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Legal Risk – Return Assessment of Public Financing Instruments

An Integrated Decision-Making Approach

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Abstract: Public financing instruments play a vital role in supporting fiscal stability, yet the main problem lies in the lack of comprehensive evaluation frameworks that integrate legal risk with financial performance. Existing practices often focus on cost-based indicators, while critical factors such as legal certainty, contingent liabilities, and institutional capacity are not systematically analysed. The literature also shows a significant gap in identifying and prioritising these multidimensional criteria within a unified decision-making structure. This study aims to develop a robust model that evaluates public financing strategies by incorporating both financial and legal dimensions. To address this gap, a novel decision-making model is proposed by integrating CRITIC and RAWEC techniques with Fermatean fuzzy sets to better capture uncertainty in expert judgments. The findings indicate that corporate and administrative applicability and contingent liability risk are the most critical criteria, while public–private partnership-supported instruments are the most suitable strategies. The proposed model contributes to the literature by offering a more flexible and realistic analytical framework. It is recommended that policymakers prioritise risk sharing mechanisms and strengthen institutional capacity for more sustainable financing decisions.

Keywords: public financing, legal risk, decision-making model, fuzzy sets, public–private partnership

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1. Introduction

Public financing instruments play a central role in enabling governments to finance budget deficits, support public investments and maintain macroeconomic stability. However, these instruments should not be evaluated only in terms of financial return and cost. Legal risk, regulatory certainty, public debt sustainability, and governance quality are also critical dimensions that shape their overall effectiveness. In many practical settings, the selection of public financing tools is largely based on short-term fiscal indicators such as interest rates or borrowing costs. This narrow focus often ignores the broader institutional and legal environment in which these instruments operate (Basse, 2020). As a result, potential legal uncertainties, changes in regulatory frameworks, and governance weaknesses may not be systematically incorporated into decision-making processes. This creates vulnerabilities that may increase fiscal risks in the long run. For instance, unclear legal provisions or weak enforcement mechanisms can reduce investor confidence and increase borrowing costs indirectly (David et al., 2022). Similarly, insufficient attention to governance quality may lead to inefficiencies in fund allocation and monitoring. Therefore, a more comprehensive evaluation framework is needed. Such a framework should integrate financial, legal and institutional perspectives in a balanced way. This approach would support more sustainable and resilient public financing decisions.

To achieve a balanced legal risk and return structure in public financing, several strategic instruments can be considered. Traditional government bonds represent one of the most established tools, as they are issued under a clear legal framework and are widely accepted by investors. In addition, thematic or purpose-driven public bonds, such as green or social bonds, provide targeted financing for infrastructure, environmental, or social projects while enhancing transparency and accountability. Public investment funds also play an important role by pooling resources and allocating them through structured mechanisms supported by the state (Rho & Saenz, 2021). Furthermore, public–private partnership-based financing instruments allow for the sharing of legal and financial risks between the public and private sectors, which can improve efficiency and reduce fiscal pressure. Direct public guarantees constitute another strategy, where the state explicitly supports borrowing or project financing, thereby reducing perceived risk for investors. Conditional or limited guarantees introduce greater flexibility by linking state support to specific conditions, although they may create off-budget risks (Hasse et al., 2024). Finally, off-budget financing instruments, such as special purpose funds or semi-public entities, provide alternative channels for financing but require careful monitoring to ensure transparency and fiscal discipline.

In this study, a public financing instrument is defined as a specific financial or institutional mechanism through which the public sector mobilises, facilitates, channels, or structures resources to finance public expenditures, investments, or policy objectives while allocating the associated financial and fiscal risks. This concept should be distinguished from a public financing strategy. A financing strategy represents the broader policy framework through which a government determines the combination, sequencing, timing, and management of different financing instruments in accordance with its fiscal objectives, financing needs, risk preferences and institutional constraints. Financing instruments are therefore

the individual mechanisms available to policymakers, whereas a financing strategy concerns how these instruments are selected and combined within an overall financing approach. The instruments examined in this study represent a selected set of alternative financing mechanisms relevant to the legal, financial and institutional dimensions considered in the analysis. They are not intended to constitute an exhaustive taxonomy of all public financing instruments, as governments may also employ other conventional or context-specific financing mechanisms depending on their fiscal, legal and institutional environments.

The selection of these strategies requires a multidimensional evaluation based on several key criteria. Legal certainty is one of the most important factors, as it reflects the clarity, predictability, and consistency of the legal framework governing each instrument. Closely related to this is regulatory change risk, which captures the likelihood of changes in laws or administrative practices that may affect financial outcomes. Another critical criterion is the impact on public debt sustainability, as different instruments have varying implications for the long-term debt burden (Izumi, 2020). Financial return and funding efficiency also play a role, particularly in terms of cost advantages and diversification of funding sources. Budget transparency and accountability are equally important, as they determine how easily the use of funds can be monitored and audited. In addition, contingent liability risk must be considered, especially for guarantee-based instruments that may generate hidden fiscal obligations. Institutional and administrative feasibility reflects the capacity of public authorities to implement and supervise these tools effectively (Gootjes & de Haan, 2022). Market confidence and legal credibility influence investor perceptions and willingness to participate. Finally, flexibility in times of crisis determines how adaptable these instruments are under economic stress conditions.

Determining priority strategies for managing the legal risk and return balance of public financing instruments is essential for timely and effective policy implementation. Without clear prioritisation, governments may struggle to respond quickly to emerging fiscal challenges, which can lead to inefficiencies and increased economic vulnerability. In cases where inappropriate instruments are selected, the consequences may extend beyond financial losses and negatively affect overall economic stability. Despite the importance of this issue, the existing literature provides limited guidance on identifying and ranking the most critical criteria in a systematic manner (Saiegh & Biglaiser, 2024). This gap creates significant challenges for both policymakers and researchers. The absence of comprehensive models that integrate legal, financial, and institutional dimensions may result in fragmented analyses and inconsistent policy recommendations. Moreover, the lack of empirical and methodological studies in this area reduces the ability to generalise findings across different contexts. As a result, decision makers often rely on simplified approaches that do not fully capture the complexity of public financing dynamics (Greco et al., 2025). Therefore, addressing this research gap is crucial for improving the quality and reliability of public finance strategies.

This study aims to develop priority strategies to ensure a balanced legal risk and return structure in public financing instruments. The motivation of the study is to address the lack of integrated decision-making models that consider both financial and legal dimensions simultaneously. In this context, a novel decision-making model is proposed. First, a comprehensive literature review is conducted to identify relevant criteria and alternative

strategies. Then, expert opinions are collected from ten specialists in the field to ensure the practical relevance of the model. The importance weights of the criteria are calculated using the CRITIC technique. After that, RAWEC methodology is applied to rank the alternatives. In addition, interval-valued fractal fuzzy sets are integrated into the model to better capture uncertainty and complexity in expert evaluations. The study seeks to answer the following research questions. 1. Which criteria are the most significant in evaluating public financing instruments in terms of legal risk and return balance? 2. Which financing strategies should be prioritised based on these criteria within the proposed analytical framework?

The methodological contribution of this study should be understood as an integrated decision architecture rather than as the development of a new fuzzy set or an entirely new MCDM algorithm. Existing fuzzy MCDM studies employ a wide range of uncertainty representations, weighting mechanisms and ranking techniques, including recent neutrosophic, interval-valued, hypersoft and hybrid extensions. The distinctive feature of the proposed framework is the functional separation and sequential integration of three decision-making tasks for the legal risk – return assessment of public financing instruments.

First, Fermatean fuzzy sets are used to represent uncertainty in experts' linguistic evaluations without introducing additional uncertainty dimensions that are not explicitly elicited from the experts. Second, CRITIC transforms the aggregated evaluation structure into criterion weights by considering both performance dispersion and inter-criterion correlation, thereby separating expert-based alternative assessment from the subsequent data-driven weighting stage. Third, RAWEC uses these weights to rank financing instruments through a dual-normalisation structure that accommodates heterogeneous benefit- and cost-oriented criteria. Thus, the contribution does not arise simply from combining three existing techniques, but from assigning each component a distinct and complementary methodological function within a unified framework designed for a decision problem in which legal, financial and institutional dimensions must be evaluated simultaneously. The framework is further supported by comparative ranking and weight-sensitivity analyses to examine whether its main conclusions remain stable under alternative methodological specifications. Accordingly, the novelty of the study lies primarily in the problem-oriented integration and application of these complementary mechanisms to the multidimensional legal risk – return assessment of public financing instruments, rather than in claiming methodological superiority over existing fuzzy MCDM approaches.

The study is structured as follows. The introduction outlines the research problem, motivation and main objectives. The literature review presents existing studies on public financing instruments and decision-making approaches, highlighting key gaps. The proposed methodology section explains the structure of the model, including the integration of fuzzy sets and weighting and ranking techniques. The analysis results section discusses the findings obtained from the application of the model and provides a comparative evaluation. Finally, the conclusion summarises the main results, discusses policy implications and suggests directions for future research.

2. Literature review

Recent scholarship tends to conceptualise the risk–return profile of public financing instruments as shaped by three interrelated dimensions: the contractual and statutory architecture of the instrument (including governing law, enforcement modalities and restructuring design), the credibility and stability of the regulatory environment (notably regulatory privileges and prudential treatment that may influence demand and pricing), and the administrative and governance capacity of the public sector (transparency, accountability and contingent liability management). Within this framework, sovereign bonds are commonly analysed through theories of legal commitment, enforcement credibility and holdout dynamics, with legal certainty often treated as a potentially priced attribute of debt contracts (Saiegh & Biglaiser, 2024), and judicial intervention understood to affect, at least in some contexts, both *ex ante* borrowing costs and *ex post* market re-entry (Schumacher et al., 2021). By contrast, public funds – particularly sovereign wealth funds and analogous state investment vehicles – are generally examined in light of governance quality, political legitimacy and macro-stabilisation functions, with performance assessed on an opportunity-cost-adjusted basis and conditioned by institutional design (Megginson & Gao, 2020). Recent models suggest that certain fund architectures may correlate with reduced currency crisis probability under specific institutional configurations (Hasse et al., 2024).

In a sovereign–bank feedback loop setting, Izumi (2020) compares the stabilising role of government guarantees with liquidity regulation, showing that guarantees can prevent self-fulfilling runs in some parameter regions while also tightening the sovereign–bank linkage through fiscal exposure. Methodologically, the field combines econometric identification of spreads, default risk and credibility premia (David et al., 2022; Rho & Saenz, 2021) with doctrinal and comparative analyses of restructuring regimes and contractual clauses (Nakajima, 2022; Hinrichsen et al., 2026). Notwithstanding the parallel development of multi-criteria decision analysis and multi-objective optimisation techniques (Greco et al., 2025; Ehrgott et al., 2026), the literature does not yet seem to offer an integrated MCDA framework that jointly models the legal risk – return balance of sovereign bonds, public funds and public guarantees across these criteria.

The scholarship linking legal certainty and regulatory change risk to financing costs and debt sustainability adopts a methodologically pluralist approach, combining high-frequency event studies, panel econometrics and comparative legal analysis. On the financing cost channel, using high-frequency identification around consolidation news events, David et al. (2022) show that the market impact of announced fiscal adjustments is mediated by credibility-relevant features of the policy process, such as whether measures are formally legislated rather than merely announced. Regarding default and sustainability risk, Rho and Saenz (2021) estimate sovereign default risk using a nonlinear probability model (a logit specification with a default episode indicator) and test whether periods of financial stress amplify the marginal effects of standard fiscal and macro fundamentals, including debt ratios and reserve buffers. Gomez-Gonzalez et al. (2022) find that well-designed fiscal rules may reduce default risk through credibility and sudden-stop mitigation channels, while emphasising that institutional design shapes their effectiveness. Gootjes and de Haan (2022) further argue that fiscal rules lacking transparency may prove ineffective in

practice, expanding regulatory change risk to include *de facto* circumvention through opaque reporting.

Parallel doctrinal work refines legal certainty by focusing on enforceability and restructuring design. Nakajima (2022) characterises collective action clauses as devices balancing creditor protection and restructuring capacity, linking certainty to accountability constraints. Hinrichsen et al. (2026) conceptualise legal certainty as dual-sided: facilitating predictable restructurings may entail limiting holdout enforceability, with potential pricing implications. From a regulatory perspective, Basse (2020) presents evidence from Euro Area bond yields indicating that default risk is reflected in spreads, raising questions about prudential assumptions under Solvency II. Betz and Pond (2023) document and theorise the political-economy correlates of 'borrowing privileges' – regulatory policies that advantage domestic government debt by shaping banks' and institutional investors' portfolio incentives – highlighting how institutional configurations are associated with the adoption of such privileges. Taken together, this literature suggests that debt sustainability and financing efficiency are best assessed through an integrated framework incorporating enforceability, transparency-conditioned rule credibility, and the temporal stability of regulatory privileges structuring investor demand.

International scholarship has increasingly treated budget transparency and accountability not merely as disclosure norms but as structural variables influencing the legal risk – return balance, insofar as transparency conditions the credibility and enforceability of fiscal constraints and shapes markets' capacity to price sovereign debt and contingent liabilities. Gootjes and de Haan (2022) provide empirical evidence that transparency complements fiscal rules, suggesting that formally binding constraints may lose effectiveness where reporting opacity enables circumvention. Heinemann et al. (2025) similarly show that state-owned enterprises can be used to shift liabilities off budget, potentially distorting measured debt paths and complicating sustainability assessments. From a public finance law perspective, these findings indicate that accountability depends not only on formal authorisation but also on reporting architectures capable of limiting legal "escape routes".

Contingent liabilities are particularly salient in the context of public guarantees and quasi-guarantees within the sovereign-financial nexus. Izumi (2020) models guarantees as policy instruments that may reduce short-term fragility while generating endogenous fiscal risks sensitive to legal design; deposit insurance-type schemes, for example, can stabilise markets yet create sizeable contingent exposures. Comparable considerations arise with sovereign wealth funds. Megginson and Gao (2020) emphasise governance structures, transparency, and political mandates as determinants of fund behaviour and performance, linking institutional capacity to financial outcomes. Amar and Lecourt (2023) further associate fund governance quality with domestic institutional frameworks, suggesting that accountability and legitimacy dynamics shape external credibility. Legal reputation also appears connected to enforcement expectations: litigation and court intervention influence restructuring outcomes and subsequent market access (Schumacher et al., 2021), while legal recourse provisions may be priced by investors (Saiegh & Biglaiser, 2024). Hasse et al. (2024) indicate that certain fund architectures may correlate with lower currency crisis risk. Collectively, this literature suggests that transparency, accountability, and contingent liability management function as governance parameters shaping legal certainty, investor confidence, and the sustainability of risk transfer and stabilisation instruments.

Crisis resilience has become a prominent theme in sovereign finance, reflecting interest in instruments that reallocate macroeconomic risk, reduce rollover fragility, and embed state contingency, while also introducing legal and regulatory complexity. Kalamov and Zimmermann (2023) analyse GDP-linked debt within a macroeconomic model of public borrowing and growth, highlighting how indexation can alter optimal debt ratios and risk-sharing properties. Climate exposure is likewise incorporated into sovereign risk analysis: Mallucci (2022) links climate shocks to risk premia and debt sustainability, suggesting that environmental tail risk increasingly informs instrument design. Sovereign wealth funds are examined as institutional buffers; Hasse et al. (2024) associate certain fund architectures with lower currency crisis probability, conditional on governance capacity.

Resilience also intersects with restructuring law. Hinrichsen et al. (2026) analyse domestic debt legislation limiting holdout litigation as an adaptive mechanism that may facilitate restructurings while reallocating creditor payoffs. Zenios et al. (2021) conceptualise sustainable sovereign debt within an integrated risk management framework, whereas Lupo-Pasini (2022) contends that such instruments are undermined by a credibility deficit stemming from incentive misalignment among issuers, investors and certifiers, thereby casting doubt on whether contractual ESG features can reliably induce domestic policy change. Although multi-criteria decision analysis (MCDA) has advanced methodologically (Greco et al., 2025), its application in sovereign finance remains partial.

Xidonas et al. (2025) employ ELECTRE-based modelling for sovereign sustainability ranking, and Ben Cheikh et al. (2021) analyse sovereign–corporate rating interdependence, yet comprehensive multi-criteria instrument comparison is rare. Conversely, legal risk scholarship – examining governing law, enforcement and litigation exposure (Schumacher et al., 2021; Saiegh & Biglaiser, 2024; Nakajima, 2022) – often relies on single-outcome metrics rather than aggregation frameworks. Persistent challenges include heterogeneous proxies for legal certainty, weight allocation for normative criteria, and instability of rankings under crisis-driven regime shifts (Greco et al., 2025). Overall, crisis resilience theory, legal risk analysis, and MCDA modelling appear to evolve largely in parallel rather than through an integrated framework (Gulati et al., 2020; Gootjes & de Haan, 2022).

The scholarship can be read as outlining an implicit multi-criteria structure in which distinct strands address separate dimensions of the legal risk – return equilibrium, though the resulting picture remains largely instrument-specific. In the sovereign bond literature, legal certainty is typically proxied by governing law, enforceability, collective action clause design and litigation exposure, variables often associated with pricing and market access (Saiegh & Biglaiser, 2024; Schumacher et al., 2021; Nakajima, 2022). Research on public funds instead emphasises governance architecture, institutional legitimacy and stabilisation capacity, treating returns as conditional on transparency, rule-bound management and fiscal credibility (Megginson & Gao, 2020; Amar & Lecourt, 2023; Hasse et al., 2024). Analyses of public guarantees generally situate them within financial stability and sovereign–bank nexus models, where benefits relate to crisis mitigation and credit intermediation, while risks arise as contingent liabilities shaped by legal definitions, regulatory design and disclosure regimes (Izumi, 2020; Betz & Pond, 2023; Basse, 2020). Across these domains, transparency and accountability function as cross-cutting criteria, influencing whether

formal commitments support sustainability or permit off-budget risk shifting (Gootjes & de Haan, 2022; Heinemann et al., 2025).

Crisis resilience research highlights adaptive instruments such as GDP-linked bonds and stabilisation funds, yet these innovations introduce contractual and measurement uncertainties rarely integrated with conventional bond law constructs (Kalamov & Zimmermann, 2023; Hasse et al., 2024). Although MCDA methods are increasingly applied in sovereign sustainability and ESG contexts (Xidonas et al., 2025), legal risk often appears indirectly, and units of analysis remain jurisdictional rather than instrument-based. Conversely, legal-economics studies quantify pricing or litigation effects without cross-instrument aggregation (Saiegh & Biglaiser, 2024; David et al., 2022). This suggests scope for a public-finance-law-consistent MCDA framework capable of integrating legally grounded criteria across sovereign bonds, public funds, and guarantees under varying regulatory scenarios (Greco et al., 2025; Ehrgott et al., 2026).

In addition to the academic literature, the institutional and policy-oriented work of the International Monetary Fund (IMF) and the World Bank provides an important practical foundation for evaluating the legal and financial risks of public financing instruments. IMF analyses emphasise that financing mechanisms such as public–private partnerships (PPPs) and government guarantees should not be assessed solely according to their immediate financing advantages, because they may generate long-term direct commitments, debt-like obligations, and contingent liabilities that are not always fully reflected in conventional fiscal indicators. From this perspective, the effectiveness of alternative financing arrangements depends on the government's capacity to identify, quantify, disclose and manage their fiscal implications. The World Bank similarly distinguishes between direct and contingent as well as explicit and implicit government liabilities and emphasises that guarantees, PPP commitments, and obligations of public entities can become important sources of fiscal risk. This institutional literature also highlights the importance of transparency, sound project appraisal, appropriate risk allocation, and strong public sector capacity in preventing financing arrangements from creating hidden or inadequately monitored fiscal exposures. These concerns are operationalised in frameworks such as the IMF – World Bank Public–Private Partnership Fiscal Risk Assessment Model (PFRAM), which assesses the fiscal costs, risks, and debt sustainability implications associated with PPP projects. This policy-oriented perspective complements the academic literature reviewed above and provides additional support for the inclusion of public debt sustainability, budget transparency and accountability, contingent liability risk, and institutional and administrative applicability among the evaluation criteria used in the present study (Irwin et al., 2018).

3. Methodology

This section introduces the hybrid model and its components proposed for use in evaluating the legal risk – return balance of public finance instruments. In this context, the uncertainty process is addressed using Fermatean fuzzy sets (FFSs), while criteria are prioritised using CRITIC. Public finance instruments are ranked using RAWEC to determine the optimal alternative. This process is shown step-by-step in Figure 1.

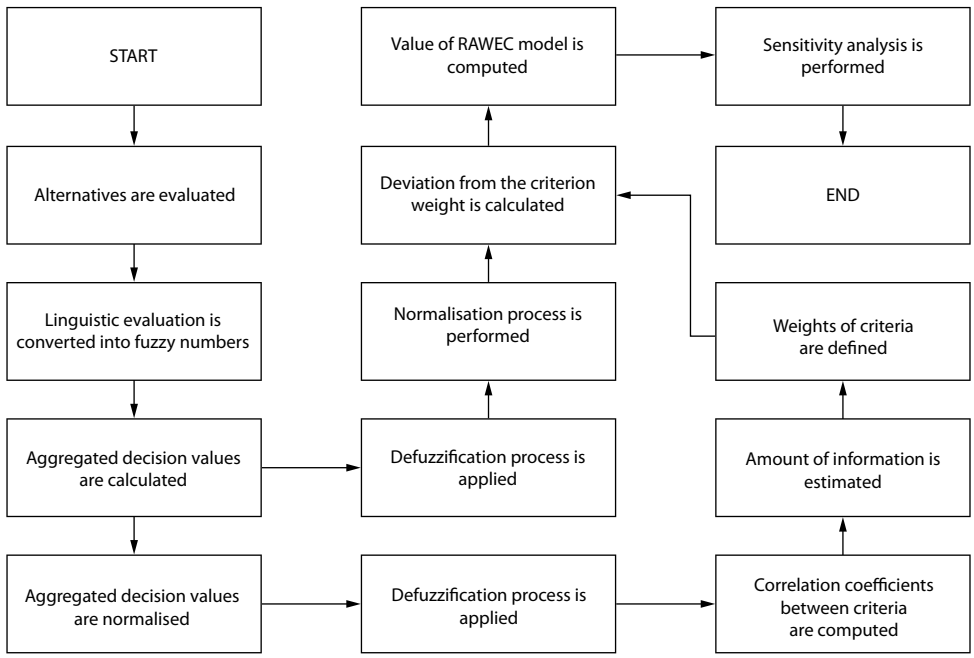

Figure 1
Process

Source: Compiled by the authors.

Figure 1 describes the analytical sequence of the proposed framework rather than prescribing a universal institutional arrangement for its implementation. In practice, responsibility for the different stages would be distributed among several actors according to the administrative structure and technical capacity of the country concerned. The responsible public authority, typically the Ministry of Finance or an equivalent institution, would retain policy ownership by defining the financing problem, identifying the relevant alternatives, and determining the institutional scope of the assessment. Expert evaluations could be provided by specialists in public finance, debt management, fiscal risk, law, budgeting, public investment and related fields. The computational stages – including the conversion and aggregation of Fermatean fuzzy evaluations, CRITIC-based criterion weighting and RAWEC-based alternative ranking – would more appropriately be undertaken by a specialist analytical unit within the ministry, where sufficient capacity exists. Where such in-house capacity is unavailable, these technical functions could be supported by an external advisory committee, research institute, or qualified technical consultants. The resulting rankings should then be communicated to ministers, senior advisers, and other responsible officials as decision support information rather than as an automatic policy prescription. Thus, institutional responsibility should be understood as functionally differentiated: policymakers define the decision context and retain final decision authority, domain experts provide informed assessments, and specialist analysts conduct the technical implementation of the model.

3.1. FFSs

The use of Fermatean fuzzy sets (FFSs) in this study is motivated by the nature of the expert-based public financing decision problem rather than by an assumption that FFSs are universally superior to more recent uncertainty-modelling structures. Evaluating public financing instruments involves substantial ambiguity because experts are required to assess qualitative legal, financial and institutional characteristics, such as legal certainty, regulatory change risk, contingent liabilities and administrative applicability, for which precise numerical judgments are difficult to obtain. FFSs are suitable for this setting because their cubic constraint provides decision-makers with a relatively flexible domain for expressing membership and non-membership assessments while preserving a tractable structure for aggregation and subsequent MCDM calculations. Recent studies have introduced richer uncertainty representations, including Fermatean neutrosophic hypersoft sets combined with machine learning (Tahir & Shahid, 2026), interval-valued Fermatean neutrosophic super hypersoft sets (Abdalla et al., 2025), interval-valued Pythagorean neutrosophic linguistic frameworks (Razak et al., 2025), and Pythagorean neutrosophic TOPSIS–VIKOR models (Kamari et al., 2025). These approaches offer important advantages when the decision problem explicitly involves independent indeterminacy information, interval-valued assessments, complex sub-parameter structures, or highly multidimensional uncertainty. However, the present study does not collect separate truth, falsity and indeterminacy assessments, interval-valued expert judgments, or hypersoft sub-parameter evaluations. Introducing these additional structures would therefore increase model complexity without corresponding information in the elicited expert data. For the present application, FFSs provide a parsimonious balance between uncertainty representation flexibility and computational interpretability and can be directly integrated with the CRITIC–RAWEC framework. Accordingly, the contribution of this study is not the development of a more general fuzzy set than recent neutrosophic or hypersoft extensions, but the problem-oriented integration of FFS-based uncertainty modelling with objective criterion weighting and alternative ranking for the legal risk – return assessment of public financing instruments. Assume that D is a universe of discourse. An FFS $\left(\widetilde{\mathrm{F}}\right)$ has an object in Equation (1) (Liu et al., 2025).

$$\widetilde{\mathrm{F}} = \left\{ \left\langle \mathfrak{f}, \left(\beta_{\widetilde{\mathrm{F}}}(\mathfrak{f}), \gamma_{\widetilde{\mathrm{F}}}(\mathfrak{f}) \right) | \mathfrak{f} \in D \right\} \right. \tag{1}$$

Wherein these functions $\beta_{\widetilde{\mathrm{F}}}(\mathfrak{f}) : D \to [0,1]$, $\gamma_{\widetilde{\mathrm{F}}}(\mathfrak{f}) : D \to [0,1]$ and $0 \leq \beta^3_{\widetilde{\mathrm{F}}}(\mathfrak{f}) + \gamma^3_{\widetilde{\mathrm{F}}}(\mathfrak{f}) \leq 1$ are the grade of belonging, non-belonging of $\mathfrak{f}$ to $\widetilde{\mathrm{F}}$, respectively. For any FFS $\left(\widetilde{\mathrm{F}}\right)$ and $\mathfrak{f} \in D$, the hesitancy grade is described in Equation (2).

$$\delta_{\widetilde{\mathrm{F}}}(\mathfrak{f}) = \sqrt[3]{1 - \beta^3_{\widetilde{\mathrm{F}}}(\mathfrak{f}) - \gamma^3_{\widetilde{\mathrm{F}}}(\mathfrak{f})} \tag{2}$$

Let us suppose FFS is $\widetilde{\mathrm{F}} = \left(\beta_{\widetilde{\mathrm{F}}}, \gamma_{\widetilde{\mathrm{F}}}\right)$. Then, score and accuracy functions are identified by Equations (3) and (4), respectively.

$$\mathbb{S}\left(\widetilde{\mathrm{F}}\right) = \tfrac{1}{2}\left(1 + \beta_{\widetilde{\mathrm{F}}}^{3} - \gamma_{\widetilde{\mathrm{F}}}^{3}\right) \tag{3}$$

$$\mathbb{A}\left(\widetilde{\mathrm{F}}\right) = \beta_{\widetilde{\mathrm{F}}}^{3} + \gamma_{\widetilde{\mathrm{F}}}^{3} \tag{4}$$

Consider that $\widetilde{\mathrm{F}}$, $\widetilde{\mathrm{F}}_1$ and $\widetilde{\mathrm{F}}_2$ are three FFSs and £ is a positive real number. Then, some calculation processes for FFSs are defined in Equations (5) – (9).

$$\widetilde{\mathrm{F}}_1 \bigoplus \widetilde{\mathrm{F}}_2 = \left(\sqrt[3]{\beta_{\widetilde{\mathrm{F}}_1}^{3} + \beta_{\widetilde{\mathrm{F}}_2}^{3} - \beta_{\widetilde{\mathrm{F}}_1}^{3}\beta_{\widetilde{\mathrm{F}}_2}^{3}}, \gamma_{\widetilde{\mathrm{F}}_1}\gamma_{\widetilde{\mathrm{F}}_2}\right) \tag{5}$$

$$\widetilde{\mathrm{F}}_1 \bigotimes \widetilde{\mathrm{F}}_2 = \left(\beta_{\widetilde{\mathrm{F}}_1}\beta_{\widetilde{\mathrm{F}}_2}, \sqrt[3]{\gamma_{\widetilde{\mathrm{F}}_1}^{3} + \gamma_{\widetilde{\mathrm{F}}_2}^{3} - \gamma_{\widetilde{\mathrm{F}}_1}^{3}\gamma_{\widetilde{\mathrm{F}}_2}^{3}}\right) \tag{6}$$

$$£ \bigodot \widetilde{\mathrm{F}} = \left(\sqrt[3]{1 - \left(1 - \beta_{\widetilde{\mathrm{F}}}^{3}\right)^{£}}, \gamma_{\widetilde{\mathrm{F}}}^{£}\right) \tag{7}$$

$$\left(\widetilde{\mathrm{F}}\right)^{£} = \left(\beta_{\widetilde{\mathrm{F}}}^{£}, \sqrt[3]{1 - \left(1 - \gamma_{\widetilde{\mathrm{F}}}^{3}\right)^{£}}\right) \tag{8}$$

$$\widetilde{\mathrm{F}}^{C} = \left(\gamma_{\widetilde{\mathrm{F}}}, \beta_{\widetilde{\mathrm{F}}}\right) \tag{9}$$

Suppose that $\widetilde{\mathrm{F}}_{\mathrm{i}}$ is a collection of FFSs. Then the Fermatean fuzzy weighted average value is calculated using Equation (10).

$$FFWA\left(\widetilde{\mathrm{F}}_i\right) = \left(\sqrt[3]{1 - \prod_{i=1}^{p}\left(1 - \beta_{\widetilde{\mathrm{F}}_i}^{3}\right)^{w_i}}, \prod_{i=1}^{p}\gamma_{\widetilde{\mathrm{F}}_i}^{w_i}\right) \tag{10}$$

Wherein $\sum w_{\mathrm{i}} = 1$.

3.2. Proposed hybrid model

The proposed hybrid model incorporates the CRITIC and RAWEC methods. The selection of an appropriate criterion-weighting approach is particularly important because different weighting mechanisms may influence the stability and robustness of MCDM results. Weighting approaches can generally be classified as subjective, objective and hybrid methods (Sarkar et al., 2026; Sarkar & Goswami, 2026). Subjective methods derive criterion importance primarily from decision-makers' judgments and preferences, whereas objective

methods determine weights from the intrinsic information contained in the decision data. Hybrid approaches combine these two perspectives and can provide a more comprehensive weighting structure, although they may also require additional preference elicitation and methodological complexity. Within this study, CRITIC is particularly suitable because the evaluations already incorporate expert judgments through Fermatean fuzzy linguistic assessments; therefore, introducing an additional subjective weighting stage could increase the influence of expert preferences on the final results. Instead, CRITIC derives criterion weights from the resulting decision matrix by simultaneously considering both the variability of criterion performance and the correlation among criteria. This feature is especially relevant to the present public financing problem because legal, financial, and institutional criteria are conceptually interconnected and may contain overlapping information. Compared with objective approaches that primarily emphasise the dispersion or information content of individual criteria, CRITIC additionally accounts for inter-criterion relationships and consequently reduces the possibility of assigning excessive importance to highly correlated criteria. Accordingly, CRITIC was selected not because it is universally superior to subjective, objective, or hybrid weighting methods, but because its data-driven and correlation-sensitive structure is particularly consistent with the multidimensional and interdependent nature of the criteria examined in this study.

Nevertheless, the use of CRITIC also entails an important limitation in the context of the present study. Because the legal, institutional, and financial criteria have a substantial normative and expert judgment component, their policy importance may not be fully represented by the variability and correlation structure of the decision matrix alone. Subjective weighting methods can explicitly capture experts' perceptions regarding the relative importance of criteria, while hybrid weighting approaches can combine such preference information with objective information derived from the decision data. These approaches may therefore provide a useful alternative when both data-driven differentiation and explicit stakeholder preferences are intended to determine criterion importance.

In the present study, however, expert knowledge is already incorporated at the evaluation stage through linguistic Fermatean fuzzy assessments of the alternatives. CRITIC was subsequently employed to derive criterion weights from the aggregated decision structure, thereby separating expert-based performance evaluation from the weighting mechanism and limiting an additional layer of subjective influence on the final ranking. Therefore, we did not rule out the hybrid weighting approach because it is methodologically inferior, but because the present research design deliberately distinguishes expert-based evaluation from data-driven criterion weighting. This choice should nevertheless be regarded as a methodological boundary of the study, since alternative subjective or hybrid weighting schemes could produce different criterion priorities. Future research may therefore combine CRITIC with methods such as AHP, BWM, or SWARA and examine whether the resulting hybrid weights affect the stability of the rankings.

Firstly, m alternatives are evaluated by p evaluators according to n criteria, using the linguistic expressions in Table 1.

Table 1
Linguistic variables

Linguistic	FFN
VVL	(.1, .9)
VL	(.1, .75)
L	(.25, .6)
ML	(.4, .5)
M	(.5, .4)
MH	(.6, .3)
H	(.7, .2)
VH	(.8, .1)
VVH	(.9, .1)

Source: Compiled by the authors.

Each linguistic evaluation is converted into fuzzy numbers. Then, aggregated decision values are calculated using Equation (11) (Rasool et al., 2025).

$$\tilde{d}_{ij} = \left(\sqrt[3]{1 - \prod_{t=1}^{p} \left(1 - \beta_{\tilde{y}_{ij}^t}^3\right)^{1/p}}, \prod_{t=1}^{p} \gamma_{\tilde{y}_{ij}^t}^{1/\mathrm{p}} \right) \tag{11}$$

Wherein $\tilde{y}_{ij}^t = \left(\beta_{\tilde{y}_{ij}^t}, \gamma_{\tilde{y}_{ij}^t}\right)$ is FFN of linguistic evaluation for i^{th} alternative regarding to j^{th} criterion of p^{th} evaluator. Next, the aggregated decision numbers are normalised by Equations (12) and (13).

$$\tilde{\mathfrak{n}}_{ij} = \left(\beta_{\tilde{d}_{ij}}, \gamma_{\tilde{d}_{ij}}\right); j \in P \tag{12}$$

$$\tilde{\mathfrak{n}}_{ij} = \left(\gamma_{\tilde{d}_{ij}}, \beta_{\tilde{d}_{ij}}\right); j \in N \tag{13}$$

Wherein P and N refer to positive and negative criterion, respectively. Later, defuzzification process is applied for normalised decision numbers as Equation (14).

$$\mathbb{S}(\tilde{\mathfrak{n}}_{ij}) = \tfrac{1}{2}\left(1 + \beta_{\tilde{\mathfrak{n}}_{ij}}^3 - \gamma_{\tilde{\mathfrak{n}}_{ij}}^3\right) \tag{14}$$

Subsequently, the correlation coefficients between criteria are computed with the help of Equation (15).

$$\rho_{jk} = \frac{\sum_{i=1}^{m}\left(\mathbb{S}(\tilde{\mathfrak{n}}_{ij}) - \frac{1}{m}\sum_{i=1}^{m}\mathbb{S}(\tilde{\mathfrak{n}}_{ij})\right)\left((\tilde{\mathfrak{n}}_{ik}) - \frac{1}{m}\sum_{i=1}^{m}\mathbb{S}(\tilde{\mathfrak{n}}_{ik})\right)}{\sqrt{\sum_{i=1}^{m}\left(\mathbb{S}(\tilde{\mathfrak{n}}_{ij}) - \frac{1}{m}\sum_{i=1}^{m}\mathbb{S}(\tilde{\mathfrak{n}}_{ij})\right)^2 \sum_{i=1}^{m}\left(\mathbb{S}(\tilde{\mathfrak{n}}_{ik}) - \frac{1}{m}\sum_{i=1}^{m}\mathbb{S}(\tilde{\mathfrak{n}}_{ik})\right)^2}} \tag{15}$$

Behind, the amount of information is estimated via Equation (16).

$$C_j = \sigma_j \sum_{k=1}^{n} (1 - \rho_{jk}) \tag{16}$$

Wherein is a standard deviation and is established using Equation (17).

$$\sigma_j = \sqrt{\frac{1}{m} \sum_{i=1}^{m} \left(\mathbb{S}(\tilde{\mathfrak{n}}_{ij}) - \frac{1}{m} \sum_{i=1}^{m} \mathbb{S}(\tilde{\mathfrak{n}}_{ij}) \right)^2} \tag{17}$$

At the end of CRITIC, the weights of criteria are defined as Equation (18).

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \tag{18}$$

After constructing the weight vector of the criteria, the ranking step of the alternatives begins. The selection of the alternative-ranking method is also important because different MCDM techniques employ different aggregation, normalisation and preference mechanisms, which may influence the resulting rankings. As highlighted by recent comprehensive reviews, well-established approaches such as TOPSIS, VIKOR, MOORA, COPRAS, ELECTRE, PROMETHEE, MARCOS, and other fuzzy and hybrid MCDM techniques provide different methodological perspectives for evaluating alternatives under multiple and potentially conflicting criteria (Sahoo et al., 2026a; Sahoo et al., 2026b). In the present study, RAWEC is selected because its structure is particularly compatible with a decision problem involving both benefit- and cost-oriented legal, financial and institutional criteria. Unlike methods relying on a single normalisation perspective or a single ideal-distance structure, RAWEC simultaneously constructs two normalisation structures and evaluates the alternatives by considering their deviations in relation to criterion weights. This dual-normalisation mechanism enables alternative performance to be examined from complementary perspectives and reduces dependence on a single normalisation orientation. Moreover, RAWEC has a relatively parsimonious computational structure, which facilitates transparency and interpretability when a large amount of uncertainty has already been incorporated through Fermatean fuzzy evaluations. Therefore, RAWEC is not considered universally superior to other MCDM ranking methods; rather, it is selected because its dual-normalisation, weight-sensitive, and computationally transparent structure is well aligned with the heterogeneous benefit- and cost-type criteria of the present public financing problem. To further avoid dependence on a single ranking algorithm, the robustness of the RAWEC results is additionally examined using alternative MCDM methods in the sensitivity analysis. Defuzzification process is applied for aggregated decision numbers as in Equation (19) (Dündar & Karadağ, 2025).

$$\mathbb{S}\left(\tilde{d}_{ij}\right) = \frac{1}{2}\left(1 + \beta^3_{\tilde{d}_{ij}} - \gamma^3_{\tilde{d}_{ij}}\right) \tag{19}$$

Afterwards, the normalisation process is performed. For this, double normalisation is shared in Equations (20) – (23).

$$\eta_{ij} = \frac{\mathbb{S}\left(\tilde{d}_{ij}\right)}{\max_i \mathbb{S}\left(\tilde{d}_{ij}\right)}; j \in P \tag{20}$$

$$\eta_{ij} = \frac{\min_i \mathbb{S}\left(\tilde{d}_{ij}\right)}{\mathbb{S}\left(\tilde{d}_{ij}\right)}; j \in N \tag{21}$$

$$\eta_{ij}^{'} = \frac{\min_i \mathbb{S}\left(\tilde{d}_{ij}\right)}{\mathbb{S}\left(\tilde{d}_{ij}\right)}; j \in P \tag{22}$$

$$\eta_{ij}^{'} = \frac{\mathbb{S}\left(\tilde{d}_{ij}\right)}{\max_i \mathbb{S}\left(\tilde{d}_{ij}\right)}; j \in N \tag{23}$$

Behind, the deviation from the criterion weight is calculated by Equations (24) and (25).

$$v_i = \sum_{j=1}^{n} w_j (1 - \eta_{ij}) \tag{24}$$

$$v_i^{'} = \sum_{j=1}^{n} w_j \left(1 - \eta_{ij}^{'}\right) \tag{25}$$

Finally, the value of RAWEC model is computed with Equation (26).

$$Q_i = \frac{v_i^{'} - v_i}{v_i^{'} + v_i} \tag{26}$$

4. Analysis

This section presents the outputs of the proposed hybrid model for evaluating public finance instruments in terms of the legal risk – return balance. The first step in the proposed hybrid model is to define the criteria. These criteria are determined based on the legal risk – return balance. The criteria are shown in Table 2.

Table 2
Criteria

Criterion	Abb	Type
Level of legal certainty	LLC	P
Risk of regulatory change	RRC	N
Impact on public debt sustainability	IPDS	N
Financial return – financing efficiency	FRFE	P
Budget transparency and accountability	BTA	P
Risk of contingent liability	RCL	N
Corporate and administrative applicability	CAA	P
Market confidence and legal reputation impact	MCLR	P
Resilience to crises	RCR	P

Source: Compiled by the authors.

The level of legal certainty refers to the clarity, consistency and predictability of the legal framework governing a financing instrument. A higher level of legal certainty reduces ambiguity and supports more stable decision-making for both public authorities and investors. The risk of regulatory change captures the likelihood that laws, rules, or administrative practices may be altered over time. Frequent or unpredictable changes can create uncertainty and negatively affect long-term financial planning. The impact on public debt sustainability reflects how a financing tool influences the government's debt burden in the medium and long term. Instruments that increase debt without adequate returns may threaten fiscal stability. Financial return and financing efficiency indicate the cost-effectiveness of the instrument and its ability to provide diversified funding sources. Efficient tools help reduce borrowing costs while ensuring adequate resource allocation. Budget transparency and accountability refer to the extent to which financial activities can be monitored and audited within the public budget system. Greater transparency strengthens public trust and improves governance quality. The risk of contingent liability relates to potential hidden obligations that may arise in the future, especially from guarantees. These risks can create unexpected fiscal pressures if not properly managed. Corporate and administrative applicability reflects the capacity of institutions to implement and supervise the financing instrument effectively. Strong administrative structures enhance operational success and reduce implementation risks. Market confidence and legal reputation impact represent how investors perceive the credibility of the government and its legal commitments. Higher confidence generally leads to better financing conditions and lower risk premiums. Resilience to crises indicates the ability of the instrument to adapt during economic or financial shocks. Flexible instruments provide greater stability and support effective crisis management. Table 2 shows that three of the criteria are negative. Furthermore, to facilitate better readability of the results, the criteria are expressed using abbreviations in subsequent tables.

From a practical perspective, the criteria included in the framework are intended to reflect dimensions that are relevant to public sector financing decisions rather than purely academic constructs. In particular, debt sustainability, fiscal and contingent liability exposure, budget transparency, legal certainty, regulatory risk, market confidence, crisis resilience, and administrative capacity correspond to issues that finance ministries and international financial institutions routinely consider when assessing financing arrangements and fiscal risks. The framework is not intended to imply, however, that these nine criteria constitute a universal or exhaustive representation of government decision-making. Their relevance and relative importance may vary across countries according to fiscal conditions, legal systems, institutional capacity, financing objectives and the characteristics of the instrument under consideration.

The intended users of the framework are therefore primarily specialist analytical units within or supporting public financial institutions, such as debt management, fiscal risk, budget, public investment and PPP units, rather than ministers or senior policymakers performing the calculations themselves. External advisory groups or research institutions could also implement the analytical procedure where sufficient in-house technical capacity is unavailable, while ministers and senior officials would use the resulting assessment as an input to, rather than a substitute for, policy judgment. The framework is not restricted to

either developing or advanced economies; however, its practical feasibility is expected to depend on country-specific institutional and analytical capacity and may be more constrained where technical resources are limited. Although the model relies primarily on expert-based linguistic assessments rather than on a large standardised quantitative dataset, informed evaluation of the criteria still requires access to reliable legal, fiscal, contractual, debt and institutional information. Consequently, incomplete disclosure of guarantees, contingent liabilities, off-budget commitments, or contractual risks may reduce the reliability of the expert inputs and, ultimately, the resulting rankings. Similarly, public financing instruments are identified and given in Table 3.

Table 3
Public financing instruments

Public financing instrument	**Abb**
Traditional government bonds	TGB
Thematic – purpose-oriented government bonds	TPG
Public investment funds	PIF
Public–private partnership (PPP) supported financing instruments	PPP
Direct government guarantees	DGG
Conditional – limited government guarantees	CLGG
Off-budget financing instruments	OFI

Source: Compiled by the authors.

Traditional government bonds are debt instruments issued by central governments under well-defined legal frameworks. They are widely used due to their transparency, predictability and strong market acceptance. Thematic or purpose-oriented government bonds are issued to finance specific areas such as infrastructure, environmental projects, or social programs. These bonds enhance accountability by linking funding to clearly defined policy objectives. Public investment funds are financial mechanisms established or supported by the state to channel resources into strategic sectors. They allow for more structured and diversified investment management compared to direct public spending. Public–private partnership-supported financing instruments involve collaboration between public authorities and private entities. These instruments distribute financial and legal risks while improving efficiency in project implementation. Direct government guarantees are explicit commitments by the state to cover financial obligations in case of default. They reduce investor risk and help secure financing under more favourable conditions. Conditional or limited government guarantees provide support only under predefined circumstances. While they offer flexibility, they may also create hidden fiscal risks if conditions are triggered. Off-budget financing instruments operate outside the formal government budget through special funds or semi-public entities. They provide additional financing capacity but require strong oversight to maintain transparency and fiscal discipline. These public finance instruments are evaluated by ten evaluators. The determining factors in the selection of these evaluators are having at least ten years of experience and being in a decision-making position within their institution.

The empirical evaluation was conducted with a panel of ten experts selected on the basis of their professional experience, academic expertise and familiarity with the legal, financial and institutional dimensions of public financing. Prior to their participation, all experts were informed about the purpose and scope of the study and the intended use of their evaluations for academic research. Written informed consent was obtained from all participants. Participation was entirely voluntary, and the experts were informed that their responses would be treated confidentially and reported anonymously. No personally identifiable information or specific institutional affiliations are disclosed in the study. All experts are academics working in Türkiye, have at least ten years of professional experience, and hold positions involving decision-making responsibilities within their respective institutions. The composition of the panel was intended to provide informed judgments on the multidisciplinary criteria considered in the study, particularly those related to legal certainty, public debt sustainability, financing efficiency, budget transparency and accountability, contingent liabilities, market confidence, crisis resilience, regulatory risk and administrative applicability. The experts were selected because their academic and professional backgrounds enable them to evaluate these dimensions from complementary perspectives. However, the panel was not specifically constructed to represent senior officials or advisers within the Ministry of Finance, and the study does not claim that the participating experts have served as senior advisers to a minister of finance or deputy minister. This should be considered when interpreting the practical and policy relevance of the expert assessments. The identities and specific institutional affiliations of the participants are not disclosed in order to preserve confidentiality. Future applications of the framework could strengthen its policy-oriented validation by incorporating a broader range of practitioners, including officials from ministries of finance, debt management and fiscal risk units, development banks, and other public financial institutions. The evaluations made by these evaluators using the linguistic expressions in Table 1 are shared in Table 4.

Table 4
Evaluations

	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	VVL	VH	MH	ML	M	VH	M	ML	ML
TPG	MH	M	ML	H	M	M	H	ML	ML
PIF	ML	L	M	ML	H	VL	H	MH	VH
PPP	VVH	L	ML	MH	VVH	VL	VH	VH	H
DGG	VH	VL	VL	VVH	VH	ML	H	MH	H
CLGG	ML	VL	M	VH	M	M	ML	ML	MH
OFI	MH	M	H	L	M	MH	MH	L	MH
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	VL	VVH	VH	ML	VVL	VVH	M	VVL	VL
TPG	ML	ML	M	M	ML	L	H	H	MH
PIF	ML	M	M	MH	VH	ML	ML	VH	M
PPP	H	ML	VL	VH	VVH	L	MH	VVH	H

DGG	VH	ML	L	MH	VH	M	VH	VVH	MH
CLGG	VH	VL	L	M	H	L	MH	H	VH
OFI	M	MH	H	MH	L	ML	MH	MH	ML
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	L	H	VH	ML	VVL	VH	VL	VL	ML
TPG	M	M	ML	ML	H	M	ML	M	H
PIF	H	L	MH	VH	M	ML	ML	ML	MH
PPP	VVH	VVL	ML	VH	H	ML	MH	H	MH
DGG	VH	M	L	H	MH	M	H	VH	H
CLGG	VH	VL	ML	M	VH	MH	ML	VH	VH
OFI	MH	M	H	MH	MH	M	L	M	M
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	VVL	VVH	VVH	ML	VL	H	M	ML	M
TPG	M	MH	L	H	M	L	H	H	M
PIF	M	VL	MH	MH	VH	M	H	MH	MH
PPP	VH	VVL	VL	VH	VVH	VL	MH	MH	MH
DGG	M	ML	VL	MH	VH	ML	H	H	VVH
CLGG	H	M	MH	H	H	VL	MH	MH	MH
OFI	MH	MH	H	L	L	ML	ML	ML	MH
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	M	H	VVH	L	VL	VVH	L	ML	ML
TPG	ML	MH	ML	M	ML	ML	H	ML	ML
PIF	MH	VL	ML	M	VH	M	ML	ML	M
PPP	MH	ML	ML	VVH	MH	ML	H	H	VVH
DGG	VH	VL	L	H	M	M	VH	M	VH
CLGG	ML	VL	VL	M	VH	VL	ML	M	VH
OFI	L	H	ML	ML	M	MH	ML	L	M
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	VVL	M	H	ML	VL	VVH	ML	ML	ML
TPG	MH	MH	L	M	ML	L	MH	MH	MH
PIF	H	M	VL	ML	ML	ML	ML	M	ML
PPP	H	VL	VVL	MH	H	VL	H	VVH	MH
DGG	VVH	L	VVL	VH	MH	VVL	M	H	M
CLGG	VH	ML	MH	MH	VH	VL	MH	MH	ML
OFI	ML	MH	MH	M	M	ML	L	ML	ML
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	ML	MH	MH	VL	L	VVH	M	ML	VL
TPG	ML	ML	ML	MH	MH	ML	ML	M	H

PIF	MH	VL	VL	M	M	VL	ML	VH	H
PPP	MH	L	VVL	VVH	VVH	VL	MH	H	VH
DGG	M	L	ML	H	MH	L	VVH	VH	M
CLGG	VH	MH	ML	H	MH	VL	M	M	ML
OFI	ML	MH	H	ML	M	M	MH	MH	ML
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	M	M	VH	VL	ML	H	L	L	ML
TPG	ML	ML	M	M	H	M	ML	ML	M
PIF	VH	ML	MH	H	MH	MH	M	VH	VH
PPP	VVH	ML	L	MH	MH	VL	H	MH	MH
DGG	M	ML	L	VH	H	ML	VVH	M	M
CLGG	MH	VL	VL	ML	M	L	VH	H	H
OFI	M	ML	ML	MH	ML	ML	MH	ML	ML
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	ML	M	VVH	VL	ML	H	ML	ML	ML
TPG	H	MH	MH	M	H	ML	MH	MH	H
PIF	MH	VL	M	H	MH	ML	M	M	H
PPP	VH	ML	ML	VH	MH	VL	H	MH	VVH
DGG	M	VVL	L	MH	H	L	VVH	MH	MH
CLGG	H	ML	ML	ML	M	VL	MH	VH	ML
OFI	MH	H	M	ML	ML	ML	M	M	ML
	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
TGB	ML	MH	H	ML	M	M	VL	L	L
TPG	ML	MH	ML	M	M	L	H	H	M
PIF	M	L	ML	VH	VH	ML	H	H	VH
PPP	MH	VVL	VVL	VH	VVH	VVL	VVH	VH	MH
DGG	MH	VL	M	MH	M	L	VH	MH	M
CLGG	M	L	MH	MH	VH	ML	ML	M	H
OFI	M	ML	H	MH	M	MH	L	ML	ML

Source: Compiled by the authors.

4.1. Weighting of criteria

Firstly, each linguistic evaluation in Table 4 is converted into fuzzy numbers using Table 1. Then, aggregated decision numbers are calculated using Equation (11). The aggregated decision numbers are illustrated in Table 5.

Table 5
Aggregated decision numbers

	LLC	RRC	IPDS	FRFE	BTA	RCL	CAA	MCLR	RCR
TGB	(.362, .605)	(.735, .217)	(.806, .143)	(.344, .575)	(.345, .619)	(.821, .141)	(.407, .514)	(.348, .573)	(.376, .54)
TPG	(.519, .394)	(.537, .37)	(.437, .471)	(.562, .346)	(.575, .338)	(.4, .503)	(.624, .286)	(.583, .328)	(.589, .321)
PIF	(.618, .291)	(.335, .594)	(.492, .435)	(.647, .261)	(.696, .207)	(.432, .493)	(.553, .363)	(.664, .243)	(.682, .222)
PPP	(.793, .16)	(.309, .644)	(.304, .659)	(.794, .139)	(.822, .16)	(.249, .689)	(.72, .205)	(.768, .171)	(.747, .199)
DGG	(.731, .194)	(.33, .607)	(.303, .616)	(.732, .191)	(.69, .211)	(.397, .524)	(.807, .141)	(.716, .211)	(.685, .249)
CLGG	(.701, .203)	(.372, .58)	(.468, .463)	(.61, .299)	(.707, .194)	(.36, .59)	(.573, .339)	(.651, .255)	(.675, .232)
OFI	(.521, .388)	(.583, .325)	(.639, .268)	(.5, .413)	(.467, .441)	(.499, .41)	(.494, .421)	(.464, .448)	(.477, .432)

Source: Compiled by the authors.

Next, the normalisation process is applied by looking at the types of criteria in Table 2. For this, Equations (12) and (13) are used. The normalised decision numbers are summarised in Table 6.

Table 6
Normalised decision numbers

	LLC	RRC	IPDS	FRFE	BTA	RCL	CAA	MCLR	RCR
TGB	(.362, .605)	(.217, .735)	(.143, .806)	(.344, .575)	(.345, .619)	(.141, .821)	(.407, .514)	(.348, .573)	(.376, .54)
TPG	(.519, .394)	(.37, .537)	(.471, .437)	(.562, .346)	(.575, .338)	(.503, .4)	(.624, .286)	(.583, .328)	(.589, .321)
PIF	(.618, .291)	(.594, .335)	(.435, .492)	(.647, .261)	(.696, .207)	(.493, .432)	(.553, .363)	(.664, .243)	(.682, .222)
PPP	(.793, .16)	(.644, .309)	(.659, .304)	(.794, .139)	(.822, .16)	(.689, .249)	(.72, .205)	(.768, .171)	(.747, .199)
DGG	(.731, .194)	(.607, .33)	(.616, .303)	(.732, .191)	(.69, .211)	(.524, .397)	(.807, .141)	(.716, .211)	(.685, .249)
CLGG	(.701, .203)	(.58, .372)	(.463, .468)	(.61, .299)	(.707, .194)	(.59, .36)	(.573, .339)	(.651, .255)	(.675, .232)
OFI	(.521, .388)	(.325, .583)	(.268, .639)	(.5, .413)	(.467, .441)	(.41, .499)	(.494, .421)	(.464, .448)	(.477, .432)

Source: Compiled by the authors.

Later, normalised decision numbers are defuzzified using Equation (14). The defuzzified decision numbers are displayed in Table 7.

Table 7
Defuzzified decision numbers

	LLC	RRC	IPDS	FRFE	BTA	RCL	CAA	MCLR	RCR
TGB	.413	.307	.240	.425	.402	.225	.466	.427	.448
TPG	.539	.448	.511	.568	.576	.532	.610	.582	.585
PIF	.606	.586	.482	.627	.664	.519	.561	.639	.653
PPP	.748	.619	.629	.749	.775	.656	.682	.724	.704
DGG	.692	.594	.603	.692	.660	.541	.762	.679	.653
CLGG	.668	.572	.499	.600	.673	.579	.575	.630	.648
OFI	.541	.418	.379	.527	.508	.472	.523	.505	.514

Source: Compiled by the authors.

Subsequently, the correlation coefficients between criteria are computed with the help of Equation (15). The correlation matrix is exhibited in Table 8.

Table 8
Correlation matrix

	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
LLC	1.000	.951	.923	.959	.960	.906	.802	.958	.942
RRC	.951	1.000	.899	.938	.969	.877	.743	.971	.981
IPDS	.923	.899	1.000	.961	.924	.920	.907	.967	.934
FRFE	.959	.938	.961	1.000	.956	.884	.864	.982	.949
BTA	.960	.969	.924	.956	1.000	.925	.726	.981	.990
RCL	.906	.877	.920	.884	.925	1.000	.696	.903	.907
CAA	.802	.743	.907	.864	.726	.696	1.000	.835	.755
MCLR	.958	.971	.967	.982	.981	.903	.835	1.000	.989
RCR	.942	.981	.934	.949	.990	.907	.755	.989	1.000

Source: Compiled by the authors.

Behind, the amount of information is estimated via Equations (16) and (17). Finally, the weights of criteria are defined as Equation (18). The results are presented in Table 9.

Table 9
Amount of information and weight value

	LLC	**RRC**	**IPDS**	**FRFE**	**BTA**	**RCL**	**CAA**	**MCLR**	**RCR**
C	.063	.073	.070	.050	.065	.123	.154	.039	.046
W	.092	.106	.102	.073	.095	.180	.225	.058	.068

Source: Compiled by the authors.

The prominence of corporate and administrative applicability (CAA) and the risk of contingent liability (RCL) requires interpretation from both methodological and substantive perspectives. Methodologically, CRITIC does not assign high weights simply because experts explicitly identify a criterion as important; rather, the weights reflect the information contained in the decision matrix through criterion variability and inter-criterion correlation. Therefore, the weight of 0.225 for CAA indicates that this criterion provides comparatively strong discriminatory information across the evaluated financing instruments after accounting for its relationships with the other criteria. Substantively, this result is meaningful because institutional and administrative capacity acts as an enabling condition for the effective implementation of public financing instruments. Legal certainty, financing efficiency, transparency, and risk-sharing arrangements may provide limited practical benefits when public authorities lack the capacity to design, implement, supervise and monitor the relevant financing structure. The second-highest weight assigned to RCL (0.180) similarly highlights an important structural feature of public financing. Guarantees, PPP arrangements and off-budget mechanisms can transfer or postpone fiscal

obligations rather than eliminate them, creating liabilities that may materialise under adverse conditions. This interpretation is consistent with the literature emphasising that guarantees may support short-term financial stability while simultaneously increasing fiscal exposure and that insufficiently transparent off-budget arrangements can obscure the actual public sector liability position. Taken together, the prominence of CAA and RCL suggests that the differentiation among public financing instruments in this application is driven not only by their expected financial benefits but also by the institutional capacity required to manage them and the possibility that transferred risks may ultimately return to the public balance sheet.

4.2. Ranking of public financing instruments

Firstly, the defuzzification process is applied for aggregated decision numbers as Equation (19). The defuzzified matrix is presented in Table 10.

Table 10
Defuzzified matrix

	LLC	RRC	IPDS	FRFE	BTA	RCL	CAA	MCLR	RCR
TGB	.413	.693	.760	.425	.402	.775	.466	.427	.448
TPG	.539	.552	.489	.568	.576	.468	.610	.582	.585
PIF	.606	.414	.518	.627	.664	.481	.561	.639	.653
PPP	.748	.381	.371	.749	.775	.344	.682	.724	.704
DGG	.692	.406	.397	.692	.660	.459	.762	.679	.653
CLGG	.668	.428	.501	.600	.673	.421	.575	.630	.648
OFI	.541	.582	.621	.527	.508	.528	.523	.505	.514

Source: Compiled by the authors.

Afterwards, the double normalisation process is performed using Equations (20) – (23). These matrices are shared in Table 11.

Table 11
Double normalisation

η	LLC	RRC	IPDS	FRFE	BTA	RCL	CAA	MCLR	RCR
TGB	.552	.550	.488	.568	.519	.444	.612	.590	.636
TPG	.721	.690	.758	.759	.742	.735	.801	.803	.831
PIF	.810	.920	.716	.837	.856	.716	.736	.883	.927
PPP	1.000	1.000	1.000	1.000	1.000	1.000	.896	1.000	1.000
DGG	.925	.939	.935	.925	.851	.749	1.000	.938	.927
CLGG	.893	.889	.740	.802	.868	.819	.755	.870	.920
OFI	.724	.655	.598	.704	.655	.653	.687	.697	.730

η'	LLC	RRC	IPDS	FRFE	BTA	RCL	CAA	MCLR	RCR
TGB	1.000	.550	1.000	.568	1.000	1.000	.612	.590	1.000
TPG	.766	.690	.644	.759	.699	.604	.801	.803	.765
PIF	.682	.920	.682	.837	.606	.620	.736	.883	.686
PPP	.552	1.000	.488	1.000	.519	.444	.896	1.000	.636
DGG	.597	.939	.522	.925	.610	.593	1.000	.938	.686
CLGG	.618	.889	.660	.802	.598	.543	.755	.870	.692
OFI	.763	.655	.817	.704	.792	.681	.687	.697	.871

Source: Compiled by the authors.

Behind, the deviation from the criterion weight is calculated by Equations (24) and (25). The results are illustrated in Table 12.

Table 12
Deviations

	v	v'
TGB	.455	.191
TPG	.241	.281
PIF	.203	.276
PPP	.023	.287
DGG	.093	.233
CLGG	.176	.301
OFI	.327	.273

Source: Compiled by the authors.

Finally, the ranking scores of public financing instruments are computed with Equation (26). The result is displayed in Table 13.

Table 13
Ranking scores

	Q
TGB	–.409
TPG	.076
PIF	.152
PPP	.850
DGG	.428
CLGG	.261
OFI	–.090

Source: Compiled by the authors.

The first-place ranking of PPP-supported financing instruments should likewise be interpreted as the result of a multidimensional performance pattern rather than superiority on a single criterion. PPP demonstrates a comparatively strong and balanced profile across several legal, financial and institutional dimensions, including legal certainty, financing efficiency, budget transparency and accountability, market confidence and legal reputation, crisis resilience and administrative applicability. This profile is particularly important in light of the criterion-weighting results, because the ranking mechanism gives greater influence to criteria carrying stronger discriminatory information, especially CAA and RCL.

From a substantive perspective, PPP arrangements can combine private sector financing and implementation capacity with public sector oversight while distributing selected financial, operational and legal risks between the parties. This can reduce the need for the government to internalise all project-related risks directly and may improve implementation efficiency when contracts and monitoring arrangements are appropriately designed. The result, however, should not be interpreted as evidence that PPPs are universally preferable to other public financing instruments. Their relative advantage is conditional on adequate institutional capacity, transparent contractual structures, appropriate risk allocation and effective management of contingent liabilities.

This qualification is especially important because the same analysis identifies administrative applicability and contingent liability risk as the two most influential criteria. Therefore, the results jointly indicate that the attractiveness of PPP financing depends precisely on the government's ability to design and supervise risk-sharing arrangements without allowing contingent obligations to generate excessive future fiscal exposure.

The findings can also be interpreted in relation to previous research on public financing, institutional capacity and fiscal risk. First, the high importance of corporate and administrative applicability (CAA) is broadly consistent with studies emphasising that the effectiveness of public financing mechanisms depends strongly on governance quality and institutional design. Megginson and Gao (2020) and Amar and Lecourt (2023), for example, associate the performance and credibility of state investment structures with governance arrangements and institutional quality, while Gootjes and de Haan (2022) demonstrate that transparency and institutional conditions affect the effectiveness of formal fiscal rules. Similarly, the high weight obtained for the risk of contingent liability (RCL) is consistent with Izumi (2020), who shows that government guarantees can reduce short-term financial fragility while simultaneously generating fiscal exposure.

These similarities suggest that the present multi-criteria results capture institutional and fiscal risk mechanisms that have also been identified through theoretical and empirical approaches in the previous literature. The first-place ranking of PPP-supported financing instruments is also broadly consistent with research emphasising the potential benefits of risk sharing, private sector expertise and financing diversification under PPP arrangements. However, previous studies also provide an important qualification to this finding. PPPs and government guarantees can create explicit and implicit contingent liabilities, and their successful implementation depends substantially on institutional capacity, transparency, appropriate contractual risk allocation and effective fiscal risk management. Therefore, the present finding should not be interpreted as unconditional superiority of PPPs. Rather, the joint result that PPPs rank first while CAA and RCL emerge as the two most influential

criteria indicates that the attractiveness of PPP financing is conditional on precisely the institutional and fiscal risk management capabilities highlighted in previous research.

Differences between the present findings and studies emphasising the fiscal risks or contractual difficulties of PPPs can thus be explained partly by differences in analytical perspective: previous studies often examine realised fiscal exposure, contract distress, or individual financing mechanisms, whereas the present study evaluates several public financing alternatives simultaneously across legal, financial and institutional criteria. Accordingly, the results complement rather than contradict this literature by identifying the conditions under which the relative advantages of PPP-supported financing may outweigh their associated risks.

4.3. Sensitivity analysis

Sensitivity analysis and validation are essential in MCDM applications because the resulting rankings may be influenced by criterion weights, input evaluations, normalisation procedures, aggregation mechanisms and the specific ranking algorithm employed. As emphasised by Sarkar et al. (2026), the robustness of an MCDM result can be examined through complementary procedures, including parameter and criterion-weight perturbation, scenario-based analysis, comparison with alternative MCDM methods, rank-stability and rank-reversal assessment, changes in input information, and, where appropriate, external or empirical validation. These procedures address different sources of uncertainty and should therefore be viewed as complementary rather than interchangeable. In the present study, two forms of validation are employed. First, cross-method validation is conducted by comparing RAWEC with TOPSIS and RAM, which have different normalisation and aggregation principles. This analysis examines whether the substantive ranking depends on the selected ranking algorithm. Second, weight-perturbation sensitivity analysis is conducted through Monte Carlo scenarios in which the CRITIC criterion weights are varied while the alternative evaluations are held constant. This procedure examines whether reasonable changes in criterion importance alter the preference ordering. The identical rankings obtained across RAWEC, TOPSIS and RAM, together with the stability of the ranking across the simulated weight scenarios, provide complementary evidence that the main conclusion is not driven solely by either the selected ranking algorithm or the baseline criterion-weight vector. Nevertheless, these procedures do not constitute exhaustive validation. Input evaluation perturbation, expert-level resampling, criterion addition or removal, and external validation using observed outcomes could provide additional evidence regarding model stability. These extensions require either alternative expert evaluation structures or suitable empirical benchmark data and are therefore identified as important directions for future research. The comparative results of public financial instruments obtained using the three methods are visualised in Figure 2.

Although RAWEC, TOPSIS and RAM produce the same ranking in the present application, this result should not be interpreted as mathematical equivalence among the three methods. The methods differ in their normalisation and aggregation mechanisms and, consequently, in the way they transform criterion-level performance into an overall

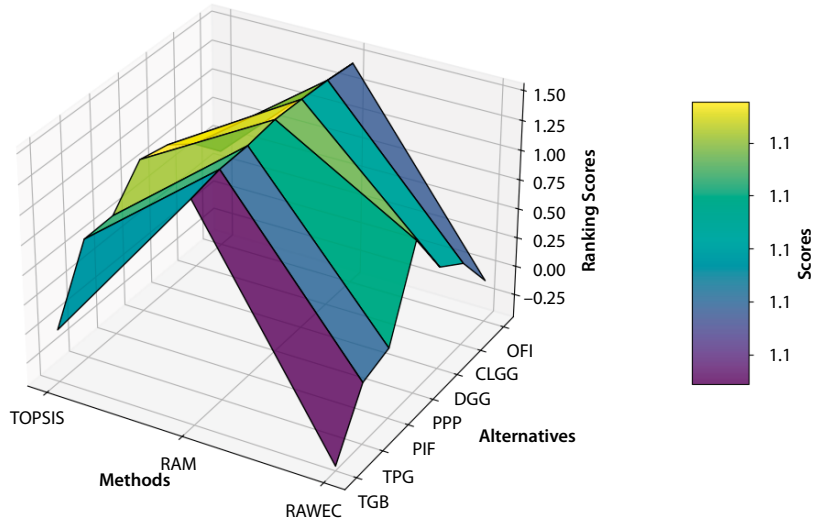

Figure 2
Comparative results

Source: Compiled by the author.

preference score. TOPSIS evaluates alternatives according to their relative distances from positive and negative ideal solutions, whereas RAM evaluates performance through its own normalisation and aggregation structure. RAWEC, in contrast, employs two normalisation structures and evaluates deviations in relation to criterion weights. The identical ranking observed in this study can mainly be attributed to the relatively clear and consistent performance structure of the decision matrix. PPP-supported financing instruments exhibit strong performance across most of the legal, financial and institutional criteria, while DGG also maintains a comparatively strong profile, especially in corporate and administrative applicability. Consequently, the differences in normalisation and aggregation among the three methods are not sufficiently large to reverse the relative positions of the alternatives. The high Pearson correlations between RAWEC and TOPSIS (0.936) and between RAWEC and RAM (0.964) further indicate that, although the numerical preference scores are generated differently, the overall performance patterns captured by the methods are highly consistent. Differences among these methods could nevertheless be expected when alternatives have very similar overall performance, when strong trade-offs exist across criteria, when extreme criterion values substantially affect normalisation, or when highly concentrated criterion weights amplify method-specific aggregation effects. Under such conditions, different treatments of normalisation, ideal solutions, and performance aggregation may lead to rank reversals or changes in the relative positions of alternatives. In the second approach, Monte Carlo simulation is applied to the criterion weights obtained from the CRITIC method. This allows for the creation of possible real-world scenarios with minimal changes in criterion weights. In each scenario, the importance weights of the criteria are differentiated. Subsequently, public financial instruments are ranked using RAWEC in each scenario. In other words, while the evaluations remain the same, the impact of changes

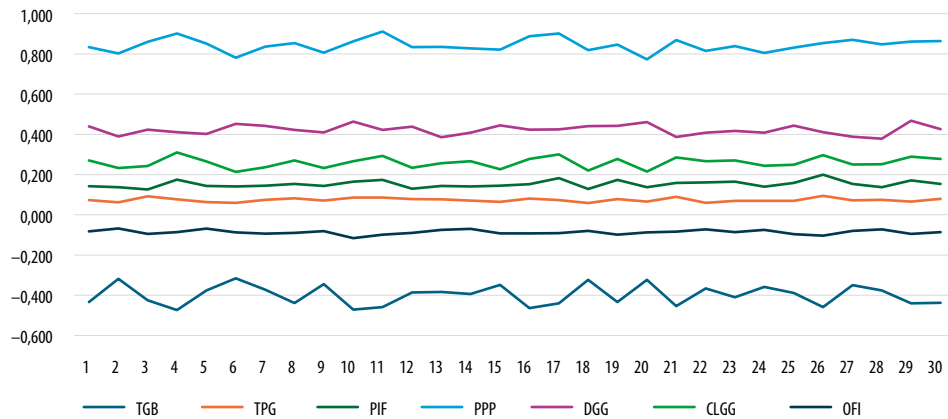

Figure 3
Scenarios

Source: Compiled by the author.

in criterion weights on the order of preference for public financial instruments is examined. The results of this approach are presented in Figure 3.

As can be seen from Figure 3, there is no difference in the ranking of public finance instruments across the 30 different scenarios. In other words, the difference in the priority of possible criteria does not affect whether public–private partnership-supported financing instruments are the most suitable public finance instrument.

5. Conclusions

This study aimed to develop a comprehensive evaluation framework for public financing instruments by focusing on the balance between legal risk and financial return. To achieve this objective, a novel decision-making model was proposed by integrating CRITIC and RAWEC techniques with Fermatean fuzzy sets, allowing for a more flexible representation of uncertainty in expert evaluations. The analysis was based on expert opinions and a structured set of criteria and alternatives derived from the literature. The findings revealed that corporate and administrative applicability and the risk of contingent liability were the most critical criteria in the evaluation process. In addition, public–private partnership-supported financing instruments were identified as the most suitable strategy, followed by direct government guarantees. These results highlight the importance of institutional capacity and risk awareness in public financing decisions. The study contributes to the literature by introducing an integrated and multidimensional decision-making framework that combines legal, financial and institutional perspectives, thereby offering a more realistic and applicable analytical approach.

Despite its contributions, this study has several theoretical, methodological and practical limitations. First, the model relies on expert judgments, which may introduce subjectivity despite the use of Fermatean fuzzy sets to better represent uncertainty in linguistic evaluations.

In addition, the selected criteria and alternatives, although comprehensive, may not fully capture context-specific factors across different countries, institutional settings, or economic conditions. The proposed model also assumes a static evaluation environment, whereas public financing decisions are influenced by dynamic and evolving regulatory, fiscal and economic conditions. Another important limitation concerns the practical implementation of the proposed framework. The integration of Fermatean fuzzy sets, CRITIC and RAWEC involves several computational stages, including fuzzy number conversion, aggregation, normalisation, defuzzification, criterion weighting and alternative ranking. Consequently, direct manual application may be technically demanding for policymakers and public officials, particularly in institutions with limited specialised staff and analytical capacity. The framework should therefore be regarded primarily as the analytical basis for a decision support system rather than as a calculation procedure that policymakers are expected to implement manually.

In practical applications, decision-makers could provide their assessments through the predefined linguistic scale, while the subsequent computational stages could be automated through a spreadsheet-based template or a dedicated software interface. However, such a practitioner-oriented implementation has not been developed or empirically tested in the present study, which represents an additional limitation. Future research can address these limitations by incorporating larger and more diverse expert groups, applying the model to different country and institutional contexts, integrating dynamic or real-time data, and comparing the results with alternative fuzzy and non-fuzzy approaches. More importantly, future studies could translate the proposed framework into a simplified and automated decision support tool and test its usability, transparency, computational requirements, and practical value with finance ministry officials and other public sector practitioners, particularly in developing countries with limited technical and institutional capacity.

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