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A Decision-Ready Framework for Sustainable Land-Use Planning Using Design Science Research

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Abstract

Sustainable land-use planning involves complex decision-making under multiple, often conflicting objectives, regulatory constraints, and uncertainty. Conventional planning approaches frequently rely on fragmented analyses or case-specific tools that limit transparency, reusability, and defensibility of decisions. To address these limitations, this study applies a Design Science Research (DSR) approach to design and evaluate a decision support framework for sustainable land-use planning. The proposed framework is conceptualized as a reusable decision support artifact that structures land-use decisions through explicit sustainability criteria, feasibility constraints, and uncertainty analysis. It integrates environmental, economic, social, and governance dimensions within a transparent decision workflow, enabling systematic comparison of competing land-use alternatives. In line with DSR principles, the contribution of this study lies in the design of a generalizable framework and associated design knowledge, rather than in the implementation of a specific software system. The framework is demonstrated using a protected-area land-use planning scenario informed by techno-environmental exploration practices in the Bombo-Lumene Hunting Estate and Reserve in the Democratic Republic of Congo. Evaluation focuses on utility, transparency, and robustness of decision outcomes. Sensitivity analysis is employed to examine the stability and interpretability of alternative rankings under varying planning priorities, complemented by qualitative assessment of decision traceability. The results indicate that the framework supports structured and defensible land-use decision-making by making sustainability trade-offs explicit and by enhancing robustness to changing assumptions. Overall, the study demonstrates the applicability of DSR to spatial planning and sustainability challenges and contributes a decision-ready framework adaptable to diverse land-use planning contexts worldwide.

1. Introduction

Land-use planning is a key instrument for achieving sustainable development, as it governs how land is allocated among competing environmental, economic, and social objectives. Decisions related to zoning, activity allocation, and development intensity involve complex

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trade-offs, spatial constraints, and long-term consequences. These challenges are intensified by rapid urbanization, environmental degradation, and increasing regulatory pressures, making land-use planning an inherently complex and uncertain decision-making problem.

Recent studies highlight the growing use of decision support approaches to address this complexity. GIS-based multi-criteria analysis has been applied to evaluate land suitability and sustainability trade-offs in developing regions (Thapa et al., 2025). Scenario-based planning frameworks enable planners to explore alternative land-use futures under uncertainty and compare development pathways (Sedighi et al., 2025). In parallel, systematic reviews of digital land-use decision support tools report increasing adoption in planning practice while identifying persistent challenges related to transparency, integration, and usability (Poggi et al., 2025). Together, these findings indicate a clear demand for structured and interpretable decision support in land-use planning.

Despite these advances, land-use planning practice often relies on fragmented or ad hoc approaches. Decisions are frequently informed by expert judgment, isolated spatial analyses, or single-criterion assessments that do not systematically integrate sustainability dimensions or make assumptions explicit. Although analytical and spatial tools are widely available, they are not always embedded within coherent decision frameworks that support comparison of alternatives, stakeholder engagement, and robustness analysis. As a result, planning outcomes may be difficult to justify, reproduce, or adapt when priorities or boundary conditions change.

Decision support frameworks have been proposed to address these limitations by structuring complex planning problems and integrating heterogeneous criteria. However, many existing approaches remain highly context-specific or focus primarily on technical optimization, limiting their generalizability and interpretability. In particular, there is a lack of reusable decision support frameworks explicitly designed for sustainable land-use planning across diverse institutional and geographic contexts, while accommodating regulatory constraints and uncertainty.

Design Science Research (DSR) provides a suitable methodological foundation for addressing this gap. DSR emphasizes the purposeful design and evaluation of artifacts—such as models, methods, and frameworks—that address identified real-world problems (Hevner et al., 2004). Conceptual frameworks are recognized as legitimate DSR artifacts when they encapsulate transferable design knowledge applicable to a class of problems rather than a single implementation (Gregor & Hevner, 2013). This perspective aligns well with land-use planning, where decision support must balance rigor with flexibility, transparency, and interpretability. Figure 1 provides a conceptual overview of the DSR framework adopted in this study and its integration with sustainability dimensions in land-use planning.

Recent methodological guidance further emphasizes that DSR artifacts may be demonstrated and evaluated through realistic scenarios rather than full operational deployment, particularly in cross-disciplinary domains such as spatial planning and sustainability (Delport et al., 2024). This allows evaluation of decision logic, robustness, and explanatory value—qualities that are central to effective land-use planning but often underemphasized in optimization-driven approaches. Akoka et al. (2023) analyze how knowledge is dynamically created in DSR projects by identifying paths of knowledge contributions, deriving seven DSR strategies, and providing guidelines to support the initiation and progression of DSR studies.

Against this background, the objective of this study is to design and evaluate a decision support framework for sustainable land-use planning using a DSR approach. The proposed framework integrates multi-dimensional sustainability criteria, feasibility constraints, and uncertainty considerations into a systematic and well-structured decision-making process. Rather than prescribing a single optimal solution, it supports informed interpretation of trade-offs among land-use alternatives.

The contribution of this paper is twofold. First, it provides a generalizable decision support artifact tailored to sustainable land-use planning challenges. Second, it demonstrates how DSR can be effectively applied to spatial planning problems through abstraction and scenario-based evaluation. The paper is structured as follows: Section 2 reviews related work, Section 3 presents the research methodology, Section 4 describes the decision support artifact, Section 5 demonstrates and evaluates the artifact using a protected-area planning context, Section 6 discusses the findings, and Section 7 concludes the paper.

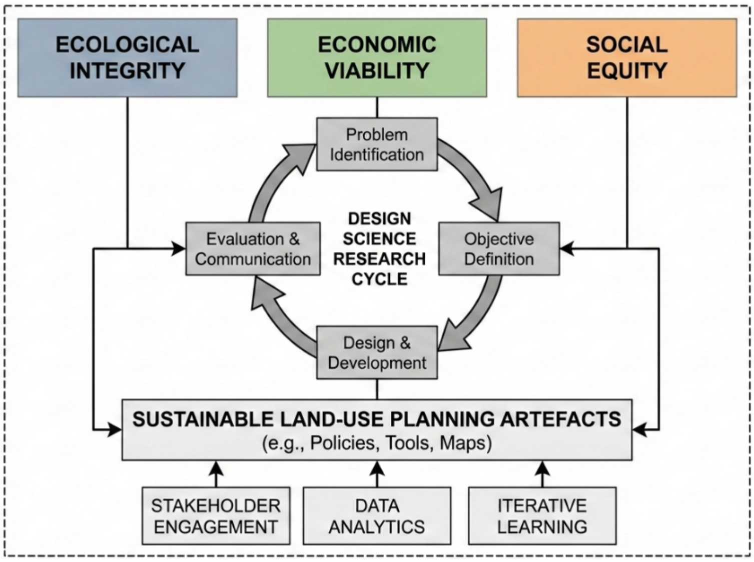

Figure 1. DSR framework integrating sustainability dimensions into land-use planning

2. Related Work

This study builds on a body of literature that addresses DSR from theoretical, methodological, evaluative, and applied perspectives, as well as domain-specific studies that motivate the need for decision support in land-use planning. To provide a coherent synthesis and avoid fragmented citation, the related literature is structured into four main streams.

2.1. Foundational DSR theory

The first stream establishes the theoretical foundations of DSR and defines its core concepts. Seminal work by Hevner et al. (2004) positions DSR as a problem-solving research paradigm focused on the purposeful design and evaluation of artifacts that address real-world problems. Within this paradigm, artifacts may take the form of constructs, models, methods, or frameworks, and their value lies in utility, rigor, and relevance.

Building on this foundation, Gregor and Hevner (2013) further clarify how DSR contributions should be positioned and communicated. They emphasize that design knowledge embodied in conceptual models and frameworks constitutes a legitimate and impactful research contribution, even in the absence of a fully instantiated software system. This perspective is particularly relevant for studies that aim to generalize decision logic across a class of problems rather than optimize a single technical solution.

Together, these foundational works provide the theoretical basis for treating a decision support framework for sustainable land-use planning as a valid DSR artifact and for evaluating its contribution in terms of transparency, robustness, and reusability.

2.2. DSR methodologies and research design guidance

The second stream focuses on methodological guidance for conducting DSR studies. Peffers et al. (2007) propose a widely adopted DSR Methodology that structures DSR into activities such as problem identification, objective definition, artifact design, demonstration, and evaluation. This process-oriented view has influenced numerous DSR applications across domains. March and Storey (2008) introduce DSR in the information systems discipline by outlining its foundations, significance, and role in addressing real-world problems, thereby framing the contributions of the special issue on DSR.

More recent contributions emphasize flexibility and methodological choice in DSR. Venable et al. (2017) discusses how researchers can select appropriate DSR methodologies depending on problem context, artifact type, and evaluation goals. Delport et al. (2024) provide updated methodological guidelines that highlight common challenges faced by DSR researchers, particularly when designing conceptual artifacts or working in cross-disciplinary settings. They stress the importance of abstraction, clarity of design requirements, and alignment between artifact purpose and evaluation strategy. Recent syntheses of DSR further consolidate these foundational principles and emphasize the role of abstraction and generalization in artifact design (vom Brocke et al., 2020).

The DSR Grid proposed by vom Brocke and Maedche (2019) further supports systematic planning of DSR studies by mapping design choices across multiple dimensions, such as problem relevance, artifact scope, and evaluation depth. In addition, Thuan et al. (2019) focus on the construction of research questions in DSR, emphasizing the distinction between design-oriented questions and explanatory questions.

These methodological contributions collectively inform the research design adopted in this study, particularly the choice to develop an implementation-independent framework, demonstrate it using a realistic planning context, and evaluate it through robustness and interpretability rather than technical performance alone.

2.3. Evaluation, knowledge production, and quality in DSR

The third stream addresses how DSR artifacts are evaluated and how they contribute to knowledge. Venable et al. (2016) propose the Framework for Evaluation in Design Science (FEDS), which emphasizes that evaluation strategies should be aligned with artifact maturity, purpose, and context. Rather than prescribing a single evaluation method, FEDS supports a range of formative and summative evaluations, including analytical, experimental, and qualitative approaches.

Baskerville et al. (2015) further enrich this perspective by introducing the concept of multiple genres of inquiry in DSR. They argue that a single DSR study may legitimately combine design, evaluation, and reflection, and that knowledge can be generated not only through empirical testing but also through structured reasoning and interpretive analysis.

These perspectives support the evaluation approach adopted in this study, where the emphasis is placed on decision transparency, robustness under uncertainty, and practical interpretability, rather than on predictive accuracy or system performance metrics.

2.4. Applied DSR and domain-oriented planning studies

The fourth stream includes applied and hybrid DSR studies, as well as domain-specific literature that motivates the research problem. Action design research, introduced by Sein et al. (2011), demonstrates how DSR can be conducted in close interaction with real-world contexts while maintaining theoretical rigor. Other applied studies, such as Apiola and Sutinen (2020), Castro et al. (2025), Teixeira et al. (2019), and Venkatesh et al. (2017), illustrate how DSR artifacts can take the form of decision aids, service designs, or assistance systems evaluated through practical use and stakeholder engagement.

In addition to applied DSR studies, domain-oriented planning research provides the problem context for this study. In particular, techno-environmental planning research conducted in protected areas, such as the Bombo-Lumene Hunting Estate and Reserve in the Democratic Republic of Congo (Monkenya et al., 2025), highlights the land-use nature of decision-making under environmental and regulatory constraints. These studies demonstrate that planning choices related to activity allocation, spatial configuration, and method selection are fundamentally land-use decisions requiring structured and transparent decision support.

2.5. Research gap

The reviewed literature indicates that while DSR provides a robust theoretical and methodological foundation for artifact-based research, and while land-use planning challenges are well documented in applied studies, there remains a gap in the form of generalizable decision support frameworks explicitly designed for sustainable land-use planning using a DSR approach. Existing planning studies often rely on case-specific analyses, while many DSR studies do not address spatial sustainability problems. This study addresses this gap by designing and evaluating a decision support framework that integrates sustainability criteria, constraints, and uncertainty within a DSR paradigm.

3. Research Methodology

3.1. DSR approach

DSR focuses on the purposeful creation of artifacts—such as models, methods, and frameworks—that address real-world problems, with scientific knowledge generated through the design and evaluation of these artifacts (Delport et al., 2024). This study adopts a DSR methodology to design and evaluate a decision support framework for sustainable land-use planning.

DSR is well suited to this research because it emphasizes both practical relevance and methodological rigor, making it appropriate for complex decision-making contexts characterized by multiple criteria, uncertainty, and regulatory constraints. Unlike descriptive or explanatory research approaches, DSR explicitly aims to produce actionable solutions while contributing transferable design knowledge. Following established DSR guidance, the contribution of this study is positioned as design knowledge embodied in a decision support framework, rather than as a fully instantiated software system (Gregor & Hevner, 2013).

The DSR process adopted in this study follows an iterative progression from problem identification and objective definition to artifact design, demonstration, and evaluation. This process is illustrated in Figure 2.

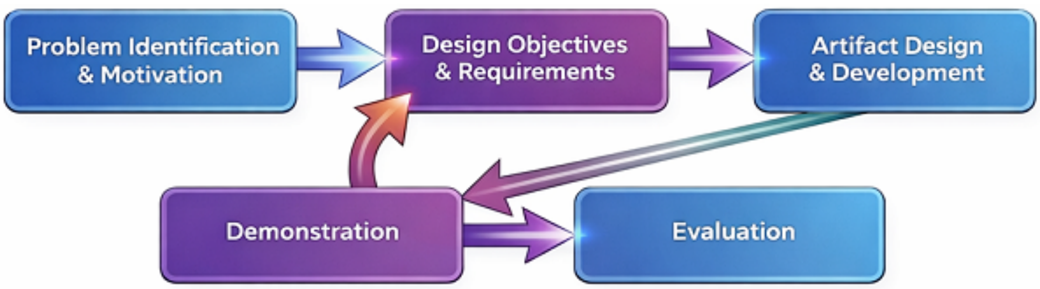

Figure 2. Iterative DSR process guiding artifact development and evaluation

3.2. Problem identification and design objectives

The research is motivated by the absence of systematic and reusable frameworks that support sustainable land-use decisions involving multiple criteria and uncertainty. As discussed in Section 1, existing land-use planning practices often rely on fragmented analyses that limit comparability, traceability, and robustness of decisions.

Based on this problem, the following design objectives were defined:

- support systematic evaluation of land-use alternatives across multiple sustainability dimensions;
- enable transparent and traceable decision logic;
- incorporate spatial and regulatory constraints into the decision process;
- address uncertainty and sensitivity to stakeholder preferences;
- allow adaptation to different land-use planning contexts.

These objectives guided the design and development of the proposed artifact.

3.3. Artifact design and development

The primary artifact of this research is a decision support framework for sustainable land-use planning. The framework was designed as a modular structure comprising a decision workflow, a multi-criteria evaluation model, and an uncertainty analysis component. Concepts from land-use planning, multi-criteria decision analysis, and sustainability assessment were employed as kernel theories to inform the design and ensure methodological rigor.

The artifact is implementation-independent, allowing it to be applied using different technical platforms, such as spreadsheets, GIS-based environments, or web-based decision support tools. This design choice supports generalizability and reuse across diverse planning contexts.

3.4. Demonstration and evaluation

The framework is demonstrated using a representative land-use planning scenario involving competing land-use alternatives. Evaluation focuses on assessing the framework's ability to produce transparent, consistent, and robust decision outcomes. Quantitative evaluation includes sensitivity analysis to examine the stability of alternative rankings under varying criteria weights, while qualitative evaluation considers the interpretability and practical usefulness of the framework for decision-makers.

The demonstration scenario is informed by real-world protected-area planning contexts, particularly techno-environmental exploration planning studies conducted in the Bombo-Lumene Hunting Estate and Reserve. These studies illustrate the land-use nature of decision-making under strict environmental and regulatory constraints and provide a realistic context for demonstrating the proposed framework.

3.5. Research contribution

In accordance with DSR principles, this study contributes both a validated decision support artifact and design knowledge in the form of explicit design objectives, architectural choices, and evaluation insights. The adopted methodology ensures that the proposed framework is not only practically relevant but also scientifically grounded and transferable to other sustainable land-use planning contexts.

4. Design of the Decision Support Artifact

4.1. Design requirements

The primary artifact developed in this study is a Decision Support Framework for Sustainable Land-Use Planning. In DSR terms, the artifact represents a conceptual model and decision-making method that structures complex land-use problems into a transparent, systematic, and reusable decision process. The artifact is designed to be implementation-independent, allowing its application across different geographic, institutional, and technological contexts.

Following methodological guidelines for DSR, the proposed decision support framework is positioned as a conceptual artifact that is intended to be applicable to a class of land-use planning problems rather than a single site-specific implementation (Delport et al., 2024).

The purpose of the artifact is to support land-use planners and decision-makers in evaluating alternative land-use options by explicitly integrating sustainability criteria, stakeholder preferences, spatial feasibility, and uncertainty considerations. Rather than optimizing a single objective, the artifact facilitates informed decision-making by making trade-offs among competing land-use objectives explicit and traceable.

The design of the artifact was guided by the following design requirements:

1. Multi-dimensional sustainability integration: The artifact must support the simultaneous evaluation of environmental, economic, social, and governance considerations.
2. Transparency and traceability: All assumptions, criteria weights, and evaluation steps must be explicit and open to scrutiny.
3. Feasibility awareness: Spatial and regulatory constraints must be incorporated to ensure that only permissible land-use alternatives are evaluated.
4. Robustness under uncertainty: The artifact must enable assessment of how sensitive decision outcomes are to changes in preferences and assumptions.
5. Generalizability and adaptability: The artifact must be reusable across different land-use planning contexts without reliance on case-specific parameters.

These requirements form the foundation of the artifact’s design and structure.

4.2. Framework architecture

The decision support artifact is organized into an integrated architecture consisting of three interrelated components: a decision workflow, a multi-criteria evaluation model, and an uncertainty assessment mechanism. The overall architecture of the proposed artifact and the interaction among these components are illustrated in Figure 3.

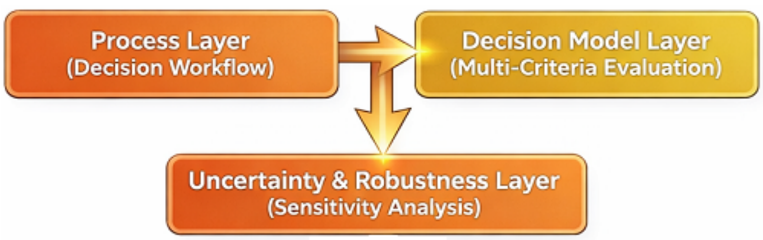

Figure 3. Architecture of the decision support artifact for sustainable land-use planning

The decision workflow provides a structured sequence of steps guiding the land-use planning process. It begins with problem definition and identification of planning objectives, followed by the specification of feasible land-use alternatives. Criteria selection and stakeholder preference elicitation are then conducted, after which alternatives are evaluated and ranked. A feedback mechanism allows iterative refinement of assumptions and preferences, supporting adaptive decision-making.

The multi-criteria evaluation model operationalizes the comparison of land-use alternatives. Using a multi-criteria decision analysis approach, the model aggregates heterogeneous criteria by combining performance scores with stakeholder-defined weights. Spatial and regulatory constraints, such as protected areas or zoning rules, are applied as feasibility filters prior to evaluation to ensure compliance with planning regulations.

In addition to supporting systematic decision-making, the proposed framework is compatible with participatory land-use planning practices, as it allows the integration of stakeholder preferences, expert judgment, and local knowledge into the evaluation of alternative land-use scenarios.

The uncertainty assessment mechanism examines the stability of decision outcomes under varying assumptions. By assessing how changes in criteria weights or input values influence alternative rankings, the artifact enables decision-makers to evaluate the robustness of planning outcomes and identify criteria that exert dominant influence on decisions.

4.3. Sustainability criteria for land-use planning

To ensure broad applicability, the artifact employs a generic sustainability criteria structure that can be adapted to different land-use contexts. The criteria are organized into four main dimensions.

- **Environmental criteria** address potential impacts on ecosystems, land cover, soil stability, and exposure to environmental risks.
- **Economic criteria** capture development costs, economic benefits, and accessibility to existing infrastructure.
- **Social criteria** reflect population needs, equity considerations, and community acceptance of land-use options.
- **Governance criteria** ensure compliance with regulatory frameworks and alignment with spatial planning policies.

This criteria structure provides a balanced representation of sustainability objectives while allowing planners to tailor specific indicators to local priorities and data availability.

4.4. Decision output and interpretation

The artifact generates a ranked set of land-use alternatives accompanied by explanatory outputs that detail the contribution of individual criteria and the results of sensitivity analysis. Rather than prescribing a single optimal solution, the framework supports decision interpretation by highlighting trade-offs among alternatives and clarifying how different sustainability priorities influence outcomes.

This emphasis on interpretability and transparency aligns the artifact with the normative and participatory nature of land-use planning. By making decision logic explicit, the artifact facilitates communication among planners, policymakers, and stakeholders and supports informed, defensible land-use decisions.

5. Demonstration and Evaluation

5.1. Demonstration scenario: Protected-area land-use planning context

The proposed decision support artifact was demonstrated using a protected-area land-use planning scenario informed by techno-environmental exploration planning practices in the Bombo-Lumene Hunting Estate and Reserve in the Democratic Republic of Congo. This reserve represents a highly constrained land-use environment in which economic activities are permitted only if they comply with strict environmental, spatial, and regulatory requirements, and where geospatial and remote sensing techniques have been used to support ecosystem monitoring and land-use control (Kalambay et al., 2024). In accordance with DSR guidelines, the artifact is demonstrated through a realistic planning context rather than full operational deployment, allowing evaluation of its decision logic, transparency, and robustness.

In the Bombo-Lumene context, land-use decisions require balancing conservation objectives with development-oriented activities, such as geological and geophysical exploration, while minimizing impacts on biodiversity and local communities. Prior studies emphasize planning choices such as prioritizing non-invasive airborne surveys, carefully orienting survey lines, and avoiding disruptive exploration techniques as effective mechanisms for reducing environmental disturbance. These choices are inherently land-use decisions, as they determine how, where, and under what conditions activities are permitted within a protected area.

For the purposes of this study, the Bombo-Lumene planning context was abstracted into a generic land-use decision problem involving competing land-use alternatives, including restricted-use zones, conservation-oriented areas, and controlled development activities. This abstraction enables demonstration of the decision support framework without reliance on site-specific operational data, while preserving the essential characteristics of protected-area land-use planning under environmental and regulatory constraints.

The relationship between the protected-area planning context, land-use alternatives, and the decision support artifact is illustrated in Figure 4.

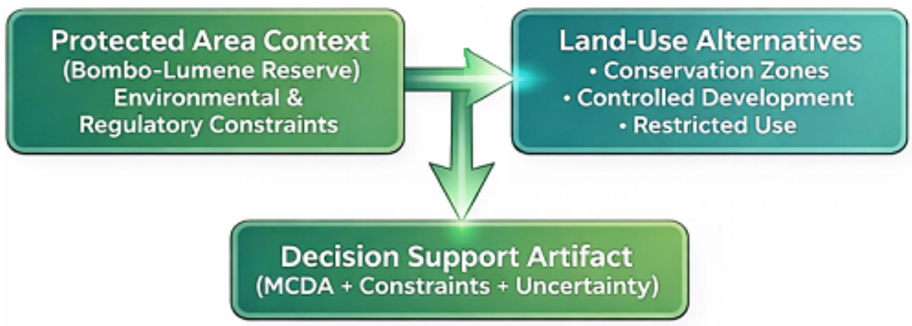

Figure 4. Demonstration context of the decision support artifact for sustainable land-use planning

5.2. Application of the decision support artifact

The demonstration followed the workflow defined by the proposed decision support artifact. First, the planning problem was specified in terms of sustainability objectives, with emphasis on environmental protection, regulatory compliance, and controlled development. Land-use alternatives were then defined to represent distinct planning strategies consistent with the constraints of a protected-area context.

Sustainability criteria were applied across environmental, economic, social, and governance dimensions, reflecting key considerations identified in techno-environmental planning studies of the Bombo-Lumene reserve. The selected criteria and their qualitative descriptions are summarized in Table 1. Criteria weights were assigned to represent a conservation-prioritized planning perspective, consistent with protected-area management objectives; the resulting weighting scheme is reported in Table 2. Spatial and regulatory constraints were incorporated as feasibility conditions within the framework, ensuring that land-use alternatives violating protection rules were excluded from further evaluation.

Table 1. Sustainability criteria used for evaluating land-use alternatives

Criterion ID	Sustainability Dimension	Criterion Name	Description	Measurement Scale	Data Type
C1	Environmental	Biodiversity Impact	Expected impact on habitats and species diversity	Qualitative (Low–High)	Expert judgment
C2	Environmental	Ecosystem Disturbance	Degree of physical disturbance to ecosystems	Qualitative (Low–High)	Expert judgment
C3	Economic	Economic Feasibility	Viability of the land-use option under constraints	Qualitative (Low–High)	Planning assessment
C4	Social	Community Impact	Expected impact on local communities and livelihoods	Qualitative (Low–High)	Stakeholder input
C5	Governance	Regulatory Compliance	Consistency with protected-area regulations	Binary / Ordinal	Regulatory rules

Table 2. Criteria weights reflecting a conservation-prioritized planning perspective

Criterion ID	Criterion Name	Sustainability Dimension	Weight	Rationale
C1	Biodiversity Impact	Environmental	0.30	Priority protection of sensitive habitats
C2	Ecosystem Disturbance	Environmental	0.25	Minimization of physical impacts
C3	Economic Feasibility	Economic	0.15	Secondary to environmental protection
C4	Community Impact	Social	0.15	Protection of local livelihoods
C5	Regulatory Compliance	Governance	0.15	Mandatory compliance requirement

Using the multi-criteria evaluation component of the framework, the remaining land-use alternatives were assessed and ranked based on their aggregated performance across the defined criteria. The resulting ranking of land-use alternatives is presented in Table 3. In addition to producing a ranking, the framework generated explanatory outputs that indicate the relative contribution of individual criteria to the overall results. These trade-off patterns are supported by transparent interpretation of how sustainability dimensions influence the final decision outcomes.

Table 3. Aggregated evaluation and ranking of land-use alternatives

Alternative ID	Land-Use Strategy	Feasible (Y/N)	Aggregated Score	Rank	Key Strengths	Key Trade-offs
A1	Conservation-Only Zone	Yes	0.82	1	Maximum ecological protection	Limited economic activity
A2	Restricted-Use Zone	Yes	0.68	2	Balanced protection and access	Moderate disturbance

A3	Controlled Development	Yes	0.55	3	Higher economic benefits	Increased environmental risk
A4	Intensive Development	No	–	Exc.	Regulatory non-compliance	–

5.3. Evaluation approach

Evaluation of the decision support artifact focused on assessing its utility, transparency, and robustness, in accordance with DSR principles. Rather than validating numerical predictions, the evaluation examined whether the artifact effectively supports structured, traceable, and defensible land-use decision-making in a protected-area context.

A sensitivity analysis was conducted by systematically varying criteria weights within plausible ranges to assess the stability of land-use alternative rankings. This analysis explored how shifts in planning priorities—such as increased emphasis on environmental protection or development feasibility—affected decision outcomes and whether ranking changes remained interpretable and consistent with planning expectations.

In addition, a qualitative evaluation was performed to assess the interpretability and practical usability of the framework. Particular attention was given to the clarity of the decision logic, the transparency and traceability of underlying assumptions, and the extent to which results could be clearly communicated to planners and stakeholders involved in protected-area management. Together, these evaluation activities provide evidence of the artifact's suitability for supporting sustainable land-use planning decisions under environmental and regulatory constraints.

5.4. Evaluation results

The evaluation results indicate that the proposed framework produces robust and interpretable decision outcomes under protected-area land-use constraints. Sensitivity analysis showed that alternative rankings remained stable across a wide range of criteria weight variations, particularly when environmental and governance criteria were prioritized, reflecting the conservation-oriented nature of protected-area planning.

When ranking changes occurred under alternative weighting scenarios, the framework clearly identified the criteria responsible for these changes, enhancing transparency and supporting informed discussion. The qualitative evaluation confirmed that the structured workflow and explicit criteria definitions improved the comprehensibility of planning decisions, compared to ad hoc or implicitly defined planning approaches commonly observed in techno-environmental studies.

5.5. Summary of demonstration and evaluation

Overall, the demonstration confirms that the proposed decision support artifact is well suited for sustainable land-use planning in protected areas, such as the Bombo-Lumene Hunting Estate and Reserve. By abstracting real-world techno-environmental planning practices into a generalized decision framework, the artifact enables transparent, robust, and reusable land-use decision-making. This demonstration satisfies the DSR requirement of showing the artifact's applicability in a realistic problem context while maintaining generalizability beyond a single case.

6. Discussion

This study demonstrates how a DSR approach can be used to develop a transparent and decision-ready framework for sustainable land-use planning. By structuring the decision process around explicit sustainability criteria, feasibility constraints, stakeholder preferences, and uncertainty analysis, the proposed framework addresses key limitations of conventional land-use planning practices. In particular, it enhances decision traceability and makes sustainability trade-offs explicit, thereby supporting more informed and defensible planning outcomes.

Compared to existing land-use decision support approaches, the proposed framework emphasizes reusability and methodological clarity rather than case-specific optimization. For example, GIS-based multi-criteria analysis has been widely applied to land suitability assessment in developing regions, providing valuable spatial insights but often remaining tightly coupled to local datasets and technical configurations (Thapa et al., 2025). Similarly, spatial scenario planning frameworks support exploration of alternative land-use futures under uncertainty but typically focus on generating plausible scenarios rather than structuring a generalizable decision logic (Sedighi et al., 2025). In contrast, the framework proposed in this study abstracts from specific spatial implementations and formalizes decision reasoning in a way that can be transferred across planning contexts.

The integration of sensitivity analysis further distinguishes the framework from many existing approaches. While recent reviews highlight the growing availability of digital land-use decision support tools, they also note recurring challenges related to transparency, interpretability, and robustness of results (Poggi et al., 2025). By explicitly examining how changes in criteria weights affect decision outcomes, the proposed framework enables decision-makers to understand the implications of shifting priorities and evolving policy objectives—an essential feature in dynamic land-use contexts.

The demonstration in a protected-area planning context illustrates the value of abstraction in DSR. Previous techno-environmental planning studies addressing protected-area exploration challenges have relied primarily on site-specific analyses to minimize environmental impacts through careful selection of exploration techniques and spatial configurations. While operationally effective, such approaches are often difficult to generalize. The proposed framework builds on these insights but generalizes them into a reusable land-use decision support artifact applicable across diverse protected-area settings.

From a methodological perspective, the study reinforces the suitability of DSR for addressing spatial planning and sustainability challenges. Consistent with DSR principles, the primary contribution lies in the design of a reusable framework and associated design knowledge applicable to a class of land-use planning problems, rather than in predictive accuracy or system deployment (Gregor & Hevner, 2013).

From a practical perspective, the proposed framework offers planning agencies and policymakers a structured decision-support approach for evaluating land-use alternatives under multiple sustainability criteria and uncertainty. By enabling systematic comparison of scenarios, the framework can support evidence-informed policy development, spatial planning, and sustainability assessments. For practitioners, including urban planners and environmental managers, the framework provides a flexible tool that can be adapted to different planning contexts and data availability levels, facilitating the integration of sustainability considerations into routine planning and decision-making processes.

Several limitations should be acknowledged. The demonstration relied on an abstract planning scenario and hypothetical preference structures rather than empirical data and direct stakeholder engagement. In addition, the framework was evaluated analytically rather than through full operational implementation. These limitations reflect the scope of a short DSR study and highlight opportunities for future work, including empirical calibration, participatory evaluation, and integration with spatial decision support systems.

7. Conclusion

This study presented the design and evaluation of a decision support framework for sustainable land-use planning using a DSR approach. Addressing the complexity of land-use decisions involving multiple sustainability objectives, uncertainty, and regulatory constraints, the research responds to the need for transparent and reusable decision support tools applicable across planning contexts.

The primary contribution is an implementation-independent decision support artifact that structures land-use decision problems through explicit sustainability criteria, feasibility constraints, and uncertainty analysis. By embedding decision logic within a clear and traceable workflow, the framework supports defensible evaluation of land-use alternatives while remaining adaptable to different planning settings. The study thus contributes transferable design knowledge applicable to a class of land-use planning problems.

The framework was demonstrated using a protected-area planning scenario informed by techno-environmental practices in the Bombo-Lumene Hunting Estate and Reserve, showing its ability to support systematic comparison of competing land-use strategies. Sensitivity analysis indicated that decision outcomes remain interpretable under changing planning priorities.

Limitations include the use of an abstract scenario and the absence of full operational implementation. Future work may extend the framework through empirical calibration, stakeholder engagement, or integration with spatial decision support systems. Overall, the study illustrates the potential of DSR to advance transparent and decision-ready land-use planning.

Authorship Contribution Statement

The author is solely responsible for the conceptualization, methodology, analysis, and manuscript preparation.

Conflict of Interest

The author declares no conflict of interest.

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