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Implementation of Decision Support System for Illegal Cosmetic Detection in Papua Based Machine Learning

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Abstract

Regulatory enforcement against illicit cosmetics in the Papua Special Autonomy regions remains constrained by profound geographical complexity and systemic data fragmentation. This study develops a robust Decision Support System (DSS) that bridges the gap between digital surveillance and legal accountability at BBPOM in Jayapura. By integrating the Simple Multi-Attribute Rating Technique (SMART) with a hybrid machine learning framework, the system operationalizes parameters derived from the Indonesian Health Law (No. 17 of 2023) and the Papua Special Autonomy Law (No. 2 of 2021). A high-fidelity dataset of 1,324 multi-source inspection records was utilized to train a hybrid ensemble architecture. Empirical results demonstrate that the Artificial Neural Network (ANN) achieves near-optimal performance, yielding a 99.62% accuracy and 99.90% F1-score, with a marginal error rate of 0.38%. The inclusion of PostGIS-driven spatial intelligence further enables real-time vulnerability mapping within a scalable Service-Oriented Architecture (SOA). Beyond its technical efficacy, this research contributes a novel paradigm for localized law enforcement, successfully unifying regional regulatory mandates with advanced predictive analytics to safeguard public health in marginalized frontiers.

Keywords*—Decision Support System, Predicitive Analytics, Regulatory Enforcement, Illegal Cosmetics, Papua Special Autonomy*

1. Introduction

The surveillance of illegal cosmetics in the Papua Special Autonomy region is significantly hindered by manual processes, suboptimal digitization, and fragmented data integration, resulting in inconsistent law enforcement. According to Effendy (2023), governance in Papua necessitates a tailored, adaptive approach that accounts for the region's unique socio-geographic and legal specificities. However, the urgency for a more robust digital intervention is underscored by the evaluation of the *ELAMAHAMEN* platform in Palangka Raya. Despite its community-driven social phenomenology approach, the platform still recorded high violation rates: 4,000 cases in 2023, 586 in 2024, and 705 in 2025 (Oktaviani et al., 2025). These figures demonstrate that current qualitative-based digital supervision remains inadequate in systematically detecting unlicensed products and mitigating associated health and economic risks (Buloto et al., 2025; Meiana et al., 2026).

This research is expected to be a means to increase synergy between lines of supervision through an integrated technology-based system. The Decision Support System (DSS) is able to process various criteria objectively to produce consistent recommendations (Simanungkalit et al., 2024; Sumarni & Patappari, 2025). Multi-criteria methods such as SMART are effectively used on semi-structured problems (Taherdoost & Mohebi, 2024), while web-based digital transformation supports collaboration between institutions more efficiently (Babu et al., 2024; Mankotia et al., 2026).

In addition, this research also compiles a comprehensive system implementation design. The use of machine learning allows the system to learn patterns from surveillance data so that predictions of breach risk can be made more accurately (Putra et al., 2025). According to Arafah et al. (2026) and Xin et al. (2024),. Therefore, this study applies machine learning-based DSS to support the supervision of illegal cosmetics in the Special Autonomy of Papua in a faster, objective, and integrated manner (Bogey et al., 2025).

2. Method

This study employs an integrated system development approach to design an accurate cosmetic surveillance tool in the Papua Special Autonomy region. The development process emphasizes cross-sector synergy and is implemented through structured technical procedures.

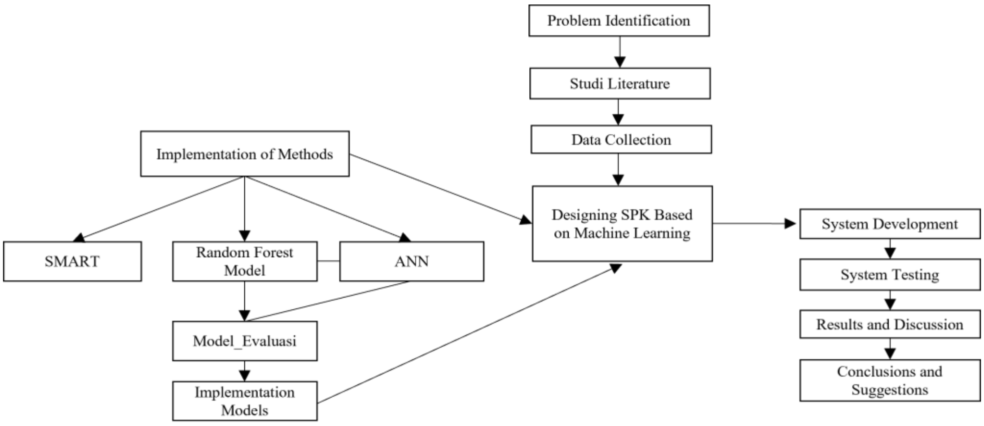


Figure 1. *Research Phases*

2.1 Problem Identification

Illegal cosmetic supervision at the Balai Besar POM in Jayapura is constrained by fragmented data, manual procedures, and reliance on pre-determined actions, prompting this study to propose digital solutions to enhance cross-sector coordination for preventing and monitoring illegal cosmetic distribution.

2.2 Studi Literature

References related to *Decision Support System*, cosmetic regulations, and Machine Learning algorithms were collected. According to Taherdoost and Mohebi (2024), the SMART method is very effective in minimizing subjectivity in semi-structured problems. In addition, Ardiansyah et al., (2023) emphasized the importance of chemical side effect parameters as an indicator of product risk. Strengthening coordination through digital infrastructure is also the main foundation of this research to overcome geographical barriers (Suryadi et al., 2025).

2.3 Data Collection

This study utilized 1,324 risk records from inspections, lab tests, and cyber patrols across Papua. Using the SMART method, seven criteria (C1–C7) were weighted by aligning Law No. 17/2023 and BPOM Regulation No. 21/2022 with expert consensus via FGDs (Yuliani et al., 2025). This framework prioritizes legality and safety as primary determinants for consistent, risk-based sanction classification. (Yuliani et al., 2025).

Table 1. Assessment Criteria for Facility Findings

Code	Criterion Name	Weight	Legal/Regulatory Reference
C1	Distribution Permit	25	Law No. 17 of 2023, Article 435
C2	Laboratory Testing	20	Law No. 17 of 2023, Article 439
C3	Product Volume	15	BPOM Enforcement Regulation
C4	Product Distribution	10	Public Health Impact
C5	Intent/Responsibility	10	Criminal Procedure of Mens Rea
C6	Recidivism	10	Law No. 17 of 2023
C7	Facility Classification	10	BPOM Regulation No. 21 of 2022

2.4 Method Implementation

At this stage, it integrates decision-making methods with machine learning algorithms to process data found by means through three layers of computation.

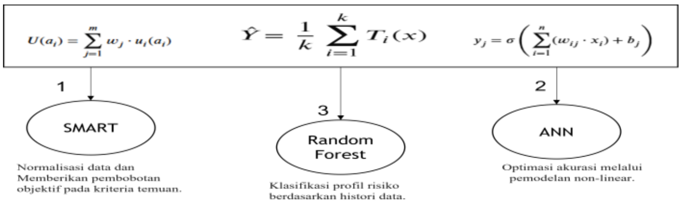


Figure 2. *Ensemble Learning Implementation*

Model performance is evaluated using Accuracy, Precision, Recall, and F1-Score. Neural network weight optimization is applied to enhance classification accuracy. The methodology also aligns with digital pharmaceutical risk assessment standards to ensure clinical validity and legal reliability (Bousmaha et al., 2022).

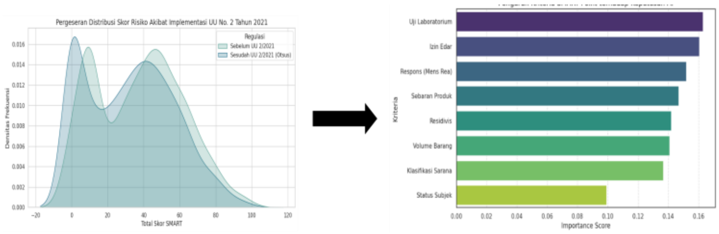


Figure 3. Regulation Graphs and Data Features

The graphs show that Law No. 2 of 2021 reduced cosmetic risk levels. Risk scores declined, with laboratory tests and distribution permits identified as the main factors influencing risk reduction.

2.5 Decision Support System Planning

The system adopts a Service-Oriented Architecture (SOA) to separate policy logic from the intelligence engine, enabling independent scalability and efficient management of geographic data across the extensive PPNS operational area in Papua. FastAPI is used to implement the service layer, providing high-performance API endpoints for communication between components (Salsabila et al., 2024).

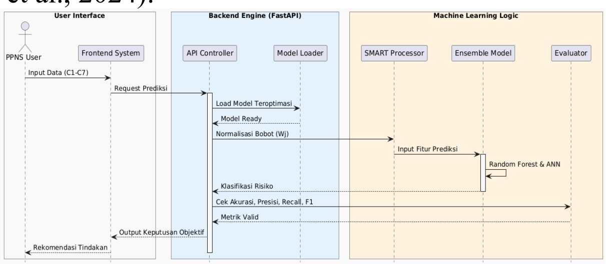


Figure 4. Decision Support System Model Integration

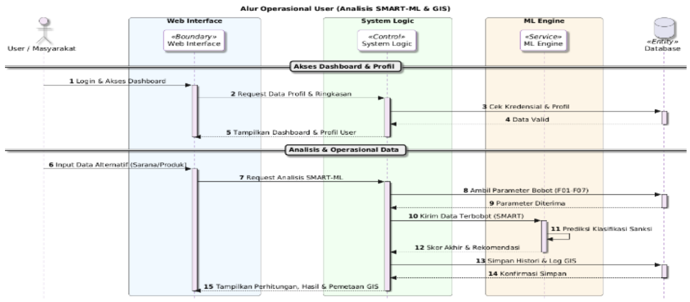


Figure 5. Use case Diagram User

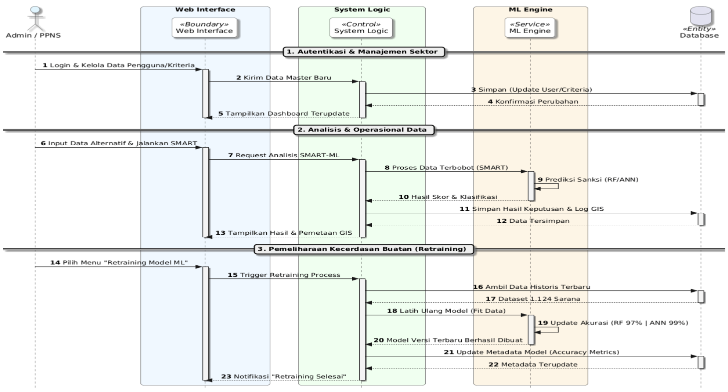


Figure 6. Use case diagram Admin

2.6 Development of Decision Support Systems

The DSS is built on a Service-Oriented Architecture (SOA) separating Policy Logic from the Intelligence Engine. NestJS handles legal workflows, audit trails, and evidence integrity per PPNS SOPs. FastAPI executes SMART algorithms and ensemble learning models (Random Forest and ANN) for objective risk classification. PostGIS adds spatial capabilities to map regional vulnerabilities in Papua, while React visualizes data to support fast and accountable decision-making.

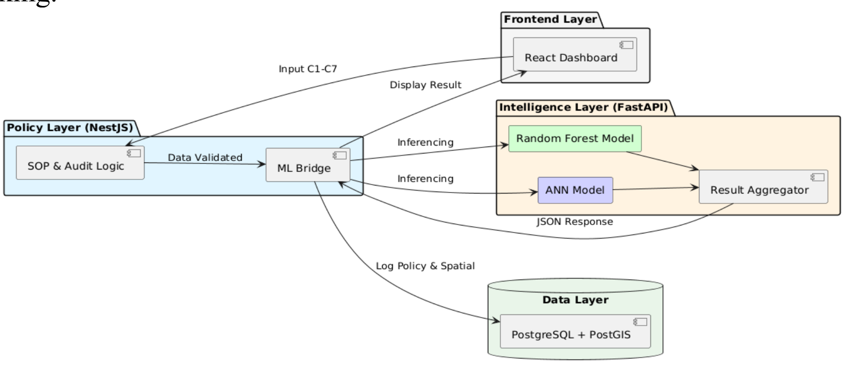


Figure 7. Infrastructure Architecture

2.7 Testing of Decision Support Systems

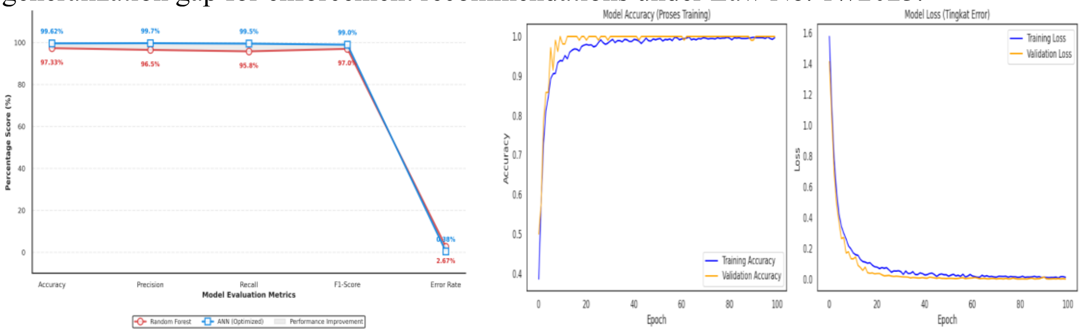
System validation is done using the Black Box Testing method which focuses on interface and workflow functionality. Evaluation is carried out periodically through analytics to maintain the quality of decision results in a sustainable manner (Yürüm, 2025). The goal is to ensure that the input criteria by the Civil Servant Investigator produces accurate sanctions prediction outputs in accordance with the policy logic that has been designed. In compiling this logic, the research also considers the principle of legal justice to ensure that the value of justice is maintained in society (Wahyuningsih et al., 2023).

3. Results And Discussion

3.1 Result

1.) Results of model evaluation

ANN achieved 99.62% accuracy and 0.38% error rate, significantly surpassing the Random Forest baseline which recorded 97.33% accuracy and 2.67% error rate. This performance stems from rigorous EDA and preprocessing of 1,324 records to eliminate noise. To mitigate imbalanced data and overfitting, SMOTE and 10-fold cross-validation were implemented, ensuring unbiased reliability for both models. Figure 8 confirms stability through synchronized convergence of training and validation curves, providing a minimal generalization gap for enforcement recommendations under Law No. 17/2023.



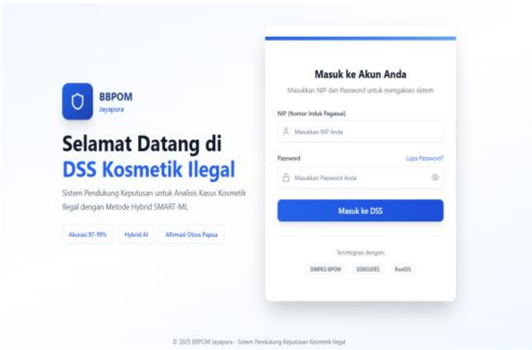
a) b)

Figure 8. *Model Evaluation Graph*

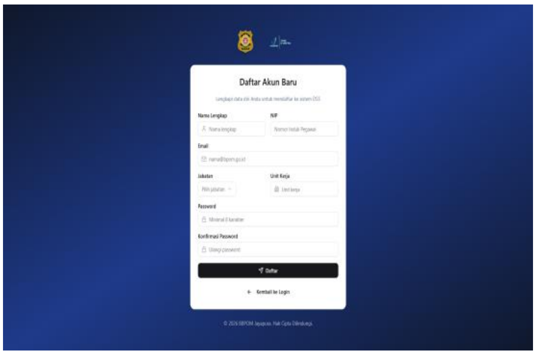
Table 2. *Comparative Performance Metrics*

Model	Accuracy	Precision	Recall	F1-Score	Error Rate
Random Forest	97.33%	96.50%	95.80%	97.00%	2.67%
ANN	99.62%	99.70%	99.50%	99.00%	0.38%

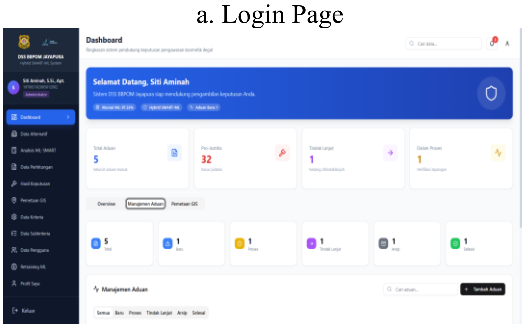
2.) Implementation of Decision Support System



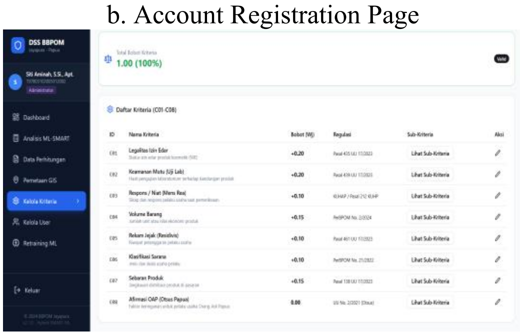
a. Login Page



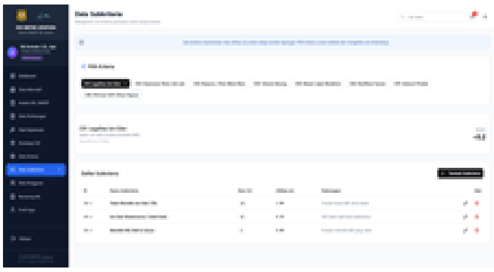
b. Account Registration Page



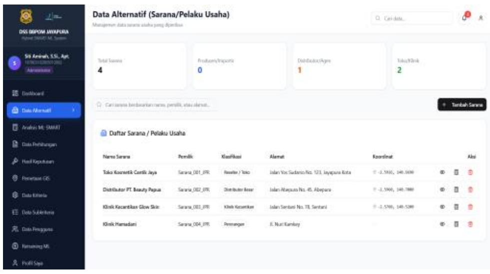
c. Admin Dashboard Page



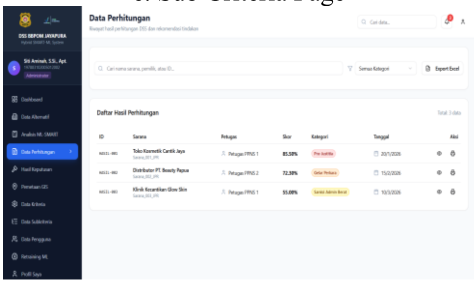
d. Criteria Date Page



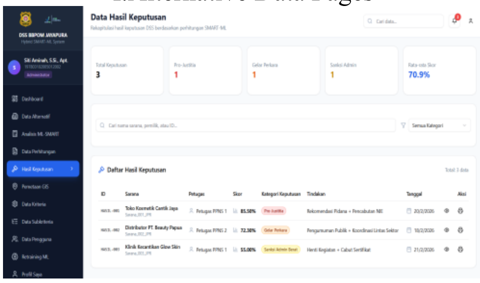
e. Sub Criteria Page



f.Alternative Data Pages

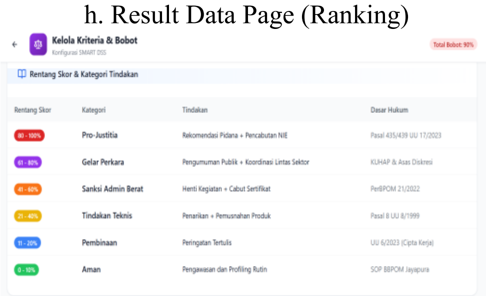


g. Calculation Data Page

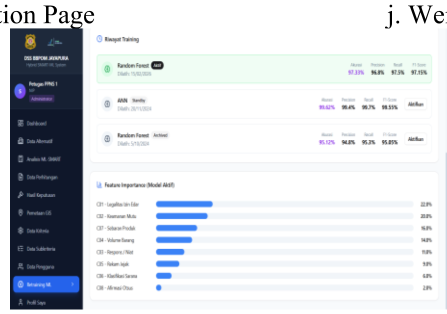


h. Result Data Page (Ranking)

i. GIS Data Location Page



j. Weight Criteria Page



j. Retraining Model Machine Learning Page

Figure 9. *Decision Support System Application Web*

Table 3. Black-Box Testing

Testing Scenarios	Test Results
PPNS/Admin Login System	appropriate
New User Registration System	appropriate
Criteria Data (C1 - C7)	appropriate
Subcriteria Data (SMART Parameters)	appropriate
Alternative Data (Facilities/Shops/Clinics)	appropriate
SMART Calculation Process	appropriate
Random Forest Prediction Process (Risk Mapping)	appropriate
ANN (Action Recommendation) Prediction Process	appropriate
Integration of Special Autonomy Variables (OAP/Non-OAP)	appropriate
Final Decision Data (Policy Logic)	appropriate
Action Result Report (PDF/Print Output)	appropriate
Admin / User Data	appropriate

3.2 Discussion

This DSS integrates AI with legal compliance to shift BBPOM Jayapura toward adaptive, objective enforcement. Combining the SMART method with a hybrid ANN-Random Forest model ensures stable risk classification sensitive to pharmaceutical regulations. The inclusion of Special Autonomy (Otsus) variables provides a crucial local adaptation to Papua's socio-geographical landscape. Furthermore, PostGIS-based spatial intelligence and SOA architecture transform fragmented data into scalable, real-time vulnerability maps. This synergy between machine learning and geospatial analysis ensures enforcement remains data-driven, legally robust, and responsive to evolving illegal cosmetic circulation.

4. Conclusions

This research successfully digitizes cosmetic supervision at BBPOM Jayapura through a Decision Support System integrating the SMART method and high-precision AI. Achieving 99.62% accuracy, the system provides a robust foundation for objective, adaptive, and humanist law enforcement under the Papua Special Autonomy mandate. By bridging pharmaceutical criteria with machine learning, it overcomes fragmented data challenges in remote regions. Future development should prioritize mobile-offline capabilities, image recognition for packaging detection, and spatial early warning systems to maintain relevance against evolving illegal circulation patterns.

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