Question 1.

1. Three major costs sources:
   * procurement cost on raw materials
   * transportation costs from farms to processing plant, and that from processing plants to home centers
   * processing cost of raw materials at the plants

Two decision variables:

* 𝒙𝒊𝒋 : amount of raw materials sent from farms to processing plants where 𝒊 = farms {1:249} and 𝒋 = processing plants {1:18}
* 𝒚**jk** : amount of fertilizers sent from processing plants to home centers where 𝒊 = processing plants {1:18} and k = centers {1:102}.

1. The minimum cost of the transportation and procurement plan is $2,297,089.97
2. Optimal Total Cost with Same Region Restriction: $2,323,488.50
3. Optimal Total Cost with High-Quality Restriction: $5,712,976.67
4. Optimal Total Cost with Sourcing Risk Mitigation Constraints: $5,053,552.54

Optimal Total Cost with Supply Risk Mitigation Constraints: $2,301,949.78

1. Based on the results, implementing all defensible options together leads to an optimal cost of $2,334,508.46, which is slightly higher than the base scenario of $2,297,089.97 (+$37,418.49 or ~1.6%). This increase is justified by the benefits provided:
   * Same Region Restriction (cost at $2323488.50) ensures logistical efficiency and compliance, reducing transportation complexity.
   * Supply Risk Mitigation (cost at $2301949.78) improves resilience by preventing over-reliance on individual facilities, reducing supply chain disruptions.

The high cost of the High-Quality Restriction (+$3,415,886.70) and the Sourcing Risk Mitigation (+$2,755,462.57) suggests they are less defensible. Implementing the defensible options balances cost efficiency with operational robustness, making it a strategic decision.

1. Implementing all defensible options together at a cost of $2,334,508.46 is a strong business decision despite the 1.6% increase compared to the base scenario. The additional cost is justified by the benefits:
   * Improved Operational Resilience: The supply risk mitigation reduces over-reliance on individual facilities, minimizing disruptions.
   * Enhanced Compliance and Efficiency: The same region restriction simplifies logistics and ensures adherence to regional requirements.

These measures strengthen the supply chain’s robustness and reliability, preventing potential losses from disruptions or inefficiencies, making it a sound long-term investment.

1. When reducing the sourcing risk mitigation percentage, the model becomes infeasible at 2.4%.

* Managerial Interpretation:
  + The 2.4% threshold highlights the minimum level of flexibility required to ensure that processing facilities can handle enough raw material to meet overall demand.
  + Reducing the percentage below this level creates constraints that conflict with the available capacity and demand distribution.
* Implications for Managing Supply Chain Risk:
  + The supply chain must maintain at least this level of operational flexibility to avoid any infeasibility on meeting all the constraints.
  + If additional sourcing risk mitigation is necessary (e.g., reducing dependence on specific facilities), investments in expanding processing capacity or re-distributing supply sources may be required.