunities within the rapidly shifting consumer landscape.



Fig. 3. Rapid growth and transaction volume of video commerce in Indonesia, 2025 (Google et al., 2025)

However, digital gold pawn services are inherently complex. They involve secure logistics integration for gold collection and storage, accurate valuation algorithms linked to real-time global gold price fluctuations, and compliance with digital legal frameworks governing collateral documentation and contractual agreements. Additionally, transparency in administrative fees and interest calculations is essential to prevent negative user perceptions. These complexities represent critical touchpoints in the user experience and can trigger dissatisfaction if system performance falls short of expectations.

The success of the Tring! by Pegadaian application is therefore closely tied to user perceptions, experiences, and satisfaction levels. In evaluating complex digital services, Google Play Store reviews constitute a particularly relevant data source. Unlike internal satisfaction surveys or structured questionnaires, public app reviews are spontaneous, voluntary, and anonymous, making them relatively free from social desirability bias (Shafa et al., 2025). Moreover, such reviews are generated in real time, enabling organizations to detect service issues at the moment they occur (Rosanti et al., 2025).

Nevertheless, user review data present several methodological challenges. The data are unstructured, voluminous, and continuously evolving. Furthermore, sentiment distributions are often imbalanced, with disproportionate representations of positive, negative, or neutral opinions, potentially biasing analytical outcomes if not addressed appropriately (Alfinsyah & Hartato, 2025). These characteristics necessitate the application of automated text analysis techniques capable of handling linguistic variability and scale.

Sentiment analysis has emerged as a widely adopted approach for identifying public opinion tendencies toward digital products and services. The evolution of natural language processing (NLP) reflects a progression from rule-based systems to statistical machine learning models, and subsequently to pre-trained language models based on transformer architectures. Early rule-based approaches relied on rigid linguistic rules and struggled with ambiguity and informal language. Statistical models such as support vector machines introduced greater adaptability but remained limited in capturing long-range contextual dependencies (Sujana, 2024).

A major breakthrough in NLP occurred with the introduction of transformer-based models, which employ self-attention mechanisms to capture contextual relationships between words simultaneously (Devlin et al., 2019). Bidirectional encoder representations from transformers (BERT) was designed to generate bidirectional contextual representations by considering both preceding and succeeding word contexts. For the Indonesian language, the development of Indonesian bidirectional encoder representations from transformers (IndoBERT) has demonstrated superior performance compared to conventional models, particularly in processing informal language, abbreviations, and linguistic variations commonly found in user-generated reviews (Setiawan et al., 2025).

Previous studies on customer satisfaction in Indonesia's digital financial sector have primarily focused on conventional banking platforms or employed questionnaire-based surveys and traditional machine learning techniques (Andrian et al., 2022). While these approaches provide valuable baseline insights, they often fail to fully capture contextual nuances and real-time user experiences. Moreover, empirical investigations leveraging unsolicited user-generated reviews and advanced Transformer-based language models within the context of digital gold pawn services remain scarce.

Despite the growing body of research on digital financial services in Indonesia, most existing studies emphasize conventional banking environments or rely on structured survey instruments. Empirical analyses utilizing unsolicited user-generated reviews and advanced Transformer-based language models in the specific context of digital gold pawn services are still limited. As a result, there is a lack of comprehensive understanding regarding customer satisfaction and innovation challenges from the perspective of real-world user experiences.

In contrast to prior research, this study proposes an evaluation framework for digital gold pawn services based on real-time sentiment analysis of user reviews using the IndoBERT model. The novelty of this research lies in the integration of an Indonesian pre-trained Transformer-based language model with large-scale public opinion data to objectively identify satisfaction levels, service challenges, and innovation opportunities within digital gold pawn services. To provide a structured analytical framework, this study addresses three fundamental research questions: First, how does the IndoBERT model perform in classifying multi-class sentiments within the specialized domain of Indonesian digital gold pawn services? Second, what are the predominant sentiment patterns and critical service issues identified from the large-scale user reviews of the Tring! application? Finally, what are the primary innovation challenges and managerial implications for state-

owned financial institutions in sustaining digital transformation based on these automated insights? Accordingly, this study aims to analyze customer satisfaction sentiment toward the Tring! by Pegadaian application using the IndoBERT model based on user reviews collected from Google Play Store. The findings are expected to contribute methodologically to the application of transformer-based language models in Indonesian-language contexts and to provide empirically grounded insights that support strategic decision-making for service improvement and the sustainability of digital transformation initiatives at PT Pegadaian.

2. Methods

2.1 Research approach, paradigm, design, object, location, and time frame

This study adopts a quantitative research approach employing deep learning-based sentiment analysis to identify user opinion tendencies toward the digital services of PT Pegadaian. Epistemologically, the research is grounded in a positivist paradigm, assuming that sentiments expressed in digital user reviews constitute observable and measurable empirical phenomena. The quantitative approach enables objective, standardized, and replicable measurement of sentiment patterns within large-scale textual data, making it particularly suitable for the analysis of digital public opinion derived from unstructured text (Creswell & Creswell, 2023).

The research design follows an experimental framework within the domain of natural language processing (NLP). This design is applied to evaluate the effectiveness of a pre-trained language model, IndoBERT, in classifying user reviews into three sentiment categories: positive, negative, and neutral. The experimental design allows systematic control of model parameters and objective performance assessment using quantitative evaluation metrics.

The object of this study is Tring! by Pegadaian, a digital gold pawn service application developed by PT Pegadaian as part of its national digital transformation strategy. The research location is defined in a digital context, namely the Google Play Store, which serves as the primary distribution platform for the Android version of the application and a key space for direct interaction between users and service providers through public reviews. Indonesia was selected as the research context due to the strategic role of PT Pegadaian as a state-owned financial institution and the country's rapid adoption of mobile-based digital financial services. Data collection was conducted over the period January 2023 to December 2024, selected to represent the most recent post-pandemic phase and to capture contemporary user experiences aligned with the latest implementation of Pegadaian's digital services.

2.2 Data sources, population, and data collection technique

The primary data used in this study consist of user-generated reviews collected from the Google Play Store page of the Tring! by Pegadaian application. Each data entry includes review text, user rating, and publication timestamp. The research population comprises all user reviews available within the specified observation period.

A census approach was applied, whereby all reviews meeting the inclusion criteria were analyzed. The inclusion criteria were; (1) reviews written in Indonesian, (2) reviews containing textual content, and (3) reviews published within the defined time frame. Duplicate reviews, empty entries, and content unrelated to service evaluation were excluded during the initial screening process to enhance dataset quality. Data collection was performed using cloud-based web scraping techniques, chosen to ensure efficiency, scalability, and data integrity when handling large volumes of textual data. This approach aligns with deep learning requirements for large datasets capable of capturing linguistic diversity and contextual variation (Erama, 2025; Zhang et al., 2018).

2.3 Text data preprocessing, data labeling, and dataset partitioning

User reviews on the Google Play Store are predominantly written in informal language, often containing abbreviations, non-standard spellings, and non-textual elements. Consequently, text preprocessing constitutes a critical stage to reduce noise while preserving contextual meaning (Setiawan et al., 2025). The preprocessing pipeline includes case folding and text cleansing to standardize text format and remove URLs, numbers, symbols, and emojis that do not contribute to sentiment classification. Subsequently, lexical normalization is applied using an Indonesian slang dictionary to convert non-standard expressions into their formal equivalents. In this study, stopword removal is intentionally omitted to preserve syntactic structure and contextual dependencies, as IndoBERT relies on full-sentence context to generate meaningful representations. The preprocessing stage concludes with tokenization, which segments text into tokens compatible with the transformer input scheme.

A supervised learning approach is employed, requiring labeled data for model training. User reviews are categorized into three sentiment classes: positive, negative, and neutral. The three-class scheme is adopted because it more comprehensively captures the spectrum of user opinions compared to binary classification (Andhika et al., 2025). The labeled dataset is divided into training (80%), validation (10%), and testing (10%) subsets. This partitioning ensures objective model training, hyperparameter tuning, and final performance evaluation. The validation set is used to monitor loss values and guide parameter adjustments during fine-tuning to prevent overfitting (Geron, 2019).

2.4 IndoBERT architecture and class imbalance handling

Sentiment modeling in this study utilizes IndoBERT, a pre-trained Indonesian language model built on the transformer architecture. IndoBERT employs a self-attention mechanism that enables bidirectional contextual understanding of textual input, allowing it to capture complex semantic relationships more effectively than sequential models such as recurrent neural networks or long short-term memory networks (Devlin et al., 2019; Wilie et al., 2020). Fine-tuning is conducted by adding a classification head in the form of a fully connected layer on top of the classification or [CLS] token representation, which maps the encoder output to the three sentiment classes: positive, negative, and neutral (Sun et al., 2019).

Given the inherent class imbalance in financial service application reviews, where positive sentiments typically dominate, this study applies a class weighting strategy within the loss function. This approach assigns higher penalties to misclassification of minority classes (negative and neutral sentiments), ensuring the model remains sensitive to user complaints without resorting to oversampling techniques that may increase overfitting risk (Alfinsyah & Hartato, 2025).

2.5 Experimental setup, model evaluation, experimental environment, and training configuration

Model performance is evaluated using standard classification metrics: accuracy, precision, recall, and F1-score. While accuracy provides an overall measure of prediction correctness, it may be misleading in imbalanced datasets. Therefore, precision and recall are used to assess class-specific performance, particularly for negative sentiment, which holds high strategic value for service evaluation. Recall is emphasized as a key metric, reflecting the model's ability to correctly identify user complaints. To balance precision and recall, the F1-score is employed as a harmonic mean. Additionally, a confusion matrix is used to visualize classification outcomes and identify systematic misclassification patterns, such as ambiguity between neutral and negative sentiments.

To ensure reproducibility, model training and evaluation are conducted in a cloud-based computing environment supporting hardware acceleration. This environment

facilitates efficient processing of large datasets and stable training of Transformer-based models, consistent with contemporary NLP research practices (Wolf et al., 2020). The fine-tuning process employs the AdamW optimizer with a learning rate adjusted for pre-trained language models to maintain training stability. The number of training epochs is determined empirically based on validation performance, while batch size is selected according to system memory capacity. An early stopping strategy is implemented by monitoring validation loss to prevent performance degradation on unseen data (Geron, 2019).

2.6 Research workflow, reproducibility, and ethical considerations in digital data research

The overall research workflow consists of the following stages; (1) collection of user reviews from the Google Play Store, (2) initial data screening and cleaning, (3) text preprocessing, (4) data labeling and dataset partitioning, (5) IndoBERT fine-tuning and training, (6) model performance evaluation, and (7) interpretative analysis of sentiment distribution and service-related implications. This explicit workflow description is provided to enhance methodological transparency and facilitate replication in similar digital financial service contexts. The approach aligns with best practices for reproducible computational research (Stodden et al., 2016).

This study utilizes publicly available and anonymous user-generated content without collecting personally identifiable information, thereby minimizing inherent privacy risks. Ethical rigor is maintained by limiting the analysis to aggregate-level interpretations and strictly avoiding any attempts to de-anonymize or identify individual users. This measure is crucial as NLP technologies often process text data that may contain sensitive personal identities, health statuses, or financial information. Ensuring maximum protection for individual privacy is essential to keep the development of artificial intelligence and natural language processing on an ethically sound path (Ma, 2023).

The utilization of public digital data for research purposes is considered ethically acceptable provided that platform policies are respected and no harm is inflicted upon the users. Furthermore, standards for responsible practice must be established from the initial stages of language model design to hold developers and users accountable for potential adverse effects. According to Ma (2023), this approach ensures that the application of NLP in decision-making processes prioritizes the reasonableness and fairness of the results from both a technical and ethical perspective.

3. Results and Discussion

3.1 Data distribution analysis and sentiment characteristics

Prior to the modeling stage, an exploratory analysis was conducted to examine the characteristics of data distribution and to identify potential class bias that could affect sentiment classification performance. The dataset used in this study consists of 21,413 user reviews, with a highly imbalanced sentiment distribution, as illustrated in Figure 4. The label distribution indicates that positive sentiment dominates the dataset, accounting for 13,680 reviews (approximately 64%), followed by negative sentiment with 6,947 reviews (approximately 32%), while neutral sentiment represents only 786 reviews (approximately 4%). The predominance of positive sentiment suggests that, in general, the digitalization of gold pawn services through the Tring! by Pegadaian application has been well received by users. This finding reflects Pegadaian's initial success in delivering a digital service that is accessible, functional, and aligned with the needs of users of mobile-based financial services.

In contrast, the extremely small proportion of neutral sentiment highlights a characteristic pattern of user behavior in digital applications. Users tend to express opinions primarily when they experience extreme conditions—either highly satisfactory or highly unsatisfactory—while moderate experiences are rarely articulated explicitly. As a

result, the neutral class becomes an extreme minority, which poses methodological challenges in sentiment modeling, particularly by increasing the risk of prediction bias toward the majority class if not addressed appropriately.

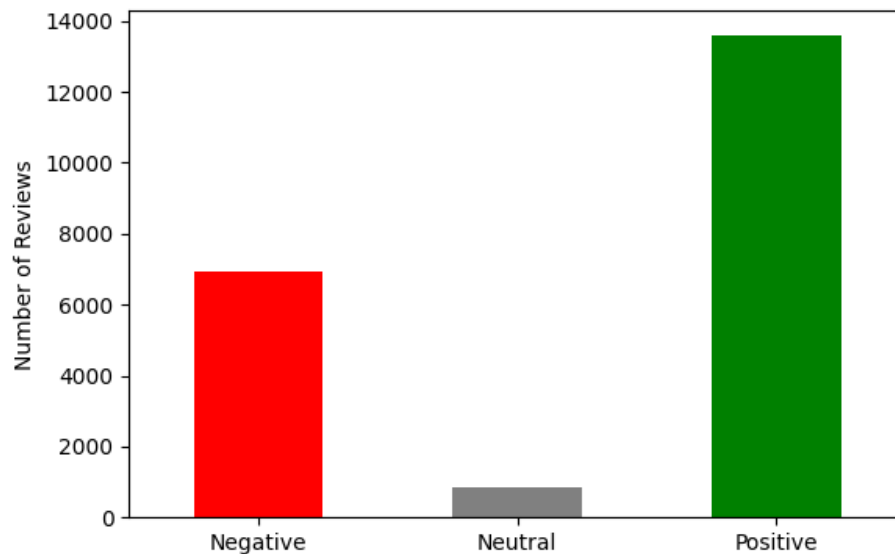


Fig. 4. Distribution of actual sentiment labels in the dataset

Despite not being the dominant class, the presence of nearly one-third negative reviews holds substantial strategic value. Negative sentiment does not merely reflect user dissatisfaction but also serves as a critical source of information regarding system failures, technical constraints, and mismatches between user expectations and actual service performance. In line with Ayertey et al. (2021), negative sentiment in digital service contexts often carries higher informational value than positive sentiment, which tends to be appreciative and confirmatory in nature.

To gain deeper insights into the aspects of service most frequently highlighted by users, a word cloud analysis was conducted for each sentiment class. Within the positive sentiment class, terms such as *mudah* (easy), *cepat* (fast), *aman* (safe), and *membantu* (helpful) appeared with high frequency. These findings reinforce that Pegadaian's core value proposition, particularly in terms of process efficiency, ease of access, and perceived transaction security, has been functionally achieved from the users' perspective.

Conversely, the word cloud for negative sentiment was dominated by keywords like login, *gagal* (fail), *lama* (slow), update, and *saldo* (balance). The prevalence of these terms indicates that the primary challenges in innovating digital gold pawn services lie not in the service concept itself, but rather in technological infrastructure and application system stability. Technical issues related to authentication failures, processing delays, and balance inaccuracies have the potential to erode user trust if not addressed promptly and systematically. Overall, this analysis of data distribution and sentiment characteristics underscores the importance of adopting a sentiment analysis approach that is sensitive to class imbalance and capable of extracting strategic insights from negative reviews. The findings from this exploratory stage provide a robust methodological foundation for the subsequent application of the IndoBERT model, particularly in capturing linguistic nuances and contextualized expressions of user feedback with greater accuracy.

3.2 Model training and convergence analysis

The IndoBERT-base-p1 model was trained using a fine-tuning scheme over three epochs, with the application of a class weighting strategy to address the imbalance in sentiment class distribution within the dataset. At the initial stage of training, the weights of the classification layer were randomly initialized; therefore, the fine-tuning process

played a critical role in adapting the semantic representations obtained from IndoBERT's pre-training phase to the specific context of user reviews of digital gold pawn services.

The training results demonstrate a stable and consistent learning pattern. The training loss decreased substantially from 0.5994 in the first epoch to 0.3234 in the third epoch, accompanied by an increase in training accuracy from 84.40% to 92.04%. This trend indicates that the model was able to progressively learn linguistic patterns and contextual sentiment cues embedded in user reviews, while simultaneously optimizing its internal parameters for the multiclass sentiment classification task.

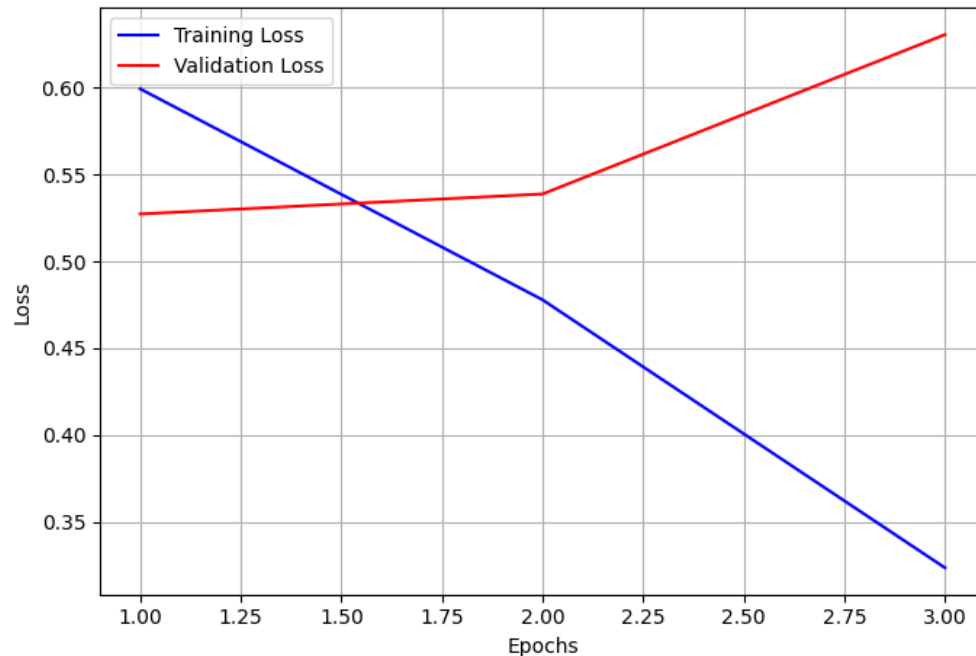


Fig. 5. Training loss and validation loss

As illustrated in Figure 5, the training loss curve exhibits a convergent downward trend, whereas the validation loss shows a fluctuating pattern with an increasing tendency (0.5273 to 0.5388 to 0.6307). During the first epoch, the model achieved a training loss of 0.5994, suggesting that the Transformer architecture rapidly captured the primary linguistic features and sentiment markers within the 21,413 reviews. This initial phase allowed the model to rapidly adapt its pre-trained knowledge to the domain-specific vocabulary of Indonesian fintech, such as terms related to *gadai* (pawn), *bunga* (interest), and *lelang* (auction). As training progressed to the second epoch, the training loss further declined to 0.4778, indicating that the model successfully refined its understanding of more complex semantic structures, particularly the informal Indonesian syntax prevalent in the dataset. This stage represents the model's peak validation performance (Acc: 0.8892). However, this trend shifted by the third epoch, where the drop in training loss to 0.3234 accompanied by a rise in validation loss to 0.6307 suggests the emergence of mild overfitting.

At this stage, the model began to fit the training data more specifically than the validation data, essentially 'memorizing' specific noise or rare tokens within the training set rather than learning generalizable patterns. A similar phenomenon is observed in Figure 6, where validation accuracy increases marginally in the second epoch but declines in the third epoch, despite the continuous improvement of training accuracy. This divergence serves as a critical technical indicator for early stopping. In the context of the Early Warning System (EWS) proposed in this study, halting the training at epoch 3 is a strategic decision to ensure the model remains robust and capable of accurately classifying new, unseen customer feedback without being biased by the specific idiosyncrasies of the training samples.

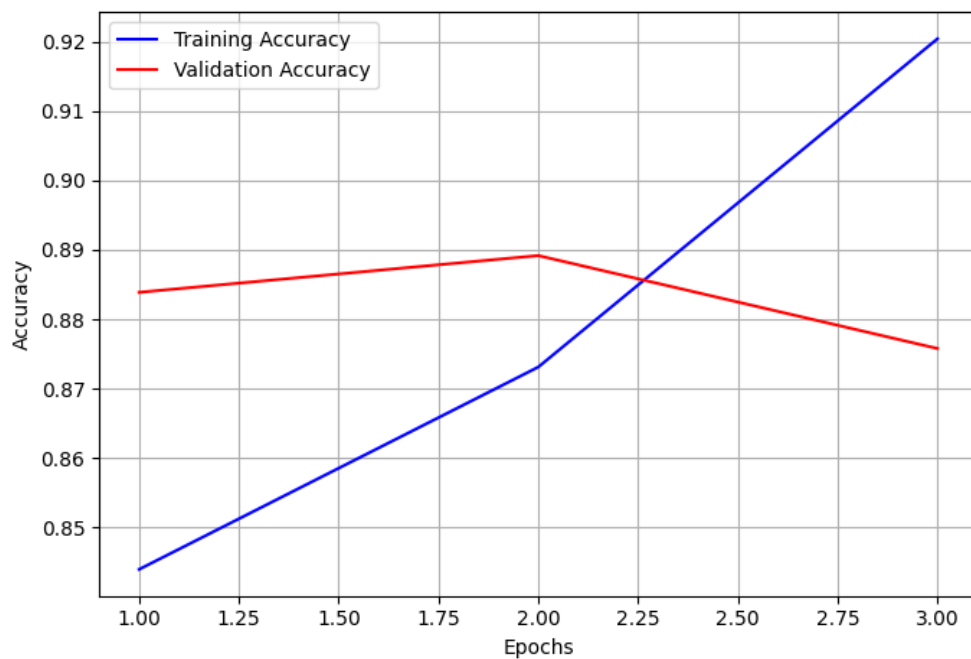


Fig. 6. Training accuracy dan validation accuracy

Nevertheless, the performance gap between training and validation remains within an acceptable range, indicating that the model's generalization capability is largely preserved. This finding suggests that the observed overfitting is moderate in nature and does not significantly degrade the overall classification performance. Such behavior is consistent with the findings of Adhim & Cahyono (2025), who reported that in Transformer-based models, an increase in validation loss does not necessarily correspond to a substantial decline in predictive performance, particularly when the models are applied to complex and imbalanced real-world textual data.

From a methodological perspective, the observed training dynamics confirm that three epochs represent an optimal configuration for balancing learning capacity and generalization performance in this study. Accordingly, the decision to limit the number of training epochs is empirically justified, as it helps prevent performance degradation caused by excessive training. These results further reinforce the validity of employing IndoBERT as a robust and reliable framework for sentiment analysis in evaluating user experiences within application-based digital financial services.

3.3 Model performance evaluation and confusion matrix analysis

The final evaluation was conducted using a test dataset consisting of 3,212 user reviews, which was completely separated from the training data. The classification report indicates that the IndoBERT model achieved an overall accuracy of 86.36%, with a weighted F1-score of 0.8840, reflecting strong classification performance on an imbalanced dataset. A visualization of the distribution of predicted labels generated by the model on the test data is presented in Figure 7, which illustrates the overall prediction tendencies across sentiment classes. For the positive sentiment class, the model demonstrates exceptionally high performance, achieving a precision of 0.9798, a recall of 0.9270, and an F1-score of 0.9526. These results indicate that IndoBERT is highly reliable in identifying user reviews that express appreciation or satisfaction with Pegadaian's digital services.

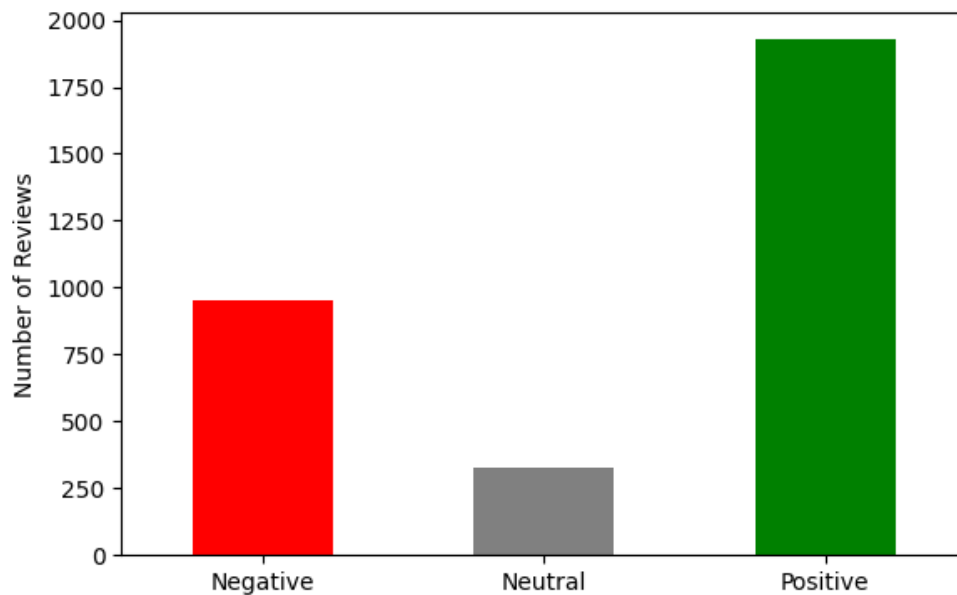


Fig. 7. Distribution of predicted sentiment labels

For the negative sentiment class, the model records a precision of 0.8688 and a recall of 0.7946, resulting in an F1-score of 0.8301. The recall value exceeding 80% holds substantial managerial significance, as it implies that the system is capable of automatically detecting more than eight out of ten user complaints. From an operational perspective, this capability is critical as a data-driven foundation for service evaluation and continuous improvement in digital financial services (Qolbu et al., 2025).

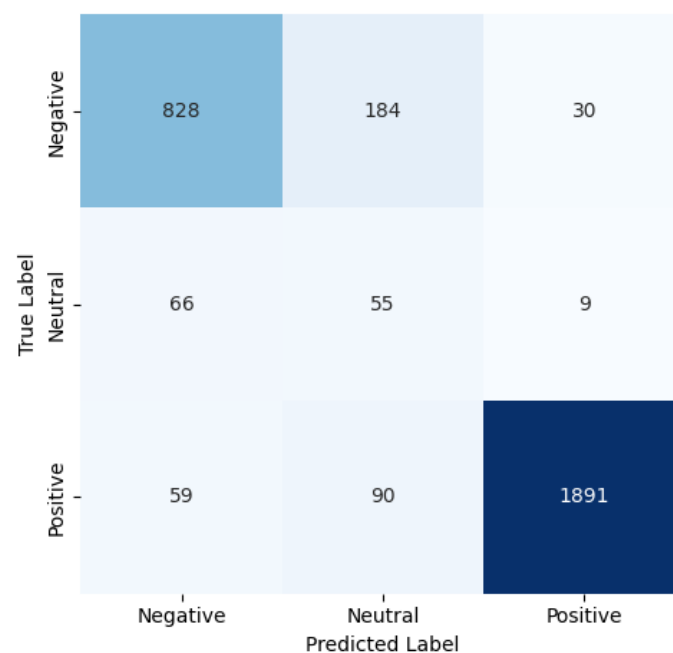


Fig. 8. Confusion matrix

The confusion matrix analysis presented in Figure 8 shows that the model correctly classified 1,891 positive reviews, 828 negative reviews, and 55 neutral reviews. In contrast, the performance on the neutral class remains relatively low, with an F1-score of 0.2397. This limitation can be attributed to the extremely limited number of neutral samples as well as the linguistic ambiguity of neutral expressions, which often overlap with mildly negative statements or constructive feedback.

Despite the overall high performance, Figure 9 illustrates the distribution of misclassified instances, with the largest proportion of errors occurring in the negative and neutral classes. Manual inspection reveals that many of these reviews contain evaluative phrases such as *perlu ditingkatkan* (needs improvement) or *tolong diperbaiki* (please revise), which are semantically positioned between neutral sentiment and mild dissatisfaction. Such linguistic characteristics increase classification ambiguity and consequently lead to confusion within the model (Johnson & Khoshgoftaar, 2019).

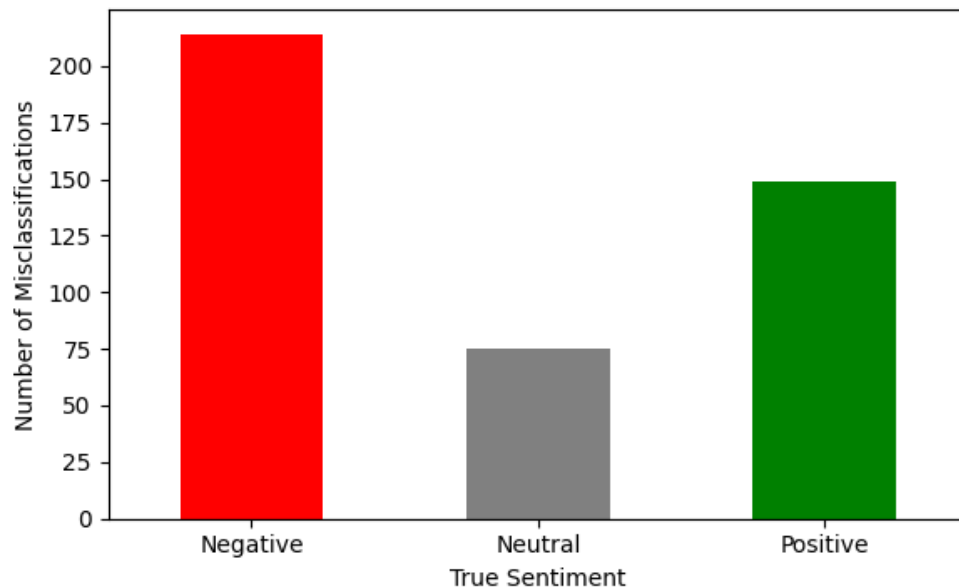


Fig. 9. Distribution of misclassifications

3.4 Linguistic case analysis: The superiority of IndoBERT

The superiority of IndoBERT over conventional sentiment analysis methods is clearly reflected in its ability to process sarcasm, colloquial language, and abbreviated expressions commonly found in user-generated reviews. In sarcastic statements such as *bagus sekali aplikasinya, tapi saldo tidak masuk* (the application is very good, but the balance was not credited), transformer-based models are able to capture the contextual relationships between clauses and accurately classify the overall sentiment as negative. In contrast, traditional bag-of-words approaches tend to exhibit bias toward lexically positive terms and often misclassify such statements as positive due to the presence of praise-related words.

Furthermore, IndoBERT demonstrates robust performance in understanding informal and abbreviated Indonesian language variants, such as *tll* (*terlalu*, too much), *sdh* (*sudah*, done), and *ttp* (*tetap*, still), without requiring extensive manual normalization or rule-based preprocessing. This capability highlights the advantage of pre-trained Transformer models that leverage large-scale Indonesian corpora, enabling them to learn contextual semantics beyond surface-level token frequencies. These findings confirm that IndoBERT is particularly well-suited for sentiment analysis tasks involving noisy, unstructured, and informal textual data, such as mobile application reviews. Its contextual embedding mechanism allows the model to handle linguistic nuances that are often problematic for conventional machine learning and lexicon-based methods. Consequently, the use of IndoBERT provides a more accurate and linguistically informed framework for capturing real user perceptions in digital service evaluations (Setiawan et al., 2025).

3.5 Innovation challenges and managerial implications

Based on the analysis of negative sentiment, three major issues were identified in the digital gold pawn service; (1) application system stability, particularly during version

updates, (2) clarity of the digital transaction workflow, and (3) transparency of balance information and administrative fees. These findings provide a strong empirical foundation for management to design data-driven service recovery strategies and innovation initiatives. The identification of these specific pain points highlights the innovation resistance often encountered by established state-owned enterprises (SOEs) during rapid digital pivots. While the move to digital platforms expands market reach, it also creates new vulnerabilities where technical glitches are no longer seen as mere inconveniences but as barriers to financial security.

The prevalence of keywords such as *update* and *gagal* (fail) in the negative word cloud underscores that technical friction during version updates often leads to immediate negative sentiment spikes, suggesting that PT Pegadaian needs to implement more robust beta testing or staged rollouts to mitigate user dissatisfaction. This proactive approach to deployment ensures that potential bugs are identified by a smaller user group before a full-scale release, thereby safeguarding the overall user experience. Furthermore, the recurring complaints regarding transparency suggest a gap in communication between the digital interface and the user's mental model of pawn transactions. In the realm of digital entrepreneurship, building algorithmic trust is paramount; users must feel that the automated calculations of interest and administrative fees are as reliable as a face-to-face consultation.

The identified issues are consistent with the findings of Shafa et al. (2025), who emphasize that digital service quality and perceived usefulness are key determinants of customer satisfaction in Pegadaian's financial services. From a managerial perspective, the ability to systematically capture and analyze user dissatisfaction enables organizations to move beyond reactive complaint handling toward proactive service improvement. This transition is central to what Plekhanov et al. (2023) describe as organizational agility in the digital age. For PT Pegadaian, this means integrating the IndoBERT-based early warning system (EWS) directly into their strategic planning cycles, allowing for a dynamic reallocation of resources toward the most critical service bottlenecks identified by real-time user feedback. Beyond internal management, these findings have broader policy implications for the Indonesian fintech regulatory framework. As the digital economy continues to scale, regulators such as the OJK could encourage the adoption of artificial intelligence-driven (AI-driven) sentiment monitoring as a standard for consumer protection. Such a move would foster a more resilient entrepreneurial ecosystem where financial institutions are held accountable not just for their fiscal performance, but for their digital service reliability. This study demonstrates that IndoBERT can serve as a bridge between high-level innovation goals and the granular reality of customer experiences, ensuring that the digitalization of gold pawn services remains inclusive and customer-centric.

The implementation of IndoBERT-based sentiment analysis allows Pegadaian to detect service-related problems at an early stage and initiate timely interventions before they escalate into a decline in user trust and loyalty (Ayertey et al., 2021; Reis et al., 2019). In the context of increasingly competitive digital financial ecosystems, such analytical capabilities are critical for aligning service innovation with actual customer expectations. Moreover, this data-driven approach plays a strategic role in digital marketing and customer experience management, as it facilitates a deeper understanding of consumer behavior derived from authentic, unsolicited user feedback. As highlighted by Hidayati et al. (2024), leveraging advanced sentiment analytics enhances organizational responsiveness and supports evidence-based decision-making in the digital transformation of financial service institutions.

3.6 Contribution to the digital transformation of state-owned enterprises

Overall, the findings of this study confirm that the application of a transformer-based IndoBERT model represents an effective and relevant approach for evaluating user satisfaction with PT Pegadaian's digital gold pawn services. The integration of sentiment

distribution analysis, model training dynamics, classification performance evaluation, and in-depth linguistic analysis demonstrates that artificial intelligence techniques are capable of capturing the complexity of informal and unstructured language more accurately than conventional methods.

The successful implementation of this approach contributes to the growing body of literature on the digital transformation of state-owned enterprises, aligning with the effectiveness of transformer-based models reported by Sanjaya et al. (2025) in assessing public opinion toward platform-based financial services. By leveraging large-scale user-generated data and advanced natural language processing models, this study extends existing research beyond survey-based evaluations and controlled experimental settings.

From a strategic perspective, the insights generated through IndoBERT-based sentiment analysis support evidence-based decision-making and enhance organizational responsiveness to customer needs. These capabilities are particularly critical for ensuring the sustainability of PT Pegadaian's digital transformation as a state-owned financial services institution operating in the digital economy. Consequently, this research underscores the practical and theoretical value of integrating advanced artificial intelligence models into the evaluation and continuous improvement of digital public financial services.

4. Conclusions

This study demonstrates that the IndoBERT-base-p1 model is effective in analyzing user sentiments of the Tring! by Pegadaian application. The model achieved an overall accuracy of 86.36% and a weighted F1-score of 0.8840, indicating strong predictive performance across most sentiment classes. Fine-tuning over three epochs reduced the training loss to 0.3234, although a slight increase in validation loss suggested potential limitations in the model's generalization when applied to a noisy and user-generated review dataset. This technical observation reinforces the necessity of balancing model complexity with the inherent volatility of informal Indonesian digital text. Scientifically, the transformer-based architecture showed superior performance in identifying positive (F1: 0.95) and negative (F1: 0.83) sentiments, confirming its suitability for sentiment classification tasks in Indonesian-language digital reviews. The model's performance on the neutral class remained low (F1: 0.23), highlighting challenges posed by data imbalance and linguistic ambiguity, which are common issues in multi-class sentiment classification. The achieved negative recall of 79.46% demonstrates practical applicability, providing a reliable mechanism for detecting customer complaints and supporting evidence-based service improvements. The success of this architecture in capturing semantic nuances underscores the potential of IndoBERT to serve as a foundational tool for broader natural language understanding tasks within the Indonesian fintech landscape.

From a managerial perspective, the model successfully identified 1,891 positive reviews and 828 negative complaints, enabling PT Pegadaian to implement a responsive service quality monitoring system. This automated detection of user sentiment offers actionable insights for digital service optimization and supports strategic decision-making in customer experience management. Furthermore, this study provides a clear roadmap for state-owned enterprises (SOEs) to navigate the complexities of digital entrepreneurship. By integrating these AI-driven early warning systems (EWS) into real-time customer service dashboards, organizations can effectively mitigate innovation resistance and transform passive feedback into a competitive advantage. This fosters an environment of continuous innovation and 'algorithmic trust' between the service provider and its digital-native users. Regarding policy and strategic recommendations, this research suggests that financial regulators and fintech developers should consider integrating automated sentiment monitoring as a standard component of consumer protection frameworks. Such integration would allow for more transparent and accountable digital financial ecosystems, where service failures are addressed with data-driven precision rather than anecdotal evidence.

For future research, the study recommends implementing data augmentation techniques for the underrepresented neutral class and exploring more stringent regularization methods to mitigate overfitting. Such approaches are expected to enhance model stability and improve generalization across both training and validation datasets. Additionally, to address the limitations of relying solely on app-based reviews, future studies should pursue data triangulation by incorporating internal helpdesk logs, transaction data, or direct customer interviews. This multi-dimensional approach would provide a more holistic view of the customer journey. Furthermore, future research could explore aspect-based sentiment analysis (ABSA) to pinpoint specific features within the application—such as security, user interface-user experience (UI/UX), or transaction speed—that drive user dissatisfaction. Additionally, incorporating larger and more diverse datasets may further strengthen the model's ability to interpret nuanced sentiment expressions in Indonesian digital reviews. In conclusion, this research provides evidence of the practical and scientific advantages of applying a transformer-based model for sentiment analysis in digital financial services, offering a robust foundation for both academic knowledge and operational efficiency in PT Pegadaian's digital platform.

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Author Contribution

Conceptualization, R.E., A.S., and S.W.M.; Methodology, R.E.; Software, R.E.; Validation, R.E. and S.W.M.; Formal Analysis, R.E. and A.S.; Investigation, S.W.M.; Resources, A.S. and S.W.M.; Data Curation, R.E.; Writing – Original Draft Preparation, R.E.; Writing – Review & Editing, A.S. and S.W.M.; Visualization, R.E.; Supervision, A.S.; Project Administration, A.S.; Funding Acquisition, S.W.M.

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Ethical Review Board Statement

The requirement for formal ethical review and approval was waived for this research as it relied exclusively on anonymous, publicly accessible user reviews from the Google Play Store. This study conducted no direct interaction or intervention with human participants. Furthermore, stringent protocols were applied to prevent the collection or processing of personally identifiable information (PII), specifically concerning sensitive financial or health data. By emphasizing individual privacy and research integrity, this methodology ensures that the advancement of natural language processing and artificial intelligence adheres to a responsible and ethical framework.

Informed Consent Statement

Not available. Direct involvement of human participants was not required for this research, as the methodology focused on secondary data analysis of anonymous, public reviews retrieved from the Google Play Store.

Data Availability Statement

The data supporting the findings of this study were derived from publicly available user reviews on the Google Play Store for the Tring! by Pegadaian application. The processed dataset generated during the study is not publicly archived but is available from the corresponding author upon reasonable request, due to privacy and ethical considerations regarding the raw textual content of the reviews.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used Gemini and ChatGPT to assist in refining the manuscript's structure, improving academic tone, and ensuring the administrative sections complied with journal standards. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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