A Design Methodology to Optimize Supply Chain Network Performance

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Research Motivation

- The design of a supply chain network (SCN) is a long-term, strategic-level decision.
  - Finding locations for facilities → plants, distribution centers (DCs), etc.
  - Allocating customers to these facilities.
- A balanced allocation of customers (BAC) with respect to transit time can help organizations develop a seamless SCN.
  - Potential to improve the flow of products and provide a manageable delivery schedule.

Research Objective & Methodology

- This research proposes a methodology to generate feasible solutions to the multi-objective, single-source capacitated facility location-allocation problem (SSCFLAP) with a BAC for a two-echelon SCN.
- Performance measures chosen to assess the quality of solutions.
  - Total cost and balance level of transit time.

- Main Steps
  - Implement a modified non-dominated sorting genetic algorithm (NSGA-II) to obtain feasible solutions to the mathematical model.
    - Fine tune probability of crossover, probability of mutation, population size, and number of generations using the response surface methodology (RSM) with central composite design (CCD).
  - Conduct a designed experiment to assess the effects that several main factors have on the five supply chain response variables total cost, average total transit time, balance level of transit time, and number of opened DCs and plants.
  - Three problem instance sizes.
    - Small (5 Ps, 10 DCs, 50 Cs), Medium (6 Ps, 10 DCs, 100 Cs), Large (8 Ps, 30 DCs, 150 Cs).

Mathematical Formulation

Objective Functions:

\[
\begin{align*}
&\text{Min } \sum_{i \in I} \sum_{j \in J} \sum_{l \in L} c_{ijl} u_{ijl} + \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \left[ q_{ijk} t_{ijk} + \sum_{i \in I} r_{ij} z_i + \sum_{j \in J} f_{ij} y_{ij} \right] \\
&\text{Min } \sum_{i \in I} \sum_{j \in J} \left[ \sum_{k \in K} (t_{ijk} x_{ijk}) - \left( \sum_{r \in R} \sum_{k \in K} \mu_{rjk} y_{rjk} \right) \right] ^2
\end{align*}
\]

Constraints:

\[
\begin{align*}
\sum_{j \in J} x_{ijk} &= 1; \quad \forall k \in K \\
\sum_{j \in J} q_{ijk} x_{ijk} &\leq c_{ij}; \quad \forall j \in J \\
q_{ijk} x_{ijk} &\geq d_{ijk}; \quad \forall j \in J, k \in K \\
\sum_{l \in L} r_{ij} z_i &\leq p_i; \quad \forall i \in I \\
\sum_{j \in J} y_{ij} &\leq M
\end{align*}
\]

Research Conclusions & Future Work

- A two-echelon supply chain network was modeled as an integer linear program with time windows.
- A modified non-dominated sorting genetic algorithm (NSGA-II) was used to obtain feasible solutions to the mathematical model.
- Conduct a designed experiment to assess the effects that several main factors have on the five supply chain response variables total cost, average total transit time, balance level of transit time, and number of opened DCs and plants.
- Three problem instance sizes. (Small, Medium, Large)

Solutions

- Pareto optimal solutions for three problem instance sizes.
- Potential to improve the flow of products and provide a manageable delivery schedule.

- Main steps:
  - Implement a modified NSGA-II to obtain feasible solutions to the mathematical model.
  - Fine tune probability of crossover, probability of mutation, population size, and number of generations using response surface methodology (RSM) with central composite design (CCD).
  - Conduct a designed experiment to assess the effects that several main factors have on the five supply chain response variables total cost, average total transit time, balance level of transit time, and number of opened DCs and plants.
  - Three problem instance sizes. (Small, Medium, Large)

- Mathematical Formulation:
  - Objective Functions:
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    \begin{align*}
    \text{Min } &\sum_{i \in I} \sum_{j \in J} \sum_{l \in L} c_{ijl} u_{ijl} + \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} \left[ q_{ijk} t_{ijk} + \sum_{i \in I} r_{ij} z_i + \sum_{j \in J} f_{ij} y_{ij} \right] \\
    \text{Min } &\sum_{i \in I} \sum_{j \in J} \left[ \sum_{k \in K} (t_{ijk} x_{ijk}) - \left( \sum_{r \in R} \sum_{k \in K} \mu_{rjk} y_{rjk} \right) \right] ^2
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  - Constraints:
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    \begin{align*}
    \sum_{j \in J} x_{ijk} &= 1; \quad \forall k \in K \\
    \sum_{j \in J} q_{ijk} x_{ijk} &\leq c_{ij}; \quad \forall j \in J \\
q_{ijk} x_{ijk} &\geq d_{ijk}; \quad \forall j \in J, k \in K \\
\sum_{l \in L} r_{ij} z_i &\leq p_i; \quad \forall i \in I \\
\sum_{j \in J} y_{ij} &\leq M
    \end{align*}
    \]

- Example solutions for three problem instance sizes:
  - Small Problem Instance
  - Medium Problem Instance
  - Large Problem Instance

- Conclusion:
  - The research provides a methodology to optimize supply chain network performance.
  - Potential to improve the flow of products and provide a manageable delivery schedule.
  - Conduct a designed experiment to assess the effects that several main factors have on the five supply chain response variables total cost, average total transit time, balance level of transit time, and number of opened DCs and plants.
  - Three problem instance sizes. (Small, Medium, Large)