

RESILIENT AND SUSTAINABLE SUPPLIER SELECTION UNDER SUPPLY DISRUPTION RISKS

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ABSTRACT

Supplier selection under disruption risk must balance cost, quality, delivery, supplier compliance, and operational continuity. This study develops a BWM–TOPSIS framework using a public anonymized procurement dataset of 777 purchase orders from five suppliers. Six criteria are derived: unit cost, defect rate, delivery lead time, compliance rate, cancellation rate, and fulfillment reliability. Since environmental and recovery data are unavailable, sustainability is represented through supplier compliance. BWM provides literature-informed weights, while TOPSIS ranks suppliers. The baseline ranking is Epsilon_Group, Alpha_Inc, Gamma_Co, Beta_Supplies, and Delta_Logistics. Sensitivity analysis identifies a disruption-risk weight threshold of approximately 0.21, beyond which Gamma_Co becomes the top-ranked supplier. The study demonstrates a transparent and reproducible approach for risk-aware supplier selection using transaction-level procurement data.

KEYWORDS

Multi-criteria decision making; Procurement analytics; Supplier selection; Sustainability; Supply disruption risk



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INTRODUCTION

Supplier selection is a strategic multi-criteria decision because supplier performance influences cost, quality, delivery, continuity, and the wider sustainability profile of a supply chain. Recent research has increasingly moved from single-dimension cost or quality models toward sustainable supplier-selection frameworks that jointly consider economic, environmental, and social criteria. (Khalili Nasr et al., 2021) formulated a fuzzy multi-objective supplier-selection and order-allocation model that explicitly minimized cost and environmental effects while considering social benefits. (Li et al., 2021) developed a sustainability-oriented supplier evaluation structure for water-environment treatment projects, while (Yazdani et al., 2021) emphasized the need to handle information uncertainty and judgmental conflicts in sustainable supplier assessment.

Methodologically, the literature shows a strong role for multi-criteria decision-making (MCDM) because supplier evaluation combines heterogeneous quantitative and

qualitative indicators. (Wu et al., 2021) proposed an integrated decision-making framework for the chemical industry using triple-bottom-line criteria. Coşkun et al. (2022) linked sustainability-based supplier evaluation to supplier development activities, while (Shang et al., 2022) combined Best-Worst Method (BWM), fuzzy Shannon entropy, and fuzzy MULTIMOORA to obtain sustainable supplier rankings. In an Indonesian context, (Rahmawati & Salimi, 2022) demonstrated the usefulness of BWM for integrating sustainability and resilience in coffee supplier selection. (Afrasiabi et al., 2022) further showed that sustainable-resilient supplier selection can be formulated through hybrid fuzzy MCDM.

The resilience dimension becomes especially important when supplier failure, regional disruptions, and uncertain recovery are considered. (Koc et al., 2023) introduced probabilistic decision-making and Monte Carlo simulation to strengthen sustainable supplier evaluation, while (Eghbali-Zarch et al., 2023) developed a fuzzy framework that jointly represented resilience and sustainability. (Suryadi & Rau, 2023) showed that supplier location risk, transportation failure, multi-sourcing, and mitigation strategies can materially influence resilience decisions. These findings support treating disruption-related indicators as explicit decision criteria rather than as an implicit managerial consideration. Recent studies have continued to integrate disruption risk with sustainability. (Lu et al., 2024) developed a two-stage supplier-selection model that explicitly incorporates disruption risk, and (Sun et al., 2024) combined BWM and extended TOPSIS for resilient supplier evaluation under uncertain linguistic information. Varchandi et al. (2024) applied BWM and fuzzy TOPSIS in a real-world resilient-sustainable supplier-selection problem and included sensitivity analysis. (Saputro et al., 2024) linked green supplier performance with supply risks using fuzzy MCDM, highlighting the dependence between green performance and risk exposure.

The 2025 literature increasingly emphasizes adaptive, data-driven, and uncertainty-aware supplier evaluation. (Song et al., 2025) proposed action-oriented practices for resilient-sustainable supplier assessment; (Asadi et al., 2025) integrated viability, Industry 5.0, sustainability, and resilience into supplier selection and order allocation; and (Messaoudi et al., 2025) modeled disruption probability and risk tolerance explicitly in sustainable supplier selection. At the 2026 frontier, (Maddah et al., 2026) integrated resilience with health, safety, and environmental performance, while (Yang et al., 2026) proposed a green-resilient supplier-selection framework for manufacturing using cloud-based MCDM. Together, these studies indicate a clear research direction toward supplier-selection models that are simultaneously transparent, risk-aware, and multidimensional.

Despite this progress, many published supplier-selection models rely on proprietary case data or expert judgments that are difficult to reproduce independently. A complementary opportunity is to reanalyse a public transaction-level procurement dataset using a transparent MCDM workflow. The present study therefore uses the supplied Procurement KPI Analysis Dataset to demonstrate how observable supplier-performance data can be transformed into a resilient and sustainable supplier-selection model. The research objectives are to: (1) derive operational supplier-performance indicators directly from the transaction data; (2) determine a transparent benchmark criterion-weight vector using BWM; (3) rank suppliers using TOPSIS; and (4) test how the supplier ranking changes when the managerial emphasis on disruption risk is increased.

RESEARCH METHOD

The study follows a quantitative secondary-data MCDM design. The unit of analysis is the supplier, while the underlying observations are purchase-order transactions. The empirical workflow consists of five steps: data provenance and cleaning, supplier-level KPI aggregation, BWM weighting, TOPSIS ranking, and disruption-risk sensitivity analysis.

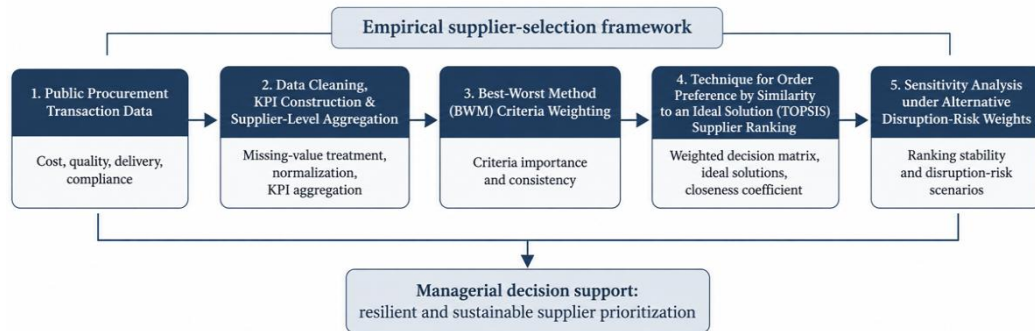


Figure 1. Empirical Workflow for Resilient And Sustainable Supplier Selection.

Data Source and Provenance

The public dataset was obtained from Kaggle and published by Shahriar Kabir under the title Procurement KPI Analysis Dataset. The dataset is described as anonymized real-world procurement data covering supplier performance, cost savings, and compliance. It contains purchase-order-level information, including supplier identity, order and delivery dates, item category, order status, quantity, unit price, negotiated price, defective units, and compliance status. The dataset is used in this study as a secondary empirical data source, and no proprietary company data or new supplier survey was collected. All analytical transformations, aggregation procedures, and derived supplier-level indicators are documented to support reproducibility.

Data Cleaning and KPI Construction

Delivery lead time was calculated as $\text{Delivery_Date} - \text{Order_Date}$. One transaction produced a negative lead time, which was treated as an invalid timestamp and excluded from the lead-time mean rather than being manually corrected. There were 87 missing delivery dates and 136 missing defect observations. Defect rate was calculated as $\text{Defective_Units} / \text{Quantity}$ for records with a reported defect value. Supplier-level indicators were then aggregated as arithmetic means or rates. Cost, defect rate, lead time, and cancellation rate were treated as cost-type criteria, while compliance rate and fulfillment reliability were treated as benefit-type criteria. Cancellation rate is used as the observable disruption-risk proxy; it should not be interpreted as a complete probability of natural-disaster, geopolitical, or transport disruption.

Table 1. Dataset profile and data-quality checks

Variable	Value
Purchase-order records	777
Suppliers	5
Item categories	5
Order statuses	4
Date range in supplied file	01 Jan 2022 – 01 Jan 2024
Missing Delivery_Date	87 (11.2%)
Missing Defective_Units	136 (17.5%)
Negative lead-time observations	1; excluded from lead-time mean

Evaluation Criteria

Table 2. Operational criteria derived from the supplied procurement dataset

Code	Criterion	Operational definition	Type	Direction
C1	Cost	Average negotiated unit price	Cost	Lower is better
C2	Quality	Average defect rate	Cost	Lower is better
C3	Delivery	Average delivery lead time (days)	Cost	Lower is better
C4	Compliance	Share of transactions marked compliant	Benefit	Higher is better
C5	Disruption Risk	Cancellation rate	Cost	Lower is better
C6	Fulfillment Reliability	Delivered orders / total orders	Benefit	Higher is better

The dataset does not contain direct environmental metrics such as carbon emissions, energy use, waste, or environmental certification, nor does it contain an explicit recovery-time or post-disruption restoration measure. Therefore, those constructs are not fabricated or statistically imputed. Compliance is used as the available responsible-procurement indicator, while cancellation and fulfillment measures provide observable disruption-related evidence. This limitation is consistent with the recent literature's warning that supplier-selection criteria should be aligned with the actual information available to the decision maker (Maddah et al., 2026); (Yang et al., 2026).

Best-Worst Method (BWM)

BWM is used to derive a benchmark criterion-weight vector with fewer pairwise comparisons than a full pairwise comparison matrix. Following the standard BWM structure, Quality is designated as the best criterion and Compliance as the worst criterion. The best-to-others and others-to-worst preference vectors are treated as literature-informed managerial benchmarks rather than newly collected expert judgments. The optimization minimizes the maximum deviation ξ subject to $\sum w_j = 1$ and $w_j \geq 0$. The resulting consistency ratio is 0.0229 using the conventional consistency index associated with a best-to-worst preference of 7.

Table 3. BWM Preference Structure and Benchmark Weights ($\xi = 0.0686$; consistency ratio = 0.0229).

Criterion	Best-to-Others	Others-to-Worst	BWM Weight
Cost	3	4	0.1275
Quality	1	5	0.3137
Delivery	2	4	0.1912
Compliance	7	1	0.0490
Disruption Risk	2	5	0.1912
Fulfillment Reliability	3	4	0.1275

TOPSIS Ranking

Table 4. Supplier-level Empirical Performance Matrix

Supplier	Orders	Avg. Cost	Defect Rate	Lead Time (d)	Compliance	Cancellation	Fulfillment
Alpha Inc	141	53.65	2.36%	10.74	93.62%	9.22%	75.89%
Beta Supplies	156	53.61	9.78%	11.27	75.64%	8.97%	70.51%
Delta Logistics	171	51.90	14.63%	10.85	60.82%	9.36%	70.18%
Epsilon Group	166	54.64	3.07%	10.87	98.19%	8.43%	72.29%
Gamma Co	143	54.71	5.02%	10.19	86.01%	4.20%	72.03%

The supplier decision matrix is normalized using vector normalization. The normalized values are multiplied by the BWM weights to form the weighted matrix. For cost-type criteria the minimum weighted value is the positive ideal, whereas for benefit-type criteria the maximum is the positive ideal.

RESULT AND DISCUSSION

The supplier-level analysis reveals substantial differences across the five suppliers. Gamma_Co records the lowest cancellation rate (4.20%) and the shortest mean valid lead time (10.19 days), while Epsilon_Group records the highest compliance rate (98.19%) and a low defect rate (3.07%). Alpha_Inc combines the lowest defect rate (2.36%) with a high compliance rate (93.62%) and the highest fulfillment reliability (75.89%). Delta_Logistics has the lowest average negotiated unit price (51.90) but also the highest defect rate and the lowest compliance rate. These trade-offs demonstrate why a single KPI can produce a different decision from an integrated MCDM model.

The empirical pattern is consistent with the broader supplier-selection literature. Sustainable supplier assessment is inherently multi-dimensional (Wu et al., 2021);(Shang et al., 2022) while resilient supplier-selection research emphasizes that cost efficiency must be examined together with disruption exposure, responsiveness, and continuity considerations (Rahmawati & Salimi, 2022);(Koc et al., 2023). The present analysis adds a transaction-data perspective: even with a relatively small number of suppliers, the underlying purchase-order records generate materially different operational profiles.

Table 5. Baseline TOPSIS ranking

Supplier	Closeness Coefficient	Rank
Epsilon Group	0.8090	1
Alpha Inc	0.7980	2
Gamma Co	0.7907	3
Beta Supplies	0.3780	4
Delta Logistics	0.0205	5

Under the benchmark BWM weights, Epsilon_Group obtains the highest TOPSIS closeness coefficient (0.8090), followed by Alpha_Inc (0.7980) and Gamma_Co (0.7907). Beta_Supplies and Delta_Logistics are substantially lower at 0.3780 and 0.0205, respectively. The ranking should be interpreted as an integrated performance profile rather than as evidence that one supplier dominates every individual criterion. Epsilon_Group's ranking is supported by very high compliance, low defect rate, and the lowest observed cancellation rate among the first three suppliers, whereas Alpha_Inc performs particularly well on defect rate and fulfillment reliability. Gamma_Co becomes increasingly competitive as disruption risk receives greater weight because it has the lowest cancellation rate in the dataset. This pattern mirrors the risk-sensitive logic reported in recent BWM-TOPSIS and disruption-risk studies (Varchandi et al., 2024).

Sensitivity Analysis

The baseline disruption-risk weight is 0.1912. When the weight is reduced to 0.10, Alpha_Inc becomes the top-ranked supplier, whereas Epsilon_Group leads around the benchmark range. When disruption risk increases to approximately 0.21, Gamma_Co overtakes Epsilon_Group; the crossover is approximately 0.209. At 0.25 and above, Gamma_Co remains the top-ranked supplier. This result demonstrates the practical value of sensitivity analysis: the preferred supplier is not invariant to managerial risk priorities. The finding is consistent with research that recommends explicit disruption-risk modeling,

robust sensitivity analysis, and adaptive supplier evaluation rather than reporting only a single static ranking (Messaoudi et al., 2025);(Asadi et al., 2025).

Table 6. TOPSIS Sensitivity to Changes in The Disruption-risk weight.

Risk Weight	Alpha	Beta	Delta	Epsilon	Gamma	Top-ranked
0.1000	0.8922	0.3909	0.0210	0.8871	0.7840	Alpha Inc
0.1500	0.8406	0.3851	0.0208	0.8457	0.7870	Epsilon Group
0.1912	0.7980	0.3779	0.0205	0.8090	0.7907	Epsilon Group
0.2000	0.7889	0.3761	0.0204	0.8010	0.7917	Epsilon Group
0.2100	0.7785	0.3739	0.0203	0.7918	0.7928	Gamma Co
0.2500	0.7373	0.3636	0.0199	0.7547	0.7983	Gamma Co
0.3000	0.6861	0.3474	0.0192	0.7075	0.8070	Gamma Co
0.3500	0.6351	0.3279	0.0183	0.6598	0.8178	Gamma Co

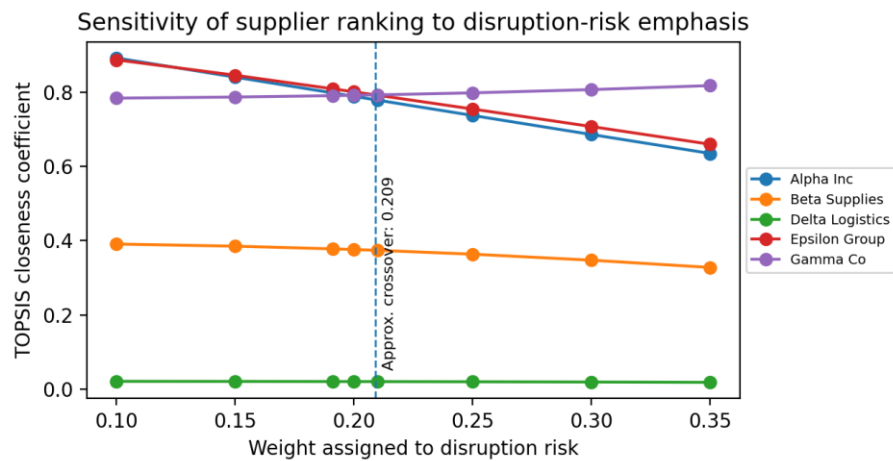


Figure 2. Sensitivity of supplier rankings to disruption-risk emphasis.

Managerial Interpretation

From a procurement-management perspective, the analysis supports three observations. First, quality and disruption risk receive the largest benchmark weights, which is consistent with the strategic concern that a low-cost supplier may still create operational exposure when defects or cancellations are frequent. Second, compliance functions as a measurable responsible-sourcing indicator in the current dataset, but it should not be interpreted as a complete environmental or social sustainability index. Third, the sensitivity results can be used as a scenario tool: organizations with a stable operating environment may place greater emphasis on routine cost, quality, and delivery performance, whereas organizations facing elevated disruption exposure can justify a higher disruption-risk weight and thereby obtain a different ranking. This scenario-based interpretation complements recent resilient-sustainable supplier-selection studies that emphasize robustness, risk tolerance, and adaptive evaluation (Song et al., 2025);(Yang et al., 2026).

Research and Methodological Implications

The study contributes a reproducible bridge between transaction-level procurement analytics and classical MCDM. Many published supplier-selection models are methodologically sophisticated, but their case data are not always available for independent replication. A public transaction dataset makes it possible to demonstrate the complete path from raw observations to supplier-level criteria, criterion weights, TOPSIS ranking, and

sensitivity analysis. The approach is deliberately transparent rather than algorithmically complex. This positioning is compatible with recent literature that uses BWM to reduce comparison burden and TOPSIS or related MCDM procedures to produce interpretable supplier rankings ((Shang et al., 2022);(Varchandi et al., 2024). At the same time, the study shows why published supplier-selection models should clearly distinguish directly observed indicators from conceptual criteria that are not measured in a dataset.

Limitations

Several limitations should be acknowledged. First, the dataset is anonymized and public; supplier identities, contractual commitments, promised delivery dates, and industry context are not available. Second, the environmental dimension of sustainability is not directly observable, so this paper uses compliance as the available responsible-procurement proxy rather than inventing environmental scores. Third, recovery capability is not directly measured; fulfillment reliability and cancellation rate provide only observable continuity-related evidence. Fourth, the BWM weighting structure is a literature-informed benchmark scenario, not a newly collected expert elicitation. Finally, the TOPSIS result is sensitive to the selected operationalization of criteria. A primary-data extension should therefore collect expert BWM judgments, supplier sustainability certifications, environmental metrics, disruption histories, recovery times, and promised-versus-actual delivery records. These limitations are important for positioning the contribution as a reproducible secondary-data analysis rather than as a complete field validation

CONCLUSION

This study developed and demonstrated a resilient and sustainable supplier-selection workflow using a public procurement transaction dataset and a BWM-TOPSIS decision framework. The supplied dataset contains 777 purchase orders from five suppliers and supports six directly observable criteria: negotiated unit cost, defect rate, delivery lead time, compliance rate, cancellation rate, and fulfillment reliability. The benchmark BWM weights prioritize Quality (0.3137), followed by Delivery and Disruption Risk (0.1912 each), Cost and Fulfillment Reliability (0.1275 each), and Compliance (0.0490). The baseline TOPSIS ranking places Epsilon_Group first, followed by Alpha_Inc and Gamma_Co. Sensitivity analysis shows that the ranking is responsive to managerial risk priorities, with Gamma_Co overtaking Epsilon_Group when the disruption-risk weight rises to approximately 0.21. The main contribution is not the claim of a universally optimal supplier, but the reproducible translation of operational procurement data into a transparent multi-criteria decision process. Future research should extend the dataset with direct environmental indicators, documented recovery capability, richer disruption histories, and expert BWM judgments, enabling a fully validated resilient-sustainable supplier-selection model.

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