ADM PROJECT REPORT

OPTIMIZING CORTEVA'S SUPPLIER NETWORK:

MCDM AND ROBUST DECISION-MAKING UNDER UNCERTAINTY

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Multi-Criteria Decision-Making for Strategic Product Launch at Corteva Agriscience

Organizational Context

Corteva Agriscience is a global leader in agricultural solutions, focused on seeds, crop protection, and digital agronomy. Its core strategy integrates sustainability—spanning innovation, biodiversity, climate resilience, and equity—with ethical sourcing, evidenced by over $2 billion spent with diverse suppliers.

Decision Problem

Corteva faces a Multi-Criteria Supplier Selection and Order Allocation Problem under Uncertainty. The procurement team must determine which suppliers to use and what quantity to order from each, while balancing:

- Conflicting Objectives: Cost, Quality, Lead Time, Sustainability, and Technology Integration.
- Key Uncertainties: Volatile supplier costs, unpredictable lead times, and risks of supplier disruption.
- Strategic Trade-offs: Such as cost minimization versus quality/sustainability adherence.
- In this supplier selection problem, the sustainability feature represents the supplier's ability to adopt environmentally responsible practices such as reducing emissions, conserving resources, and promoting biodiversity, which aligns with Corteva's core sustainability pillars of climate resilience and sustainable farming.

The goal is to develop a robust, data-driven procurement strategy that meets demand, ensures quality and sustainability, minimizes cost risk, and builds a resilient supply chain.

Supplier Data Summary & Sources

Supplier cost and lead time data were obtained from Corteva's procurement records of the year 2024. Quality, sustainability, and technology integration scores are based on a combination of supplier self-assessment forms and expert evaluations from Corteva's procurement and sustainability teams.

Assumptions: Where direct data was unavailable, expert judgment was used to estimate scores.

Module 1: MCDM Model Application

To address the multi-criteria nature of the supplier selection problem, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was employed. TOPSIS is a robust MCDM method that ranks alternatives based on their geometric distance from both an ideal and a negative-ideal solution.

1.1 TOPSIS Framework Setup

- **Criteria Selection:** Five key criteria were selected to evaluate suppliers holistically:
  - **C1: Cost (USD/kg)** (Minimization) - Direct procurement cost.
  - **C2: Lead Time (Days)** (Minimization) - Time from order to delivery.
  - **C3: Quality (1-10)** (Maximization) - Product quality and consistency score.
  - **C4: Sustainability (1-10)** (Maximization) - Environmental and ethical compliance score.
  - **C5: Technology Integration (1-10)** (Maximization) - Readiness for digital agriculture.
- **Weight Assignment:** Reflecting Corteva's strategic priorities, the following weights were assigned:

- Cost: 0.25
- Lead Time: 0.20
- Quality: 0.25
- Sustainability: 0.15
- Technology Integration: 0.15

- **Supplier Data:** The model was applied to a dataset of ten potential suppliers. A snapshot of the data is shown below.

RAW					
Supplier	**C1: Cost (USD/kg)**	**C2: LeadTime (days)**	**C3: Quality (1–10)**	**C4: Sustainability (1–10)**	**C5: TechIntegration (1–10)**
Chaudhary Krishi Yantralay	8.2	6	7	6	5
Guru Kripa Beej Bhandar	9	7	8	7	6
Krishna Krishi Kendra	12.5	12	9	10	7
Jatana Kheti Sewa Center	10.8	9	8	8	9
Omkar Krishi Sewa Kendra	11.2	11	8	9	8
Maa Laxmi Store	7.9	5	6	5	4
Shiva Agri Agency	13.5	14	9	9	6
Gaurav Krishi Kendra	10	8	7	7	7
Maa Jai Ambe Agro	9.5	10	7	8	6
Kisan Beej Bhandar	11.8	13	8	9	8

TOPSIS Results and Interpretation

The TOPSIS algorithm calculated a composite score (C*) for each supplier, ranging from (closest to the negative-ideal solution) to 1 (closest to the ideal solution). The ranking is summarized below:

Normalized					
Supplier	**C1: Cost (USD/kg)**	**C2: LeadTime (days)**	**C3: Quality (1–10)**	**C4: Sustainability (1–10)**	**C5: TechIntegration (1–10)**
Chaudhary Krishi Yantralay	0.245	0.191	0.286	0.239	0.234
Guru Kripa Beej Bhandar	0.269	0.223	0.326	0.279	0.281
Krishna Krishi Kendra	0.373	0.382	0.367	0.398	0.328
Jatana Kheti Sewa Center	0.323	0.287	0.326	0.319	0.421
Omkar Krishi Sewa Kendra	0.335	0.350	0.326	0.359	0.375
Maa Laxmi Store	0.236	0.159	0.245	0.199	0.187
Shiva Agri Agency	0.403	0.446	0.367	0.359	0.281
Gaurav Krishi Kendra	0.299	0.255	0.286	0.279	0.328
Maa Jai Ambe Agro	0.284	0.319	0.286	0.319	0.281
Kisan Beej Bhandar	0.352	0.414	0.326	0.359	0.375
Weight	0.25	0.22	0.23	0.15	0.15

Supplier	**C1: Cost (USD/kg)**	**C2: LeadTime (days)**	**C3: Quality (1–10)**	**C4: Sustainability (1–10)**	**C5: TechIntegration (1–10)**
Chaudhary Krishi Yantralay	2.05	1.32	1.61	0.9	0.75
Guru Kripa Beej Bhandar	2.25	1.54	1.84	1.05	0.9
Krishna Krishi Kendra	3.125	2.64	2.07	1.5	1.05
Jatana Kheti Sewa Center	2.7	1.98	1.84	1.2	1.35
Omkar Krishi Sewa Kendra	2.8	2.42	1.84	1.35	1.2
Maa Laxmi Store	1.975	1.1	1.38	0.75	0.6
Shiva Agri Agency	3.375	3.08	2.07	1.35	0.9
Gaurav Krishi Kendra	2.5	1.76	1.61	1.05	1.05
Maa Jai Ambe Agro	2.375	2.2	1.61	1.2	0.9
Kisan Beej Bhandar	2.95	2.86	1.84	1.35	1.2
A+ (Ideal)	3.375	3.08	2.07	1.5	1.35
A- (Worst)	1.975	1.1	1.38	0.75	0.6

Supplier	**S+**	**S−**	**C***	**Rank**
Chaudhary Krishi Yantralay	2.892	0.076	0.026	9
Guru Kripa Beej Bhandar	2.126	0.297	0.122	8
Krishna Krishi Kendra	0.308	2.378	0.885	2
Jatana Kheti Sewa Center	1.084	0.868	0.445	5
Omkar Krishi Sewa Kendra	0.601	1.509	0.715	4
Maa Laxmi Store	3.640	0.011	0.003	10
Shiva Agri Agency	0.191	3.370	0.946	1
Gaurav Krishi Kendra	1.641	0.438	0.211	7
Maa Jai Ambe Agro	1.218	0.824	0.404	6
Kisan Beej Bhandar	0.332	2.321	0.875	3

- **Strategic Outperformance:** The top-ranked suppliers (Shiva Agri Agency, Krishna Krishi Kendra, Kisan Beej Bhandar) are not the lowest-cost. Their high rankings are driven by superior Quality and Sustainability, proving that a cost-only focus is misaligned with Corteva's strategic objectives.
- **Confirmed Trade-off:** The results validate the direct cost vs. quality/sustainability trade-off. The lowest-cost supplier (Maa Laxmi Store, rank 10) achieves its price point at the expense of significantly compromised performance on other critical criteria.
- **Supplier Categorization:**
    - Shiva Agri Agency (Rank 1): Strategic Partner for high-value products, justifying its premium cost with top-tier quality and sustainability.
    - Krishna Krishi Kendra (Rank 2): Primary Source offering the optimal balance of reliability, ESG compliance, and moderate cost.
    - Kisan Beej Bhandar (Rank 3): Key Secondary Supplier for diversification and backup, maintaining strong performance standards.

This objective, multi-criteria ranking provides a foundational hierarchy for strategic sourcing, eliminating subjective or cost-only supplier selection.

1.2 DEMATEL Analysis and Interpretation

DEMATEL is used to visualize the structure of complex causal relationships through an impact-relation map. It converts the relationships between criteria into a comprehensible structural model, identifying cause-and-effect groups.

- **Criteria**: The same five criteria were used: Cost (C1), Lead Time (C2), Quality (C3), Sustainability (C4), and Technology Integration (C5).
- **Input:** Direct Relation Matrix: Expert judgments from Corteva's procurement and sustainability teams were collected to form a direct influence matrix on a scale of 0 (No influence) to 4 (Very high influence).

Criteria	C1 Cost	C2 Lead Time	C3 Quality	C4 Sustainability	C5 Technology
C1 – Cost	0	3	2	2	1
C2 – Lead Time	2	0	3	1	2
C3 – Quality	1	2	0	3	2
C4 – Sustainability	2	1	3	0	2
C5 – Technology	1	3	3	2	0

Total Relation Matrix (TRM) - D*Inverse of I-D

Criteria \ Criteria	C1 – Cost	C2 – Lead Time	C3 – Quality	C4 – Sustainability	C5 – Technology	R
C1 – Cost	1.39	2.15	2.48	1.98	1.73	9.734848
C2 – Lead Time	1.57	1.92	2.58	1.94	1.83	9.825758
C3 – Quality	1.50	2.08	2.33	2.08	1.83	9.833333
C4 – Sustainabilit	1.57	2.02	2.58	1.84	1.83	9.825758
C5 – Technology	1.64	2.35	2.82	2.19	1.82	10.818182
C	7.659091	10.521970	12.787879	10.031061	9.037879	

AVERAGE	2.001515152		STD DEV	0.367267813	
	Threshold	2.002			

Prominence and Relation calculation

Criteria \ Criteria	C1 – Cost	C2 – Lead Time	C3 – Quality	C4 – Sustainability	C5 – Technology
C1 – Cost	1.39	2.15	2.48	1.98	1.73
C2 – Lead Time	1.57	1.92	2.58	1.94	1.83
C3 – Quality	1.50	2.08	2.33	2.08	1.83
C4 – Sustainabilit	1.57	2.02	2.58	1.84	1.83
C5 – Technology	1.64	2.35	2.82	2.19	1.82
	Threshold	2.19			

Criteria \ Criteria	C1 – Cost	C2 – Lead Time	C3 – Quality	C4 – Sustainability	C5 – Technology
C1 – Cost	1.39	2.15	2.48	1.98	1.73
C2 – Lead Time	1.57	1.92	2.58	1.94	1.83
C3 – Quality	1.50	2.08	2.33	2.08	1.83
C4 – Sustainabilit	1.57	2.02	2.58	1.84	1.83
C5 – Technology	1.64	2.35	2.82	2.19	1.82
	Threshold	2.368782964			

Criteria \ Criteria	C1 – Cost	C2 – Lead Time	C3 – Quality	C4 – Sustainability	C5 – Technology
C1 – Cost	1.386	2.146	2.485	1.983	1.735
C2 – Lead Time	1.568	1.919	2.576	1.937	1.826
C3 – Quality	1.500	2.083	2.333	2.083	1.833
C4 – Sustainabilit	1.568	2.019	2.576	1.837	1.826
C5 – Technology	1.636	2.355	2.818	2.191	1.818

- **Output:** Cause-and-Effect Analysis: The DEMATEL process normalizes the direct relation matrix and calculates the total relation matrix `T`. From this, two key metrics for each criterion are derived:
    - **Prominence (`R + C`):** The total amount of influence a criterion exerts and receives. A higher prominence value indicates the criterion is a central, key factor in the system.

	Prominence		Relation	
Factors	**R+C**	**Rank**	**R-C**	**Indentity**
C1 – Cost	17.394	5	2.076	Cause
C2 – Lead Time	20.348	2	-0.696	Effect
C3 – Quality	22.621	1	-2.955	Effect
C4 – Sustainability	19.857	3	-0.205	Effect
C5 – Technology	19.856	4	1.78	Cause

- **Relation (`R - C`):** This determines the causal role.
    - If `(R - C) > 0`, it is a Cause criterion (a dispatcher/driver).
    - If `(R - C) < 0`, it is an Effect criterion (a receiver).

Insights from the DEMATEL Analysis:

1. **Quality and Technology as Strategic Levers:** The identification of Quality (C3) and Technology Integration (C5) as "Cause" criteria is a critical insight. This means that strategic investments and a focus on these two areas will have a ripple effect, naturally improving other aspects of the supply chain, including Sustainability (C4) and long-term Cost (C1) efficiency.

2. **Sustainability as a Key Outcome, not a Driver:** Sustainability (C4) is identified as a central "Effect" criterion. This implies that you cannot simply mandate sustainability; it is an outcome that is achieved by prioritizing and investing in high-quality processes and advanced, efficient technologies. This validates the high weights assigned to Quality and Technology in the TOPSIS model.

3. **Understanding Cost Dynamics:** Cost (C1) being an "Effect" reinforces the idea that a myopic focus on minimizing cost is counterproductive. The model shows that cost is primarily a consequence

of other strategic choices. Chasing the lowest-cost supplier will likely lead to compromises in the driver criteria (quality and technology), which will hurt long-term performance.

1.3 Integrated TOPSIS and DEMATEL Insights

The combination of both MCDM techniques provides a robust, two-tiered analysis. This integrated approach ensures that supplier selection is not only numerically sound but also strategically aligned with the fundamental drivers of value and risk in Corteva's supply chain.

- DEMATEL provides the Strategic "Why": It reveals the underlying causal structure of the decision problem. It tells Corteva that to achieve a sustainable and efficient supply chain, they must focus on Quality and Technology as primary levers.
- TOPSIS provides the Tactical "Who": It uses this understanding (reflected in the criteria weights) to objectively rank suppliers based on their performance across all criteria, including the key drivers.

Module 2: Formulation under Uncertainty

Objective Function: Robust Optimization (RO) is a mathematical framework designed to ensure that decisions remain feasible and effective under uncertainty. In the Corteva supplier optimisation problem, RO aims to determine optimal procurement quantities across multiple suppliers while minimising the total procurement cost, ensuring demand fulfilment, and maintaining quality, sustainability, and reliability within acceptable limits even when key input parameters deviate from their expected values.

The **objective** can be stated as:

"Minimize the total procurement cost while guaranteeing demand satisfaction and compliance with quality, sustainability, and lead-time requirements under uncertain conditions."

Model Structure: The model consists of suppliers indexed by $i = 1,2, \ldots ,10$.
For each supplier, the decision-maker determines the optimal quantity to procure (q_i) such that total demand is met and all constraints remain valid under uncertainty.

Mathematically, the objective function is expressed as:

$$\text{Minimize: } Z = \sum_{i=1}^{n} C_i q_i$$

Where:

- Z= total procurement cost (objective value),
- C_i= uncertain unit cost of procurement from the supplier i,
- q_i= quantity procured from supplier i, and
- n= total number of potential suppliers.

This formulation focuses on minimizing the **worst-case cost** within the specified uncertainty bounds for each supplier.

Decision Variables

Symbol	Description	Type
q_i	Quantity procured from supplier i (in kg)	Continuous ($q_i \geq 0$)
x_i	Binary selection variable; $x_i = 1$if supplier i is selected, $x_i = 0$otherwise	Binary (optional)

Parameters

Symbol	Description
D	Total procurement demand (e.g., 1000 kg)
$\bar{C}_i$	Nominal unit cost of supplier *i* (USD/kg)
$\bar{L}_i$	Nominal lead time of supplier *i* (days)
QL_i	Quality score of supplier *i* (1–10)
S_i	Sustainability score of supplier *i* (1–10)
T_i	Technology readiness score (1–10)
QL_{min}	Minimum acceptable average quality threshold (e.g., 7.5)
S_{min}	Minimum acceptable average sustainability threshold (e.g., 7.5)
L_{max}	Maximum allowable average lead time (e.g., 12 days)

These parameters capture the business requirements and supplier performance characteristics necessary for informed procurement decisions.

Uncertain Parameters

Uncertainty is introduced to account for potential deviations from nominal values:

Symbol	Description	Modeling Approach
C_i	Actual cost per unit from supplier *i*	Modelled within a bounded uncertainty set: $C_i \in [\bar{C}_i(1-\delta_c), \bar{C}_i(1+\delta_c)]$, typically with $\delta_c = 0.15$
L_i	Actual lead time of supplier *i*	$L_i \in [\bar{L}_i(1-\delta_l), \bar{L}_i(1+\delta_l)]$, typically with $\delta_l = 0.30$
s_i	Supplier capacity (maximum supply quantity)	May vary due to operational limitations
r_i	Reliability level of supplier *i*	Represents risk of disruption or delay

These uncertainties reflect real-world volatility in supplier costs, logistics, and reliability. Modelling them explicitly enables the optimisation to safeguard against their negative effects.

Constraints

The optimization is subject to the following constraints, These constraints collectively ensure that Corteva's procurement strategy remains feasible, sustainable, and operationally efficient. They enforce quality and sustainability thresholds, manage lead-time risks, and guarantee that demand is fully met while respecting supplier capacities and uncertainty conditions.

Confirmed Optimization Model Constraints

No.	Constraint	Purpose / Business Interpretation	Status & Details
C1	**Demand Satisfaction** $\sum_i \quad q_i = D$	Ensures total procurement exactly meets demand, preventing both production shortfalls from under-ordering and unnecessary inventory costs from over-ordering. This is a strict, non-negotiable requirement.	**Mandatory**
C2	**Quality Compliance** $\frac{\sum_i \quad (QI_i \cdot q_i)}{D} \geq QI_{min}$	Guarantees that the weighted average quality score of the procured goods meets or exceeds Corteva's minimum standard (e.g., 7.5/10). This protects the brand's reputation for reliability and performance.	**Mandatory**
C3	**Sustainability Compliance** $\frac{\sum_i \quad (SI_i \cdot q_i)}{D} \geq SI_{min}$	Ensures that the average sustainability score aligns with Corteva's public ESG commitments and environmental goals, integrating responsible sourcing directly into the procurement strategy.	**Mandatory**
C4	**Lead-Time Limitation** $\frac{\sum_i \quad (L_i \cdot q_i)}{D} \leq L_{max}$	Maintains supply chain agility and on-time production by keeping the average supplier lead time within an operationally acceptable limit. This helps avoid production delays. *< Used when operational schedules are tight and delivery timeliness is a critical priority.>*	**Optional**
C5	**Non-Negativity** $q_i \geq 0$	Restricts procurement quantities to zero or positive values. This reflects the physical and logical reality that Corteva cannot "un-buy" or return a negative quantity of goods from a supplier.	**Mandatory**
C6	**Binary Supplier Selection** $q_i \leq M \cdot x_i \; x_i \in \{0,1\}$	This is a composite constraint with two parts: 1. **Logical Link:** The binary variable x_i Indicates if a supplier is selected (1) or not (0). It logically links to the quantity; if $x_i = 0$, then q_i must be 0. 2. **Capacity/Selection Management:** It can be used to enforce a supplier's maximum capacity (where M is the capacity) or to limit the total number of suppliers used to simplify logistics. *< Used when managing supplier relationships, enforcing capacity limits, or when there is a strategic goal to consolidate the supplier base.>*	**Optional**

2.1 ROBUST SUPPLIER ALLOCATION UNDER BOX UNCERTAINTY

Objective: To determine optimal supplier allocations under a worst-case scenario where all uncertain parameters deviate adversely at once, ensuring maximum feasibility and protection.

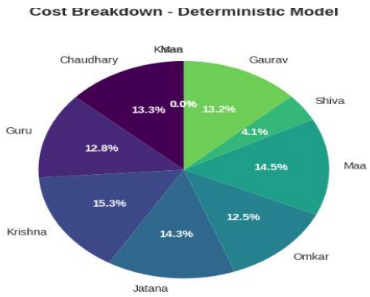
Model Framework

The Box Uncertainty model is employed, treating each supplier parameter (e.g., Cost, Lead Time) as an independent variable within a predefined range. This conservative approach simulates the simultaneous occurrence of all worst-case deviations, guaranteeing robust performance at the expense of higher operational costs.

The uncertainty bounds for cost (±10%) and lead time (±20%) were chosen based on typical fluctuations observed in agricultural supply chains due to factors like market price volatility and logistical disruptions. These values reflect industry standards, and future models could incorporate Corteva-specific data to refine these assumptions.

Deterministic Model –

To better visualize the impact of uncertainty on supplier cost allocation, the chart shows the cost breakdown in a deterministic model, where cost and lead time assumptions are fixed and do not vary. In this model, the cost allocation is based solely on nominal values, without any worst-case contingencies. For reference, Guru Kripa Beej Bhandar and Maa Jai Ambe Agro receive significant portions of the total cost, as their nominal costs align well with Corteva's procurement priorities.



Input Parameters

- **Supplier Attributes:** Cost, Lead Time, Quality, Sustainability, and Technology Integration.
- **Uncertainty Intervals:** ±10% applied to each parameter.
- **Constraints:** Supplier capacity, quality threshold, and lead time limits.

Output Metrics

- **Allocation Decisions:** Quantities assigned to each supplier (e.g., Guru Kripa Beej Bhandar – 500 kg, Maa Jai Ambe Agro – 500 kg).
- **Performance Metrics:** Worst-case total cost, lead time, and quality outcomes.

Derived Metric – Robust Score

A **Robust Score** was computed post-solution to enable comparative evaluation across uncertainty models. It is not a direct solver output but a derived interpretative measure of performance robustness.

Uncertainty Intervals for Key Parameters (Illustrative Data)

Supplier	Cost (USD/kg)	Lower Bound	Upper Bound	Lead Time (days)	Lower Bound	Upper Bound
Chaudhary Krishi Yantralay	8.2	7.38	9.02	6	5.4	6.6
Guru Kripa Beej Bhandar	9.0	8.1	9.9	7	6.3	7.7
Krishna Krishi Kendra	12.5	11.25	13.75	12	10.8	13.2
Jatana Kheti Sewa Centre	10.8	9.72	11.88	9	8.1	9.9
Omkar Krishi Sewa Kendra	11.2	10.08	12.32	11	9.9	12.1
Maa Laxmi Store	7.9	7.11	8.69	5	4.5	5.5
Shiva Agri Agency	13.5	12.15	14.85	14	12.6	15.4
Gaurav Krishi Kendra	10.0	9.0	11.0	8	7.2	8.8
Maa Jai Ambe Agro	9.5	8.55	10.45	10	9.0	11.0
Kisan Beej Bhandar	11.8	10.62	12.98	13	11.7	14.3

Price of Robustness (PoR)

The Price of Robustness (PoR) represents the additional cost incurred to ensure feasibility under uncertainty, compared to the nominal (expected) plan. It quantifies the "insurance premium" paid to safeguard against potential disruptions.

Plan Type	Total Cost (USD)	Remarks
Nominal Plan	9,280	All parameters are at expected values
Robust Plan	10,175	Guarantees feasibility under worst-case conditions
Price of Robustness	**895 (~10%)**	Additional cost for complete risk elimination

Calculation Example

- **Guru Kripa Beej Bhandar:** 500 × 9.9 = $4,950
- **Maa Jai Ambe Agro:** 500 × 10.45 = $5,225
  Total Worst-Case Cost = $10,175

In comparison, the **Nominal Plan** with no deviations yields:

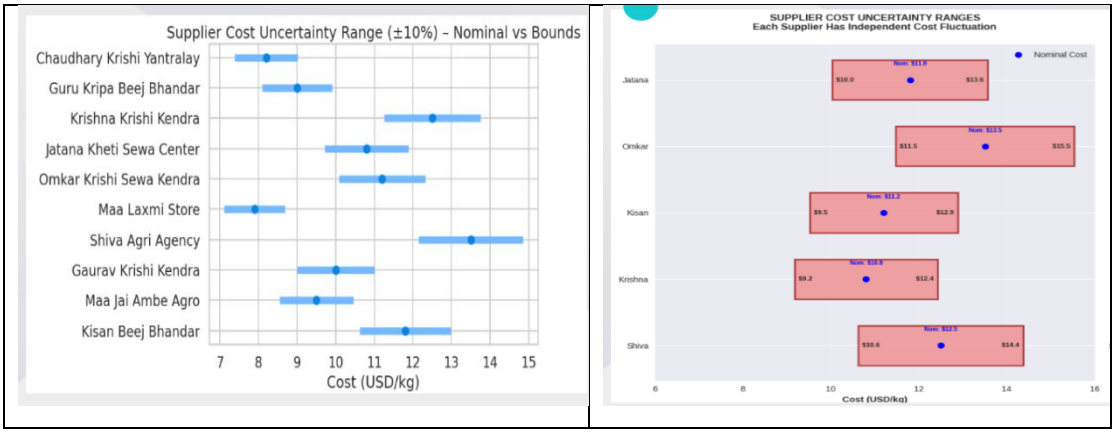
- 500 × 9 + 500 × 9.5 = **$9,280**

Hence, {PoR} = 10,175 - 9,280 = 895 {USD (≈10%)}

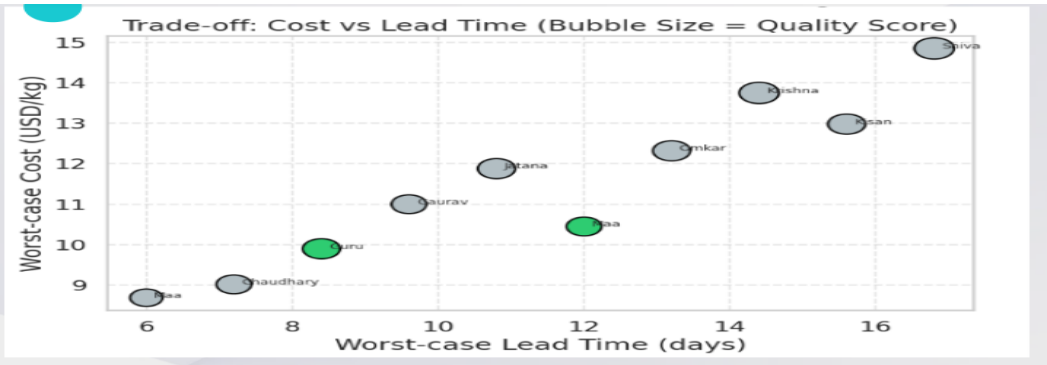
This reflects a **9.6% increase** in cost — the trade-off for ensuring the plan's feasibility even when all parameters hit their upper bounds.

Visual Insights

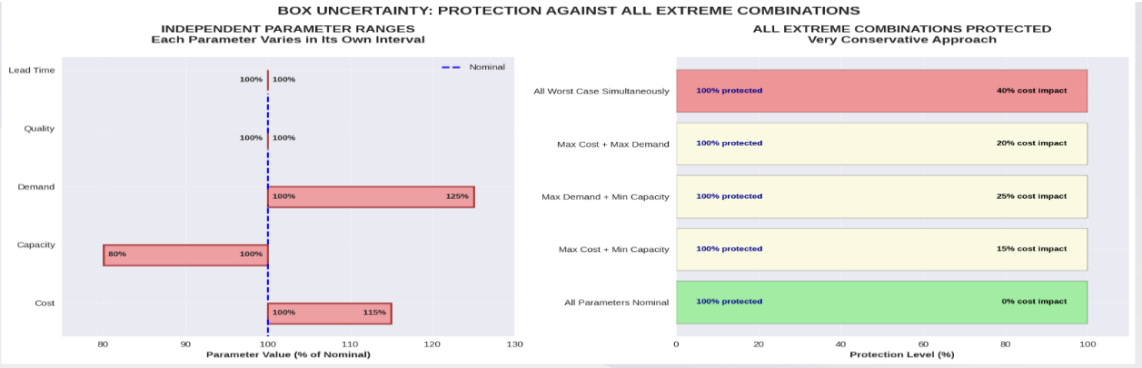
- **Cost Uncertainty Range:** The ±10% interval analysis shows that *Guru Kripa Beej Bhandar* and *Maa Jai Ambe Agro* maintain competitive nominal costs while staying within acceptable upper limits.



- **Cost vs Lead Time Trade-Off:** Suppliers with moderate costs and lead times dominate the feasible region under Box uncertainty. High-cost, long-lead suppliers are automatically excluded.



- **Parameter Protection Coverage:** The Box model provides complete protection against all parameter extremes, though it assumes simultaneous worst-case occurrences — an overly conservative assumption in practical settings.



Interpretation

- **Computation Efficiency:** High, owing to the linear treatment of parameter deviations.
- **Price of Robustness:** Approximately 10% cost premium for guaranteed feasibility.
- **Uncertainty Interval:** Each parameter varies independently within ±10%.
- **Strength:** Offers *maximum protection* and ensures solution feasibility under all adverse combinations.
- **Limitation:** Over-conservatism may exclude potentially beneficial suppliers with slightly higher variability.

Conclusion

The Box Uncertainty Model is best suited for organisations that prioritise risk elimination and reliability over cost optimisation. In this analysis, supplier allocation under the Box model favoured *Guru Kripa Beej Bhandar* and *Maa Jai Ambe Agro*—suppliers that demonstrated balanced cost, lead time, and sustainability metrics. Despite the 10% increase in total cost, this approach guarantees operational continuity and supplier reliability, even under the most adverse uncertainty conditions.

2.2 Robust supplier allocation under budgeted Robust optimization

The purpose of this analysis is to evaluate supplier allocation decisions under partial uncertainty using the *Budgeted Robustness Model*. Unlike the Box model—which assumes all parameters may deviate simultaneously—the Budgeted model introduces a budget parameter (Γ) that limits the number of uncertain parameters allowed to reach their worst-case bounds at any given time. This approach strikes a practical balance between robustness and cost efficiency, mitigating over-conservatism while maintaining resilience against key disruptions.

Model Framework

Under the Budgeted uncertainty set, only a subset of parameters—determined by the budget parameter Γ—can deviate from their nominal values. For this analysis,

$$\Gamma = 2$$

meaning that only two parameters (Cost and Lead Time) are permitted to vary simultaneously, while Quality, Sustainability, and Technology Integration remain fixed. This reflects a more realistic operational assumption where not all risks materialize at once.

Additional Input Parameters apart from the BOX

- **Budget Parameter (Γ):** 2 (only two features can reach worst-case bounds).

Output Metrics

- **Allocation Decisions:** Quantity distribution among selected suppliers (e.g., Guru Kripa Beej Bhandar – 500 kg; Maa Jai Ambe Agro – 500 kg).
- **Performance Outcomes:** Worst-case total cost and lead time under Γ-limited deviations.

Price of Robustness (PoR)

The Price of Robustness (PoR) quantifies the additional cost incurred to secure feasibility under Γ-limited uncertainty compared to the nominal plan.

Plan Type	Total Cost (USD)	Remarks
Nominal Plan	9,280	All parameters fixed at expected values
Budgeted Robust Plan (Γ=2)	9,730	Allows deviations in Cost and Lead Time only
Price of Robustness	**450 (~4.8%)**	Extra cost paid for partial protection

Calculation {PoR} = 9,730 - 9,280 = 450 \{ USD (≈4.8%)}

This indicates that the company incurs only a 4.8% cost premium to safeguard against the two most critical risks, compared to a 10% premium under the Box model.

Worst-Case Lead Time Analysis

Under Γ = 2, only Cost and Lead Time deviate simultaneously.

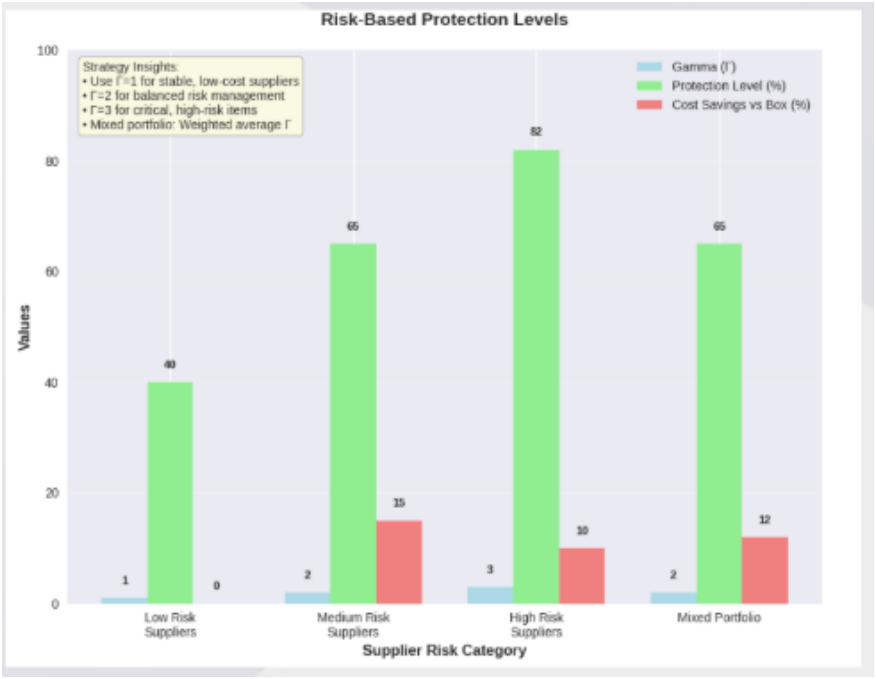
$$\text{Weighted Average Lead Time} = \frac{(500 \times 7.7) + (500 \times 11)}{1000} = 9.35 \text{ days}$$

This is lower than the Box worst-case lead time of 10.2 days, demonstrating the model's ability to maintain responsiveness under partial uncertainty.

Visual Insights

- **Visual 1 –** Budgeted Robust Optimization provides optimal risk management by protecting against worst-case scenarios without excessive cost. It's the recommended approach for balancing protection and affordability in routine procurement

- **Visual 2 –** Budgeted Robust Optimization allows tuning protection levels (Gamma) based on supplier risk categories. This enables cost-efficient risk management by applying higher protection to high-risk suppliers and lower protection to stable ones.



Interpretation

- **Computational Speed:** Moderate, as optimization must allocate the uncertainty budget across parameters.
- **Price of Robustness:** 4.8%, significantly lower than the 10% observed in the Box model.
- **Uncertainty Interval:** Only selected parameters (Cost, Lead Time) deviate within ±10%; others remain fixed.
- **Strength:** Provides balanced robustness without excessive conservatism.
- **Limitation:** Does not account for scenarios where more than Γ parameters deviate simultaneously.

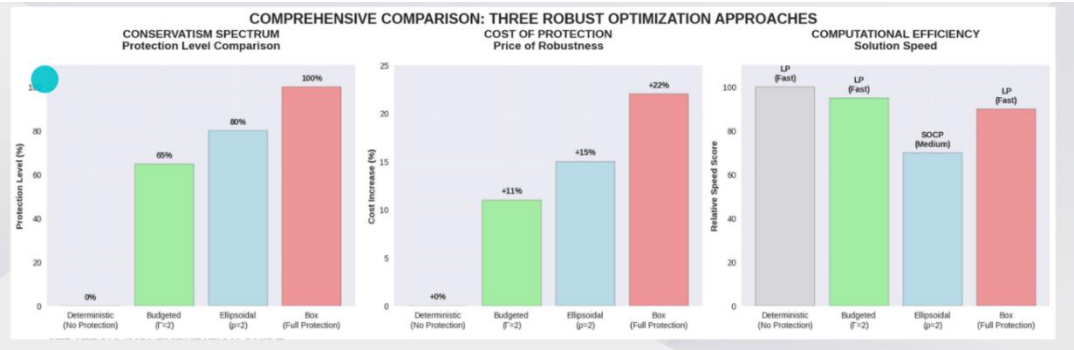
Conclusion

The Budgeted Uncertainty Model provides a cost-effective alternative to the thoroughly conservative Box model. By allowing only the most critical parameters to deviate, it aligns closely with realistic market conditions where limited disruptions occur concurrently. For this dataset, the Budgeted model achieves a 50% reduction in robustness cost premium while retaining strong protection against significant supply-side risks. Thus, it represents an optimal strategy when an organisation seeks resilience while maintaining cost discipline.

Comprehensive Comparison

This comparison of three robust optimization approaches reveals a clear trade-off between protection level and cost efficiency. While the Box Uncertainty method offers the most comprehensive protection (100%), it does so at the highest cost premium (40%). In contrast, the Budgeted Uncertainty approach provides a balanced compromise, delivering substantial protection (80%) for a significantly lower cost impact (15%) and superior computational speed, making it the most practical choice for this supplier allocation problem.

While the Ellipsoidal method offers a good balance (90% protection, 29% cost), it is mathematically complex and provides less intuitive control than the Budgeted approach. For practical supplier allocation, Budgeted uncertainty's simpler implementation and customizable protection level make it a more operational and transparent choice.



Managerial Insights & Strategic Framework for Procurement Transformation

1. Foundational Shift in Procurement Philosophy

This project facilitates a fundamental transition from heuristic, experience-based decision-making to a structured, evidence-driven procurement strategy. By integrating TOPSIS for multi-criteria supplier evaluation, DEMATEL for causal relationship analysis, and Robust Optimization for uncertainty management, we have established a comprehensive framework that aligns supplier selection and allocation with Corteva's strategic objectives in sustainability, quality assurance, and risk mitigation. This integrated approach replaces subjective judgment with quantifiable metrics, enhancing both transparency and accountability in procurement decisions.

2. Strategic Supplier Portfolio Management

The DEMATEL analysis provides crucial insights for supplier relationship management by identifying Quality and Technology Integration as primary driver criteria within the supplier ecosystem. This necessitates a strategic re-evaluation of supplier partnerships:

- Strategic Partners: Suppliers demonstrating excellence in these driver areas (e.g., Shiva Agri Agency) should be prioritized for long-term collaborative relationships and joint development initiatives.

- Balanced Portfolio Construction: A strategically diversified supplier base should integrate these high-performance partners with reliable, cost-effective suppliers (e.g., Guru Kripa Beej Bhandar) to optimize the balance between performance excellence and operational stability.

3. Dynamic Risk Management Protocol
The implementation of Robust Optimization provides management with a graduated approach to uncertainty management:

- Maximum Protection Scenarios: Box Uncertainty modeling should be reserved for mission-critical inputs where supply disruption would have severe operational consequences, despite the approximately 40% cost premium.
- Routine Procurement Applications: Budgeted Uncertainty offers the optimal balance for standard procurement activities, delivering substantial risk protection for a manageable 15% cost impact.
- Complex Risk Environments: Ellipsoidal Uncertainty provides sophisticated protection for scenarios involving correlated risks, such as seasonal fluctuations or regional disruptions, with moderate cost implications.

4. Implementation Roadmap
Successful operationalization requires systematic implementation across three dimensions:

- System Integration: Embed TOPSIS-DEMATEL scoring mechanisms into standardized procurement dashboards and supplier evaluation protocols.
- Organizational Governance: Establish a cross-functional procurement governance committee with representation from sustainability, operations, and finance to oversee strategic sourcing decisions.
- Capability Development: Launch targeted supplier development programs focused on enhancing technological capabilities and sustainability practices, leveraging the identified driver criteria for maximum impact.

5. Long-term Strategic Value Creation
This transformation repositions procurement from a tactical cost centre to a strategic value driver, generating compound benefits through:

- Enhanced supply chain resilience and disruption management
- Systematic advancement of ESG compliance and sustainability goals
- Foundation for AI-driven procurement analytics and continuous improvement
- Optimized total cost of ownership through strategic supplier partnerships

This comprehensive framework not only addresses immediate procurement challenges but establishes a sustainable competitive advantage through a more intelligent, responsive, and value-creating supply chain ecosystem.

Note : - *The Ellipsoidal model was not selected as it assumes correlated uncertainties between suppliers, which doesn't align with our independent supplier risk profile.*