

Collaborative and argumentative decision support system applied to land use planning

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ABSTRACT

Group decision-making in land-use planning is based on complex processes, due to the diversity of stakeholders and the plurality of criteria to be considered. This article presents the design of a collaborative group decision support system, K-ProSWOT, combining a multi-agent system and multi-criteria approaches to support decision-making processes. The methodology combines the K-means clustering algorithm to group similar actions together and reduce the number of options to be studied, the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE II) method for quantitative ranking of possible alternatives, and Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis to structure qualitative collective argumentation. These tools are integrated into a participative process, culminating in a collective, well-argued decision-making process. An interactive dashboard accompanies the system, keeping track of the various stages in the decision-making process. The proposed approach aims to enhance the quality of territorial decisions by reconciling an objective assessment of data with the active involvement of stakeholders.

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1. INTRODUCTION

Collective decision-making in land use planning is a major strategic issue, involving environmental, economic, and social criteria that often cause disagreements between stakeholders with diverse interests. Given this complexity, group decision support systems (GDSS) offer solutions that aim to integrate the preferences of multiple decision-makers and facilitate the emergence of acceptable compromises. Over the past several decades, various approaches have been developed to meet these needs, combining multi-criteria analysis (MCA), multi-agent systems (MAS), and negotiation protocols [1], [2]. Recent advances in digital technologies, particularly machine learning and intelligent models, further enhance the potential of these tools by structuring and automating decision-making processes [3].

The central issue lies in the ability to simultaneously process heterogeneous criteria (both qualitative and quantitative) while effectively structuring interactions between decision-makers and producing transparent, reasoned, and collaborative collective decisions. MAS, combined with MCA methods and negotiation protocols, has thus been widely used to address these challenges [1], [2]. However, these approaches still have limitations, particularly in managing conflicting preferences and ensuring transparency in the decision-making process. Multi-criteria methods struggle to clearly represent divergent priorities [4], [5], and argumentative or automated negotiation approaches often offer limited traceability of decisions and their justifications [6], [7].

Several studies have attempted to overcome these limitations by combining MAS, geographic information systems (GIS), and negotiation. For example, Joerin [8] proposed one of the first MAS–GIS approaches in a single-decision-maker framework, laying the foundations for a structured methodology to support spatial decisions. At the same time, the integration of MAS into spatial decision-making and negotiation has been strengthened thanks to pioneering systems [1]. Subsequently, Hamdadou [2] proposed a model combining MCA and negotiation for territorial decision-making, adding a collaborative dimension. Since then, several studies have extended this effort to complex decision-making contexts, developing multi-agent models for group decision-making [9], interactive decision support systems, mechanisms combining MAS and game theory, and web-based communication platforms for collective decision-making [10]–[12].

Other contributions have incorporated automated negotiation [13], argumentative models [14], and hybrid MAS–machine learning or GIS–MAS approaches [15]–[18]. Existing approaches, focused on MCA, MAS, negotiation, or GIS integration, do not allow for the simultaneous management of heterogeneous criteria, the reconciliation of divergent preferences, and the traceability of decisions. To address this need, this article proposes an integrated approach combining MAS and MCA, based on three main steps: (i) initial classification of alternatives using the K-means algorithm, (ii) multi-criteria evaluation using Preference ranking organization method for enrichment evaluation (PROMETHEE) II, and (iii) strategic argumentation based on strengths, weaknesses, opportunities, threats (SWOT) analysis. This combination effectively addresses both qualitative and quantitative criteria. The entire process is monitored and visualized using a dashboard, ensuring collaboration, transparency, and traceability.

The originality of this work lies in the MAS–MCA synergy, enhanced by initial filtering via K-means and the integration of strategic reasoning with SWOT, as well as the implementation of a collaborative system supported by the decision-making dashboard. The article is structured as follows: Section 2 presents the conceptual framework and methodology adopted for the proposed system, Section 3 details the application to a real-world case in land use planning and discusses the results obtained, and Section 4 presents the conclusions and research perspectives.

2. METHOD

This section presents the methodology adopted for the proposed K-ProSWOT system, based on a collaborative platform combining MAS and GIS for group decision support in land use planning [19]. The process follows three main steps: grouping alternatives using the K-means method, ranking them using MCA, and then consolidating the results using SWOT analysis, as illustrated in Figure 1.

2.1. K-ProSWOT system architecture

The K-ProSWOT system is based on two main modules, integrated into a client–server architecture to model cooperation, negotiation, and argumentation between decision-makers [20], [21].

2.1.1. GIS module

The GIS module manages geographic data, archives it, and displays it. It prepares the information needed for evaluation by assigning values to criteria to create the decision matrix, known as the performance matrix [22].

2.1.2. MAS module

- MAS models the decision support system by representing decision-makers with two types of agents:
- Coordinating agent (server): management and coordination of the process, orchestration of exchanges, and final validation of the selected action.
 - Participating agents (customers): represent decision-makers, defend their preferences, and ensure collaborative and reasoned decision-making.

The integration of MAS into collaborative decision-making and land-use planning processes is supported by recent work [23], [24].

2.2. Description of the proposed decision-making protocol

The coordinator first applies the K-means algorithm to group similar (alternative) actions. Each agent then ranks the actions using multiple criteria via the PROMETHEE II method, according to their own weighted criteria. In addition, each agent performs a SWOT analysis to justify their position on the selected actions. The coordinator then aggregates all the rankings and SWOT matrices, incorporating the decision-makers' weights into the group decision, in order to generate a final decision. The overall decision-making process is illustrated in Figure 2.

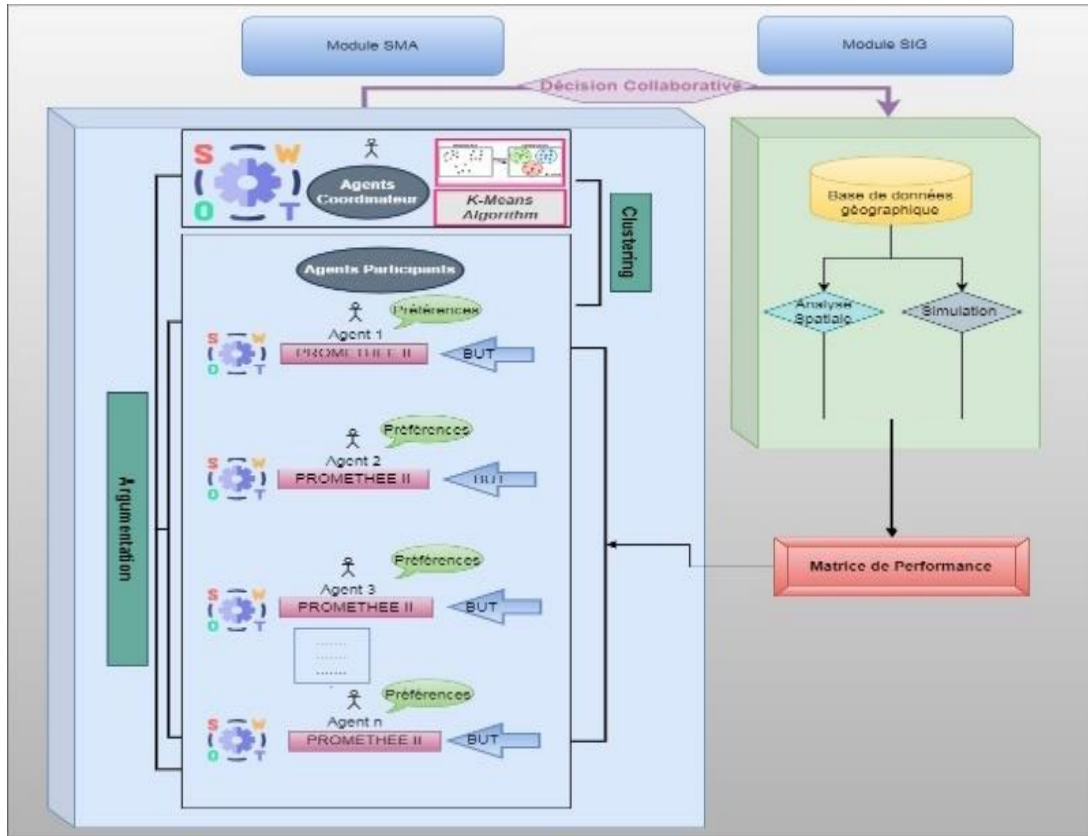


Figure 1. Overall architecture of the K-ProSWOT system

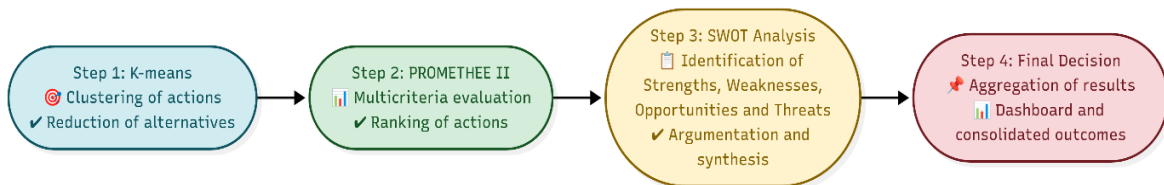


Figure 2. Proposed group decision-making protocol

2.2.1. Step 1: selecting relevant actions using K-means

This step aims to reduce the number of actions to be analyzed by effectively grouping similar actions into homogeneous groups based on an initial performance matrix [25]. The most representative actions from each group are then selected to form a relevant subset for MCA.

a. Choosing the number of clusters

The number of clusters K is determined based on the analysis objectives. Groupings are performed solely on the basis of the selected data and criteria.

b. Application of K-means

The algorithm is applied to distribute the actions into the defined clusters, based on their normalized scores on the selected criteria. Each cluster thus consists of similar alternatives sharing common characteristics. The centroid of each cluster is calculated to serve as a reference.

c. Calculating distances and selecting actions

Measure the Euclidean distance of each action from its centroid. Select, in each cluster, the actions located within a distance threshold around the centroid to ensure their representativeness.

d. Creation of the reduced set

A subset of actions from the clusters, selected according to their proximity to the centroids, is used as input for the MCA. This first step simplifies the analysis by focusing the study on a sample of optimized actions that are representative of the different profiles identified by the clustering. Figure 3 illustrates the clustering process adopted by the proposed system.

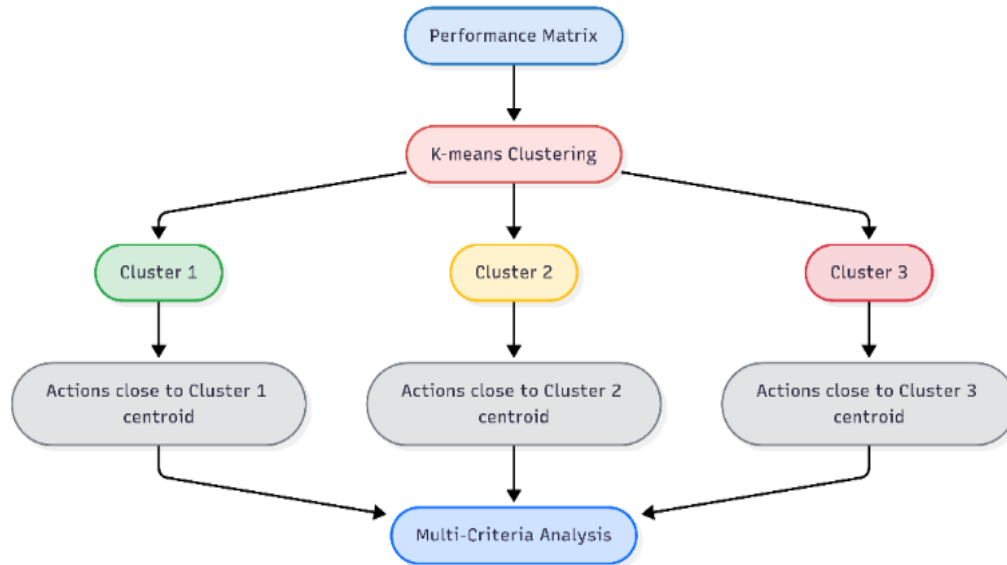


Figure 3. Classification and reduction steps using K-means

2.2.2. Step 2: MCA using the PROMETHEE II method

After selecting the relevant actions using the K-means algorithm, each agent ranks the selected actions according to multiple criteria using the PROMETHEE II multicriteria method [26]-[28]. The purpose of this analysis is to rank the actions according to the individual preferences of each decision-maker, incorporating the criteria deemed decisive and the associated parameters (weightings, indifference and preference thresholds). This ranking provides a structured basis for the arguments that will be developed during the SWOT analysis.

a. Definition of criteria and weights

Each agent assigns a weight to each evaluation criterion, reflecting the relative importance they attach to each aspect.

b. Threshold parameterization

For each criterion, agents define:

- an indifference threshold (Q): a difference between two actions that is considered negligible,
- a preference threshold (P): a difference above which one action is clearly preferred,
- a veto threshold (V): a value above which an action is unacceptable.

c. Performing the MCA

The PROMETHEE II analysis is applied individually for each agent. Each decision-maker thus obtains a personalized ranking of actions based on their own weights, thresholds, and priorities defined for each criterion.

2.2.3. Step 3: individual SWOT analysis at the level of each decision-maker

This step consists of structuring collective decision-making based on the actions selected by decision-makers, following the application of the K-means and PROMETHEE II methods. It is based on a combination of quantitative MCA (PROMETHEE II) and qualitative assessment based on SWOT analysis, a strategic tool used in urban planning and territorial development studies [29]. In our protocol, we propose an original application of SWOT to structure the argumentation around the selected actions, identifying for each of them:

- Strengths (S): advantages related to the internal characteristics of the action.
- Weaknesses (W): internal limitations affecting the action.
- Opportunities (O): external factors favorable to the action.
- Threats (T): external constraints likely to harm the action.

This structure helps to objectify the negotiation and guide collective decision-making based on shared and weighted criteria. The complete SWOT analysis process is presented in Figure 4.

a. Construction of the individual SWOT matrix

For each decision-maker, the SWOT matrix is constructed based on the individual PROMETHEE II ranking. The actions to be analyzed are those in the top half of the ranking, corresponding to the highest-

ranked alternatives for that decision-maker. Each selected action is then examined according to the defined criteria: for each criterion, the following must be identified:

- Its nature, internal (strength or weakness) or external (opportunity or threat),
- its objective, to be maximized or minimized, and
- the value obtained in relation to its performance scale.

SWOT assessments are assigned according to the following rules:

- Strength (S): internal criterion with good performance.
 - Weakness (W): internal criterion with poor performance.
 - Opportunity (O): external criterion with good performance.
 - Threat (T): external criterion with poor performance.
- b. Determination of the final status of the action by the decision-maker

b. Determination of the final status of the action by the decision-maker

The final status of the action for each decision-maker is determined by comparing the number of Strengths and Opportunities with the number of weaknesses and threats. An action is:

- Accepted if $(S+O) > (W+T)$
- Rejected if $(S+O) < (W+T)$
- Rejected if the action is not in the top half of the PROMETHEE II ranking.

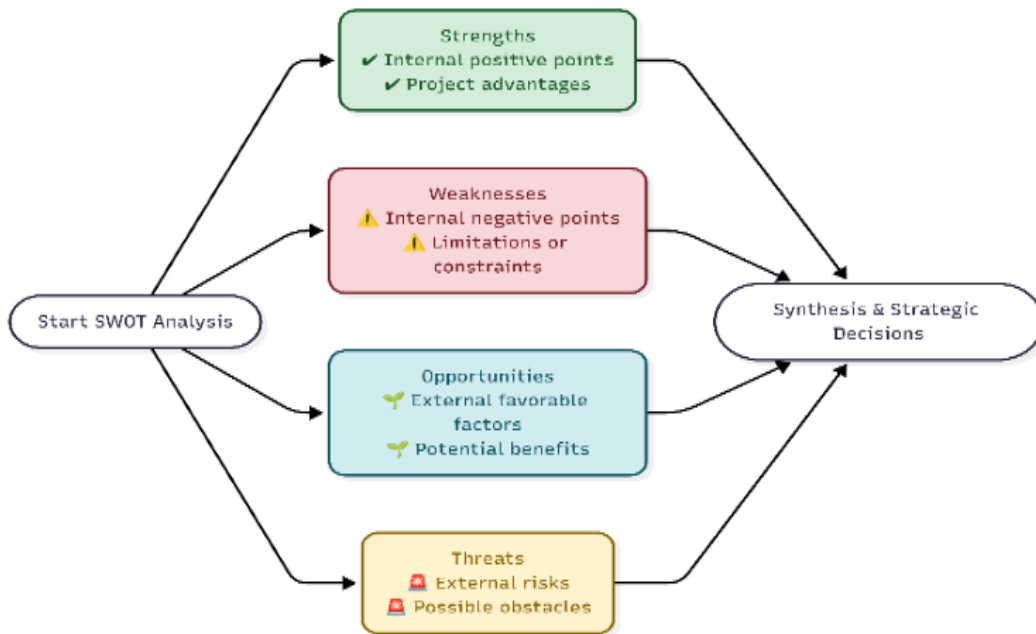


Figure 4. SWOT analysis process for evaluating alternatives

2.2.4. Step 4: weighted aggregation of SWOT results and collaborative decision validation

This final step combines two complementary actions, carried out by the coordinating agent, and aims to transform individual assessments into a reasoned collective decision. The aggregation of SWOT results is carried out at this stage. The coordinator centralizes all the individual matrices and collects, for each action, the PROMETHEE II ranking of each decision-maker as well as the SWOT status assigned (accepted or rejected).

a. Argumentation and validation of the final decision

The final collective decision is based on two possible scenarios, summarized in Table 1. Based on the weighted PROMETHEE II ranking in Case 1, or the weighted SWOT in Case 2, the coordinator presents the chosen decision, accompanied by a structured argumentation built around:

- The dominant Strengths and Opportunities identified for the selected action.
- Weaknesses and Threats identified, justifying the actions that were rejected.

This final decision is therefore based on a twofold justification:

- Quantitative, via the weighted PROMETHEE II results.
- Qualitative, via the collective SWOT analysis.

It ensures that the individual priorities and weighted preferences of decision-makers are taken into account in a balanced manner within the collective process.

The outcome of this phase is the formulation of a final collective decision that is reasoned, validated, and shared by all decision-makers, identifying the priority actions to be implemented.

Table 1. Rules for action selection

| Case | Situation | Procedure |
|------|-------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | No action accepted by all decision-makers (minimum number of acceptances = 0) | - Calculate the weighted PROMETHEE ranking using the weights associated with the decision-makers. - Select the highest-ranked action according to this weighted ranking. - In the event of a tie, give preference to the action proposed by the decision-maker with the highest weight. |
| 2 | At least one action accepted by all (minimum number of acceptances ≠ 0) | - For each accepted action, calculate the weighted SWOT by multiplying the SWOT rating assigned by each decision-maker by their respective weight: Weighted SWOT = $\sum (SWOT_i \times weight_i)$ - Select the action with the highest total weighted SWOT. - In the event of a tie, choose the action supported by the decision-maker with the highest weight. |

b. Creation of the final dashboard

The dashboard aims to display the results of each phase (K-means, PROMETHEE II, SWOT, final decision), allowing decision-makers to monitor the progress of actions at each stage and access the associated justifications. It is structured into several distinct sections:

- K-means: cluster membership of each action.
- PROMETHEE II: evaluation of each action by each decision-maker and weighted aggregation of evaluations according to the weights assigned to decision-makers.
- Weighted SWOT: SWOT status assigned by each decision-maker and calculation of the overall weighted SWOT status.
- Final decision: final status of the action based on the weighted aggregation of PROMETHEE II and SWOT evaluations, accompanied by a supporting argument.

This dashboard is a communication and monitoring tool that facilitates transparency and collective decision-making.

2.3. Cardinality of interaction

The proposed collaborative process is based on a series of structured exchanges between a coordinating agent and several participating agents. At each stage of the protocol, a specific number of interactions is observed, corresponding to the actions necessary to ensure the progress of decision-making. Details of these interactions are summarized in Table 2.

Table 2. Cardinality of decision-making interactions

| Step | Involved actors | Number of interactions |
|-----------------------------|------------------------------------------------------------|------------------------------|
| 1. Clustering (K-means) | Coordinator agent (CA) | 1 interaction |
| 2. Ranking (PROMETHEE II) | n Decision-Making Agents (DA ₁ to DAn) | n interactions (1 per agent) |
| 3. Individual SWOT analysis | n Decision-Making Agents (DA ₁ to DAn) | n interactions (1 per agent) |
| 4. Argumentation SWOT | Between the n DA ₁ , DA ₂ , ..., DAn | n × (n - 1) interactions |
| 5. Final decision | CA and all DAs | 1 interaction |

2.4. Communication primitives

To ensure smooth and rigorous exchanges, the protocol relies on formalized communication primitives, specifying for each step the nature, sender, recipient, and content of messages, as shown in Table 3.

2.5. Decision-making strategies

Within the proposed multi-agent architecture, two types of decision-making actors are involved: participating agents and the coordinating agent. Each implements strategies aligned with their role and objectives within the collaborative decision-making process. These strategies ensure consistent and reasoned decision-making at the group level.

Participating agents aim to defend their own preferences and interests by following a dual strategy:

- Optimization of individual preferences based on PROMETHEE II analysis to prioritize actions that maximize satisfaction.
- Conducting a targeted SWOT analysis to support the argument in negotiations.
 - The coordinating agent, guaranteeing the neutrality of the process, ensures:
- Weighted consolidation of results from PROMETHEE II and SWOT.
- The selection of a reasoned compromise based on SWOT exchanges and expressed preferences.

Table 3. Primitive exchanges and communication flows between system agents

| Sender | Receiver | Primitive | Description |
|-------------|-------------|-----------------------------|-----------------------------------------------------------|
| GIS | Coordinator | Receive(Performance_Matrix) | Loading of the performance matrix |
| Coordinator | Agents | Send(Selected_Actions) | Broadcast of selected actions after clustering |
| Agents | Coordinator | Send(PROMETHEE_II_Ranking) | Transmission of individual rankings |
| Agents | Coordinator | Send(Individual_SWOT) | Transmission of individual SWOT analyses |
| Coordinator | Agents | Send(Global_Ranking) | Communication of the consolidated ranking |
| Agents | Agents | Argue(SWOT_Arguments) | Argumentative exchanges between agents during negotiation |
| Coordinator | Dashboard | Display(Final_Table) | Presentation of the final decision |

2.6. UML modeling of the proposed decision-making protocol

The sequence diagram shown in Figure 5 models the interactions between the coordinating agent and the participating agents within the proposed decision-making protocol. It illustrates the sequence of steps incorporating K-means classification, PROMETHEE II multi-criteria ranking, and reasoned SWOT analysis.

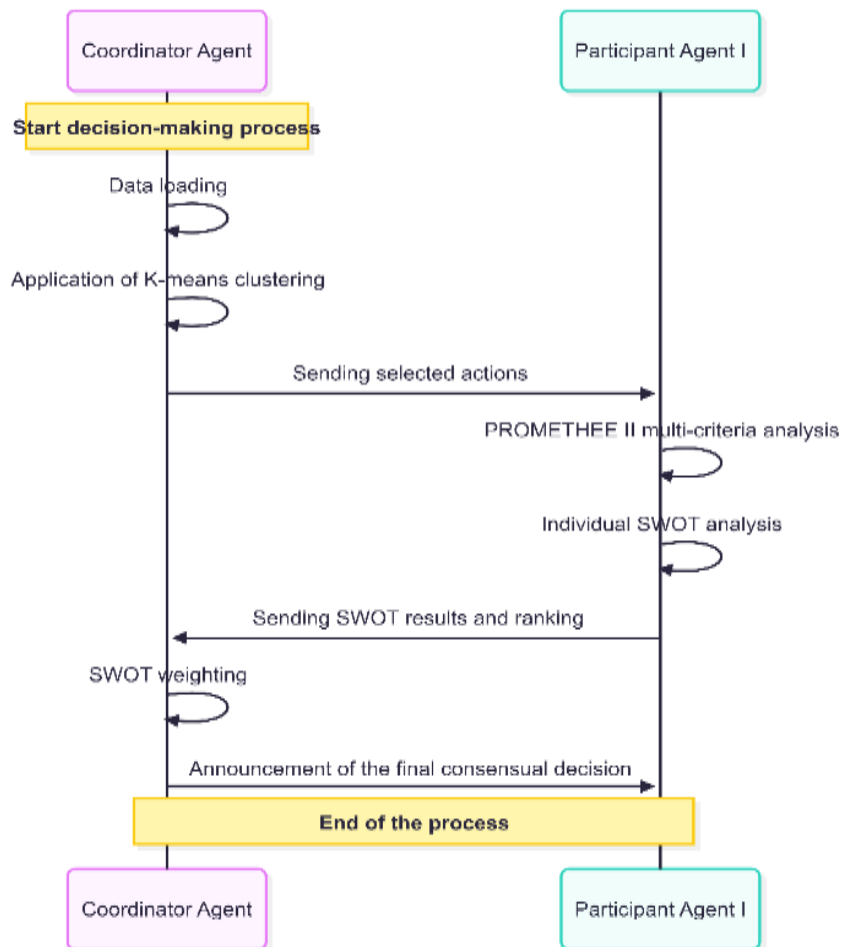


Figure 5. UML sequence diagram associated with the proposed protocol

Algorithm 1 explains the role of the coordinator agent in managing the multi-agent decision-making process. The coordinator agent is responsible for integrating data, grouping actions, and synthesizing analysis results to produce a final decision. Algorithm 2 illustrates the role of participating agents in evaluating alternative actions provided by the coordinator. Each agent performs a preference analysis using PROMETHEE II and SWOT methods to provide input to support the decision-making process.

Algorithm 1. Role of the coordinator agent

Coordinator agent algorithm

Inputs:

- MP: Performance matrix from the GIS
- LD: List of participating agents
- Poids_agents: Weight assigned to each agent

Outputs:

- ACT: Number of actions selected after clustering
- Décision_finale: Final decision result displayed on the dashboard

```

1 Start
2 Receive(MP) # Reception of the GIS matrix
3 Actions_clust = KMeans_Clustering(MP) # Clustering via K-means
4 Actions_retenues = Select_best_clusters(Actions_clust) # Selection of retained actions
5 ACT = Number_of_actions(Actions_retenues)
6 Send(LD, Actions_retenues) # Transmission to participating agents
7 For each agent ∈ LD do
    Receive Classement_PROMETHEE_II (agent)
    Receive SWOT_individuel(agent)
  End For
8 SWOT_agregé = Aggregate_SWOT(LD, Poids_agents) # Weighting and synthesis of SWOT
9 Argumentation = Organize_negotiation(SWOT_agregé) # Argumentation process on SWOT
  analyses
10 Décision_finale = Make_argumented_decision(Argumentation)
11 Display_Dashboard(Décision_finale)
12 End.
```

Algorithm 2. Role of the participant agent

Participant Agent Algorithm

Inputs:

- Actions_retenues: List of actions received from the coordinator

Outputs:

- Classement_PROMETHEE_II: PROMETHEE II ranking of actions
- SWOT_individuel: Individual SWOT analysis of the retained actions

```

1 Start
2 Receive(Actions_retenues)
3 Critères_évaluation = Define_criteria()
4 Poids_critères = Define_weights()
5 Classement_PROMETHEE_II = Apply_PROMETHEE_II(Actions_retenues, Critères_évaluation,
  Poids_critères)
6 Send(Coordinator, Classement_PROMETHEE_II)
7 SWOT_individuel = Perform_SWOT(Actions_retenues)
8 Send(Coordinator, SWOT_individuel)
9 End.
```

2.7. Tools for implementing the K-ProSWOT system

The tools used to design the proposed K-ProSWOT system:

- GIS: generation of the performance matrix.
- Python: data manipulation and processing with pandas and scikit-learn, visualization with matplotlib.
- CSV: data exchange between the server and clients.

3. RESULTS AND DISCUSSION

3.1. Case study

This study aims to select the most suitable site for housing construction in the canton of Vaud, approximately 15 km north of Lausanne, from 650 undeveloped blocks identified in [8]. Each plot was evaluated according to seven criteria relating to the territory and housing, presented in Table 4, allowing for an objective comparison of the sites. These evaluations serve as the basis for the K-ProSWOT methodology to identify the most favorable alternatives.

Table 4. Evaluation criteria and associated procedures

| Criterion | Type | Scale | Associated factors | Assessment method |
|--------------------------------|----------|-----------|-------------------------------------------------|---------------------|
| Nuisances | Natural | [0,1] | Air pollution, odors | Score assignment |
| Noise | Social | [0,1] | Proximity to roads, highways, railways | Score assignment |
| Impacts | Social | {0,...,6} | Natural sites, landscapes, forests, groundwater | Score assignment |
| Geotechnical and natural risks | Natural | {0,...,6} | Landslides | Spatial analysis |
| Facilities | Economic | [0,2244] | Distance to infrastructure networks | Expert consultation |
| Accessibility | Economic | [0,15] | Commuting time | Expert consultation |

3.2. K-ProSwot decision-making process

3.2.1. Phase 1: classification and reduction of actions with K-means

a. Loading the performance matrix and decision-maker weights

Importing the performance matrix in CSV format, incorporating the 650 actions and their values for the 7 defined criteria, Figure 6.

| | A | B | C | D | E | F | G |
|----|--------------------------------------------------------------------------------|---|---|---|---|---|---|
| 1 | ID_ZONE, NUISANCES, BRUIT, IMPACTS, GEOTECHNIQ, EQUIPEMENT, ACCESSIBIL, CLIMAT | | | | | | |
| 2 | 202,1.00,0.68,0,1,816,8,0.92 | | | | | | |
| 3 | 209,1.00,0.45,0,1,1249,9,0.91 | | | | | | |
| 4 | 210,1.00,0.69,0,1,1165,9,0.89 | | | | | | |
| 5 | 211,1.00,0.48,0,1,1518,9,0.92 | | | | | | |
| 6 | 213,1.00,0.92,0,1,1356,9,0.89 | | | | | | |
| 7 | 215,1.00,1.00,0,1,1434,8,0.75 | | | | | | |
| 8 | 216,1.00,0.97,0,1,1490,10,0.83 | | | | | | |
| 9 | 218,1.00,1.00,0,1,1556,8,0.70 | | | | | | |
| 10 | 219,1.00,1.00,0,1,1638,12,0.68 | | | | | | |
| 11 | 220,1.00,1.00,0,1,1629,8,0.68 | | | | | | |
| 12 | 221,1.00,0.95,0,1,1641,10,0.84 | | | | | | |
| 13 | 223,1.00,1.00,0,1,1697,8,0.68 | | | | | | |
| 14 | 224,1.00,0.98,0,1,1758,10,0.70 | | | | | | |
| 15 | 225,1.00,1.00,0,1,1801,8,0.67 | | | | | | |
| 16 | 226,1.00,0.91,0,1,1809,10,0.84 | | | | | | |
| 17 | 228,1.00,1.00,0,1,1840,8,0.67 | | | | | | |
| 18 | 229,1.00,0.97,0,1,1870,10,0.68 | | | | | | |
| 19 | 230,1.00,0.09,0,1,1848,12,0.55 | | | | | | |
| 20 | 231,1.00,0.97,0,1,1927,8,0.67 | | | | | | |
| 21 | 232,1.00,0.94,0,1,1954,11,0.68 | | | | | | |
| 22 | 234,1.00,0.97,0,1,1997,8,0.67 | | | | | | |

Figure 6. Extract from the performance matrix of the 650 blocks according to the 7 criteria

b. Application of the K-means algorithm

The negotiator applies the K-means algorithm to classify the 650 actions into 3 homogeneous clusters, as shown in Figure 7.

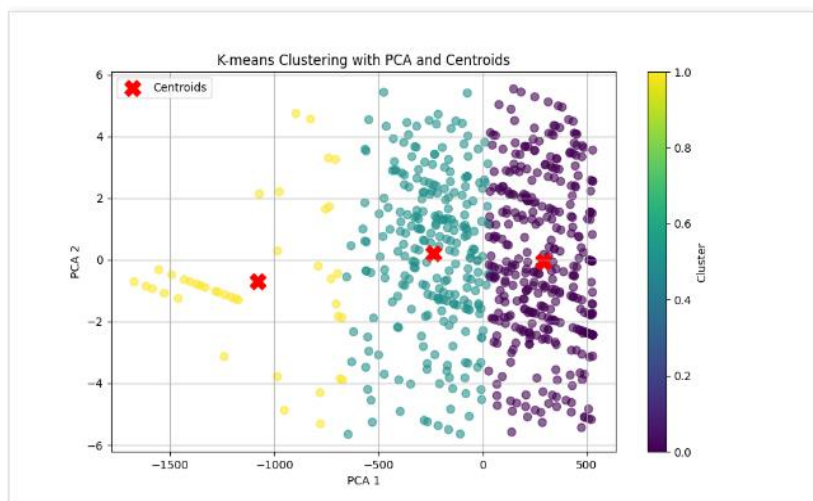


Figure 7. Execution of the K-means algorithm

The clustering results presented in Figure 8 indicate:

- Cluster 0: 355 actions
- Cluster 1: 255 actions
- Cluster 2: 40 actions



Figure 8. Actions grouped by cluster 0, cluster 1, and cluster 2

c. Generation of a reduced performance matrix

After clustering by K-means, the six actions closest to the centroid of each cluster were selected, forming a reduced matrix of 18 representative actions for the final decision, as shown in Figure 9, thereby reducing computational complexity.

| ID_ZONE | NUISANCES | BRUIT | IMPACTS | GEOTECHNIQ | EQUIPEMENT | ACCESSIBIL | CLIMAT |
|---------|-----------|-------|---------|------------|------------|------------|--------|
| 8933 | 1.0 | 0.51 | 2 | 6 | 2006 | 11 | 0.3 |
| 2436 | 1.0 | 0.94 | 4 | 6 | 2006 | 9 | 0.7 |
| 5258 | 0.0 | 0.36 | 4 | 6 | 2006 | 10 | 0.67 |
| 6663 | 1.0 | 0.58 | 4 | 6 | 1999 | 11 | 0.49 |
| 8069 | 0.0 | 0.34 | 4 | 6 | 1999 | 10 | 0.28 |
| 3838 | 0.86 | 0.95 | 4 | 6 | 2001 | 6 | 0.7 |
| 616 | 1.0 | 1.0 | 2 | 3 | 1471 | 11 | 0.85 |
| 6438 | 1.0 | 1.0 | 4 | 1 | 1477 | 10 | 0.31 |
| 2725 | 0.01 | 0.11 | 6 | 6 | 1470 | 10 | 0.67 |
| 4927 | 1.0 | 1.0 | 2 | 6 | 1469 | 12 | 0.36 |
| 1922 | 1.0 | 0.98 | 2 | 1 | 1481 | 10 | 0.61 |
| 516 | 1.0 | 0.99 | 2 | 1 | 1481 | 10 | 0.76 |
| 902 | 1.0 | 0.76 | 4 | 3 | 640 | 8 | 0.88 |
| 7417 | 1.0 | 1.0 | 0 | 6 | 539 | 2 | 0.82 |
| 1002 | 1.0 | 1.0 | 4 | 6 | 726 | 2 | 0.79 |
| 402 | 1.0 | 1.0 | 0 | 6 | 727 | 5 | 0.78 |
| 7418 | 1.0 | 1.0 | 0 | 6 | 526 | 2 | 0.74 |
| 602 | 1.0 | 0.96 | 2 | 3 | 736 | 7 | 0.92 |

Figure 9. Reduced performance matrix (18 actions) resulting from K-means clustering

3.2.2. Phase 2: multi-criteria evaluations

a. Individual parameterization

Each decision maker enters their own evaluation parameters (criteria weightings, indifference thresholds (Q), preference thresholds (P), and veto thresholds (V)) via a dedicated interface, as shown in Figure 10.

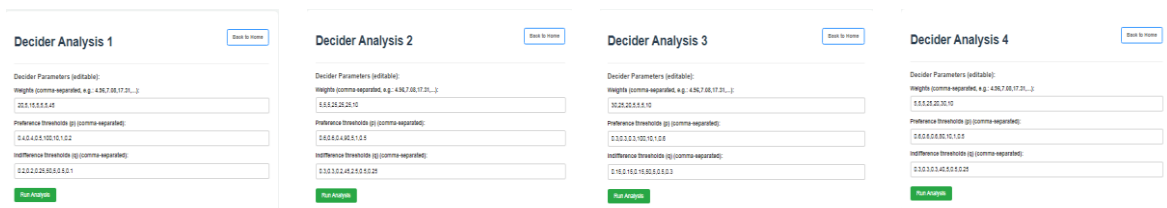


Figure 10. Individual setting of criteria for each decision maker

b. Ranking using PROMETHEE II

Each decision-maker evaluates the reduced matrix using the PROMETHEE II method to establish a multi-criteria ranking of the 18 selected actions. Figure 11 shows this ranking for each decision-maker.

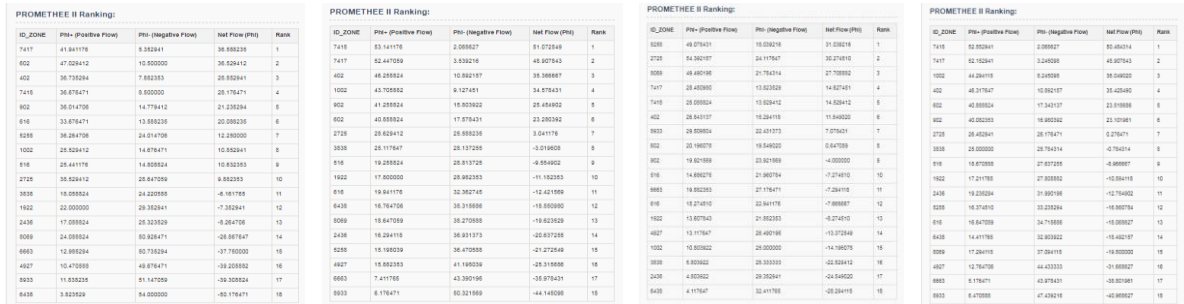


Figure 11. PROMETHEE II rankings of the actions selected for each of the four decision-makers

3.2.3. Phase 3: argumentation through SWOT

After applying PROMETHEE II and ranking the actions for each decision-maker, Figure 12 presents the individual SWOT results. It illustrates the actions accepted and rejected for each decision-maker, highlighting the alternatives deemed positive or negative according to their individual SWOT. Four main actions (ID_ZONE 7418, 7417, 402, 602) were unanimously accepted.

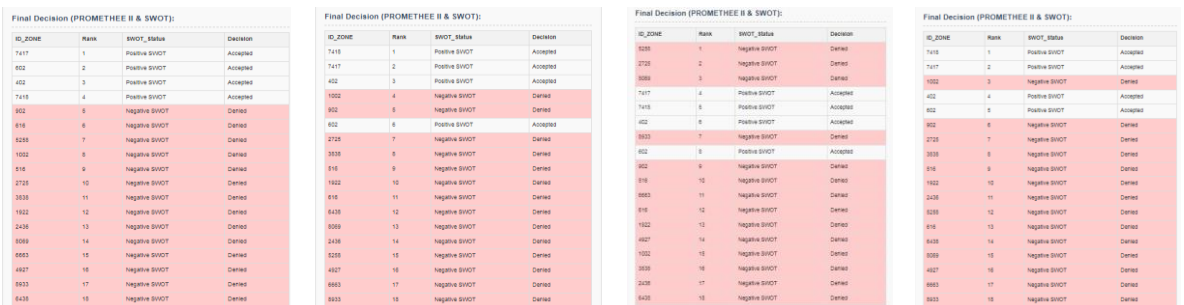


Figure 12. Individual SWOT results for each decision-maker

3.2.4. Phase 4: processing and final decision-making using weighted SWOT analysis

The final decision, based on the aggregation of individual SWOT assessments, selects action 7418 as the optimal site, as illustrated in Figure 13.

3.3. Decision-making dashboard: K-means clusters, PROMETHEE II, and SWOT analysis

Figure 14 presents the decision-making dashboard, summarizing the K-means clustering, the multicriteria evaluation using PROMETHEE II, and the SWOT consolidation of the alternatives.

Analysis of the decision table highlights a strong consistency between the three stages of the K-means → PROMETHEE II → weighted SWOT method. The alternatives with the best weighted NetFlows (7418, 7417, 402, and 602) all belong to Cluster 2, confirming that this cluster contains the most favorable alternatives. Their systematic validation by SWOT, dominated by Strengths and Opportunities, logically leads to their acceptance. The concentration of the selected solutions in the same cluster confirms that K-means has correctly structured the decision space, separating from the outset the alternatives with high-performing profiles on the underlying criteria.

Conversely, alternatives characterized by dominant weaknesses and threats (such as 1002, 902, 2725, etc.) display intermediate or negative NetFlows and are systematically located in Clusters 0 or Cluster 1. Their rejection by the weighted SWOT shows that the final decision is not based solely on the PROMETHEE score, but also on the overall strategic structure of the alternative. This confirms that SWOT acts as a final qualitative filter, capable of confirming successful actions and rejecting those with an unfavorable W+T strategic profile, even if their numerical ranking is acceptable.

The acceptance of alternative 602, despite an intermediate NetFlow, illustrates this complementarity: its location in Cluster 2 and its positive SWOT profile (S+O) justify its retention among the selected actions. This case shows that the method can recognize strategically sound alternatives. The convergence between the initial clustering, the PROMETHEE II ranking, and the weighted SWOT validation confirms that the K-ProSWOT process provides robust, consistent, and defensible decisions, while effectively reducing the decision space.



Figure 13. Aggregation of individual SWOTs and selection of action 7418

| ID | K-means Cluster | NetFlow D2 | NetFlow D3 | NetFlow D4 | Weighted NetFlow (0.1;0.3;0.2;0.4) | SWOT D1 | SWOT D2 | SWOT D3 | SWOT D4 | Weighted SWOT Status |
|------|-----------------|------------|------------|------------|------------------------------------|----------|----------|----------|----------|----------------------|
| 7418 | Cluster 2 | 51.072549 | 14.529412 | 50.484314 | 41.239 | Accepted | Accepted | Accepted | Accepted | Accepted (max S+O) |
| 7417 | Cluster 2 | 48.907843 | 14.627451 | 48.907843 | 40.8198 | Accepted | Accepted | Accepted | Accepted | Accepted (max S+O) |
| 402 | Cluster 2 | 35.366667 | 11.54902 | 35.42549 | 29.9753 | Accepted | Accepted | Accepted | Accepted | Accepted (max S+O) |
| 1002 | Cluster 2 | 34.578431 | -14.196078 | 36.04902 | 23.0392 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 602 | Cluster 2 | 23.280392 | 0.647059 | 23.515686 | 20.1727 | Accepted | Accepted | Accepted | Accepted | Accepted (max S+O) |
| 902 | Cluster 2 | 25.454902 | -4 | 23.101961 | 18.2008 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 2725 | Cluster 1 | 3.041176 | 30.27451 | 0.276471 | 8.0661 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 5258 | Cluster 0 | -21.272549 | 31.039216 | -16.860784 | -5.6932 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 3838 | Cluster 1 | -3.019608 | -22.529412 | -0.784314 | -6.3417 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 516 | Cluster 1 | -9.554902 | -7.27451 | -8.966667 | -6.8448 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 1922 | Cluster 0 | -11.182353 | -8.27451 | -10.594118 | -9.9825 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 616 | Cluster 0 | -12.421569 | -7.666667 | -18.068627 | -10.4784 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 8069 | Cluster 1 | -19.623529 | 27.705882 | -19.8 | -10.9526 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 2436 | Cluster 1 | -20.637255 | -24.54902 | -12.754902 | -17.0294 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 6438 | Cluster 0 | -18.55098 | -28.294118 | -18.492157 | -23.6386 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 4927 | Cluster 1 | -25.315686 | -13.372549 | -31.668627 | -26.8573 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 6663 | Cluster 0 | -35.978431 | -7.294118 | -38.801961 | -31.5481 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |
| 8933 | Cluster 0 | -44.145098 | 7.078431 | -40.968627 | -32.1462 | Rejected | Rejected | Rejected | Rejected | Rejected (min W+T) |

Figure 14. Decision-making dashboard

3.4. Comparison and added value of K-ProSWOT

K-ProSWOT goes beyond traditional approaches combining GIS and MAS [30], [31] by introducing initial filtering through clustering, which reduces the number of alternatives to be analyzed while retaining representative profiles. Unlike traditional methods focused on numerical or spatial performance [32], [33], K-ProSWOT combines a weighted multi-criteria ranking for each decision-maker with a collective qualitative assessment via SWOT. This approach ensures that the alternatives selected are not only effective, but also strategically sound and accepted by all stakeholders. The sequential nature of the process, incorporating filtering, ranking, and SWOT validation, is its main added value, guaranteeing a robust, transparent, and defensible collective decision, reinforced by a decision-making dashboard that allows results to be tracked at each stage and clearly visualizes the justifications for the choices made.

3.5. Limitations and critical considerations

Despite the robustness of K-ProSWOT, certain limitations should be noted. The number of clusters selected during the K-means stage affects the initial structuring of alternatives and can influence the scope of preliminary filtering. PROMETHEE II results remain sensitive to the weightings assigned by decision-makers, which may vary depending on their expertise or individual preferences. Finally, the weighted SWOT assessment relies on qualitative judgments, which may be subject to cognitive or strategic biases, particularly when stakeholders have divergent interests. These limitations highlight areas for improvement and open avenues for future research.

4. CONCLUSION

The objective stated in the introduction was to propose an integrated methodology to support group decision-making through a combination of multi-criteria, multi-decision-maker analysis (PROMETHEE II), K-means clustering, and weighted SWOT-based argumentation. The results obtained confirmed compatibility with this objective: The integrated K-ProSWOT process combining K-means, PROMETHEE II, and SWOT produced consistent results. It made it possible to effectively structure the decision-making process, take into account the individual preferences of decision-makers, and justify the final decision in a transparent and reasoned manner. Weighted SWOT proved particularly relevant in deciding between alternatives and ensuring a conclusion consistent with the weighted preferences of stakeholders.

Following on from this work, several avenues for further research can be considered: i) advanced automation of argumentation through the automatic generation of SWOT arguments from raw data, while taking into account possible stakeholder biases; ii) comprehensive sensitivity analysis of weightings, thresholds, and clustering parameters to enhance model robustness; and iii) integration of machine learning methods to anticipate collective agreements and automatically recommend priority actions. These perspectives pave the way for methodological improvements and broader applications, while strengthening the relevance and credibility of collaborative decisions.

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C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nvestigation

R : **R**esources

D : **D**ata Curation

O : Writing - **O**riginal Draft

E : Writing - Review & **E**ditng

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

DATA AVAILABILITY

Data availability does not apply to this paper as no new data were created or analyzed in this study.




REFERENCES

- [1] N. Ferrand, "Modèles multi-agents pour l'aide à la décision et la négociation en aménagement du territoire," Université Joseph-Fourier, 1997.
- [2] D. Hamdadou, "Un modèle pour la prise de décision en aménagement du territoire: une approche multicritère et une approche de négociation," Université d'Oran Es-Sénia, Algérie, 2008.
- [3] R. Ali, A. Hussain, S. Nazir, S. Khan, and H. U. Khan, "Intelligent decision support systems—an analysis of machine learning and multicriteria decision-making methods," *Applied Sciences*, vol. 13, no. 22, p. 12426, Nov. 2023, doi: 10.3390/app132212426.
- [4] T. L. Saaty, *Decision making for leaders : the analytic hierarchy process for decisions in a complex world*, 5th ed. Pittsburgh, PA, USA: RWS Publications, 2008.
- [5] K. Yoon and C.-L. Hwang, *Multiple attribute decision making*. SAGE Publications, Inc., 1995. doi: 10.4135/9781412985161.
- [6] N. Karacapilidis and D. Papadias, "Computer supported argumentation and collaborative decision making: the HERMES system," *Information Systems*, vol. 26, no. 4, pp. 259–277, Jun. 2001, doi: 10.1016/S0306-4379(01)00020-5.
- [7] A. Kakas and P. Moraitis, "Argumentation-based decision making for autonomous agents," in *Proceedings of the second international joint conference on Autonomous agents and multiagent systems - AAMAS '03*, New York, New York, USA: ACM Press, 2003, p. 883. doi: 10.1145/860714.860717.
- [8] F. Joerin, "Décider sur le territoire: proposition d'une approche par utilisation de SIG et de méthodes d'analyse multicritère," École Polytechnique Fédérale de Lausanne (EPFL), 1998.
- [9] N. Taghezout, A. Adla, and P. Zaraté, "Coordination in multi-agent decision support system - application to a boiler combustion management system (GLZ)," in *Proceedings of the 11th International Conference on Enterprise Information*, SCITEPRESS - Science and Technology Publications, 2009, pp. 194–199. doi: 10.5220/0001999301940199.
- [10] S. Oufella and D. Hamdadou, "A collaborative spatial decision support system applied to site selection problems," *International Journal of Applied Management Science*, vol. 10, no. 2, p. 127, 2018, doi: 10.1504/IJAMS.2018.092078.
- [11] D. Hamdadou and K. Bouamrane, "A spatial group decision support system: coupling negotiation and multicriteria approaches," *Intelligent Decision Technologies*, vol. 10, no. 2, pp. 129–147, Mar. 2016, doi: 10.3233/IDT-150244.
- [12] M. Abdelhadi, D. Hamdadou, and N. Menni, "A communication platform for group decision support system," *International Journal of E-Services and Mobile Applications*, vol. 10, no. 3, pp. 19–41, Jul. 2018, doi: 10.4018/IJESMA.2018070102.
- [13] M. Okumura, K. Fujita, and T. Ito, "An implementation of collective collaboration support system based on automated multi-agent negotiation," 2013, pp. 125–141. doi: 10.1007/978-3-642-30737-9_8.
- [14] M. Morge and P. Mancarella, "Arguing over goals for negotiation: adopting an assumption-based argumentation decision support system," *Group Decision and Negotiation*, vol. 23, no. 5, pp. 979–1012, Sep. 2014, doi: 10.1007/s10726-012-9324-4.
- [15] Y. Omari, D. Hamdadou, and M. A. Mami, "Coupling multi-criteria analysis and machine learning for agent based group decision support: spatial localization," *International Journal of Computing and Digital Systems*, vol. 12, no. 1, pp. 55–72, Jul. 2022, doi: 10.12785/ijcds/120106.
- [16] A. B. Djelloul and D. Hamdadou, "An ontology-based spatial group decision support system for site selection application," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 13, no. 4, p. 4488, Aug. 2023, doi: 10.11591/ijece.v13i4.pp4488-4503.
- [17] P. Brom, K. Engemann, C. Breed, M. Pasgaard, T. Onalapo, and J.-C. Svenning, "A decision support tool for green infrastructure planning in the face of rapid urbanization," *Land*, vol. 12, no. 2, p. 415, Feb. 2023, doi: 10.3390/land12020415.
- [18] M. Başeğmez, A. Doğan, and C. C. Aydın, "Management of sustainable urban green spaces through machine learning-supported MCDM and GIS integration," *Environmental Science and Pollution Research*, vol. 32, no. 18, pp. 11466–11487, Apr. 2025, doi: 10.1007/s11356-025-36367-7.
- [19] R. Greene, R. Devillers, J. E. Luther, and B. G. Eddy, "GIS-based multiple-criteria decision analysis," *Geography Compass*, vol. 5, no. 6, pp. 412–432, Jun. 2011, doi: 10.1111/j.1749-8198.2011.00431.x.
- [20] V. Di Lecce and A. Amato, "Multi agent negotiation for a decision support system in route planning," in *2008 International Conference on Computational Intelligence for Modelling Control & Automation*, IEEE, 2008, pp. 458–463. doi: 10.1109/CIMCA.2008.177.
- [21] A. Dorri, S. S. Kanhere, and R. Jurdak, "Multi-agent systems: a survey," *IEEE Access*, vol. 6, pp. 28573–28593, 2018, doi: 10.1109/ACCESS.2018.2831228.
- [22] D. A. Q. Badang, C. F. Sarip, and A. P. Tahud, "Geographic information system (GIS) and multicriteria decision making (MCDM) for optimal selection of hydropower location in Rogongon, Iligan City," in *2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM)*, IEEE, Nov. 2018, pp. 1–5. doi: 10.1109/HNICEM.2018.8666266.
- [23] P. Zhang, A. Huang, L. Wu, R. Li, and Z. Fu, "A multi-agent simulation-based decision support tool for sustainable tourism land use planning in rural China," *Land*, vol. 14, no. 12, p. 2342, Nov. 2025, doi: 10.3390/land14122342.
- [24] C. Caprioli, "The integration of multi-agent system and multicriteria analysis for developing participatory planning alternatives in urban contexts," *Environmental Impact Assessment Review*, vol. 113, p. 107855, Jun. 2025, doi: 10.1016/j.eiar.2025.107855.
- [25] Y. Chen, "Research on the spatial distribution of garden landscape based on the optimization of K-means clustering algorithm," *Applied Mathematics and Nonlinear Sciences*, vol. 9, no. 1, Jan. 2024, doi: 10.2478/amns-2024-2518.
- [26] J.-P. Brans and B. Mareschal, "Promethee methods," in *Multiple criteria decision analysis: state of the art surveys*, New York, NY.: Springer, 2005, pp. 163–186. doi: 10.1007/0-387-23081-5_5.
- [27] S. Corrente, S. Greco, F. Leonardi, and R. Słowiński, "The hierarchical SMAA-PROMETHEE method applied to assess the sustainability of European cities," *Applied Intelligence*, vol. 51, no. 9, pp. 6430–6448, Sep. 2021, doi: 10.1007/s10489-021-02384-5.




- [28] Y. Song, Q. Xu, M. Al-Badkubi, and F. Alimova, "Evaluating green urban underground spaces using PROMETHEE II for ecological suitability," *Applied Water Science*, vol. 15, no. 12, p. 301, Dec. 2025, doi: 10.1007/s13201-025-02651-7.
- [29] A. Azmi, "Strengths, weaknesses, opportunities and threats of sustainable urban development in Kermanshah," *International Review for Spatial Planning and Sustainable Development*, vol. 11, no. 4, pp. 224–239, Oct. 2023, doi: 10.14246/irspds.11.4_224.
- [30] A. Demir, A. E. Dinçer, C. Çiftçi, S. Gülçimen, N. Uzal, and K. Yılmaz, "Wind farm site selection using GIS-based multicriteria analysis with Life cycle assessment integration," *Earth Science Informatics*, vol. 17, no. 2, pp. 1591–1608, Apr. 2024, doi: 10.1007/s12145-024-01227-4.
- [31] A. Mendas, A. Mebrek, and Z. Mekranfar, "Group decision-making based on GIS and multicriteria analysis for assessing land suitability for agriculture," *Revue Internationale de Géomatique*, vol. 33, no. 1, pp. 383–398, 2024, doi: 10.32604/riq.2024.055321.
- [32] A. Yaman, "A GIS-based multi-criteria decision-making approach (GIS-MCDM) for determination of the most appropriate site selection of onshore wind farm in Adana, Turkey," *Clean Technologies and Environmental Policy*, vol. 26, no. 12, pp. 4231–4254, Dec. 2024, doi: 10.1007/s10098-024-02866-3.
- [33] A. Zaniboni, P. Tassinari, and D. Torreggiani, "GIS-based land suitability analysis for the optimal location of integrated multi-trophic aquaponic systems," *Science of The Total Environment*, vol. 913, p. 169790, Feb. 2024, doi: 10.1016/j.scitotenv.2023.169790.

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