From Practice to Decision Models: Eliciting and Structuring Requirements Prioritization Criteria for Military Systems and Materiel

Igor Sena Melo[1], Orivalde Soares da Silva Júnior[1], Antonio Eduardo Carrilho da Cunha[1]
[1]Military Institute of Engineering (IME), Rio de Janeiro/RJ – Brazil

***Abstract* – Prioritizing requirements for complex defense systems is a challenging task due to the multidimensional nature of military projects and the absence of standardized decision criteria. Although many studies propose multicriteria decision-making (MCDM) techniques for requirements prioritization, limited attention has been given to identifying and structuring the prioritization criteria themselves, especially in Military Systems and Materiel (MSM) projects. This paper proposes a structured approach for eliciting and weighting prioritization criteria in MSM development. The methodology combines a Systematic Literature Mapping (SLM), semi-structured expert interviews, thematic analysis, and a Delphi-based Fuzzy Analytic Hierarchy Process (FAHP). The SLM identified candidate criteria and methodological trends, while interviews with 19 defense specialists validated the criteria. Subsequently, 18 stakeholders evaluated the criteria through a two-round Delphi-FAHP process. Results show that five criteria represent the main decision dimensions for defense Research and Development prioritization.**

***Keywords* – Requirements Prioritization, Defense, FAHP**

I. INTRODUCTION

The modern defense landscape has seen an increase in technological complexity, uncertainty in geopolitics, and the integration of cyber-physical systems, presenting considerable difficulties for defense research and development initiatives [1]. Modern military systems should be able to function in environments that are unpredictable and risky and ensure interoperability, resilience, adaptability, and technological sovereignty [2]. In such situations, Systems Engineering becomes a critical tool for dealing with the complexity of defense projects and matching technological advancements to the needs of the system [3]. As such, Requirements Engineering becomes necessary, especially prioritizing requirements, since not all requirements can be implemented due to resource constraints, tight deadlines, and different stakeholder perspectives [4].

Despite the fact that various MCDM methods for requirements prioritization, including AHP, TOPSIS, and PROMETHEE, have been described in the literature, the vast majority of the existing literature focuses on mathematical solutions and prioritization algorithms and pays little attention to criteria identification and validation performed during decision making [5]. It is particularly relevant to the field of Military Systems and Materiel (MSM) projects, where priorities should be taken into account not only from the perspective of technical and economic factors but also from an operational, strategic, and even doctrinal viewpoint [6]-[7].

I. Sena Melo, igor.melo@ime.eb.br; O. S. da Silva Júnior, orivalde@ime.eb.br; A. E. C. da Cunha, carrilho@ime.eb.br

This paper proposes a framework for eliciting and weighting requirements prioritization criteria in MSM projects. First, a Systematic Literature Mapping (SLM) identifies candidate criteria and methodological trends. The research methodology, presented in Section III, combines expert interviews, thematic analysis, and a Delphi-based Fuzzy Analytic Hierarchy Process (FAHP) to identify, consolidate, and weight the prioritization criteria. The results, discussion, and conclusions are presented in Sections IV, V, and VI, respectively.

II. SYSTEMATIC LITERATURE MAPPING

This review followed the Systematic Literature Mapping (SLM) methodology proposed by Petersen [8], including planning, execution, and result mapping phases. Searches were conducted in Scopus and Web of Science using combinations of the term "requirement*" and prioritization-related keywords connected using the NEAR/2 operator (CE1), including terms such as "prioritization," "criteria," "method," and "evaluation." The review considered studies published between 2014 and 2025 (CE2) addressing requirements prioritization and multicriteria decision-making approaches.

The selection and filtering process is summarized in Fig. 1. Non-peer-reviewed sources such as theses and books were excluded (CE3), followed by non-English studies (CE4), duplicate studies (CE5), studies focused on agile methodologies (CE6), unrelated abstracts (CE7), inaccessible studies (CE8), and studies not addressing prioritization criteria or multicriteria methods (CE10). Backward snowballing (CE9) was employed to identify additional relevant studies. Finally, all remaining studies were assessed according to quality criteria (CE11). From the 28 studies assessed through full-text reading, 23 satisfied the minimum quality criteria and were included in the final analysis.

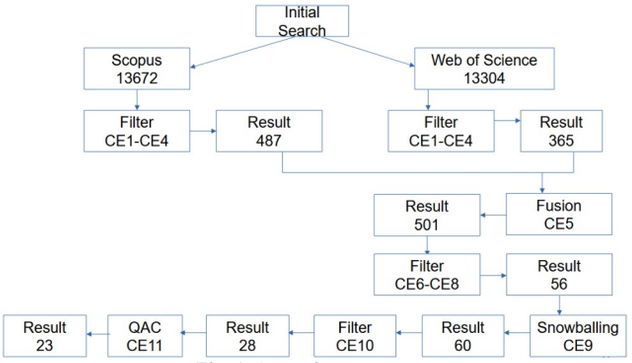

Fig. 1. Screening process.

The analysis of the 23 selected studies, shown in Table 1, revealed significant variation in how prioritization criteria were defined, although expert-based approaches were the

most common. Several studies combined multiple methods; thus, references may appear in multiple categories and frequencies represent method occurrences, not unique studies. The stakeholder-based approach was the most frequently adopted, appearing in 11 studies. In these cases, the criteria were defined through the participation of specialists, domain experts, steering committees, or collaborative discussions. Some studies also combined stakeholder input with other methods, such as categorization, hierarchical models, or structured validation processes. Variations included expert validation after initial identification of needs and stakeholder consultation followed by explicit selection stages.

TABLE I. METHODS USED TO ELICIT PRIORITIZATION CRITERIA IN THE LITERATURE

Articles	*Method to identify the criteria*	*Quantity*
[14]-[24]	Stakeholder discussion	11
[10][15][16] [20]-[22]	Author selection	6
[20] [10] [23] [24]	Literature review	4
[20]	Survey	1
[24]	Focus group	1
[25]	Meta-model extraction	1
[19]	Direct observation	1
[26]-[31]	Not specified	6

From the 23 studies selected in the SLM, all prioritization criteria used in requirements evaluation processes were manually extracted. Initially, the criteria were recorded exactly as presented in each study, including differences in spelling, terminology, and plural forms. In the next stage, the terms were normalized and consolidated to remove semantic redundancies. Conceptually similar expressions, such as "business value" and "value to the project," were grouped into broader unified criteria based on their meaning within requirements engineering and multicriteria decision-making contexts. This process resulted in an initial set of 36 consolidated criteria. After the consolidation stage, a reduced and more representative set of criteria was obtained, allowing a clearer analysis of which attributes are most frequently used in the literature. Table 2 presents the most commonly employed criteria and their frequencies of occurrence.

TABLE 2. CRITERIA AND FREQUENCY OF OCCURRENCE IN THE ANALYZED STUDIES

Criteria	*Frequency*	*Criteria*	*Frequency*
Cost	13	Ease of Use	2
Importance	10	Dependency	2
Risk	6	Environment	2
Value	5	Product Differentiation	2
Time	5	Satisfaction	2
Difficulty	4	Efficiency	2
Safety	3	Effectiveness	2
Strategic Benefit	3	Volatility	2

The criteria that appeared only once in the analyzed studies were interpreted as context-specific attributes associated with particular applications or case studies. Although potentially relevant in certain domains, these criteria did not demonstrate sufficient recurrence to justify their inclusion as essential attributes during the preliminary stakeholder phase. The findings contributed to the identification of candidate prioritization criteria and revealed that many studies fail to clearly explain how criteria are defined and operationalized within decision models. This lack of transparency highlighted the importance of adopting systematic approaches for criteria elicitation and structuring. Meanwhile, most recurrent prioritization dimensions in the literature, particularly cost, importance, risk, value, time, and difficulty were identified.

Together, the results of mapping established a structured foundation for the empirical phase of the study. These findings guided the interview protocol, supported the selection of candidate criteria, and influenced the development of the FAHP weighting model.

III. METHODOLOGY

This paper adopts a sequential exploratory mixed-method design combining qualitative and quantitative approaches to identify and weight prioritization criteria for MSM. The methodology was chosen due to the lack of consolidated prioritization criteria in the literature. The empirical phase began with qualitative interviews involving 19 specialists from different areas of the defense innovation ecosystem to understand how requirements prioritization decisions are perceived and conducted in defense projects. The overall research design combines three methodological stages: a SLM, a qualitative exploratory phase, and a quantitative multicriteria phase using the Delphi method and the Fuzzy Analytic Hierarchy Process (FAHP) [32]. The SLM provided the theoretical basis and candidate criteria, the interviews refined the criteria according to the MSM context, and the Delphi-FAHP process enabled the iterative elicitation and refinement of criteria weights.

The criteria elicitation was inspired by the stakeholder-oriented perspective of Strategic Options Development and Analysis (SODA) [33], particularly its emphasis on capturing stakeholders' perspectives in the structuring of complex problems. However, no formal cognitive mapping was performed; instead, thematic consolidation, redundancy elimination, and iterative refinement were used to structure the criteria. Fig. 2 presents the methodological framework adopted for criteria elicitation, consolidation, and weighting in this study.

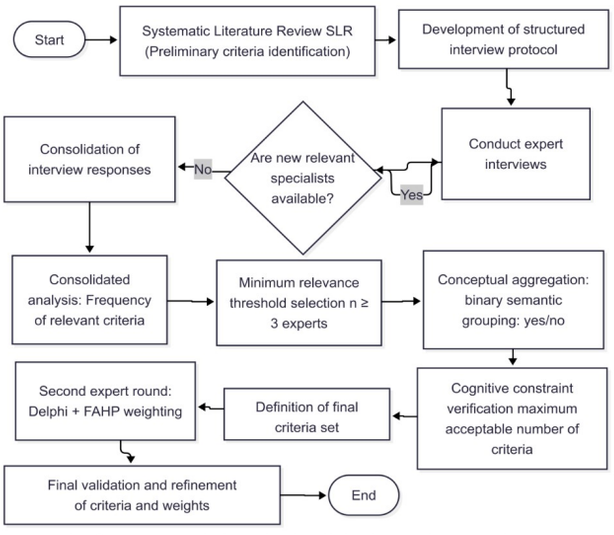

Fig. 2. Framework for criteria elicitation and structuring.

The process begins with a SLM, which provides an initial set of candidate prioritization criteria. These findings support the development of a structured interview protocol applied

through iterative expert interviews until thematic saturation is achieved. The collected responses are then consolidated and analyzed according to recurrence and perceived relevance, allowing the exclusion of less significant criteria. Subsequently, semantically similar criteria are grouped to reduce redundancy while preserving the main decision dimensions. The generated structure is further optimized using cognitive constraint verification, which guarantees a small number of criteria that can be easily used in real-life decision-making scenarios. Lastly, the consolidated criteria are verified and weighted by using the Delphi method and FAHP technique, which helps in achieving expert agreement on weights and consistency of criteria.

Data collection was conducted through semi-structured interviews organized into four analytical blocks: participant characterization, current decision-making processes, explicit prioritization criteria, and implicit or informal practices influencing decisions. The interviews incorporated criteria identified in the SLM as discussion support, while still allowing new contextual factors to emerge from expert experience. A total of 19 specialists from the Brazilian Army participated in the study, with interviews conducted remotely between January and February 2026.

Snowball sampling was adopted to identify qualified experts with experience in MSM projects. To reduce network bias, participants were selected from different military organizations and decision-making roles.

The interview data were transcribed and analyzed through thematic analysis using open and axial coding procedures. Initially, 11 candidate criteria derived from the literature review and preliminary interviews were considered. The coding process enabled the extraction of decision factors, their grouping into thematic categories, and the consolidation of overlapping concepts into five final prioritization criteria. Reliability was supported through periodic reviews and researcher discussions.

Following the qualitative phase, the consolidated criteria were evaluated through a Delphi-based FAHP process. Experts completed pairwise comparison matrices over two Delphi rounds, enabling weight elicitation, iterative refinement, and consistency verification.

FAHP was selected because the objective of this stage was to determine the relative importance of the consolidated prioritization criteria rather than rank alternative requirements. Since only five final criteria were considered, pairwise comparisons were cognitively manageable and enabled more precise judgments than direct rating scales. The method also supports consistency verification through the Consistency Ratio (CR), which is valuable when collecting judgments from experts with different professional backgrounds. Additionally, FAHP allows the use of linguistic assessments (e.g., “moderately more important” or “strongly more important”), represented by fuzzy numbers to capture uncertainty and vagueness in human judgment.

In this study, trapezoidal fuzzy numbers were adopted following the trapezoidal fuzzy AHP approach described in [34]. This approach preserves compatibility with Saaty’s AHP scale while incorporating uncertainty into the decision process. Given the variability in expert judgments and the uncertainty inherent in defense decision-making, FAHP was considered more suitable than classical AHP due to its ability to handle uncertainty and provide greater robustness in complex decision environments.

Nineteen specialists participated in the qualitative interview phase. Subsequently, eighteen of these participants provided valid pairwise comparison matrices for the Delphi-FAHP weighting process. Thus, the qualitative phase comprised 19 participants, whereas the quantitative FAHP analysis was based on 18 valid individual judgment matrices.

Two aggregation techniques were employed: Aggregation of Individual Judgments (AIJ) and Aggregation of Individual Priorities (AIP). AIJ was used to aggregate the individual pairwise comparison matrices through the geometric mean, producing a representative group matrix from which the consensus criteria weights were obtained. AIP was used to aggregate the individual priority vectors obtained from each stakeholder, allowing the group-level priorities to be compared with the AIJ results and the variability among individual judgments to be examined.

All procedures involving human participants followed institutional ethical guidelines. Participation was voluntary, informed consent was obtained, and all personally identifiable information was removed to ensure confidentiality.

IV. RESULTS

The analysis shows that the process of requirements prioritization in MSM projects is rather informal and poorly systematized. Requirements are categorized as either absolute or desirable, where absolute requirements are considered essential for accomplishing the mission. Priority ranking methods and weighting requirements are not utilized successfully and are decided by personal opinion, discussion, hierarchy, and precedent.

Some experts mentioned that numerous requirements were simply taken from previous projects without any re-assessment. The other major problem is the abundance of absolute requirements, which limits flexibility and causes complications. It was also noted that there were difficulties associated with distinguishing requirements and technical specifications. This caused an inflation of requirements and complicated their evaluation and prioritization. Moreover, from the interviews, it became clear that verification and validation abilities have a great impact on priorities because certain technically possible requirements are hard to verify due to the absence of infrastructure and specific resources. The respondents also noted that there are no common requirements elicitation and prioritization guidelines within the organization, which led to the heterogeneity of approaches. Finally, the importance of ensuring the traceability of requirements to mission goals was recognized as necessary to reduce development and verification efforts.

The interview analysis followed a structured consolidation process in which raw concepts extracted from the interviews, such as maintenance cost and safety, were progressively grouped into broader categories and later refined into a final set of consolidated prioritization criteria. The results showed that requirements prioritization in MSM projects is inherently multidimensional, involving operational, technical, strategic, and organizational aspects simultaneously.

In terms of operational issues, mission-oriented factors linked to CONOPS [6] and mission profiles were identified as the most significant drivers of prioritization. It is essential that requirements which are crucial for mission execution

have the highest priority. In terms of technical aspects, relevant factors include *costs, technological feasibility, maintainability, integration difficulty, testing, technological maturity, and innovation potential*. *Strategic and its organizational aspects, including industrial robustness, logistics, and compliance with defense policies*, are also important for complicated defense projects.

Furthermore, there appeared the issue of the practical side of using too many criteria in prioritization models. As was stated by the interviewees, an MSM program may consist of several hundreds of requirements, and hence the complexity of such models would be unacceptable. The majority of the interviewed specialists (9) suggested that only five criteria were acceptable for such prioritizations. To be exact, on the basis of the data acquired during the survey, 9 specialists suggested that the highest number of criteria was 5, 3 specialists mentioned 7 criteria, 2 specialists mentioned 9 criteria, 1 specialist mentioned either 4 or 10 criteria, while 3 did not mention any figures.

Five participants highlighted that prioritization criteria may vary depending on whether the decision context involves off-the-shelf acquisition or research and development (R&D). To ensure methodological consistency, this study standardized the analysis to the MSM R&D context. Among all interview topics, the definition of prioritization criteria presented the greatest divergence among experts, leading to a two-phase elicitation process composed of selection and conceptual aggregation.

In the selection phase, literature findings and expert judgments were combined to define the initial pool of criteria. From the literature, the most recurrent criteria were Cost, Importance, Risk, Value, Time, and Difficulty, although conceptual overlaps were identified between Value and Importance and between Difficulty and Risk. The interviews contributed additional context-specific criteria, including Impact, Performance, Safety, Technical Risk, Requirement Integration, Verification Risk, Volatility, Innovation, and Political Factor. Criteria classified as "not relevant" by at least 16 of the 19 participants were excluded from further analysis. As a result, three criteria were removed: Innovation and Political Factor, each considered not relevant by 18 participants, and Volatility, considered not relevant by 17 participants

During the aggregation process, it became clear that among the 19 experts, 16 considered Performance to be part of Mission Impact, while 17 supported the inclusion of Safety into Mission Impact. Requirement Integration was integrated within Technical Risk by the agreement of 18 experts because of its close relation with system complexity and technology maturity. In contrast, Verification Risk remained an individual criterion, where 10 experts agreed on the independency of Verification Risk, 3 favored its integration with Technical Risk, while 6 considered Verification Risk as irrelevant in this context. Ultimately, the resulting criteria priority model included five criteria: Mission Impact, Total Cost, Schedule, Technical Risk, and Verification Risk, with their meaning summarized on Table 3.

The proposed framework is aligned with the Brazilian Army's NEGAPEB standard [6], incorporating the five criteria: Mission Impact, Total Cost, Schedule, Technical Risk, and Verification Risk. All experts considered this structure appropriate for MSM prioritization because it balances clarity and practicality. It was also observed that qualitative evaluation tables represent the best way since they provide flexibility and transparency of the judgment representation as well as maintain operability.

TABLE 3. CONSOLIDATED PRIORITIZATION CRITERIA

Criteria	***Definition***
Mission Impact	Degree to which the implementation of the requirement contributes to achieving the mission, considering jointly: (i) direct operational impact, (ii) required performance for mission execution, and (iii) consequences to operational and functional safety resulting from its non-implementation.
Total Cost	Total financial effort associated with requirement implementation, including acquisition, development, integration, system adaptation, and lifecycle impacts.
Schedule	Time required to implement the requirement, from the start of development to integration, validation, and operational availability.
Technical Risk	Degree of uncertainty associated with implementing the requirement, based on the national technological maturity and the complexity of the required integration.
Verificati-on Risk	Degree of uncertainty associated with the institutional capability to verify and validate the requirement in the national context.

The values of the Consistency Ratio (CR) for 18 stakeholders who gave valid judgments in the first Delphi round varied from 0.03 to 0.18, with the mean value of 0.12. After having received individual feedback, the stakeholders with CR exceeding the acceptable level (0.10) were asked to reconsider their judgments. At first, 10 stakeholders had CR $\leq$ 0.10, while 8 stakeholders had CR > 0.10. In the second Delphi round, all stakeholders had CR $\leq$ 0.10, CR varying from 0.03 to 0.09, with the mean value of 0.087.

The FAHP results revealed a strong dominance of Mission Impact, which consistently received the highest weights among stakeholders, reflecting the operational focus of defense systems as shown in Fig.3.

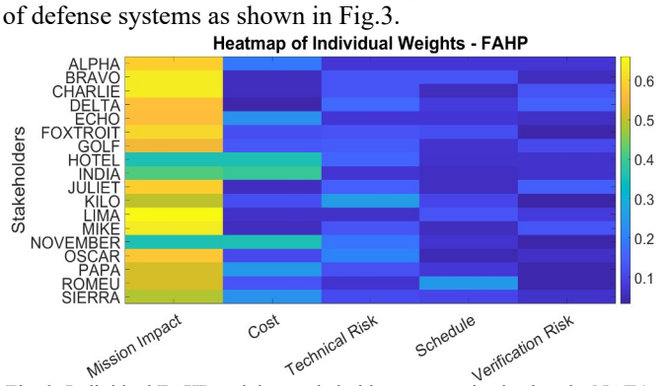

Fig. 3. Individual FAHP weights; stakeholders anonymized using the NATO phonetic alphabet.

Only three stakeholders assigned weights below approximately 45% to this criterion. In contrast, Cost presented the greatest variability, indicating significant disagreement regarding its importance and highlighting trade-offs between operational needs and budget constraints. Technical Risk showed intermediate variability, while Schedule and Verification Risk consistently received lower and more homogeneous weights. The coefficient of variation (CV) corroborated these results. Mission Impact had the minimum CV (16.9%), which implies high consistency, while Cost had the maximum CV (70.8%), thus making it the most controversial criterion. Technical Risk, Schedule, and Verification Risk had CVs in between, implying medium-level consistency among experts.

The priority vector was determined using the AIJ technique, in which the individual pairwise comparison

matrices were combined through the geometric mean into one common matrix. In parallel, AIP was used to aggregate the individual priority vectors and assess differences among stakeholder judgments. As seen from the FAHP outcomes (Fig. 4), Mission Impact gained the highest defuzzified weight (0.57), indicating that it was the most important criterion. Moreover, Mission Impact had the largest fuzzy interval, reflecting fuzziness in the aggregated linguistic judgments rather than stakeholder variability.

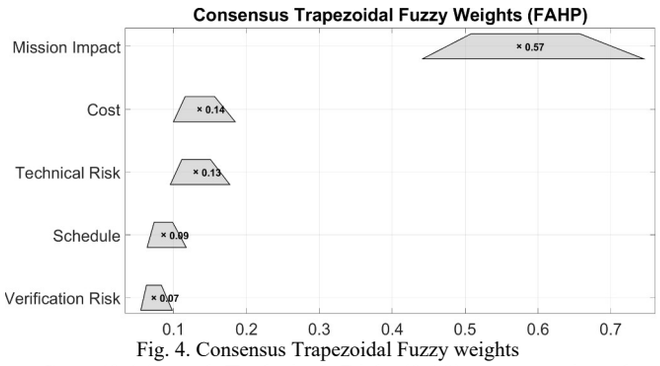

Fig. 4. Consensus Trapezoidal Fuzzy weights

Cost (0.14) and Technical Risk (0.13) were assigned a medium value on the scale, having almost identical fuzzy sets, which indicates that economic restrictions and technical feasibility were equally significant in the decision-making process. The lowest weight values and the least degree of variance were assigned to Schedule (0.09) and Verification Risk (0.07), indicating comparatively lower importance in the aggregated weighting. The AIJ-aggregated matrix had a CR of 0.008, distinct from the mean individual CR of 0.087 in the second Delphi round, which indicates high consistency of the group matrix. Furthermore, the fact that opinions provided by different stakeholders differed from one another shows the applicability of the FAHP approach since fuzziness allows capturing uncertainty in the decision-making process. The combined use of AIJ and AIP increases the transparency of the weighting process by providing both consolidated group priorities and information on differences among stakeholder judgments.

V. DISCUSSION

The findings indicate that the priority setting process in defense research and development is based on mission-oriented criteria, with cost, time and risk playing a secondary role. The set of criteria identified proved to be consistent with the MCDM literature concerning the relevance of cost, importance, risk, schedule and performance criteria, but also offered modifications of a contextual nature pertaining specifically to MSM programs. In particular, performance and safety criteria were merged in the Mission Impact category, while requirement integration was added to the Technical Risk category, taking into consideration the unique circumstances of defense systems development. The addition of the Verification Risk criterion underscores the significance of institutional capacity to test and the need for technological independence, which are factors not normally considered in generic priority setting frameworks.

The results showed a significant difference in the evaluations made by different stakeholders on the relative importance of the prioritization criteria. The differences were linked to profession, position in the organization, development of the project, strategic environment, and personal experience. Stakeholder perspectives differed according to professional role and experience. Management stakeholders tended to emphasize Cost and Schedule, whereas technical experts placed greater emphasis on Performance, Safety, and Technical Risk. In the aggregated FAHP results, however, Schedule received a weight of 0.09.

From a theoretical perspective, this study contributes to the literature by shifting the focus from prioritization algorithms toward the identification and structuring of decision criteria. Practically, the framework supports more transparent, traceable, and consistent decision-making in military R&D projects. The variability observed in stakeholder judgments further justifies the adoption of methods capable of representing uncertainty, such as FAHP and future stochastic simulations. Finally, the research indicates the value of integrating qualitative and quantitative approaches to develop context-specific prioritization frameworks for complex defense systems.

VI. CONCLUSION

This paper proposed a structured framework for requirements prioritization in MSM projects by integrating literature evidence, expert knowledge, Delphi-based iterative refinement, and FAHP weighting. The results demonstrated that Mission Impact is the dominant prioritization criterion, followed by Cost, Technical Risk, Schedule, and Verification Risk, reflecting the operational nature of defense decision-making. The research also highlighted the limitations of informal and experience-based prioritization practices, proposing a more transparent and traceable decision-support approach aligned with the Brazilian Army context. Although limited to the Brazilian defense R&D environment, the study provides an empirically grounded set of prioritization criteria that can support future multicriteria decision-making models for complex defense systems.

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