Research Motivation

- The design of a supply chain network (SCN) is a long-term, strategic-level decision.
  - Finding locations for facilities \( \rightarrow \) 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:

\[
\begin{align*}
\text{Min } & \sum_{i=1}^{s} \sum_{j=1}^{K} u_{ij} r_{ij} + \sum_{k=1}^{K} \sum_{j=1}^{K} q_{jk} q_{ik} + \sum_{i=1}^{s} \sum_{j=1}^{K} \sum_{k=1}^{K} f_{ij} x_{jk} \\
\text{Min } & \left( \sum_{k=1}^{K} \sum_{j=1}^{K} \left( t_{jk} x_{jk} - \frac{\sum_{i=1}^{s} \sum_{j=1}^{K} t_{ij} x_{ik}}{t_{ij}} \right)^{2} \right) ^{1/2}
\end{align*}
\]

Constraints:

\[
\begin{align*}
\sum_{j=1}^{K} x_{jk} &= 1 \quad ; \quad k \in K \\
\sum_{j=1}^{K} d_{k} x_{jk} &\leq c_{j} y_{j} \quad ; \quad \forall j \in J \\
q_{jk} &\geq 0 \quad \text{and integer} \quad ; \quad \forall j \in J, k \in K \\
\sum_{j=1}^{K} r_{ij} &\leq \sum_{i=1}^{s} \sum_{j=1}^{K} p_{ij} z_{i} \quad ; \quad \forall i \in I \\
\sum_{j=1}^{K} y_{j} &\leq M
\end{align*}
\]

Results

Table 1. Optimal values for the four NSGA-II parameters for three problem instance sizes

<table>
<thead>
<tr>
<th>Problem Size</th>
<th>Probability of Crossover</th>
<th>Probability of Mutation</th>
<th>Pop. Size</th>
<th>No. of Generations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>0.8</td>
<td>0.03</td>
<td>148</td>
<td>1,250</td>
</tr>
<tr>
<td>Medium</td>
<td>0.24</td>
<td>0.16</td>
<td>198</td>
<td>1,463</td>
</tr>
<tr>
<td>Large</td>
<td>0.43</td>
<td>0.15</td>
<td>147</td>
<td>1,136</td>
</tr>
</tbody>
</table>

- Factoral experiment
  - Customer demand has the largest effect on the total cost of the SCN.
  - Unit shipping cost has the largest effect on the balance level of transit time and the average total transit time because it is proportional to transit time.
- Harder to balance the total transit time assigned to the opened DCs when customers are located farther away from the DCs.
- An increase in customer demand has different effects on the balance level of transit time depending upon the size of the problem instance.
- The number of opened plants is not influenced by unit shipping cost.

Sample Problem Instance

![Figure 2: Pareto Optimal Solutions for Medium Problem Instance](image)

Table 2. Customer Allocation to Opened DCs for Solution 1

<table>
<thead>
<tr>
<th>DC</th>
<th>Customer</th>
<th>Plant 1</th>
<th>Plant 2</th>
<th>Plant 3</th>
<th>Plant 4</th>
<th>Plant 5</th>
<th>Plant 6</th>
<th>Plant 7</th>
<th>Plant 8</th>
<th>Plant 9</th>
<th>Plant 10</th>
<th>Remaining Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusions & Future Work

- Solution methodology is applicable to regional retail chains that distribute product types that are large in size, including aluminum rods, decking boards, drywall panels, and lumber, to name a few.
- It is anticipated that the results of this research will improve the strategic decision making of manufacturing firms when locating facilities or redesigning the SCN.
- It was assumed that customer demand should be fulfilled by a single DC with a full truckload.
- Research could be extended to include routing or shared truckload among customers if the capacity of the truck was not filled.
- A more complex supply chain network could be studied that includes multiple levels (e.g., suppliers and/or third party logistics) with multiple types of products.