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Smart Contract Architecture for a Blockchain-Driven Multi Criteria DSS in Forest Fire Monitoring and Response

Fajar Yusuf Nur Cahyo[1)], Djarot Hindarto[2)] *
[1,2)] Prodi Informatika, Fakultas Teknologi Komunikasi dan Informatika, Universitas Nasional, Jakarta, Indonesia
[1)]fajaryusufnurcahyo26@email.com, [2)]djarot.hindarto@civitas.unas.ac.id

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Abstract: The current centralized system is vulnerable to data manipulation due to the absence of independent verification mechanisms, thereby compromising the reliability of information. In addition, the inconsistency of formats and data silos across agencies exacerbates information fragmentation. Delays in data distribution hamper rapid response in emergency situations, while uneven communication infrastructure—especially in remote areas—reduces real-time monitoring capabilities. Lack of coordination among stakeholders—such as BNPB, forestry agencies, local communities, and the private sector—adds to the complexity of disaster management and often leads to overlapping tasks. The decision-making process is further complicated by competing criteria, such as priority areas, resource availability, dynamic weather conditions, and limited IoT sensor coverage. Additionally, high operational costs for system maintenance and limited audit trails make it difficult to track data history and ensure accountability. Therefore, the Multi-Criteria Decision Making (MCDM) method is necessary to handle uncertainty, combine different geospatial factors in an organized way, and make sure the decision-making process is reliable and clear. This research fills the technological gap by introducing a decentralized audit trail while facilitating cross-sector collaboration in fire mitigation decision-making and minimizing the risk of evidence-based data errors. Evaluation of the system's performance was conducted through security testing of the smart contract and performance testing of transaction speed, ensuring that the system is secure and efficient in handling decision-making tasks.

Keywords: Blockchain; SmartContract; Recommendation System; SAW; PROME HEE II

INTRODUCTION

Indonesia faces one of the persistent natural disasters, such as forest wildfires, which result in ecosystem destruction, the degradation of air quality, and adverse effects on the health and economy of local people. The National Disaster Management Agency, BNPB, reported that every year, extensive areas of peat and tropical forests are set on fire, mainly due to shifting agricultural practices and unsustainable oil palm plantation. Due to the dry climate because of climate change, the risk of fires becomes more prevalent, thus requiring a stronger evidence-based approach to disaster management to mitigate impact (Tawade et al., 2022). The ecological damage and health ramifications caused by the forest fires have profoundly impacted Indonesia's economy as well. An example includes the agriculture sector, which depends on forest lands and ecosystems. The fires not only disrupt farming activities but also systematically demolish crops as well as agricultural facilities that have taken years to construct. In the same way, the tourism sector has sustained losses as forest fires occur in many tourist hotspots. Hence, there is a need for prompt and effective action dealing with the mitigation and management of forest fires due to the scant resources in relation to the magnanimous problem (Kala, 2023).

Problem Statement

The primary issue in forest fire prevention systems stems from not having trustworthy and dependable data and information, which leads to poor decisions made during the rescue operations. Alarming systems that utilize centralized databases have challenges of information distortion, with the BNPB, various forestry agencies, local

*name of corresponding author

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citizens, and private organizations as members of the data supplier network (Fillmore & Paveglio, 2023). Problems that are multifactorial and oriented towards crucial geospatial regions, finite natural structures, and evolving climatic conditions also require integrated spatial decision-making techniques (Hindarto & Hariadi, 2024).

The current centralized system is vulnerable to data manipulation due to the absence of independent verification mechanisms, thereby compromising the reliability of information (Hindarto, 2023). In addition, the inconsistency of data formats and data silos across agencies exacerbates information fragmentation. Delays in data distribution hamper rapid response in emergency situations, while uneven communication infrastructure—especially in remote areas—reduces real-time monitoring capabilities. Lack of coordination among stakeholders—such as BNPB, forestry agencies, local communities, and the private sector—adds to the complexity of disaster management and often leads to overlapping tasks. Decision-making is further complicated by competing criteria (Goswami, 2020), such as the priority of vulnerable areas, resource availability, dynamic weather conditions, and limited IoT sensor coverage. Moreover, the absence of thorough audit trails to monitor the history and accountability of data prevents efficient maintenance of systems and incurs high operational costs (Huy et al., 2022). Therefore, there is a need for multi-criteria decision-making (MCDM) methods that also incorporate systematic integration of different geospatial parameters, since decision-making on the whole requires consideration of uncertainty, as well as integrity and transparency.

Research Objective

In response to these persistent challenges, the current study integrates permissioned blockchain systems with a multi-criteria decision-support framework grounded in decision-analytic theory. Provinces at risk of fire will be evaluated and ranked using two well-known methods, Simple Additive Weighting (SAW) and PROMETHEE II, based on factors like changes in land use, rainfall, humidity, and local fire-fighting resources (Sutriono et al., 2023). Every step of the data journey—satellite imagery uploads, internet-of-things sensor feeds, and ranking outputs—will be encoded in smart contracts on a private blockchain ledger, guaranteeing that records are immutable, timestamped, and openly viewable by authorized parties. By pairing the decentralized trust model of blockchain with the transparent weighting logic of multi-criteria analysis, the platform aims to deliver rapid, verifiable, and cost-effective prescriptive alerts for on-the-ground responders. This advance over conventional forest-fire monitoring systems, which rely on a single storage hub and are therefore susceptible to tampering, lies in its real-time audit trail that holds all actors accountable while protecting sensitive environmental data. A further methodological innovation is the within-comparison of SAW and PROMETHEE-II under blockchain conditions together with a validated uncertainty-propagation filter, an approach expected to enhance the precision of strategic guidance and the orchestration of mitigation efforts across Indonesia.

Novelty Statement

To date, no integrated system has combined smart contracts with both SAW and PROMETHEE-II in a permissioned blockchain environment for forest fire response.

Research Questions

Several research questions emerged from the initial description and became the basis for the implementation of blockchain technology in a decision support system for forest fire mitigation:

1. How can we ensure that the data used in decision-making is accessible in a transparent manner and cannot be manipulated? (Research Question 1).
2. How can decision-making methods that can handle uncertainty in forest fire management be applied efficiently and effectively? (Research Question 2).

These research questions are expected to clarify the potential, implications, and challenges in implementing blockchain technology in decision support systems for forest fire mitigation.

LITERATURE REVIEW

An increasingly popular tool for multi-criteria decision-making is the PROMETHEE method. It assesses competing options across a set of distinct criteria and is now seen in business, finance, and natural-resource management. Within the literature, two main versions are recognized: PROMETHEE I, which produces a partial ranking, and PROMETHEE II, which yields a complete ranking. Evidence suggests that either variant streamlines the evaluation process while remaining objective and transparent. Notwithstanding its advantages, users often struggle to assign realistic weights and may encounter counterintuitive reversals when new options are introduced or existing ones withdrawn (Taherdoost & Madanchian, 2023). Researchers are increasingly turning to blockchain to boost data security and transparency in environmental stewardship. One noteworthy initiative merges

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blockchain with TOPSIS—the Technique for Order Preference by Similarity to Ideal Solution—to create a real-time landslide risk assessment tool. In this setup, blockchain locks geospatial records against tampering, while TOPSIS sorts of locations based on how closely they approach an ideal, stable state. Preliminary tests show that the hybrid method reaches high scores for precision, recall, and overall accuracy, bolstering confidence in its practical value. Nonetheless, substantial costs for running and validating the network nodes and unclear regulatory frameworks for disaster use still loom as serious hurdles (Hindarto, Hariadi, et al., 2025). Other studies have combined blockchain with other MCDM methods, such as the Analytic Hierarchy Process (AHP) and TOPSIS, to assess and rank landslide-prone areas. By using blockchain, geographic data can be securely and transparently stored in an immutable ledger, enhancing accuracy and reducing data manipulation. Although this approach demonstrates excellent results, challenges such as limitations in scaling this technology and transaction costs (gas fees) remain obstacles that need to be addressed (Hindarto, Damastuti, et al., 2025). Within the wider domain of blockchain research, multi-criteria decision-making (MCDM) methods are increasingly applied to choose the most suitable consensus protocol for a given system. In one recent study, the authors combined straightforward tools—the Simple Additive Weighting (SAW) method, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and the VIKOR approach—to rank protocols according to throughput, degree of decentralization, incentive structure, long-term sustainability, and overall security (Hindarto et al., 2023). This approach results in recommendations for appropriate protocols for various types of blockchain networks. However, this study acknowledges limitations in the subjective evaluation of criterion weights, which may lead to bias, as well as the lack of valid data from real-world testing (Filatovas et al., 2022).

The observed gap stems from the current MCDM system's struggle to adapt when the importance of decision criteria shifts during a project. By pairing the Simple Additive Weighting (SAW) method with PROMETHEE II, analysts gain the fast aggregation offered by SAW along with the richer preference insight that PROMETHEE delivers. SAW calculates scores quickly, so weights can be refreshed immediately using the most recent evidence. PROMETHEE II then organizes all alternatives by explicitly mapping the pairwise preference flows that reveal subtle trade-offs. When these combined models run as a smart contract on a permissioned blockchain, stakeholders receive a transparent audit trail and the agility to modify criterion weights without compromising data integrity.

Blockchain is a decentralized digital ledger that records transactions chronologically. This technology offers transparency and data security. Blockchain eliminates the role of intermediaries in transactions. Ethereum is a blockchain platform that supports smart contracts (Wahyuni et al., 2023). Ethereum uses the Ethereum Virtual Machine to execute code. A smart contract is a computer program that runs on a blockchain. This program executes agreements automatically without intermediaries. Smart contracts improve the efficiency and security of transactions. Web3.js is a JavaScript library for interacting with the Ethereum network. Web3.js makes it easy to send transactions and read data from smart contracts. MetaMask is a digital wallet connected to the Ethereum network. With MetaMask, users can send and receive cryptocurrencies. MetaMask allows access to decentralized applications without running a full node. Ganache is a tool for testing Ethereum applications on a local network. Ganache provides fake Ether accounts and balances for testing (Khan et al., 2020).

Syntesis Of Literature

Previous studies have explored the integration of blockchain with various multi-criteria decision-making (MCDM) methods, such as TOPSIS, AHP, and VIKOR, in the context of environmental and disaster management. While these methods effectively enhance data security and transparency by utilizing blockchain's immutable ledger, challenges remain in terms of transaction costs, scalability, and subjective bias in evaluating criteria weights (Hindarto, Damastuti, et al., 2025; Hindarto et al., 2023) In contrast, this research advances the field by combining both the Simple Additive Weighting (SAW) and PROMETHEE II methods under a permissioned blockchain environment, offering a more dynamic solution. Unlike previous studies, this approach provides greater flexibility by allowing for the real-time modification of decision criteria weights while ensuring transparency and accountability through blockchain's decentralized nature. The integration of blockchain with SAW and PROMETHEE II, particularly for forest fire management, represents a significant innovation over existing MCDM models, which often struggle to adapt to shifting criteria during decision-making processes.

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METHOD

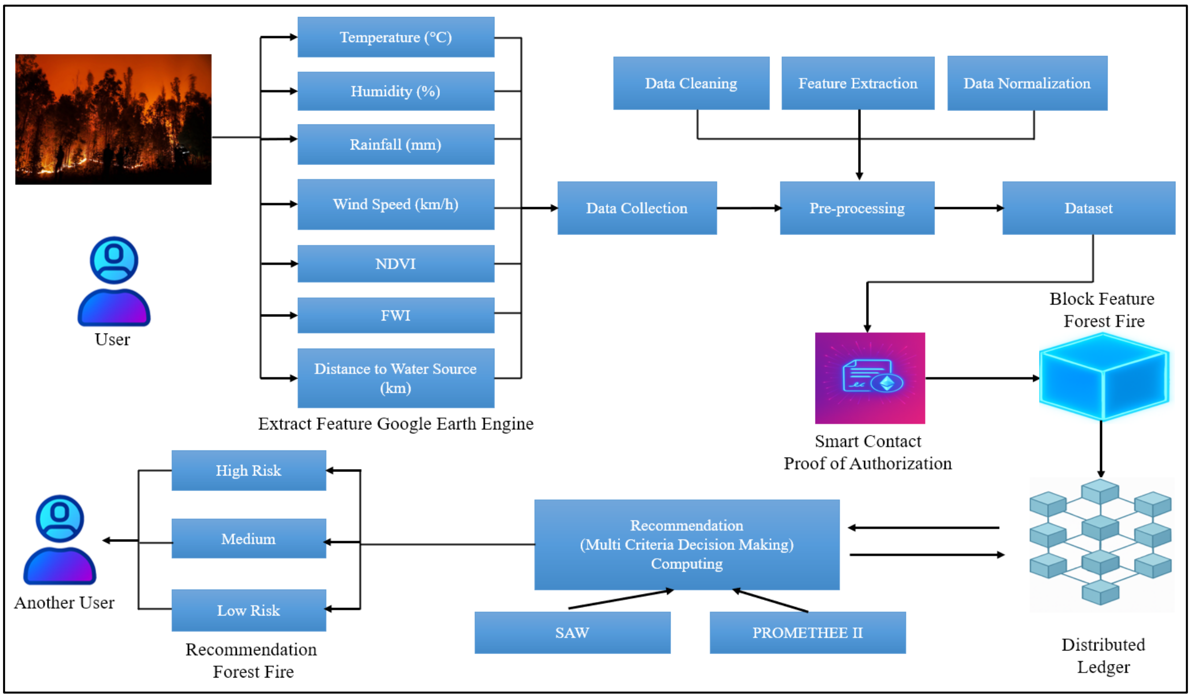

Fig.1 Proposed framework fire forest MCDM SAW and PROMETHEE 2

Figure 1 show proposed framework fire forest MCDM SAW and PROMETHEE 2. During the initial phase of the data extraction workflow, users navigate to Google Earth Engine (GEE) and log in using their Google accounts. Users visually scan the coverage area to confirm if the retrieved region has sufficient data after choosing it based on the appropriate geographic coordinates. In the dataset collections available in GEE, temperature, humidity, rainfall, wind speed, NDVI, FWI, and distance to water bodies are some of the features fetched, and the corresponding extraction results are saved in CSV files. The data obtained is processed for accuracy to ensure that the data is in the right format, and appropriate systems are utilized to enhance its integrity. The extraction results are standardized, and the value formats are adjusted, including temperature in degrees Celsius, humidity in percent, rainfall in millimeters, and wind speed in kilometers per hour. Unique identification numbers are generated and organized, while missing, erroneous, or outlier values are checked, and the appropriate range-validating logic is applied. After standardization, the pre-processed data is organized and stored in a centralized repository in a structure as “forest_fire_dataset.csv” for subsequent retrieval.

This dataset is then entered into a user interface (UI) form where it is further processed with a smart contract on the blockchain to validate and authorize the data. Smart contracts are critical in safeguarding the data’s security and its integrity. Data that has been smart-verified and authorized is then stored within the blockchain architecture. The processed and encrypted data is now a single unit referred to as “Block Feature Forest Fire,” which is stored on a distributed ledger, ensuring the data’s transparency, security, and immutability. Within a blockchain network, data cannot be modified after being stored, and multiple nodes within the network can access the data, guaranteeing that changes can be accounted for. Data processing results are then used to issue recommendations based on “Multi Criteria Decision Making” (MCDM). With the use of SAW (Simple Additive Weighting) and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) techniques, forest fire risk is evaluated and categorized into three tiers: high, medium, or low. These recommendations, alongside the analyzed risk level, are made available to other users, allowing timely preventive actions to be taken.

The combination of SAW (Simple Additive Weighting) and PROMETHEE II (Preference Ranking Organization Method for Enrichment Evaluation) was selected because of their complementary strengths in handling multi-criteria decision-making problems. SAW is effective for standardizing data and ensuring a fair comparison between alternatives, especially when criteria are numerical. It normalizes data by dividing each value by the maximum (for benefit criteria) or minimum (for cost criteria) value, which ensures a consistent scale. On the other hand, PROMETHEE II excels in comparing alternatives directly, calculating the preference flow (positive and negative) based on each criterion, and then ranking alternatives according to the net preference flow. The combination of both methods allows for a more robust and thorough evaluation, with SAW providing a reliable base for normalization, and PROMETHEE II offering a precise ranking of the alternatives.

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Experimental Scheme

The experiment begins by collecting data from various forest fire-prone regions, including parameters such as temperature, humidity, rainfall, wind speed, NDVI, FWI, and distance to water bodies. This data is extracted using Google Earth Engine (GEE) and then processed for accuracy, including data cleaning and standardization. Once processed, it is entered into the analysis framework using SAW and PROMETHEE II.

Number of Tests

The experiment involves 30 data points representing various forest fire scenarios from different regions. These data points are analyzed using both SAW and PROMETHEE II methods to validate the performance of the multi-criteria decision-making framework.

Audit Tools Used

To ensure the integrity and security of the data used in the experiment, several audit tools were employed. The tool used include:

Remix IDE was utilized to develop and audit the smart contracts deployed on the Ethereum blockchain. It offers comprehensive debugging and security analysis features, ensuring that the smart contract code is free from vulnerabilities. Remix's built-in static analysis and testing functionalities help identify potential security risks, such as reentrancy attacks, overflow issues, and gas-related vulnerabilities, guaranteeing that the data processing steps within the blockchain remain secure and tamper-proof.

Success Criteria

The success of the experiment is measured by several key factors: the accuracy of forest fire risk assessment, which evaluates the ability of the SAW and PROMETHEE II combination to accurately classify forest fire risks (high, medium, low) compared to historical data or actual fire events; the reliability of the smart contracts, ensuring the security, transparency, and integrity of the processed data with no modifications after storage in the blockchain; and the timeliness of decision-making, which reflects the framework's ability to provide actionable recommendations quickly, enabling preventive actions to be taken promptly when forest fire risks are detected.

SAW (Simple Additive Weighting)

The Simple Additive Weighting (SAW) method begins by constructing a decision matrix containing the values of each alternative against the established criteria, then normalizing the criterion values to standardize the scale by dividing each alternative value on the benefit criteria by the maximum value or on the cost criteria by the minimum value; after that, each normalized value is multiplied by the respective criterion weights to reflect their level of importance, then summed per alternative to produce a final score; the alternative with the highest score is considered the best choice; these steps ensure a systematic, objective, and easily interpretable evaluation process. The first step is to create a decision matrix by placing each alternative in a row and each criterion in a column. Next, the values are normalized so that the scale between criteria is uniform: for beneficial criteria, each value is compared to the highest value, while for cost criteria, each value is compared to the lowest value. This process of normalization allows for fair comparison among all available alternatives since they produce values within the same range. The resulting matrix is utilized to weight criteria as well as compute the final score of each alternative. Thus, the appraisal of the alternatives becomes objective, systematic, and straightforward.

For benefit criteria (higher values are better), use:

$$X'_{ij} = \frac{x_{ij}}{\max(X_j)} \quad (1)$$

For cost criteria (lower values are better), use:

$$X'_{ij} = \frac{\min(X_j)}{x_{ij}} \quad (2)$$

During the weighting stage, each criterion is assigned a weight according to its level of importance in analyzing forest fire mitigation: temperature (cost) and wind speed (cost) are each given a weight of 0.15 because fluctuations in both can accelerate the spread of fire; humidity (benefit), rainfall (benefit), NDVI (benefit), and Fire Weather Index (benefit) are also each given a weight of 0.15 because higher benefit values improve fire detection and prevention capabilities; while distance to water sources (cost) is given a weight of 0.10 due to the role of water as a fire extinguishing medium, despite its smaller proportion. These weights are proportional indicators of the importance of each criterion and shall be applied to the normalized values in order to compute a weighted score for each alternative. Following this procedure, the weighted scores are aggregated for the determination of the best alternative selected from a multi-criteria decision analysis (MCDA) approach.

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Formula for calculating the final score:

$$V_i = \sum_{j=1}^{n} W_j \cdot X'_{ij} \quad (3)$$

PROMETHEE II (Preference Ranking Organization Method for Enrichment Evaluation)

PROMETHEE II begins by compiling a table containing all alternatives and criteria, then normalizing the values so that each criterion has a uniform scale. Next, each pair of alternatives is compared to assess the extent to which one alternative is preferred based on its performance on each criterion and the nature of the criterion (benefit or cost). The preferences from all comparisons are summed to produce two main values: how strongly an alternative outperforms others (positive flow) and how often it is outperformed (negative flow). The difference between positive and negative flows yields a net preference score reflecting the relative advantage of each alternative. Finally, alternatives are ranked based on their net preference scores from highest to lowest, resulting in a complete ranking.

Determining Preference Values:
The formula for calculating preference values using the PROMETHEE II algorithm is as follows

$$H(d)\begin{cases} 0\ if\ d = 0 \\ 0\ if\ d \le 0 \\ 1\ if\ d \ge 1 \end{cases} \quad (4)$$

Calculate leaving Flow:

$$\Phi^+ (a) = \frac{1}{n-1} \sum_{n=k} \varphi (a, x) \quad (5)$$

Calculate Entering Flow:

$$\Phi^- (a) = \frac{1}{n-1} \sum_{n=k} \varphi (a, x) \quad (6)$$

Calculate Net Flow:

$$\Phi(\mathrm{a}) = \Phi^+ (\mathrm{a}) - \Phi^- (\mathrm{a}) \quad (7)$$

The alternative with the highest Net Flow is considered the best.

RESULT

The DApps prototype's implementation encompasses several interrelated components, starting with the user interface (UI), which employs React and Tailwind CSS for displaying interactive maps, input forms for environmental data, and a dashboard for real-time risk ranking. Also, smart contracts are written in Solidity to record the transactions of geospatial data and the results of MCDM calculations in the ledger, and they have checked the log-and-access functions using unit tests. Also, local blockchains are simulated using Ganache for permissioned networks, allowing for the testing of smart contract deployment, transaction execution, and block monitoring at no real gas cost. Moreover, Node.js and Web3.js serve as the middleware interfaces that connect the UI with the smart contracts running on Ganache. They manage the connection to the Ganache network, sign transactions on MetaMask, and call smart contract functions from the web interface. End-to-end testing for all components through data input, executing the SAW and PROMETHEE II methods on-chain, and rendering rank results on the UI confirm the seamless functioning of the DApps prototype in a decentralized environment capable of enabling audit trails and transparency.

Continued assessments concentrating on response accuracy during simulated load scenarios demonstrated that the system continued to maintain responsiveness during peak periods of activity. Security audits of the Solidity contracts left unresolved some minor vulnerabilities, which, when fixed, bolstered the prototype's security. Integration tests conducted with simulated IoT sensor streams verified the DApps ability to ingest and process real-time environmental data streams. Feedback from users among the stakeholder group pointed to the ease with which they could use the dashboard and the lucid presentation of risk rankings according to predefined thresholds. Measurements of throughput indicated that the permissioned Ganache network sustained demand for dozens of transactions per second without noticeable degradation in performance. Latency profiling showed that the on-chain execution of the SAW and PROMETHEE II methods for multi-criteria decision making (MCDM) responded quickly enough that there were no issues for emergency situations. The modular design of the application allows seamless addition of new criteria or migration to other blockchain platforms. Future work will involve deploying

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the DApps on a consortium network with actual agency partners and integrating oracle services to guarantee the authenticity of incoming data.

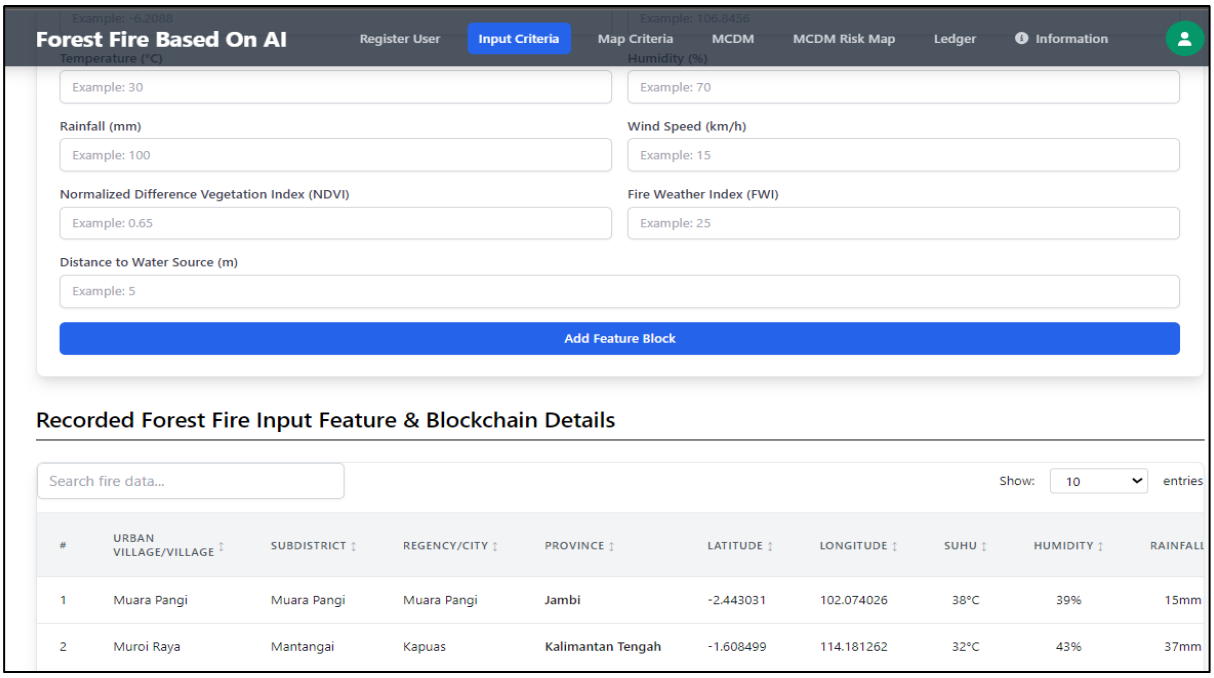

Fig 2. User interface input block store to ledger

On the interface screen of the "Forest Fire Based On AI" DApps, there is a navigation bar at the top with options such as Register User, Input Criteria, Map Criteria, MCDM, MCDM Risk Map, Ledger, and Information. Below that, there is an "Input Criteria" form that allows users to enter environmental variables—temperature (°C), humidity, rainfall (mm), wind speed (km/h), NDVI, FWI, and distance to water source (m)—as well as an "Add Feature Block" button to save new data. Following that, the "Recorded Forest Fire Input Feature & Blockchain Details" section presents a table with the village, sub-district, district/city, and province, as well as the tracked coordinates (latitude and longitude) and fire parameters (temperature, humidity, and rainfall) that have been blockchain. Like any other table in the application, it allows performing queries and setting the number of records on a page to be displayed, which facilitates data exploration. The general structure design combines input in real time with the actual state of the blockchain, thus ensuring the integrity and the simplicity of control for the audit trail.

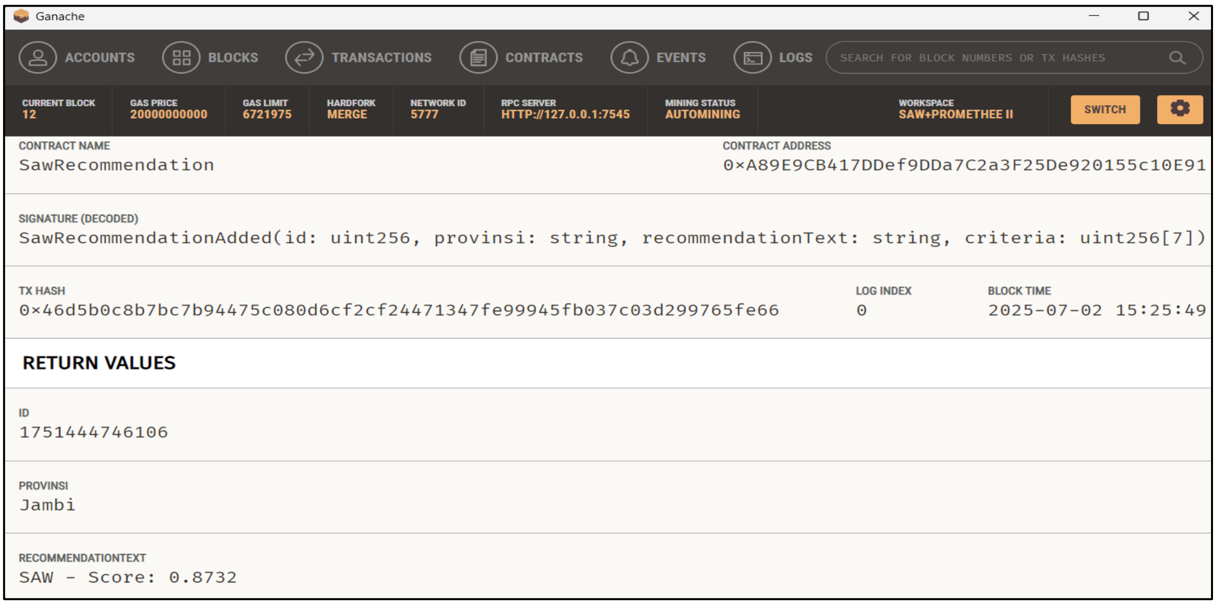

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Fig 3. Ganache for storage ledger

Figure 3 shows the Ganache interface as a local blockchain that stores the transaction ledger for the "Saw Recommendation" smart contract. At the top, you can see network information—including the current block, gas price, gas limit, hard fork, and network ID—as well as the RPC connection to the local server. Inside the CONTRACTS panel, the Saw Recommendation contract is indicated as deployed at a certain address. Additionally, the "SawRecommendationAdded" event is decoded, revealing parameters with entry ID, province name as "Jambi," and recommendation text bearing a SAW score of 0.8732, alongside the criteria array. The RETURN VALUES section also captures execution results, confirming that every recommendation is stored permanently and immutably. Ganache makes it easier for developers to check their deployments, monitor event logs, and test smart contract features in real-time without paying gas fees, which makes it essential for testing before going live on the network.

A. Simple Additive Weighting (SAW) Manual Calculation

Table 1. Decision Matrix

No	Alternative (A)	Criteria						
		C1	C2	C3	C4	C5	C6	C7
1	Banyuasin (A1)	33	79	41	21	0.88	71	19
2	Kapuas (A2)	34	43	9	13	0.9	52	6
3	Pulang Pisau (A3)	36	59	38	30	0.88	57	20
4	Mempawah (A4)	36	70	4	27	0.46	70	20
5	Kotawaringin Timur (A5)	29	57	42	19	0.82	65	20
6	Tebo (A6)	28	38	48	18	0.70	68	6
7	Indragiri Hilir (A7)	29	73	38	29	0.74	80	20
8	Criteria Type	Cost	Benefit	Benefit	Cost	Benefit	Cost	Cost
9	Result Max/Min	Min: 28	Max: 79	Max: 48	Min: 13	Max: 0.9	Min: 52	Min: 6

The decision matrix in Table 1 presents seven alternative provinces—Banyuasin (A1), Kapuas (A2), Pulang Pisau (A3), Mempawah (A4), Kotawaringin Timur (A5), Tebo (A6), and Indragiri Hilir (A7)—which are evaluated according to seven environmental criteria. The criteria of temperature (C1), wind speed (C4), fire weather index (C6), and distance to water source (C7) are cost criteria where lower values are preferred, while humidity (C2), rainfall (C3), and NDVI (C5) are benefit criteria with a preference for higher values. For example, Tebo (A6) has the lowest temperature of 28°C and humidity of 38%, while Banyuasin (A1) has the highest humidity of 79% and rainfall of 41 mm. The criterion type row confirms the cost or benefit role of each column, while the Max/Min result row sets the reference values for normalization—such as a minimum temperature of 28°C and a maximum humidity of 79%. With this structure, each data point is ready for normalization and weighting in the SAW calculation stage.

Final SAW Score Calculation Results

Table 2. SAW Calculation Results

No	Alternative (A)	Preferensi	Rank
1	Banyuasin (A1	0.75453	6
2	Kapuas (A2)	0.783295	2
3	Pulang Pisau (A3)	0.725960	5
4	Mempawah (A4)	0.552405	7
5	Kotawaringin Timur (A5)	0.773595	3
6	Tebo (A6)	0.811855	1
7	Indagiri Hilir (A7)	0.746340	4

Table 2 shows the SAW method calculations, with Tebo (A6) ranking first with a final score of 0.8119 as the most optimal location for measures to mitigate forest fires. Kapuas (A2) is in second place with a score of 0.7833, followed by Kotawaringin Timur (A5) in third place (0.7736). Indragiri Hilir (A7) is in fourth place with a score of 0.7463, while Pulang Pisau (A3) is in fifth place with a score of 0.7260. Banyuasin (A1) is in sixth place with a score of 0.7545, which, although relatively excellent, is still below the top three. Mempawah (A4) is in last place

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with a score of 0.5524, indicating the need for improved mitigation strategies in that area. These results show how variations in criteria values—such as temperature, humidity, rainfall, and distance to water sources—influence location rankings and form the basis for prioritizing intervention recommendations. The transparency of SAW scores for each alternative supports evidence-based location selection and facilitates coordination among stakeholders.

B. Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE II)

Table 3. Determining Preference Values

No	Alternative (A)	Criteria						
		C1	C2	C3	C4	C5	C6	C7
1	Banyuasin (A1)	33	79	41	21	0.88	71	19
2	Kapuas (A2)	34	43	9	13	0.9	52	6
3	Pulang Pisau (A3)	36	59	38	30	0.88	57	20
4	Mempawah (A4)	36	70	4	27	0.46	70	20
5	Kotawaringin (A5)	29	57	42	19	0.82	65	20
6	Tebo (A6)	28	38	48	18	0.7	68	6
7	Indagiri Hilir (A7)	29	73	38	29	0.74	80	20

Table 3 shows the performance values of seven alternative provinces—Banyuasin (A1), Kapuas (A2), Pulang Pisau (A3), Mempawah (A4), Kotawaringin Timur (A5), Tebo (A6), and Indragiri Hilir (A7)—based on seven environmental criteria that will be used as the basis for calculating PROMETHEE II preferences. Criteria C1 (Temperature), C4 (Wind Speed), C6 (Fire Weather Index), and C7 (Distance to Water Source) are classified as costs, so lower values are preferred, while C2 (Humidity), C3 (Rainfall), and C5 (NDVI) are classified as benefits, with higher values being better. For example, Tebo (A6) has the lowest temperature of 28°C and the lowest humidity of 38%, while Kapuas (A2) has the highest NDVI of 0.90 and Indragiri Hilir (A7) has the highest FWI of 80. These values will be used in the preference function to compare each pair of alternatives and calculate positive and negative preference flows. By inputting this raw data into the PROMETHEE II algorithm, the system will determine how much each province is favored or disadvantaged by other alternatives on each criterion. The final result is a complete ranking reflecting the relative strengths and weaknesses of each location in forest fire mitigation.

Result PROMETHEE 2

Table 4. Promethee 2 Results

No.	Alternatif (A)	Leaving Flow	Entering Flow	Net Flow	Rank
1	A1	0.690	0.358	0.332	1
2	A2	0.286	0.571	-0.285	7
3	A3	0.572	0.333	0.239	2
4	A4	0.643	0.452	0.191	3
5	A5	0.429	0.357	0.072	5
6	A6	0.334	0.286	0.048	6
7	A7	0.572	0.405	0.167	4

Based on the results derived from the PROMETHEE II calculation, Banyuasin (A1) emerges as the highest-ranking region with a net flow value of 0.332, demonstrating consistent relative advantage over the other alternatives. In contrast, Kapuas (A2) ranks as the lowest performer with a net flow of –0.285, indicating the lowest contribution in the multi-criteria assessment. The other regions, Pulang Pisau (A3), Mempawah (A4), Kotawaringin Timur (A5), Tebo (A6), and Indragiri Hilir (A7), have intermediate ranking positions with differing net flow values; Tebo (A6), while having the lowest net flow among these regions, is still better than A2. The mentioned net flow values are derived from the difference between preference flows and blocking flows, reflecting the frequency with which an alternative is preferred or dominates over another alternative. Therefore, through PROMETHEE II, locations are ranked comprehensively, which allows for assessment of each location's value for forest fire mitigation.

*name of corresponding author

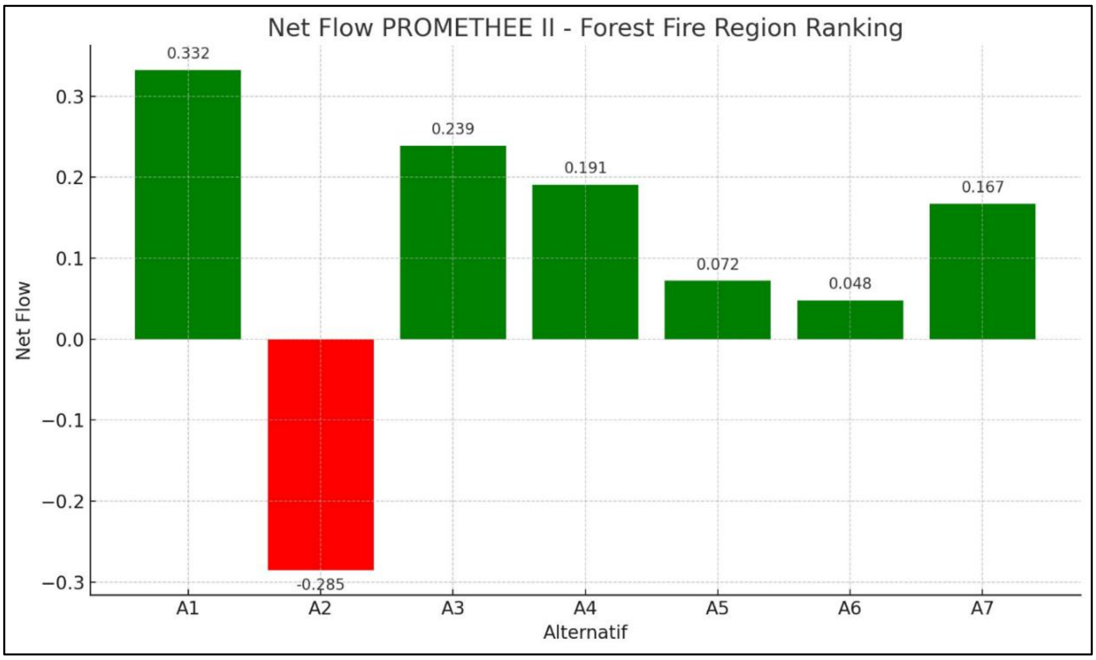

Fig 4. Promethee II Net Flow Bar Chart Visualization

Figure 4 illustrates the Net Flow visualization derived from the PROMETHEE II method, applied to seven alternative regions assessed based on environmental criteria. The horizontal axis displays the alternatives (A1–A7), while the vertical axis indicates their respective Net Flow values. Green bars represent positive Net Flow values—signifying that an alternative is more frequently preferred over others—whereas red bars indicate negative Net Flow values, suggesting a less favorable position relative to other regions. As shown, Banyuasin (A1**)** obtains the highest Net Flow value of 0.332, designating it as the most dominant and top-ranked region in terms of forest fire mitigation priority. In contrast, Kapuas (A2) registers the lowest Net Flow of **–**0.285, positioning it at the bottom of the ranking due to frequent inferiority in pairwise comparisons.

The remaining regions—Pulang Pisau (A3), Mempawah (A4), and Indragiri Hilir (A7)—exhibit moderate Net Flow values ranging between 0.167 and 0.239, reflecting balanced yet non-dominant performances. Meanwhile, Kotawaringin Timur (A5) and Tebo (A6) show relatively lower Net Flow scores, though still ranking above Kapuas. This bar chart provides a more insightful perspective than a simple ordinal ranking, as it conveys the magnitude of dominance or disadvantage each alternative holds relative to others. Consequently, PROMETHEE II proves valuable in decision-making processes that require nuanced evaluations across multiple, and potentially conflicting, criteria.

Comparison of SAW and PROMETHEE II Rankings

The comparison between the SAW and PROMETHEE II results reveals a significant discrepancy in the regional rankings. For instance, Banyuasin (A1) ranks first in the PROMETHEE II evaluation with the highest Net Flow value (0.332), yet only places sixth under the SAW method. This divergence arises from the fundamental differences in methodology: SAW calculates scores using a linear additive approach based on weighted aggregation, whereas PROMETHEE II performs comprehensive pairwise comparisons to assess the relative preference between alternatives. In essence, SAW emphasizes absolute performance per criterion, while PROMETHEE II accounts for how strongly one alternative dominates others in a multi-criteria context.

Analysis of Strengths and Weaknesses of Each Method

Table 5. Comparison of Strengths and Weaknesses of SAW and PROMETHEE II

No.	Methods	Strengths		Weaknesses
1	SAW	- Fast and simple calculation process - Easy to implement without complex preference functions		- Does not account for pairwise preferences - Sensitive to extreme values

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		- Suitable for structured numerical data		- Less effective in complex decision scenarios
2	PROMETHEE II	- Incorporates relative dominance through pairwise comparisons - Provides richer and more balanced rankings - Suitable for complex and dynamic decision environments		- More complex and time-consuming computations - Requires proper selection of preference functions - May be difficult to interpret for non-technical users

The comparison of the SAW and PROMETHEE II methods highlights distinct advantages and limitations inherent in each approach. The Simple Additive Weighting (SAW) method excels in terms of computational simplicity and implementation ease. It requires only basic normalization and weighted summation, making it highly suitable for structured numerical data and rapid decision-making contexts. However, SAW does not consider the relative performance between alternatives, making it less effective in scenarios where trade-offs and inter-criteria dynamics are significant. Furthermore, its results can be sensitive to extreme values, potentially skewing the ranking outcomes.

On the other hand**,** PROMETHEE II offers a more robust analytical framework by incorporating pairwise comparisons to evaluate how strongly one alternative dominates another. This allows for more nuanced and context-aware rankings, especially in complex and multi-dimensional decision environments. It also accommodates dynamic preference settings. Despite these advantages, PROMETHEE II requires more computational effort, a well-justified choice of preference functions, and is generally less intuitive for users unfamiliar with advanced decision-making models. These differences reinforce the importance of selecting the appropriate method based on the complexity and requirements of the decision context.

DISCUSSIONS

The selection of the SAW and PROMETHEE II methods in this study was based on the ability of both methods to address the challenges of transparent, efficient, and effective decision-making in forest fire management, especially in blockchain-based systems. The application of blockchain ensures that the data used is accessible in a transparent manner and cannot be manipulated, guaranteeing data integrity and security so that all information related to forest fire management can be accessed clearly and cannot be altered after being recorded. The SAW method, with its ability to manage and weight criteria systematically, ensures that the data used in the calculations can be accounted for with a high degree of transparency. Meanwhile, PROMETHEE II takes into account preferences between alternatives by using leaving flow, entering flow, and net flow values, providing a more in-depth picture of the comparison between alternatives and strengthening transparency in decision-making.

With regard to both algorithms, SAW performs optimally when the evaluative criteria are sequential, linear, and quantifiable as a result of generating straightforward ordinal rankings. On the other hand, PROMETHEE II performs best in handling complex interrelated preferences owing to its consideration of interactions among criteria, which results in more thorough and conditionally responsive rankings. Both approaches are useful within blockchain-based systems where it is imperative that decisions are made from data that is not only accurate and precise but also securely protected from any form of tampering. With respect to uncertainty, SAW offers solutions bounded within valid parameters considering some level of uncertainty in other parameters, while PROMETHEE II's response to changes within a forest fire scenario is more flexible and adaptable by taking into consideration differing selection priorities among alternatives and dynamic field conditions.

Practical Implications

The integration of SAW and PROMETHEE II within a blockchain framework offers significant practical benefits, particularly for agencies like BNPB (National Disaster Management Agency). In real-world applications, such as forest fire management, the system could enhance the agency's ability to make rapid, transparent, and well-informed decisions. The use of blockchain ensures that all decision-making processes are auditable, preventing tampering or manipulation of critical data. For example, in a scenario where NDVI (Normalized Difference Vegetation Index) drops drastically, indicating a potential fire risk, the system would automatically flag this as a high-priority region. Based on predefined criteria and the dynamic data inputs (such as weather conditions,

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available firefighting resources, and proximity to vulnerable areas), the system would suggest appropriate mitigation actions, which could include resource allocation or real-time alerts to local responders. This decision would be stored in an immutable blockchain, providing a transparent audit trail that all stakeholders can access and verify.

Comparison with Conventional Systems

When compared to conventional systems such as WFDSS (Wildland Fire Decision Support System) or SIPONGI (Sistem Pemantauan Kebakaran Hutan dan Lahan), the blockchain-integrated system in this study offers several advantages. WFDSS, for example, relies on centralized data storage, making it vulnerable to data manipulation and delays in data updates, particularly in remote or disaster-prone areas. SIPONGI, although a good tool for monitoring forest fires, does not provide the same level of transparency and security in decision-making processes. The proposed blockchain system, by contrast, guarantees data integrity and enables real-time updates from multiple sources (e.g., satellite imagery, IoT sensors), which allows for faster and more reliable decision-making. Furthermore, the flexibility and adaptability of PROMETHEE II in responding to changing conditions, coupled with SAW's efficient weight management, make this system more resilient and responsive to varying criteria in the face of dynamic fire events.

CONCLUSION

Every year, forest fires in Indonesia result in ecosystem destruction, air pollution, and economic losses. These forest fires are exacerbated by climate change and land-clearing activities. Information reliability, information flow and distribution delays, stakeholder collaboration, and inter-organizational frameworks are central concerns. Centralized frameworks lack data accountability, are susceptible to data tampering, and offer no audit trails. The difficulty of prioritizing areas based on resource availability, shifting weather patterns, and available dynamic weather conditions adds complexity to the mitigation process. We propose the development of a blockchain-based decision support system that combines the SAW and PROMETHEE II methods. Implementation of smart contracts on a permissioned network guarantees data transparency and immutability. The SAW method streamlines criterion weighting through simple weight aggregation. Comprehensive ranking among alternatives is achieved by PROMETHEE II, which also offers preference-based consideration. Results from this study illustrate greater stakeholder confidence and trust alongside enhanced efficiency in the decision-making processes. There is improved consistency across methods in fire mitigation recommendations for conflict resolution. There are real-time audit trails and no opportunity for data manipulation with blockchain integration. The new part of this research is how it updates weights in real-time and combines SAW and PROMETHEE II into one decision support system that uses blockchain. Future work includes the implementation of a Multilayer Perceptron (MLP) model for more accurate forest fire risk classification. This approach will enhance the system's predictive capability by leveraging features such as temperature, humidity, wind speed, NDVI, and fire weather index (FWI). Additionally, future research will explore the integration of real-time data feed**s** from IoT sensors and satellite imagery to provide live inputs into the MLP model, enabling dynamic risk assessments. Future work will also focus on hyperparameter tuning to optimize the MLP model's performance, ensuring the best possible outcomes for timely decision-making in forest fire management. Furthermore, the scalability of the MLP model will be evaluated for broader implementation across different regions in Indonesia, allowing the system to adapt to varying environmental conditions and fire risk levels.

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*name of corresponding author