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Integrating ISO 31000:2018 with the Analytic Hierarchy Process for Qualitative Enterprise Risk Prioritization: Evidence from Airport Services State-Owned Enterprise in Indonesia

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ABSTRACT

Purpose – This study addresses the limitations of ordinal likelihood impact matrices in ISO 31000:2018-based risk management, particularly their inability to differentiate risks assigned to identical matrix cells. **Design/methodology/approach** – An integrated ISO 31000–Analytic Hierarchy Process (AHP) framework was applied to the 2023 risk register of an Indonesian airport-services state-owned enterprise. Six impact criteria were weighted by four senior managers. Risk priorities combined normalized likelihood–impact scores with category weights. Robustness was assessed through ±20% sensitivity analysis, analytical crossover thresholds, and Monte Carlo simulations. **Finding/Results** – The framework differentiated seven tied high-level risks into three priority tiers: financial (14.39%), business/strategic (8.65%), and operational (5.19%). The financial criterion dominated (weight = 0.341), with consistent AHP judgments (CR = 0.012). Tender-loss risk (R5) retained its leading position above a financial-weight threshold of 0.237 under fixed ratings. When ratings varied, financial risks ranked first in 85.5% of simulations, while R5 uniquely ranked first in 49.3%. Same-category ties remained unresolved, and monitoring comparisons did not establish predictive validity. **Originality/Value –** This study integrates AHP into ISO 31000 risk assessment while maintaining compatibility with existing treatment (FRR03) and monitoring (FRR04) systems. It provides a replicable prioritization framework incorporating rank-reversal thresholds and uncertainty analysis, while acknowledging its limitations in resolving within-category risk ties.

ARTICLE INFO

Keywords: Enterprise Risk Management, ISO 31000:2018, Analytic Hierarchy Process, Multi-Criteria Decision Making, Risk Prioritization.

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1. Introduction

Enterprise risk management (ERM) has moved from being a compliance-based activity to a strategic competency that links organizational uncertainty to the achievement of the organization's objectives. ERM is the systematic process of identifying risks, assessing their likelihood and impact, prioritizing and allocating resources for treatment. Two international standards dominate the field, ISO 31000:2018, published by the International Organization for Standardization (confirmed without revision at its 2023 systematic review), and COSO ERM: Integrating with Strategy and Performance, published in 2017 by the Committee of Sponsoring Organizations of the Treadway Commission. COSO structures its guidance around five components: Governance and Culture, Strategy and Objective-Setting, Performance, Review and Revision and Information and Reporting, and places emphasis on internal control activities (COSO, 2017). ISO 31000 adopts a deliberately non-prescriptive principles-based approach based on three interrelated elements: eight principles, a framework for embedding risk management into governance and a cyclic process of establishing context, assessing risk, treating risk and monitoring-review (ISO, 2018; Purdy, 2010). The eight principles of ISO 31000:2018 indicate that effective risk management should be embedded in all organizational activities, adapted to a systematic and thorough process, adapted to the organization's context including stakeholders, responsive to change, based on the best available information, sensitive to human and cultural factors, and aimed at continual improvement (ISO, 2018, clause 4). The 2018 revision simplified the language, increased attention to leadership commitment and organizational culture, and retained the definition of risk, introduced in the 2009 edition, as the "effect of uncertainty on objectives" moving away from threats to a more general idea of uncertainty that results in both downside risk and upside opportunity (Lalonde & Boiral, 2012; Hopkin, 2018). The main reference for state-owned enterprises in Indonesia is ISO 31000. The regulatory framework established by the 2003 SOE Law, the four-tier systemic classification under PER-5/MBU/09/2022 (Systemic A/B, Significant, Neutral), and the 2025 establishment of BP BUMN, the national SOE regulatory agency, mandates that boards of commissioners oversee a formal risk function. Companies providing airport services in this ecosystem face a distinctive amalgamation of risks: their revenue relies on regulated concessions, the rebound of passenger volumes following external disruptions, and facility-management contracts acquired through competitive bidding, all while adhering to aviation-security regulations, domestic-content requirements (P3DN regulations), and investing in new business ventures such as solar energy facilities and digital monitoring systems. Consequently, the board must evaluate qualitative financial, operational, business, and strategic risks using a standardized scale, a task for which a qualitative risk matrix, used on its own, offers limited discrimination.

2. Literature Review & Hypothesis Development

There is a wealth of literature on the implementation of ISO 31000. Purdy (2010) traced the evolution of the original 2009 edition from risk management as compliance to risk management as decision support. Lalonde and Boiral (2012) analyzed the theoretical basis of the standard and concluded that, although it provides a coherent structure, it is intentionally

flexible and therefore prone to superficial implementation. Sassaoui et al. (2023) presented a framework review and case study of ISO 31000 in procurement risk management, in which the process stages of the standard are followed and the assessment stage is operationalized with qualitative likelihood–consequence scoring. Purwanti et al. (2025) investigated the impact of ISO 31000 adoption at the principles, framework and process levels on the financial performance of Indonesian banks (2019–2023) using a panel-data analysis and concluded that implementation quality is more important than adoption. The dominance of qualitative assessments has been challenged in the risk analysis literature in the last decade. Cox (2008) showed mathematically that ordinal risk matrices suffer from "range compression" (i.e., qualitatively different risks are assigned to the same cell) and that they correctly rank fewer than 10% of randomly selected pairs of hazards. Krisper (2021) catalogued 24 problems of ordinal risk matrices, including range compression and risk inversion, using examples drawn from the MIL-STD-882C system-safety standard and ISO 26262 automotive risk matrices. Aven and Thekdi (2021) also caution that the apparent clarity of such matrices can discourage a more rigorous treatment of uncertainty. Duijm (2015) offered recommendations for the design and use of risk matrices, which mitigate rather than remove the ordinal limitation. Nevertheless, ordinal matrices remain widespread in practice. A single-organization case study at a subsidiary of a telecommunications holding group in Indonesia similarly relied on an ordinal risk matrix before applying AHP to differentiate risks sharing the same level (Wishnu Shandhika, 2023). Multi-criteria decision-making (MCDM) methods, in particular the Analytic Hierarchy Process (AHP) proposed by Saaty (1980), can mitigate some of these limitations. The pairwise expert judgments are transformed into ratio-scale weights by the principal eigenvector, while a consistency ratio (CR) is provided as an internal consistency check (Saaty, 2008). Kumar and Pamucar (2025) reviewed 3,655 peer-reviewed MCDM articles published between 2004 and 2024 and traced the field's development from foundational methods such as AHP and TOPSIS to hybrid fuzzy and AI-based models. In risk and project-evaluation settings, AHP has been combined with SCOR to assess road-transport risk in the petroleum supply chain of an Algerian SOE (Abdi et al., 2024), with TOPSIS for maritime cybersecurity risk (Putra et al., 2023), and applied to the evaluation of air transport development projects (Alharasees & Kale, 2024). Barabea et al. (2026) applied AHP to supply chain risk in the Saudi aviation sector and obtained the highest weight for operations risk mitigation (42.5%), followed by strategic performance (32.8%) and financial health (24.7%). However, in the applications reviewed here, AHP is reported as a ranking exercise in its own right: the studies establish a priority order but do not document how it feeds the treatment and monitoring records that the ISO 31000 process cycle requires. Their inputs are also more often elicited through surveys or focus groups than taken from a board-reviewed corporate risk register. Finally, sensitivity analysis, which is needed to show that a ranking is not an artefact of particular weight choices, is reported unevenly; Barabea et al. (2026), for example, describe a ±20% weight perturbation but report only qualitative stability labels, without rank-reversal thresholds. Because this review is narrative rather than systematic, these observations describe the studies examined here and are not a claim about the entire AHP-risk literature.

2.1 Research Aims and Contribution

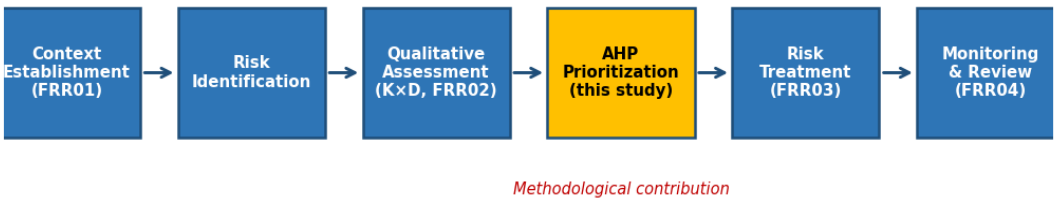
The objective of this study is to develop and illustrate a hybrid framework that integrates AHP into the assessment phase of ISO 31000:2018 to differentiate risks that an ordinal matrix leaves tied, while remaining compatible with the organization's existing risk-register system. The framework is an AHP-weighted extension of the ordinal assessment; it is not a solution to the general measurement problem of ordinal risk matrices. Specific objectives were: (1) to derive AHP criterion weights for six risk-impact categories via pairwise comparisons with consistency verification; (2) to synthesize global risk priorities that differentiate risks residing in the same matrix cell; (3) to examine the stability of the ranking under uncertainty in the criterion weights and in the likelihood and impact ratings; and (4) to illustrate the framework by applying it to the actual 2023 corporate risk register of an Indonesian state-owned airport services SOE.

This study extends existing ISO 31000–AHP applications in three respects. First, AHP is embedded within the full ISO 31000 process, with its output feeding directly into the existing treatment (FRR03) and monitoring (FRR04) Risk Register Forms (FRR), thus completing the loop between prioritization and action. Second, the data inputs were developed from a real corporate risk register that had been board-reviewed, rather than an example dataset. Third, the stability of the ranking is examined with one-at-a-time perturbation, a parametric sweep with analytically derived crossover thresholds, and a Monte Carlo analysis of both criterion weights and ratings, so that the conditions under which the ranking holds are stated explicitly. Appendix A provides an AHP questionnaire instrument to facilitate replication.

2.2 The Proposed Method: Integrated ISO 31000–AHP Framework

The proposed approach keeps the full process sequence of ISO 31000:2018 and places AHP only at one well-defined point between the qualitative assessment and risk treatment (Figure 1). This deliberate positioning allows the existing context-establishment (FRR01) and risk-identification stages to proceed unmodified, ensuring that the AHP output feeds directly into the treatment (FRR03) and monitoring (FRR04) artifacts that the firm already uses.

Figure 1. AHP-integrated framework with ISO 31000:2018.



The AHP prioritization stage (highlighted) is inserted within the assessment stage; all other stages remain unchanged.

2.3 Architecture of the Integration

The integration was based on two inputs. The first is the ordinal likelihood–impact score from FRR02 (the existing risk assessment working paper), which gives a local priority for each risk. Each risk i has a likelihood score K_i (1–5) and an impact score D_i (A–E mapped to 1–5). The raw magnitude of the risk is given by the product $K_i \times D_i$. The second input is a set of criterion weights derived from AHP that reflects the relative importance of six impact

categories defined in FRR01: financial (C1), operational (C2), business (C3), strategic (C4), legal and compliance (C5), and reputational (C6).

The synthesis rule is: the global priority of risk i equals the normalized local priority multiplied by the weight of the impact category to which it belongs. That is, two risks with the same score $K_i \times D_i$ (for example, both at 4C = 12) will have different global priorities if they belong to categories with different weights. Because the local priority Li is still the ordinal product $K_i \times D_i$, this synthesis is best described as an AHP-weighted extension of the existing ordinal assessment rather than a replacement of it: AHP supplies the criterion weights that differentiate risks sharing the same ordinal cell, while the underlying ordinal scoring of likelihood and impact is retained unchanged. Each risk is assigned to a single dominant impact category, following the categorisation already used operationally in FRR01; this preserves compatibility with the firm's existing ISO 31000 documentation but is a simplification, since a risk's consequences can plausibly span more than one category (see Section 6).

The scale status of the resulting index needs to be stated precisely. The product $K_i \times D_i$ is an ordinal score that the firm's register already treats as if it were a magnitude; the integrated model inherits this assumption and does not remove it. The AHP weights, by contrast, are ratio-scale in Saaty's (1980) sense: weights of 0.341 and 0.123 express the panel's judgment that financial consequences matter about 2.8 times as much as operational ones. Multiplying an ordinal local score by a ratio-scale category weight therefore yields a weighted ordinal index, which is useful for prioritization for two reasons. First, within any one category the weight is a common positive factor, so the ordering given by $K_i \times D_i$ is preserved exactly and no information already in the register is overwritten. Second, between categories the weight acts as an explicit, documented trade-off rate that replaces the implicit assumption of the plain matrix that one unit of K × D carries the same importance in every category. The cross-category comparisons the index makes (for example, a 3C financial risk ranking above a 4C business risk) remain conditional on treating K × D as approximately interval-scaled, the same assumption the organization already makes when it multiplies the two ratings. The global percentages should therefore be read as relative priority shares that support ordering and deliberation, not as cardinal measures of expected loss or of a risk's true magnitude; Section 4.4 reports how the ordering changes when the ratings themselves shift by one ordinal step.

2.4 Why AHP and Not Other MCDM Methods

Several MCDM methods can provide criterion weights in principle TOPSIS, PROMETHEE, DEMATEL, and BWM among them. The choice of AHP was justified on three context-specific grounds. First, the pairwise comparison format is intuitive for non-specialist board members and risk owners accustomed to making relative judgments but not to assigning numerical scores on abstract scales (Saaty, 2008). Second, the consistency ratio provides a built-in quality check for inconsistent judgments, which only some other weighting methods, such as BWM, also provide (Vaidya & Kumar, 2006). Third, AHP has an extensive record of applications, including in risk management, which makes it easier for practitioners to find

benchmarks and for reviewers to compare results with similar studies (Ho, 2008; Vaidya & Kumar, 2006).

3. Methodology

3.1 Research Design and Case Description

This study adopted an illustrative single-case design (Yin, 2018). The case organization is an Indonesian airport-services SOE (hereinafter 'APS'), a subsidiary of a state airport operator. APS has four business segments: (1) Facility Services (cleaning, maintenance and engineering), (2) Resource Services (aviation security and support staff), (3) Passenger Services (VIP handling, Hajj–Umrah travel and concierge), and (4) Strategic New Business (solar energy, BPO, and digital tracking). In fiscal year 2023, APS set board-approved revenue, EBITDA, and net income targets (RKAP). Consistent with the confidentiality terms under which the firm's internal documents were made available for this study, absolute Rupiah figures are withheld here; performance against these targets is reported only in relative terms (Section 4.1, Section 4.3).

Empirical data were obtained from four internal working papers constituting the firm's ISO 31000 process documentation: context establishment (FRR01), risk assessment with the ordinal matrix (FRR02), risk treatment plans (FRR03), and quarterly monitoring results (FRR04). Additional data were obtained from the management report of April 2023 and the minutes of the joint Board of Commissioners and Directors meeting of 17 April 2023. FRR02 identified fourteen corporate-level risks, each rated on a five-point likelihood scale (K = 1–5) and a five-category impact scale (D = A–E, mapped 1–5): seven high-rated risks, five medium, and two low. Seven of the fourteen risks fell in the same 4C cell (all rated High), which constitutes the tie problem this study addresses; a further three risks were separately tied within the 3C/Medium cell.

3.2 AHP Computation Procedure

The AHP computation proceeds in four steps, each recorded in sufficient detail to enable replication by other researchers.

Step 1: **Pairwise comparison matrix.**

A 6×6 reciprocal matrix A = [a(i,j)] was constructed, where a(i,j) represents the relative importance of criterion i over criterion j on Saaty's (1980) fundamental scale (1 = equal; 3 = moderate; 5 = strong; 7 = very strong; 9 = extreme; even numbers for intermediate judgments). For n = 6 criteria, the number of unique pairwise comparisons was n(n-1)/2 = 15. The expert panel comprised the Head of Risk Management, the Chief Financial Officer, and two senior directors, who reached a single consensus matrix in one facilitated group session: the 15 pairwise judgments were discussed jointly and each comparison was recorded only once the panel agreed on it, rather than being elicited individually from each member and then aggregated. This procedure yields the panel's collective judgment but does not permit reporting inter-rater dispersion (e.g., a per-expert consistency ratio); we note this as a limitation in Section 6. The exercise is therefore best characterized as a facilitated managerial consensus exercise. Because individual matrices were never elicited, geometric-mean aggregation of separate judgments cannot be applied retrospectively, and the consistency ratio reported in Section 4.1 refers to the consensus matrix only. The geometric-mean

aggregation protocol documented in Appendix A.4 applies to future multi-respondent rounds using the instrument provided there.

Step 2: **Criterion weights (eigenvector approximation).**

The normalized matrix is obtained by dividing each column of A by the sum of its column. The row averages of this normalized matrix give an eigenvector approximation w = (w1, w2, ..., w6) via the normalized column-sum method (Saaty, 1980), used throughout this study as the estimate of each criterion's global weight; this approximation, rather than the exact principal eigenvector, is also what is reported in Figure 2 and used consistently in Appendix A.4.

Step 3: **Consistency verification**

The maximum eigenvalue λmax is estimated as the mean of $(Aw)_i/w_i$ across i = 1, ..., 6, where Aw is the matrix-vector product of A and the weight vector w obtained in Step 2. The consistency index $CI = (\lambda max - n)/(n - 1)$ and the consistency ratio CR = CI/RI are then calculated, where RI is the random index (1.24 for n = 6) (Saaty, 1980). If CR > 0.10, the expert panel revises the most inconsistent comparisons. CR measures the internal logical consistency (approximate transitivity) of a single matrix; it does not measure agreement among panel members.

Step 4: **Synthesis of global risk priorities.**

The local priority of risk i is calculated by normalizing the product of the likelihood and impact scores of risk i across the full set of assessed risks: $Li = (Ki \times Di) / \Sigma j(Kj \times Dj)$, where the summation runs over all 14 risks in the register (not within-category). Applying this formula to the three-decimal criterion weights in Figure 2 and the K×D values in Table 1 reproduces every global-priority percentage in Table 1 at two decimal places. The global priority is $Gi = Li \times w(c(i))$, where c(i) is the impact category to which risk i belongs. Vector G is re-normalized to sum to 100%. This means that risks within the same ordinal cell but in different impact categories are given different global scores; risks that share the same K×D and belong to the same category, or to categories with equal weights, remain tied (see Section 4.2).

3.3 Sensitivity and Uncertainty Analysis Design

Test 1 – One-at-a-time (OAT) perturbation: Each of the six criterion weights is multiplied in turn by 1.2 or 0.8, and the full weight vector is then rescaled to sum to one (so the effective change in the perturbed weight after rescaling is somewhat smaller than ±20%). The effect on the aggregate score and rank of the highest ranked risk (R5) and a typical medium ranked risk (R1) was measured. Using this test, the most influential criterion in the ranking is identified.

Test 2 – Parametric sweep: the weight of the dominant criterion (financial, identified in Test 1) is changed from 0.15 to 0.50, in steps of 0.05, and the other five weights are renormalized proportionally. The sweep tracks the ranks of the top seven risks, and the exact crossover weights are obtained analytically by equating the global scores of competing risks as functions of the financial weight. Agreement with the baseline ranking is summarized with Spearman's ϱ and Kendall's τ-b computed on the global scores, so that tied scores receive tied (mid-)ranks rather than the sequential display order of Table 1.

Test 3 – Monte Carlo uncertainty analysis: Tests 1 and 2 hold the local priorities fixed and therefore describe stability conditional on the recorded ratings. To represent uncertainty in the inputs themselves, 10,000 replications were drawn under each of three scenarios: (a) weights only, with each criterion weight multiplied by an independent log-normal factor (σ = 0.20) and the vector rescaled to sum to one; (b) ratings only, with each likelihood and impact rating independently shifted by −1, 0 or +1 ordinal step with probabilities 0.10, 0.80 and 0.10 (bounded to the 1–5 range); and (c) both simultaneously. Category assignments were held fixed, and the random seed was fixed for reproducibility. Because individual pairwise judgments were not elicited (Section 3.2), uncertainty in the pairwise comparisons is represented indirectly through the weight perturbation rather than by resampling the comparison matrix.

3.4 Data exclusion and inclusion decisions

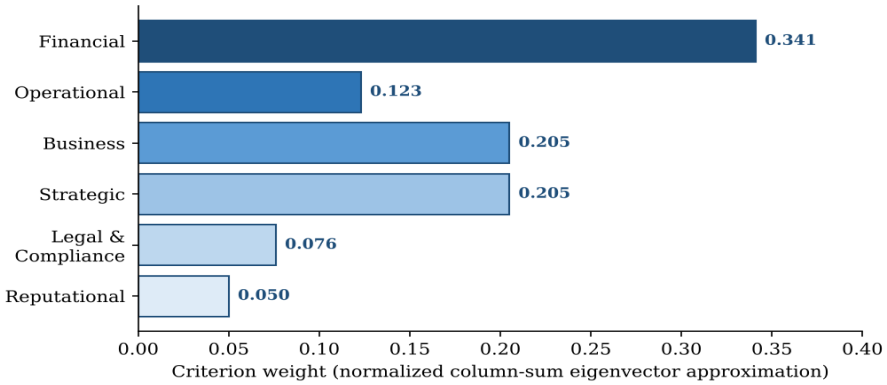
All 14 risks in the FRR02 register were included in the analysis; no risk was excluded. The FRR04 monitoring data (actuals for March 2023) were used only for a post-hoc comparison with the AHP ranking, not as an input to the AHP computation, to keep the prioritization model separate from the comparison evidence. The financial performance data (revenue, EBITDA, BOPO and NPM) from the management report of April 2023 were used to contextualize the criterion weights and the board's concerns but were not included in the AHP calculation.

4. Results and Discussion

4.1 Criterion Weights and Consistency

The criterion weights obtained from the pairwise comparison matrix are shown in Figure 2. The financial criterion had the highest weight (0.341), followed by business and strategic (0.205 each), operational (0.123), legal and compliance (0.076), and reputation (0.050). The consistency ratio of the consensus matrix was 0.012, well below the acceptance threshold of 0.10 (Saaty, 1980). This shows that the 15 agreed judgments are logically coherent with one another; it does not show that the four panel members agreed independently, that the panel represents all relevant stakeholder perspectives, or that the result is free of group-dominance effects.

Figure 2. AHP global criterion weights derived via the normalized column-sum eigenvector approximation (CR = 0.012).



The weighting pattern differs from that reported in other settings. In a Saudi aviation supply chain study, Barabea et al. (2026) found operational risk mitigation to have the highest weight (42.5%), followed by strategic performance (32.8%) and financial health (24.7%). The contrast between a financial-first weighting here and an operational-first weighting there plausibly reflects a difference in organizational context. APS is a facility management subsidiary whose primary exposure is loss of revenue from failed tenders, whereas aviation supply chains face physical disruption risks that directly affect operations. This is consistent with Saaty's (2008) observation that AHP weights should be context dependent and not transferable across organizations. The applications reviewed by Vaidya and Kumar (2006) likewise show weight structures that differ with the application setting. This weighting pattern is consistent with the board's priorities as documented in the April 2023 management report, which noted concerns about net profit margin (achieved 8.01% vs. RKAP target of 9.92%), operating expense ratio (86.91% vs. target of 85.99%), and revenue impact of lost tenders outside the parent group. The AHP weights make these priorities explicit rather than implicit.

The composition of the panel matters for how these weights are read. The panel consisted of senior executives, including the CFO, and its judgments were formed in a single facilitated discussion. In such settings, hierarchy and the persuasiveness of individual members can shape the agreed value of each comparison, and a dominant financial criterion (0.341, nearly three times the operational weight) is the kind of outcome such effects could produce. The close fit with the board's documented profitability concerns is consistent with two readings: that the weights express the firm's genuine risk appetite, or that they reflect the priorities of the members best placed to shape the discussion. The present design cannot separate these readings. The weights are therefore interpreted here as the declared priorities of the firm's senior management coalition for the 2023 cycle, not as a stakeholder-neutral estimate of category importance, and Section 4.4 shows how far the ranking depends on the financial weight in particular.

4.2 Integrated Risk Priority Ranking

Table 1 and Figure 3 present the global priority ranking produced by synthesizing local priorities with the criterion weights.

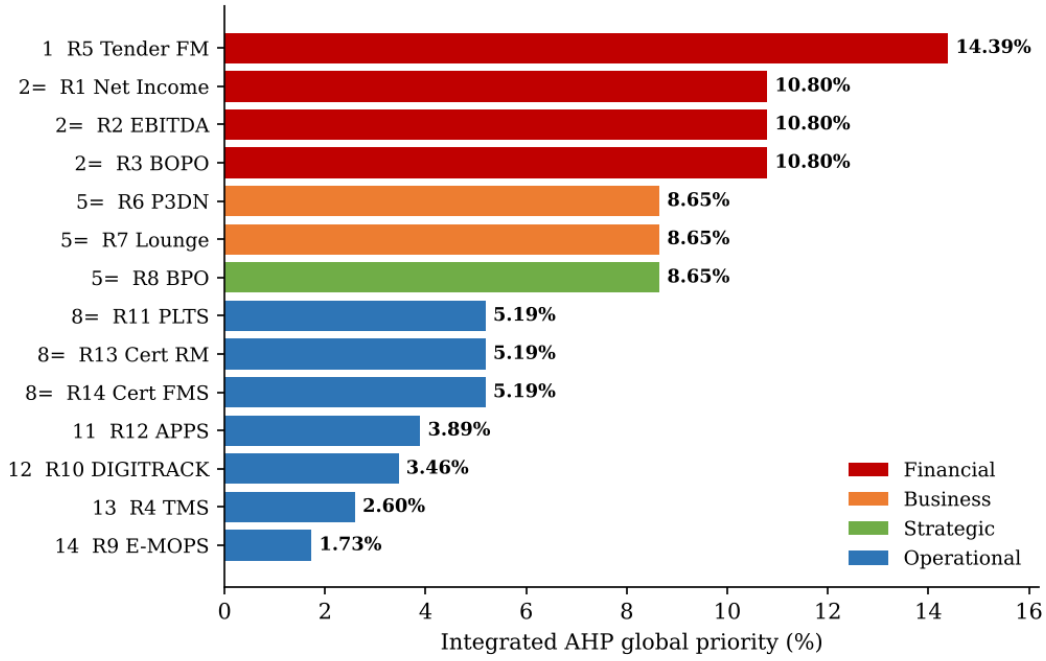
Table 1. Integrated ISO 31000–AHP risk priority ranking.

Rank	ID	Risk	Category	K×D	Cell	Level	AHP (%)
1	R5	Loss in tenders outside AP II Group	Financial	12	4C	High	14.39
2=	R1	Net income target shortfall	Financial	9	3C	Medium	10.80
2=	R3	Operating expense ratio exceeds budget	Financial	9	3C	Medium	10.80
2=	R2	EBITDA target shortfall	Financial	9	3C	Medium	10.80
5=	R7	Delayed lounge self-management transition	Business	12	4C	High	8.65

Rank	ID	Risk	Category	K×D	Cell	Level	AHP (%)
5=	R6	Domestic-content (P3DN) target not met	Business	12	4C	High	8.65
5=	R8	BPO portfolio mismatch with market	Strategic	12	4C	High	8.65
8=	R11	Delayed solar plant construction	Operational	12	4C	High	5.19
8=	R14	FMS certification pass-rate shortfall	Operational	12	4C	High	5.19
8=	R13	Risk-management certification shortfall	Operational	12	4C	High	5.19
11	R12	New-branch APPS not implemented	Operational	9	3C	Medium	3.89
12	R10	Delayed DIGITRACK implementation	Operational	8	4B	Medium	3.46
13	R4	TMS not implemented	Operational	6	3B	Low	2.60
14	R9	E-MOPS system enhancement not realized	Operational	4	2B	Low	1.73

Note. K = likelihood (1–5); D = impact (A–E mapped to 1–5). AHP (%) is the renormalized global priority. Tied risks share a rank (marked =). Risks with identical K×D in the same category, or in categories with equal weights (Business and Strategic, both 0.205), receive identical AHP (%) scores and are tied (R1/R2/R3; R6/R7/R8; R11/R13/R14). All values are computed from the three-decimal weights in Figure 2.

Figure 3. Integrated risk priority ranking colored by impact category; tied risks share a rank (=) and an identical score.



The most important result is the differentiation of the seven risks collected under the 4C/High cell of the ordinal matrix. Under the integrated model, these seven risks were classified into three priority tiers: the financial risk (R5 at 14.39%), the business and strategic risks (R6, R7, R8 at 8.65% each), and the operational risks (R11, R13, R14 at 5.19% each). The ordering is driven by the criterion weights. R5 (loss in tenders) and R11 (delayed solar plant) have the same value of K×D=12, but R5 belongs to the financial category (weight 0.341), while R11 belongs to the operational category (weight 0.123), which gives R5 a global score 2.77 times that of R11. This differentiation resolves ties only between categories with different weights. R6 and R7 (both Business, K×D = 12) and R8 (Strategic, K×D = 12) remain identical at 8.65% because the business and strategic criteria received equal weights, and R11, R13 and R14 (all Operational, K×D = 12) remain identical at 5.19%; these risks are tied within their tier rather than strictly ordered (see Table 1 note).

The second finding is reordering of levels. The financial 3C/Medium risks (R1, R2, R3) rank second through fourth overall, ahead of five of the seven nominally high risks, because the financial category's weight magnifies even moderate local scores. In the traditional matrix, medium risks are by definition lower than high risks, regardless of category. The integrated model permits cross-level comparisons and suggests that, given the panel's weights, financial target shortfalls with a moderate likelihood warrant more mitigation attention than nominally high operational risks. This cross-level reordering is also the part of the result that depends most on treating K × D as interval-scaled (Section 2.1), and the Monte Carlo results in Section 4.4 show that it is sensitive to one-step changes in the ratings. This is in line with Aven's (2016) claim that risk assessment should be a tool to support decision making and not a way of classifying risks into colored bands.

4.3 Post-hoc Monitoring Comparison (Internal Plausibility Check)

The AHP ranking was compared post hoc with FRR04 monitoring data (March 2023) from the same organizational risk cycle used to construct the model. This comparison is an internal plausibility check, not a validation of ranking accuracy: the ranking was constructed after these outcomes were observed, and the outcomes themselves were shaped by treatment decisions taken during the cycle.

Table 2. Illustrative comparison of the conventional matrix, the integrated AHP ranking, and observed monitoring outcomes.

Conventional Matrix	Integrated AHP	Monitoring Outcome (Mar 2023)
7 risks at High (undifferentiated)	3 tiers: financial > business > operational	Financial risks improving; operational risks stalled
5 risks at Medium (undifferentiated)	Financial-Medium outranks some High	Net income at 101% RKAP; EBITDA at 125% RKAP
2 risks at Low	R9 ranked lowest (1.73%)	R9 (E-MOPS) fully resolved Mar 2023

Note. The integrated model preserves ISO 31000 level bands but adds within-band and cross-band ordering. Monitoring outcomes are shown for illustration only; they do not establish whether the ordering is correct, because they reflect treatment already undertaken.

The direction of this comparison is its central limitation. Improved outcomes for the higher-ranked financial risks may reflect successful mitigation rather than confirm that these risks were intrinsically more important, and the full resolution of a low-ranked risk may result from treatment already under way rather than confirm that its priority was correctly low. With that caveat, the observations are as follows. E-MOPS (R9), ranked last (1.73%), had been fully resolved by March 2023 (Berita Acara, official completion letter, No. APS/FIN/BA/III/2023/38.1, dated 13 March 2023). Net income (R1) and EBITDA (R2), tied second, reached 101% and 125% of RKAP respectively, and the three operational 4C risks (R11, R13, R14) were progressing slowly. These observations are compatible with the integrated ranking, but they would also be compatible with several other orderings, so they indicate plausibility rather than accuracy.

A more demanding test would specify in advance what evidence would challenge the ranking. In a prospective design, priorities would be fixed at the start of a cycle and compared with outcomes observed afterwards, such as realized losses, KRI breaches, treatment urgency, or mitigation expenditure. The ranking would be challenged if, for example, risks in the lowest tier (R4, R9, R10, R12) produced KRI breaches or realized losses larger than those of the top tier while receiving comparable treatment; if the operational 4C risks (R11, R13, R14) generated greater financial impact than R5 within the same period; or if an independent expert panel, ranking the same register without seeing the AHP output, consistently placed the business and strategic risks above the financial ones. The present data do not permit such a test, and Section 6 identifies it as future work.

4.4 Sensitivity Analysis Results

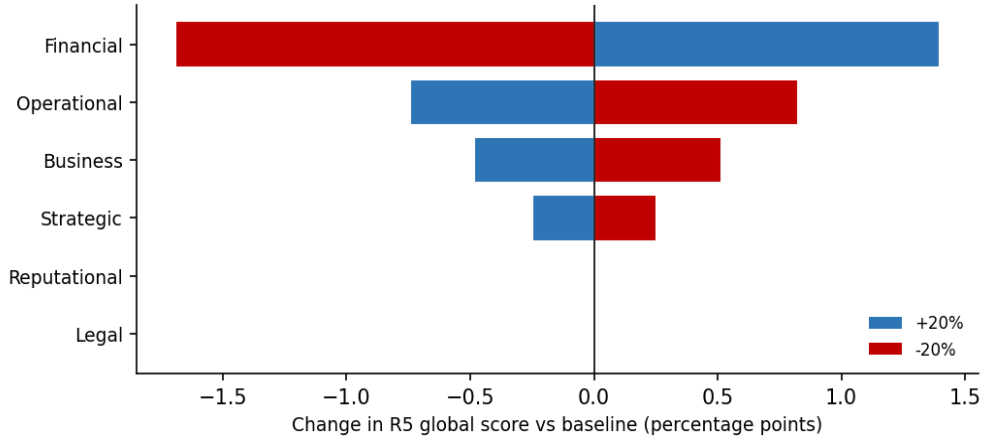
The OAT perturbation results for three criteria are shown in Table 3 and Figure 4.

Table 3. Effect of ±20% criterion-weight changes on R5 and R1 global scores.

Perturbed Criterion	R5 (+20%)	R5 (−20%)	R1 (+20%)	R1 (−20%)
Financial	15.80%	12.70%	11.85%	9.53%
Operational	13.65%	15.22%	10.24%	11.42%
Business	13.91%	14.92%	10.43%	11.18%
Strategic	14.15%	14.65%	10.61%	10.99%
Legal & Compliance	14.39%	14.39%	10.80%	10.80%
Reputational	14.39%	14.39%	10.80%	10.80%

Note. Baseline: R5 = 14.39%, R1 = 10.80%. Each weight is multiplied by 1.2 or 0.8 and the vector rescaled to unit sum. Legal and reputational perturbations have no effect because no leading risk belongs to these categories.

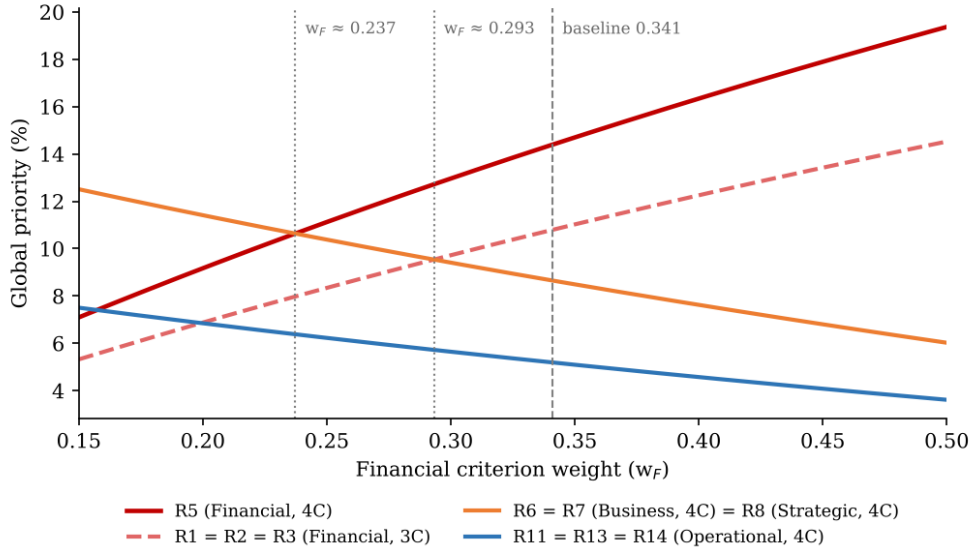
Figure 4. R5 tornado diagram of sensitivity to ±20% OAT perturbation.



The most influential parameter is the financial weight: a +20% change raises R5 by 1.40 percentage points and a −20% change lowers it by 1.69 points. The operational and business weights have smaller, opposite-signed effects. No ±20% perturbation changed the identity of the top-ranked risk; conditional on the recorded ratings and this perturbation scheme, the top rank is therefore stable under moderate weight uncertainty. The parametric sweep (Figure 5) extends this over a wider range. Solving the model analytically (holding local priorities Li fixed and renormalizing the five non-financial weights proportionally, as specified in Section 3.3), R5 loses the top rank to the business/strategic risks (R6, R7, R8) at a financial weight of wF ≈ 0.237, below the elicited baseline of 0.341; a second crossover occurs at wF ≈ 0.293, where R6/R7/R8 overtake the financial-medium risks R1/R2/R3. Rank agreement with the baseline, computed on the global scores so that tied risks receive mid-ranks (Spearman's ϱ and Kendall's τ-b), stays at 1.00 for wF ≥ 0.30 and falls to ϱ = 0.88 and τ-b = 0.78 at wF = 0.25, 0.81 and 0.71 at wF = 0.20, and 0.35 and 0.34 at wF = 0.15. The ordering is therefore unchanged across a wide band around the elicited weight but degrades below the two analytic thresholds.

There are two reversals as the financial weight decreases from the elicited baseline: first, below wF ≈ 0.293, R1-R3 are overtaken by the business/strategic risks R6/R7/R8; second, below wF ≈ 0.237, R5 itself is overtaken by R6/R7/R8. Both are a logically coherent consequence of deprioritizing financial impact. The financial 3C risks (R1-R3) are the most rank-volatile of the top tier, consistent with their position on the border between the Medium and High bands.

Figure 5. Global priority of the top-tier risks as the financial criterion weight varies (0.15–0.50).



Tied risks share one line; dotted lines mark the analytic crossover thresholds (wF ≈ 0.237 and 0.293) and the dashed line the elicited baseline (0.341).

The OAT and sweep results hold the local priorities fixed. Table 4 summarizes the Monte Carlo analysis, which relaxes this assumption. Under weight uncertainty alone, R5 remained uniquely first in 93.7% of replications and the three-tier separation of the seven 4C risks was preserved in 87.6%. Allowing each likelihood and impact rating a 20% chance of shifting by one ordinal step changed the picture: R5 was uniquely first in 52.9% of replications (first or tied first in 81.2%), and with both sources of uncertainty combined these figures fell to 49.3% and 74.1%. The category-level result was more stable: a financial-category risk ranked first in 93.6% of rating-only and 85.5% of combined replications. The median Kendall's τ-b against the baseline was 0.84 (5th–95th percentile 0.63–0.95) in the combined scenario. Two conclusions follow. The prominence of the financial category is robust to the uncertainty modelled here, but the identity of the single top risk and the exact three-tier separation depend on ratings that a one-step disagreement among assessors could change. Because this sensitivity originates in the ordinal ratings rather than in the AHP weights, it reinforces the point made in Section 2.1: the AHP layer differentiates tied risks but does not remove the imprecision of the underlying ordinal scores.

Table 4. Monte Carlo uncertainty analysis of the integrated ranking (10,000 replications per scenario).

Scenario	R5 uniquely first	R5 first or tied	A financial risk first	Three-tier order of 4C risks	Median τ-b [P5–P95]
(a) Weights only (log-normal, σ = 0.20)	93.7%	93.7%	93.7%	87.6%	0.99 [0.77–0.99]

Scenario	R5 uniquely first	R5 first or tied	A financial risk first	Three-tier order of 4C risks	Median τ-b [P5–P95]
(b) Ratings only (±1 step, p = 0.10 each way)	52.9%	81.2%	93.6%	70.4%	0.86 [0.74–0.96]
(c) Weights and ratings	49.3%	74.1%	85.5%	55.5%	0.84 [0.63–0.95]

Note. Three-tier order = R5 above R6/R7/R8, and R6/R7/R8 above R11/R13/R14. τ-b is computed on global scores against the baseline; values below 1 in scenario (a) partly reflect the breaking of baseline ties rather than rank reversals. Category assignments are held fixed in all scenarios.

Among the AHP-risk studies reviewed in Section 1.1, Barabea et al. (2026) report an OAT-style weight-perturbation sensitivity analysis ($\delta \in [-0.20, +0.20]$); however, that study reports qualitative stability labels and does not derive rank-reversal thresholds or a rank-agreement summary. The present study adds analytically exact thresholds ($wF \approx 0.237$ and $wF \approx 0.293$), tie-adjusted rank-agreement statistics, and a Monte Carlo analysis that includes rating uncertainty, which together show the board both where the ranking would change and how much of its stability is conditional on the recorded ratings. This level of transparency is consistent with Aven's (2016) call for risk assessments that make their assumptions and uncertainties explicit rather than hiding them behind color codes.

5. Conclusion

This study addressed a specific implementation problem in qualitative enterprise risk management: risks that an ordinal matrix leaves tied. ISO 31000:2018 provides a structured and internationally accepted framework for risk management (ISO, 2018; Purdy, 2010; Lalonde & Boiral, 2012); the standard itself does not prescribe a 5×5 matrix or the multiplication of ordinal likelihood and consequence scores, but many organizations operationalize its risk-analysis and evaluation stages with ordinal likelihood-impact matrices that are subject to range compression (Cox, 2008), illogical inversions (Krisper, 2021), and misleading clarity (Aven & Thekdi, 2021). When seven of fourteen business risks are clustered in the 4C/High quadrant, the matrix alone gives the board no basis for ordering them. Neither the flexible process architecture of ISO 31000 nor the more prescriptive control-activity structure of COSO ERM (2017) resolves this implementation-level problem on its own.

The Analytic Hierarchy Process (Saaty, 1980), which converts qualitative pairwise assessments into ratio-scale weights, with an internal consistency check ($CR < 0.10$), was identified as a suitable method for the evaluation phase of the study. The non-prescriptive nature of ISO 31000:2018 accommodates this integration: clause 6.4.3 allows qualitative, semi-quantitative or quantitative analysis. Whereas the AHP and MCDM risk-ranking approaches reviewed here generally stop at the ranking (Ho, 2008; Liu et al., 2013), the proposed framework incorporates AHP priorities directly into current treatment (FRR03) and monitoring (FRR04) artifacts, thus ensuring that prioritization guides resource allocation. The model applied to the 2023 corporate risk register of a state-owned enterprise in airport services in Indonesia produced a consensus matrix with a consistency ratio of

0.012, within the acceptable limit of Saaty (2008), a result that speaks to the internal coherence of the agreed judgments rather than to agreement among panel members, and differentiated the seven tied 4C risks into three priority tiers, resolving ties between categories with different weights but not within a category or between equally weighted categories. The financial category weight (0.341) was dominant, consistent with the board's emphasis on profitability metrics (NPM, EBITDA, BOPO) and possibly also with the composition of a panel of senior executives, while operational risks received a lower weight (0.123) despite their numerical predominance. This is in contrast to the findings of aviation supply chain research where operational hazards are dominant (Barabea et al., 2026), illustrating the context-specificity of AHP weights and the need to avoid transferring them across enterprises (Vaidya & Kumar, 2006). The contribution is therefore a practical one: the framework differentiates otherwise tied risks across impact categories while remaining compatible with an existing risk-register system. It does not solve the general ordinal-risk-matrix problem, because the local scores remain ordinal products, and the global percentages are relative priority shares rather than cardinal measures of risk.

Conditional on the recorded ratings, the OAT perturbation and parametric sweep showed that the highest-ranked risk (R5: loss in tenders, 14.39%) kept its rank down to an analytically derived financial-weight threshold of ≈0.237, with a second reversal among the lower tiers at ≈0.293. When ratings were allowed to shift by one ordinal step, a financial-category risk still ranked first in most replications, but R5's unique first place held in only about half, showing that the finer ordering depends on the precision of the underlying ratings. Reporting exact thresholds, tie-adjusted rank agreement, and a Monte Carlo analysis provides a reproducible account of the conditions under which the ranking would change. In a post-hoc monitoring comparison, the FRR04 (March 2023) data were broadly consistent with the integrated ranking: the lowest ranked risk (R9: E-MOPS, 1.73%) was fully resolved, the financial risks (R1, R2) improved to 101-125% of RKAP, and the operational 4C risks were stagnant. Because these outcomes were observed before the ranking was constructed and were shaped by treatment already undertaken, they indicate plausibility only and do not establish the predictive validity of the ranking.

6. Limitations and Future Research

These findings are subject to seven limitations. First, the pairwise assessments were provided as a single consensus matrix by one expert panel, so the reported CR describes that matrix only and inter-rater agreement cannot be assessed; future rounds should collect individual matrices using the instrument in Appendix A and aggregate them by geometric mean (Saaty, 2008). Second, AHP assumes criterion independence; when financial and business risks share common revenue drivers, the Analytic Network Process (Saaty, 1996) would be more appropriate. Third, the Monte Carlo analysis relies on assumed perturbation distributions for weights and ratings and holds category assignments fixed; uncertainty in the pairwise judgments themselves could be modelled directly only if individual matrices were available. Fourth, single-case evidence supports analytic rather than statistical generalization (Yin, 2018); transferability requires replication across other SOE sectors such as manufacturing,

plantation, and mining. Fifth, each risk was assigned to a single dominant impact category, which loses information for risks with genuinely multidimensional consequences (for example, a lost tender carries financial, strategic, and reputational exposure simultaneously); a fuller multi-criteria design would score every risk against all six criteria and aggregate the criterion-specific scores with the AHP weights, which we identify as the natural next step rather than attempt post-hoc here. Sixth, the criterion weights depend on judgments from a single managerial coalition (Head of Risk Management, CFO, two senior directors) drawn from one organizational period; a stakeholder-sensitivity analysis comparing finance, operations, strategy, and risk-management perspectives would clarify how much of the financial criterion's dominance reflects the firm's genuine risk appetite versus who participated in the elicitation (see Section 4.1). Seventh, the FRR04 comparison in Section 4.3 is a post-hoc plausibility check rather than a validation; testing predictive validity would require a prospective design in which priorities are fixed before outcomes such as realized loss, treatment urgency, KRI breaches, mitigation expenditure, or an independent expert ranking are observed, using the falsification criteria set out in Section 4.3.

Promising directions for future research include: (a) applying Fuzzy AHP to accommodate ambiguity in expert assessments (Kumar & Pamucar, 2025); (b) incorporating Key Risk Indicators as dynamic variables for adjusting local priorities between review periods in line with the ISO 31000 principle of continuous improvement (ISO, 2018, clause 4h); and (c) linking AHP-derived risk priorities to actual financial performance using the panel-data methodology of Purwanti et al. (2025) to evaluate whether prioritized mitigation enhances return on equity and enterprise value.

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Appendix A. Expert Elicitation Instrument (AHP Pairwise-Comparison Questionnaire)

The following instrument is the AHP pairwise-comparison questionnaire used to elicit the criterion weights reported in Section 4.1. For the present study it was completed once, as a single consensus form agreed jointly by the four-member panel (Section 3.2); it is provided here, together with the geometric-mean aggregation protocol below, for future multi-respondent rounds in which individual matrices are collected and aggregated separately.

A.1 Saaty Fundamental Scale

Table A1. Saaty fundamental scale.

Value	Definition	Explanation
1	Equal importance	Two criteria contribute equally
3	Moderate importance	Judgment slightly favors one criterion
5	Strong importance	Judgment strongly favors one criterion
7	Very strong importance	One criterion is strongly dominant in practice
9	Extreme importance	Evidence of the highest order favoring one criterion
2, 4, 6, 8	Intermediate values	Compromise between two adjacent judgments

A.2 Risk-Impact Criteria

Table A2. Risk-impact criteria definitions.

Code	Criterion	Scope
C1	Financial	Revenue/profit deviation from target; cost overruns
C2	Operational	Service delivery delays; KPI non-attainment
C3	Business	Lost profit opportunity; failed portfolio development
C4	Strategic	Vision–mission misalignment; partnership performance
C5	Legal & Compliance	Administrative/legal sanctions; regulatory non-compliance
C6	Reputational	Stakeholder complaints; negative media coverage

A.3 Pairwise-Comparison Response Form (15 Comparisons)

For each pair, circle one value: left when Criterion A is more important, right when Criterion B is more important, and centre [1] when equal.

Table A3. Pairwise-comparison form.

#	**Criterion A**	**Scale (9…1…9)**	**Criterion B**
1	C1 Financial	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C2 Operational
2	C1 Financial	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C3 Business
3	C1 Financial	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C4 Strategic
4	C1 Financial	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C5 Legal & Compl.
5	C1 Financial	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C6 Reputational
6	C2 Operational	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C3 Business
7	C2 Operational	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C4 Strategic
8	C2 Operational	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C5 Legal & Compl.
9	C2 Operational	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C6 Reputational
10	C3 Business	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C4 Strategic
11	C3 Business	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C5 Legal & Compl.
12	C3 Business	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C6 Reputational
13	C4 Strategic	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C5 Legal & Compl.
14	C4 Strategic	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C6 Reputational
15	C5 Legal & Compl.	9 8 7 6 5 4 3 2 [1] 2 3 4 5 6 7 8 9	C6 Reputational

Note. [1] = equal-importance midpoint.

A.4 Data-Processing Protocol

(1) Each answer is transformed to matrix entry a(i,j). (2) For multiple respondents, aggregate by geometric mean prior to normalization. (3) Column normalization → row average → eigenvector. (4) Calculate CR = CI/RI where RI = 1.24 for n = 6; accept if CR < 0.10. (5) Synthesize global priorities as described in Section 3.2, Step 4.

Data Source

Data source and disclosure. The case organization is referred to throughout this manuscript by the pseudonym 'APS'; absolute financial figures have been withheld (Section 3.1), consistent with the confidentiality terms governing the firm's internal documents. The organization studied has since undergone a corporate name change, further limiting its identifiability beyond the anonymization already applied here. The AHP elicitation involved four senior executives providing pairwise judgments as part of the firm's ordinary risk-management process; only the aggregate criterion weights derived from these judgments are reported (Figure 2), and no individually identifiable responses are disclosed. Institutional permission for the academic use and publication of the internal documents and data reported in this study was obtained from the organization prior to this research.