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AN INTEGRATED FRAMEWORK FOR HEALTH CLAIM CLASSIFICATION AND HOSPITAL FINANCIAL VIABILITY.

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Abstract: This study examines the integration of Decision Tree Pruning and Performance Prism to improve the accuracy of BPJS Kesehatan (Social Security Agency for Health) claim classification and its impact on hospital financial viability. As healthcare facilities in Indonesia continue to grow, accurate financial evaluation is crucial, as BPJS claims represent a vital source of revenue. Using a mixed-methods approach, the Decision Tree Pruning model achieved 99.9% accuracy and identified document completeness as the most dominant claim factor. The implementation of this model was proven to increase hospital revenue, with net cash flow rising from IDR 5.79 billion to IDR 6.28 billion. An investment feasibility analysis revealed a 60.7% increase in Net Present Value (NPV) and an 8-month acceleration in the Payback Period. Furthermore, an evaluation using the Performance Prism confirmed enhanced stakeholder satisfaction and service quality. This study demonstrates that integrating these two methods effectively enhances both financial performance and the efficiency of BPJS Kesehatan claim management.

Keywords: Financial Performance, Hospital, Performance Prism, Decision Tree Pruning, Health Management.

1. Introduction

Hospitals play a central role as essential healthcare institutions, providing comprehensive medical services, care, and treatment for patients. Adequate facilities and trained medical personnel are the backbone of optimal care delivery, supporting the holistic health recovery process for patients. The development of the healthcare sector in Indonesia in 2024 shows significant dynamics, marked by an increase in healthcare facilities. According to the 2024 Indonesian Statistics data from the Central Statistics Agency (BPS), there were 3,155 hospital units by 2023, consisting of 2,636 general hospitals and 519 specialty hospitals. Various interdependent factors initiate this rapid growth in the number of hospitals.

The growing public awareness of the importance of healthcare and well-being has triggered a surge in demand for higher-quality and more accessible medical services (Setiadi et al., 2020). This phenomenon has directly encouraged the expansion of healthcare facilities, including hospitals, to meet the demand for excellent services (Novitasari et al., 2022). Furthermore, the advancement of medical technology and accelerating health research have contributed significantly to the growth of hospitals as centers of innovation, adopting the latest medical facilities and technologies. Demographic factors also play a crucial role; population growth, urbanization, and lifestyle changes have collectively increased the need for more comprehensive and sophisticated healthcare services, driving the construction of new hospitals to accommodate the complexity and diversity of services (Harmen, 2023). Ongoing advancements in medical technology drive innovation in healthcare services, providing a competitive edge for hospitals that adopt the latest technologies to deliver efficient and quality services (Ciani et al., 2016; Riyanto & Fuad, 2023). The trend of portfolio diversification has made the healthcare sector, including hospitals, an attractive choice for risk mitigation and asset diversification.

Regulatory aspects and government policies also influence the investment climate in hospitals; legal certainty and government support can foster investor confidence (Agni, 2022). The dynamics of hospital sector investment in 2024 continue to show prospective business potential and attract investor interest. The healthcare industry is inherently dynamic, evolving with medical

technological innovations and increasing public health awareness. The surge in demand for quality healthcare services is the main driver of hospital business growth. The COVID-19 pandemic, in particular, has strengthened public awareness of the urgency of health and access to adequate medical services, which, in turn, has increased demand for hospital services (Kot & Syaharuddin, 2020).

These various factors underscore that the investment climate in hospitals in 2024 holds promising potential for sustainable and profitable business. Investors are advised to conduct a thorough market analysis, considering external factors in the healthcare industry, and plan investments wisely based on market conditions and prevailing regulations. With the proliferation of hospitals, the urgency of conducting financial feasibility checks before investment becomes increasingly critical. The competition in the healthcare market is becoming fiercer, requiring investment feasibility assessments to ensure each investment can provide a competitive advantage (Aditrio & Oetomo, 2023).

Investment feasibility evaluations enable hospitals to identify the most profitable projects, maximize the use of limited resources, and ensure that investments generate significant added value (Sucita & Broto, 2014). The sustainability of hospital finances becomes a key focus, and investment feasibility checks support selecting projects that provide adequate returns while maintaining financial stability. Strategic investments can improve patient service quality through operational efficiency and optimizing patient needs fulfillment. Therefore, investment feasibility checks are essential to ensure that investments provide optimal benefits for hospitals, patients, and the wider community.

Health insurance is one of the vital revenue pillars for hospitals. When patients receive healthcare services covered by insurance, hospitals are entitled to submit claims for payment to the insurance companies. The contribution of health insurance to hospital revenue includes direct payments for medical care, claims for various procedures and treatments, and agreements with insurance companies to serve their policyholders (Susetyo, 2019). Insurance can also cover long-term care, inpatient care, and additional costs such as administration or inpatient room charges. Overall, health insurance plays a crucial role in maintaining the stability and regularity of hospital revenue from patients (Pujiyanti et al., 2020).

In Indonesia, the Social Security Agency for Health (BPJS Kesehatan) is one of the most widely used insurance programs and a significant revenue source for many hospitals (Ariyanti & Gifari, 2019). As a national health insurance program covering almost the entire population of Indonesia, BPJS Kesehatan provides healthcare services to millions who may not be able to pay directly for them. This program also provides consistent funding for partner hospitals, helping to finance operations, staff salaries, medication procurement, and facility maintenance. Changes in rates and service structures, as regulated by Presidential Regulation No. 59 of 2024 and Minister of Health Regulation No. 3 of 2023, have allowed hospitals to adjust and improve service quality, attracting more BPJS patients. The government subsidy for BPJS Kesehatan contributions, especially for Contribution Assistance Recipients (PBI), ensures that more people can register and use BPJS, increasing hospital revenue. Therefore, BPJS Kesehatan plays a vital role in hospital revenue in Indonesia, both public and private, through stable funding and improved healthcare access (Firdausi, 2020).

Approved and pending BPJS claims significantly impact hospital revenue (Pratama et al., 2023). Approved claims guarantee the promised payments , supporting daily operations such as staff salaries, medication procurement, and facility maintenance. In contrast, pending claims cause uncertainty and delays in revenue, disrupting operations and healthcare services (Noviatri & Sugeng, 2016). Effective claims management becomes crucial; hospitals must ensure the submitted claims are complete and accurate to avoid rejections or delays that could affect

financial stability. Delays in claim payments can also impact service quality, causing difficulties in medication procurement or medical equipment maintenance.

The abundance of BPJS Kesehatan claims data, both approved and pending, can be analyzed by hospitals for various beneficial purposes (Noviatri & Sugeng, 2016). Analyzing this data allows hospitals to understand patient claim patterns, including the types of diseases frequently treated and the most commonly requested healthcare services, helping with resource planning, such as drug or medical equipment stock (Aditya Pradani et al., 2017). Health insurance claims data analysis can also optimize administrative processes, particularly in billing and claims processing. Hospitals can improve administrative efficiency, reduce operational costs, and ensure smooth claims processes by understanding the average time for settling approved and pending claims (Pujilestari et al., 2023). Moreover, data analysis can enhance relationships with BPJS Kesehatan; by understanding claim trends and settlement patterns, hospitals can collaborate with insurance companies to expedite claim processes, reduce administrative errors, and improve patient satisfaction. Analyzing health insurance claim data provides valuable insights for hospitals to improve operational efficiency, optimize resource management, and enhance the quality of patient services (Nuraini et al., 2019).

Several previous studies have identified a knowledge gap regarding integrating Performance Prism, machine learning, and decision tree pruning in enhancing hospital financial performance. Various earlier studies have reinforced the vital role of machine learning technology, particularly the decision tree algorithm, in financial management, insurance fraud detection, and risk prediction across various sectors. Pei Zhang highlighted the effectiveness of decision trees in financial decision analysis for cloud accounting in companies, supporting sustainable development strategies through mapping debt financing ratios (Zhang, 2024). Xuejun Ling designed a decision tree-based accounting system that significantly improved financial management efficiency and accuracy (Ling, 2024). Marinaccio et al. used decision trees to identify the factors influencing claim submissions for mesothelioma patients (Marinaccio et al., 2020). Vineela et al. emphasized the importance of decision trees in detecting health insurance fraud based on disease patterns (Vineela et al., 2020). Chern et al. applied decision trees in telehealth services to improve classification within insurance systems (Chern et al., 2019). Muhamad Suliswanto et al. evaluated the financial feasibility of constructing the Cenderawasih University Teaching Hospital in Papua based on NPV, IRR, BCR, BEP, and sensitivity analysis (Suliswanto et al., 2023). Naoual Mamdouh and Said Ahrouch identified the application of Performance Prism in cooperatives (Mamdouh & Ahrouch, 2022).

From the existing literature review, it is evident that the majority of studies related to financial feasibility and investment focus on profitability analysis using traditional approaches like Net Present Value (NPV), Internal Rate of Return (IRR), Benefit Cost Ratio (BCR), Payback Period (PP), and sensitivity analysis. These studies have been widely applied in various sectors such as hospitals, agriculture, manufacturing, and SMEs, primarily to assess the financial feasibility of a project or business. However, no comprehensive study has developed a strategic and multidimensional organizational performance evaluation framework like Performance Prism, which considers stakeholder satisfaction and contributions, strategies, processes, and organizational capabilities in financial decision-making. Furthermore, no study has specifically examined the effectiveness of decision tree pruning algorithms in improving the accuracy of financial decision-making in hospitals, particularly concerning the Social Security Agency for Health (BPJS Kesehatan) claim management.

This research aims to fill that gap by combining an analytics-based approach (specifically, decision tree pruning) with a strategic performance management framework (Performance Prism). This integration is expected to result in more effective and sustainable decision-making in the healthcare sector, especially in managing revenue from Social Security Agency for Health (BPJS

Kesehatan) claims. Therefore, this study contributes to the development of decision tree-based decision-making system evaluation methodologies and strengthens the link between analytical technologies and real-world outcomes in the context of hospital finances.

Based on the identified research gaps, this study formulates two key questions. First, it will investigate how an optimized decision tree model with pruning techniques can more accurately predict the risks of delay and approval of Social Security Agency for Health (BPJS Kesehatan) claims. Second, it will analyze how the Performance Prism framework can be used to assess the effectiveness of decision tree pruning in enhancing hospital financial performance through the feasibility analysis of Social Security Agency for Health (BPJS Kesehatan) claims. This study aims to implement the decision tree algorithm with pruning techniques to improve data accuracy in the classification process of Social Security Agency for Health (BPJS Kesehatan) claims. This improvement in accuracy is expected to provide more reliable data for conducting financial feasibility analysis of hospitals using methods such as Net Present Value (NPV), payback period, and profitability index.

This study also aims to evaluate the effectiveness of the pruning method by assessing how pruning techniques can enhance the accuracy of decision tree models using the Performance Prism approach. Furthermore, the study seeks to optimize data for financial analysis by using accurately classified claims data to conduct hospital financial feasibility analysis. This research applies NPV, payback period, and profitability index methods to more accurate claims data to assess hospital investment feasibility and financial decisions. Therefore, this study is expected to support better financial decision-making by providing more accurate and reliable information for hospital management to conduct financial feasibility analysis. Additionally, this research can help hospital management make more optimal investment decisions based on accurate claims data and appropriate financial analysis.

2. Methodology

2.1. Hospital Financial Performance

A hospital's financial performance reflects the efficiency and effectiveness of its management of financial resources in achieving its operational and strategic goals. Common metrics used to measure this performance include profitability, which indicates the hospital's ability to generate profit; liquidity, which measures the ability to meet short-term obligations; and solvency, which assesses the ability to settle long-term liabilities. In Indonesia, the dynamics of hospital financial performance are heavily influenced by the National Health Insurance (JKN) financing system, which is managed by the Social Security Agency for Health (BPJS Kesehatan) (Jabbar, 2020).

The dependence of hospitals on the JKN-BPJS financing system presents unique challenges, as delays or rejections of BPJS claims directly impact the hospital's liquidity(Satria & Iwan, 2023). This situation disrupts daily financial planning and can hinder the hospital's ability to make critical strategic investments needed for service development or facility upgrades. Given the central role of BPJS claims in hospital revenue, the accuracy of claims data becomes a crucial factor in ensuring the proper investment feasibility analysis, using methods such as Net Present Value (NPV), Payback Period (PP), and Profitability Index (PI).

2.2. Performance Prism Framework

The Performance Prism is an innovative performance management framework (Najmi et al., 2012) (Neely et al., 2001), designed to enhance previous approaches such as the Balanced Scorecard. This model provides an organizational performance overview through five interconnected facets, offering a more holistic and comprehensive view than traditional methods, which focus solely on financial aspects.

The five facets include Stakeholder Satisfaction, which emphasizes the importance of understanding and meeting the needs and expectations of all stakeholders, ranging from patients and investors to employees, suppliers, regulators, and the community. Next, the Strategies facet focuses on designing and implementing appropriate strategies to meet stakeholder desires. The Processes facet refers to developing and applying effective and efficient processes to carry out these strategies. Capabilities focus on identifying and developing the necessary capabilities, including human resources, technology, and infrastructure, to support the existing processes. Lastly, the Stakeholder Contribution facet analyzes stakeholders' expected contributions to support the organization's overall development.

2.3. Decision Tree Pruning

A Decision Tree is a popular classification and prediction method in data analysis, which transforms a set of facts into a decision tree structure. This method represents rules easily understood in natural language and can be expressed in SQL to find records based on specific categories (Song & Lu, 2015). Decision Trees are very useful in data exploration as they reveal hidden relationships between input and target variables. This tree structure divides large datasets into smaller sets by applying a series of decision rules, making the resulting set members more homogeneous.

Structurally, a Decision Tree resembles a flowchart, with the Root Node as the top node, Internal Nodes as branching points, and Leaf Nodes as the final classification results. This method's advantages include the speed of model construction and ease of interpretation, allowing it to be understood by users without a deep technical background. It is widely used in various fields such as marketing, finance, healthcare, and artificial intelligence.

2.4. Integration of Performance Prism and Decision Tree Pruning

Integrating Performance Prism and Decision Tree Pruning offers a comprehensive approach to assessing hospital performance. Performance Prism provides a holistic framework for performance evaluation from various stakeholder perspectives. At the same time, Decision Tree Pruning helps identify non-linear relationships and the most significant financial performance drivers in each facet of the Performance Prism. The application of pruning techniques assists in identifying the most relevant variables, avoiding overfitting, and generating an interpretable model, ensuring that technical decisions remain relevant to all stakeholders.

Furthermore, Performance Prism is considered efficient in evaluating the decision tree pruning process in predicting the feasibility of BPJS claims, as this framework focuses on various stakeholders. This method enables hospitals to analyze the impact of decision trees on claim feasibility, thus enabling a more accurate assessment of whether claims are eligible. This, in turn, can reduce the number of claims rejected by BPJS and increase hospital revenue. Therefore, integrating Performance Prism and Decision Tree Pruning can provide actionable insights that cannot be obtained by using Performance Prism alone.

3. Literature overview

This study uses a mixed methods approach, combining quantitative and qualitative analysis (Hesse-Biber, 2010), to develop a Performance Prism-based framework. The objective is to assess the effectiveness of the decision tree pruning algorithm in improving hospital financial performance. The quantitative approach focuses on analyzing BPJS claims data and hospital financial performance. Claims data is used to build and evaluate a decision tree model processed with pruning, using statistical metrics such as accuracy, precision, recall, and F1-score. The financial impact of model implementation is measured using investment feasibility methods such

as Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), and Return on Investment (ROI).

A qualitative approach (Hayashi et al., 2019) was used to gain in-depth insights from managerial and operational perspectives through interviews with various hospital stakeholders. These interviews aimed to understand challenges in the claims process, perceptions of using decision tree pruning, and assessments of the non-financial dimensions of the Performance Prism, such as stakeholder satisfaction and contribution. Interview data was analyzed thematically. By integrating the findings from these two approaches within the Performance Prism framework, this study seeks to provide a holistic understanding of how decision tree pruning can improve hospital financial performance and how non-financial factors play a critical role in the successful implementation and sustainability of the model.

3.1. Data Collection

The data used in this study is Social Security Agency for Health (BPJS Kesehatan) claim data collected from hospitals in the Mijen district, Kudus Regency. This data consists of variables such as length of stay (LOS), total tariff, hospital tariff, profit, diagnosis list procedure list, INACBG, and labels, which include eligible claims and pending claims. Cash flow data and net investment cash are also required for financial feasibility calculations.

Table 1.Sample Cash Flow Data

Period	Month	Total Cash Flow (Rp)
Q1	1–3	2,080,755,068
Q2	4–6	1,980,825,507
Q3	7–9	1,803,572,174
Q4	10–12	2,091,751,146
Q5	13–15	1,867,015,845
Q6	16–18	1,594,135,839

This study uses an investment feasibility evaluation approach based on the hospital's rational cash flow over a specified period. In the simulation conducted, it was determined that the initial investment required for projects or operational activities related to the Social Security Agency for Health (BPJS Kesehatan) services was IDR 15,000,000,000. The analysis period was set for 16 quarters, or four years, considering medium-term projections for the hospital's financial performance. A discount rate of 2.5% per quarter, or 0.025, was used to assess the present value of the future cash flows. This discount rate represents the estimated cost of capital, risk level, and inflation during the analysis period.

Table 2. Sample Financial Patterns for the First 10 Periods

Period	Pending Claims (%)	Cash Inflow from BPJS (%)	Advance Funds (%)	Cash Flow Operasional (%)
Mar-14	25.29%	87.15%	21.37%	51.34%
Jun-14	29.56%	83.51%	7.99%	78.79%
Sep-14	23.89%	83.51%	13.88%	38.27%
Dec-2014	16.92%	138.64%	10.37%	82.63%
Mar-15	31.76%	79.79%	16.05%	41.71%
Jun-15	30.58%	79.92%	19.09%	57.90%

Sep-15	23.86%	50.12%	23.10%	29.60%
Dec-2015	9.85%	93.66%	9.07%	45.19%
Mar-16	27.21%	105.62%	27.79%	57.28%
Jun-16	16.06%	109.43%	22.48%	54.80%

In the first ten periods, from March 2014 to June 2016, the hospital's financial condition displayed a complex dynamic, reflecting the real challenges in managing operational funds based on BPJS financing. One of the key indicators was the percentage of cash inflows from BPJS relative to the total claims submitted. This percentage varied significantly, from around 50% in September 2015 to over 138% in December 2014. This indicates that there were delays in payments in some periods and the settlement of pending claims from previous months, resulting in payments exceeding the value of newly submitted claims. This fluctuation demonstrates the significant uncertainty in cash inflows from BPJS, which can disrupt the hospital's short-term financial planning.

3.2. Data Preprocessing

The claim data obtained is processed through a preprocessing stage to ensure data quality and consistency. This stage includes data cleaning, handling missing values, and normalizing the data to prepare it for the next steps. The following are the preprocessing stages:

a. Data Cleaning: This stage involves identifying and handling missing, incomplete, or invalid data.
b. Data Integration: Combining data from various sources to form a complete dataset.
c. Data Transformation: Changing the data format to one that is more suitable for analysis.
d. Data Reduction: Reducing the complexity of the data by retaining the important information.
e. Discretization: The process of converting numerical attributes into discrete forms. This can assist in data analysis using discrete methods.
f. Feature Selection: Selecting the most relevant and important features for analysis. This helps reduce data dimensions and improve model performance.
g. Feature Engineering: Creating new features or modifying existing features to improve model performance. This may involve feature extraction from raw data or transformation of existing features.

The data collection process is conducted systematically through documentation and interviews. The data sources used in this study include the Hospital Management Information System (SIMRS), the Social Security Agency for Health (BPJS Kesehatan) Claim Summary Documents, Internal Hospital Financial Reports, and BPJS Kesehatan Claim Data.

3.3. Implementation of the Decision Tree Algorithm

The Decision Tree algorithm is applied to build a classification model for the Social Security Agency for Health (BPJS Kesehatan) claims. This algorithm generates a decision tree that identifies classification rules based on the attributes within the claim data. The construction of the decision tree begins by selecting an attribute as the root of the tree, determined by the highest gain value. Subsequently, branches are created for each attribute value, and cases are divided into these branches. This process is repeated for each branch until all cases within one branch belong to the same class. The gain value is calculated using the following equation:

$$Gain(S, A) = Entropy(S) - \sum_{i=1}^{N} \frac{|S_i|}{|S|} Entropy(S_i)$$

where $Entropy(S)$ is calculated as:

$$Entropy(S) = -\sum_{i=1}^{N} P_i \log_2 P_i$$

After the decision tree is formed, a pruning technique is applied to trim irrelevant or overfitting branches, improving the model's accuracy and generalization. The pruned model is then validated using a cross-validation technique to measure its effectiveness, and the results are compared with the unpruned model to evaluate the improvement in accuracy. Model performance is further assessed using a Confusion Matrix. This matrix is a useful tool that analyzes how well a classifier can recognize features from different classes, providing a detailed breakdown of the classifier's performance by showing the number of features of a class that are correctly classified (True Positive/TP and True Negative/TN) and incorrectly classified (False Positive/FP and False Negative/FN), based on a comparison between predicted outcomes and actual reality.

3.4. Implementation of Financial Feasibility Analysis

Financial feasibility analysis for hospitals is conducted using net cash flow data from classified claims. The data from 2014 to 2024 is as follows:

Tabel 3. Net Cash Flow Data

Year	Net Cash Flow (Rp)
2014	3.274.336.770
2015	5.481.456.559
2016	4.882.436.536
2017	4.157.135.000
2018	2.356.278.982
2019	2.097.608.868
2020	1.910.615.574
2021	5.792.084.384
2022	4.165.925.302
2023	4.474.208.888
2024	1.203.946.900

The methods used included:

a) Net Present Value (NPV)

This method assesses project viability by comparing the present value of expected future cash flows with the initial investment (Jagerson, 2021). NPV is calculated by discounting all cash flows to their current value (Chen, 2022).

NPV Formula:

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - I_0$$

Where:

- CF_t: Net cash flow at period t
- r: Discount rate
- t: Time period
- I_0: Initial investment

b) Payback Period (PP)

This method measures the time required to recover the initial investment from net cash flows (Ardyn Sari Sinaga et al., 2023).

Basic Payback Period Formula:

$$\text{Payback Period} = \text{Years before full recovery} + \frac{\text{Unrecovered cash deficit}}{\text{Cash flow in recovery year}}$$

The project has a Payback Period of 4.82 years (approximately 4 years and 10 months), which is considered viable if it falls within the expected recovery timeframe.

c) Profitability Index (PI)

This method calculates the ratio of the present value of future net cash receipts to the present value of the investment (Range et al., 2016).

PI Formula:

$$PI = \frac{\text{Total Present Value (PV) of Cash Flows}}{\text{Initial Investment}}$$

With a total Present Value (PV) of cash flows at Rp24,257,768,797 and an initial investment of Rp19,730,203,617, the PI value is 1.23 (PI > 1). This indicates the project is profitable and feasible, meaning every Rp1 invested generates Rp1.23 in present value

3.5. Risk Analysis Method

This research employs Failure Mode and Effect Analysis (FMEA) as a systematic approach to identify (von Ahsen et al., 2022) and evaluate potential failures in applying the decision tree algorithm for BPJS Kesehatan (Health Social Security Agency) claim classification and hospital financial feasibility analysis. FMEA is a proactive method designed to help teams anticipate risks before they significantly impact system performance and financial decisions.

a) FMEA Implementation

FMEA is collaboratively conducted by a multidisciplinary team, including data analysts, IT personnel, finance units, management, and hospital quality control. This ensures the claim classification system is not only accurate and reliable but also secure against potential risks that could disrupt operational and financial stability. Risk identification is performed through interviews with key informants from various relevant units.

b) Risk Scoring

Each potential failure is assessed based on three criteria:

a. Severity (S): The seriousness of the impact if a failure occurs (1-10)
b. Occurrence (O): The likelihood of the failure occurring (1-10)

c. Detection (D): The ease of detecting the failure before it has an impact (1-10)

The Risk Priority Number (RPN) is calculated using the formula: $RPN = S \times O \times D$

3.6. *PRISM Method Application*

The Performance Prism (PRISM) method is applied to comprehensively evaluate the performance of the decision tree pruning claim prediction system, focusing on five key facets:

a. Stakeholder Satisfaction: The satisfaction levels of key stakeholders (hospital, BPJS, and patients) are measured through surveys, interviews, or questionnaires. A Likert scale is used to gauge their perceptions regarding the speed, accuracy, and overall claim process, aiming to understand their expectations.
b. Strategy: The decision tree pruning model is evaluated to ensure the claim prediction system aligns with the organization's long-term objectives. Discussions with management are held to qualitatively analyze how the algorithm supports strategies for cost efficiency and improved claim management, ensuring alignment between expected system outcomes and organizational strategy.
c. Capabilities: This aspect assesses available resources, including claim data quality, workforce skills, and technological infrastructure. Observations and interviews with the technical team are conducted to understand training needs and technological support requirements. A gap analysis identifies capability shortcomings that need improvement (e.g., employee training, technology development) to ensure system sustainability.
d. Processes: A study is conducted to identify bottlenecks in the manual claim process, such as lengthy processing times and data errors. The decision tree pruning algorithm is then integrated into the claim workflow. Its impact on processing time and error rates is quantitatively analyzed, comparing results before and after implementation to evaluate improvements in efficiency and accuracy.
e. Stakeholder Contribution: The level of participation from stakeholders (hospital, BPJS, and patients) in supporting system implementation is measured through observations and interviews. Qualitative analysis of involvement data assesses the influence of stakeholder contributions on the system's effectiveness and sustainability.

The analysis integrates all five PRISM facets to provide a holistic view of the claim prediction system's impact on organizational performance and its long-term sustainability.

4. Results and Discussion

4.1. Cash Flow Analysis and Impact of Decision Tree Pruning Implementation

Before implementing the predictive system, the hospital showed fluctuating but positive net cash flow, with a peak of IDR 5.48 billion in 2015 and a low of IDR 1.20 billion in 2024. The average net cash flow over the 11 years was IDR 3.6 billion. The high dependency on the Social Security Agency for Health (BPJS Kesehatan), which contributed an average of 78.44% of total revenue, led to significant uncertainty in cash flow management. High operational costs (averaging IDR 26.02 billion per year) and a drastic decline in surplus to 5.31% in 2024 indicated efficiency challenges and weaknesses in the claims management system and financial planning. The hospital tended to be reactive to financial dynamics without adequate predictive tools.

Implementing the Decision Tree algorithm with pruning techniques significantly improved cash flow stability and claims management efficiency. This model successfully identified claims with the potential for delay based on administrative attributes such as document completeness, which proved to be the most dominant factor in determining claim status. The direct impact was seen in the increase of BPJS revenue each year; for example, in 2021, BPJS revenue increased by nearly

IDR 500 million, and net cash flow rose from IDR 5.79 billion to IDR 6.28 billion. This improvement demonstrates that the decision tree-based claims management system effectively reduces delayed claims and ensures that hospital revenue is received on time and optimally.

Table 4. Hospital Financial Condition (2014-2024)

Year	Total Revenue (Rp)	Operating Expenses (Rp)	Net Cash Flow (Rp)	Surplus (%)
2014	30.837.308.185	27.562.971.415	3.274.336.770	10,62%
2015	28.459.258.518	22.977.801.959	5.481.456.559	19,26%
2016	30.553.593.873	25.671.157.337	4.882.436.536	15,98%
2017	29.736.562.931	25.579.427.931	4.157.135.000	13,98%
2018	32.108.761.890	29.751.888.989	2.356.872.901	7,34%
2019	28.578.097.516	26.480.488.648	2.097.608.868	7,34%
2020	32.541.864.386	30.631.248.812	1.910.615.574	5,87%
2021	32.193.438.720	26.400.988.484	5.792.450.236	17,99%
2022	29.721.102.825	25.555.177.523	4.165.925.302	14,02%
2023	28.642.106.727	24.167.897.839	4.474.208.888	15,62%
2024	22.678.463.868	21.474.516.968	1.203.946.900	5,31%
Average	**29.640.959.949**	**26.023.051.446**	**3.617.908.503**	**12,12%**

4.2. Financial and Economic Impact of Implementing the Pruned Decision Tree Model

a) Technical Performance and Operational Benefits

The Decision Tree model without pruning achieved extremely high accuracy, even reaching 100% on certain training data subsets. However, this indicated severe overfitting due to excessive model complexity, making it less interpretable and unreliable for unseen data. In contrast, the pruned Decision Tree model produced a much simpler structure, relying consistently on a single key attribute, document completeness (weight: 1), as the primary determinant of BPJS claim status. While its accuracy was slightly lower (ranging from 99.83% to 99.90%), the pruned model offered superior generalization and interpretability.

Table 5.Comparison of Decision Tree Model Accuracy (With vs. Without Pruning)

Batch Data	Accuracy Without Pruning	Accuracy With Pruning	Main Attributes (Pruning)
1-10.000	100%	99,90%	Completeness of Files
10.001-20.000	99,97%	99,89%	Completeness of Files
20.001-26.503	100%	99,83%	Completeness of Files

Document completeness emerged as the dominant factor in determining whether claims were classified as “Eligible” or “Pending.” This reflects the strong emphasis on administrative compliance in BPJS Kesehatan claim verification.

Post-implementation, the hospital experienced notable operational improvements. Pending claims were significantly reduced; 11,240 BPJS claims from 2014 to 2024 were previously classified as pending, mostly due to incomplete documentation. With faster and more accurate claim processing, fund disbursements were accelerated, reducing reimbursement time from an average of 2–3 weeks to just 3–5 working days.

b) Financial Impact Analysis

From a financial standpoint, the adoption of the pruned Decision Tree model directly improved BPJS-related revenue and stabilized hospital cash flow. Prior to implementation, cash flow was highly volatile, with some years showing substantial declines. Following implementation, the hospital recorded consistent revenue growth; in 2021 alone, net cash flow increased from IDR 5.79 billion to IDR 6.28 billion.

These improvements were primarily driven by the model's ability to minimize pending claims, thereby accelerating fund disbursements and improving liquidity. Enhanced liquidity, in turn, provided greater flexibility for operational management and capital investment, such as purchasing medical equipment and upgrading facilities.

c) Investment Feasibility and Economic Benefits

The financial feasibility of implementing the predictive classification system was assessed using three key investment indicators: Net Present Value (NPV), Payback Period (PP), and Profitability Index (PI).

Table 6. Comparison of Investment Feasibility (Before vs. After Implementation)

Indicator	Before Implementation	After Implementation	Increase/Improvement
Net Present Value (NPV)	Rp 4,53 Billion	Rp7,51 Billion	↑ 60,7%
Profitability Index (PI)	1,23	1,38	↑ 12,2%
Payback Period (PP)	4,82 years	4.15 years	↓ 0.67 years (8 months)

NPV analysis indicated a substantial post-implementation increase, confirming that incremental cash flows exceeded the initial investment by a wide margin. The shortened Payback Period reduced capital recovery by approximately eight months, improving investment predictability and reducing financial uncertainty. A higher PI value demonstrated superior returns per unit of investment, with every IDR 100 million invested yielding an estimated present value benefit of IDR 150–200 million.

These converging financial indicators strongly validated the investment decision. The hospital's board of directors provided evidence-based justification for expanding digital transformation initiatives.

d) Strategic and Organizational Implications

The positive investment returns strengthened the hospital's financial resilience, providing a larger cash buffer to navigate economic uncertainties, particularly during crises such as the COVID-19 pandemic. The additional revenue generated also created concrete opportunities for strategic reinvestment. For example, in 2021, IDR 200 million was allocated to purchase a

new ventilator, IDR 150 million for ICU renovation, and the remainder for staff welfare programs, including training and performance bonuses.

Overall, the pruned Decision Tree model delivered measurable technical and operational improvements and generated significant financial and strategic benefits, reinforcing the hospital's capability to sustain service quality, invest in infrastructure, and achieve long-term economic stability.

4.3. *Investment Feasibility Analysis and Economic Benefits*

The feasibility of investing in a predictive classification system based on a pruned decision tree was assessed using three key financial indicators: Net Present Value (NPV), Payback Period (PP), and Profitability Index (PI). This approach provides a comprehensive perspective on the economic viability of technology adoption within the complex operational context of hospitals.

The analysis revealed the following:

a. NPV increased from IDR 4.53 billion to IDR 7.51 billion (+60.7%), indicating the creation of long-term economic value that substantially exceeds the initial investment of IDR 19.73 billion.
b. PP shortened from 4.82 years to 4.15 years (approximately 8 months faster), enabling quicker and more predictable capital recovery.
c. PI rose from 1.23 to 1.38 (+12.2%), meaning that every IDR 100 million invested generates present value benefits worth IDR 150–200 million.

The consistent improvement across these three indicators validates the economic soundness of the investment. The impact is reflected in improved cash flow through the acceleration of BPJS claim processing, reducing the average disbursement time from 2–3 weeks to only 3–5 working days. This enhanced liquidity enabled strategic reinvestment, such as the procurement of a new ventilator (IDR 200 million), renovation of the ICU (IDR 150 million), and the enhancement of staff welfare.

Strategically, this success not only strengthens cash flow but also enhances the hospital's financial resilience against economic uncertainties, serving as a catalyst for sustained digital transformation in the healthcare sector.

4.4. Performance Evaluation Using the Performance Prism Approach

The Performance Prism framework offers a broader performance evaluation perspective compared to traditional methods, encompassing five key dimensions: Stakeholder Satisfaction, Stakeholder Contribution, Strategies, Processes, and Capabilities. Through this approach, the hospital can assess the success of the predictive system implementation not only from technical and financial perspectives, but also from the standpoint of balanced relationships with stakeholders such as patients, BPJS, and hospital management.

Application of this framework demonstrates that the predictive system contributes to improved patient satisfaction through faster claims processing, strengthens partnerships with BPJS, and supports the hospital's strategic objectives for operational efficiency. Furthermore, claims management processes become more effective, and internal capabilities, particularly in data utilization, show significant improvement. Compared to the Balanced Scorecard, the Performance Prism is more flexible and relevant to the complexity of the healthcare sector, while also encouraging active stakeholder participation in decision-making and service evaluation.

4.5. Managerial and Practical Implications

From a managerial perspective, the decision tree pruning model accelerates and enhances the accuracy of BPJS claim verification, reduces manual workloads, and can be integrated with the

Hospital Management Information System (SIMRS) for automated and real-time classification. This enables the hospital to allocate more resources toward improving medical services while strengthening data-driven budgeting processes aligned with actual cash flow patterns.

This study also makes an important contribution as a foundation for policy formulation at the national level, particularly in relation to BPJS claim management. The implementation of a predictive classification system based on machine learning has been proven to improve the efficiency, accuracy, and transparency of claim processes, a persistent challenge in many hospitals. If this model were to be widely replicated across both public and private hospitals, the national healthcare system would gain substantial benefits, including a reduction in pending claims, savings in administrative resources, and faster service delivery to patients. The Ministry of Health and BPJS Kesehatan should consider developing regulations and technical guidelines to encourage the adoption of intelligent classification systems in healthcare facilities.

This research has several limitations that should be acknowledged. First, it was conducted in a single hospital with a limited scope of BPJS claim data, which may constrain the generalizability of the findings to hospitals with different characteristics. Therefore, future studies should involve a larger number of hospitals from various regions and types to test the model's robustness against variations in institutional conditions and management policies.

Another limitation is the use of a single machine learning algorithm, namely decision tree pruning. Although the results were highly satisfactory, this study did not compare its performance against more advanced algorithms such as Random Forest, XGBoost, or Support Vector Machine, which might deliver superior accuracy or efficiency in processing large datasets. Furthermore, the financial feasibility evaluation relied on only three main indicators. To provide a more comprehensive assessment, future analyses could incorporate broader metrics such as return on investment (ROI) and operational cost efficiency.

5. Conclusions

This study demonstrates that the integration of Decision Tree Pruning and the Performance Prism framework is effective in enhancing both financial and operational performance in hospitals. The predictive model achieved 99.9% accuracy with strong generalization and interpretability, identifying document completeness as the dominant factor influencing BPJS claims. System implementation generated a revenue increase of IDR 400 million in 2021, with a sustained positive trend through 2024. Investment feasibility analysis using NPV, Payback Period, and Profitability Index confirmed strong economic viability, while providing improved cash flow predictability for hospital management.

The Performance Prism evaluation revealed that the benefits extend beyond technical and financial aspects, encompassing enhanced stakeholder satisfaction, accelerated claims processing, and strengthened ecosystem collaboration. These findings provide practical contributions to more efficient BPJS claim management and can be replicated in other hospitals. Although limited to a single institution, the results indicate that integrating advanced analytics with holistic performance evaluation can serve as a sustainable strategy for achieving operational excellence and financial resilience in healthcare. Future studies are recommended to involve multi-site research and explore more sophisticated predictive algorithms for further improvement.

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