Cooperative capacity planning and resource allocation by mutual Outsourcing using ant algorithm in a decentralized supply chain

Expert Systems with Applications (2009)
Kung-Jeng Wang, M-J Chen

Kyung Cheol Jang
2015.07.24
Introduction
Capacity planning and resource allocation with negotiation

The study focuses on
- Capacity planning with negotiation framework
- Allocating resources to fulfill all orders of products in each production period
Literature review

  - Resource allocation + SA approach

  - Resource allocation + GA approach

  - Resource allocation + Capacity expansion + GA approach

  - Resource allocation + Capacity expansion + Multiple resource + Budget + GA approach

  - Resource allocation + Capacity expansion + Multiple resource + Budget + Inventory + GA approach
2 Problem description
Problem description

- **Problem**
  - The cooperative capacity planning and resource allocation

- **Objective**
  - Maximize the total profit

- **Decision variables**
  - Capacity Planning Decision
  - Resource Allocation Decision

- **Assumptions**
  - the quality of product is not considered
  - no backlogging
Parameters
- $a_{t,j}$: Configuration relationship between orders and manufacturing cells, $a_{t,j} \in \{0,1\}$
- $d_{k,j}$: Demand quantity (in pieces) of order $j$ in planning period $k$, $k = \{1,2, \ldots, p\}$
- $\mu_{t,j}$: Throughput of manufacturing cell $t$ when used to produce order $j$ (in pieces per planning period)
- $W$: Working hours of each period of time
- $u_{k,t}$: Costs of purchasing manufacturing cell $t$ in period $k$
- $c_{k,t}$: Costs of purchasing manufacturing cell $t$ in period $k$
- $l$: Capital interest rate
- $C_{t}$: Unit price of selling capacity of remaining manufacturing cells $t$ of a capacity seller
- $C_{t,j}$: Capacity seller’s unit price of manufacturing cell $t$ to produce capacity buyer’s order $j$
- $CC$: Upper bound of initial budget
- $R$: Adjustable parameter of price of resource capacity
- $P_j$: Unit profit of order $j$

Decision variables
- $N_{k,t}$: Number of manufacturing cell $t$ in period $k$
- $x_{k,t,j}$: Quantity produced by manufacturing cell $t$ to meet order $j$ in period $k$
- $\delta_{k,t}$: Increment (or decrement) number of manufacturing cell $t$ from period $k - 1$ to period $k$
- $N_{k,t}^\text{'}$: Number of remaining manufacturing cell $t$ in period $k$
- $d_{k,j}$: Number of remaining quantities of order $j$ in period $k$ after task allocation of an individual factory is done.
Problem description

- Formulation – Individual factory capacity planning model
  (a factory with capacity over demand) – demand need to be fulfill – Model 1

Object Function

\[ \text{Max} \quad z = \sum_{k=1}^{p} \frac{1}{(1 + I)^k} \sum_{t=1}^{v} N_{k,t} C_{t} \]

Subject to

(1) Obj. : Maximize Total profit

(2) Capacity balancing equation

(3) Upper bound of budget

(4) Capacity limit of manufacturing cells

(5) Remanding capacity of manufacturing cells

(6) The change in the number of machines
Formulation – Individual factory capacity planning model
(a factory with capacity over demand) – demand need not to be fulfill – Model 2

Object Function

\[
\begin{align*}
\text{Max} & \quad z = \sum_{k=1}^{p} \sum_{t=1}^{v} \frac{\sum_{j=1}^{n} p_{jt} x_{ktj} - c_{kt} \delta_{kt}}{(1 + I)^k} \\
\text{Subject to} & \\
\sum_{t=1}^{v} a_{tj} x_{ktj} & \leq d_{kj} \\
0 & \leq \sum_{k=1}^{p} \sum_{t=1}^{v} \frac{c_{kt} \delta_{kt}}{(1 + I)^k} \leq CC \\
N_{kt} - \sum_{j=1}^{n} \frac{a_{tj} x_{ktj}}{W u_{kt} \mu_{tj}} & \geq 0 \\
\delta_{kt} & = N_{kt} - N_{(k-1),t} \\
N_{kt}, x_{ktj} & \in Z^+, \quad \delta_{kt} \in Z
\end{align*}
\]

(1) Obj. : Maximize Total profit

(2) Capacity balancing equation

(3) Upper bound of budget

(4) Capacity limit of manufacturing cells

(5) The change in the number of machines
Problem description

- Formulation – Inter-factories capacity planning model
  (a factory with capacity over demand) – Model 3

Object Function

\[
\text{Max} \quad z = \sum_{k=1}^{p} \sum_{t=1}^{v} \sum_{j=1}^{n} \frac{(p_j - C_{tj})x_{ktj}}{(1 + l)^k}
\]

Subject to

1. \( \sum_{t=1}^{v} a_{tj} x_{ktj} \leq d'_{kj} \)

2. \( N_{kt} - \sum_{j=1}^{n} \frac{a_{tj} x_{ktj}}{W_{ukt} \mu_{tj}} \geq 0 \)

3. \( N_{kt}, x_{ktj} \in Z^+ \)

(1) Obj. : Maximize Total profit

(2) Capacity balancing equation

(3) Capacity limit of manufacturing cells
3 Solution algorithms
Solution algorithms

- Overall solution approach

- Concept of ant colony optimization algorithms
Solution algorithms

- **Ant colony algorithm**

Graph $G=(V,E)$

Amount of pheromone $\tau_A((x_j,v)) = \tau_{(x_{j-1},m)\in A((x_{j-1},m),(x_j,v))}$

Probability of transition $p_A((X_j,v)) = \frac{[\tau_A((x_j,v))]^{\alpha}[\eta_A((x_j,v))]^{\beta}}{\sum_{w\in D(x_j)}[\tau_A((x_j,w))]^{\alpha}[\eta_A((x_j,w))]^{\beta}}$

**Local**

$\tau(i,j) \leftarrow (1 - \rho) \cdot \tau(i,j) + \Delta \tau(A_k,i,j)$

**Global**

$\tau(i,j) \leftarrow (1 - \gamma) \cdot \tau(i,j) + \Delta \tau(A_l,i,j)$

SET $A = \{(x_1,v_1), ..., (x_k,v_k)\}$

$N_{kt} = \sum_{j=1}^{n} \frac{a_{tj}x_{ktj}}{W u_{kt} \mu_{tj}} \geq 0$

$N_{kt}$ is ceiling integer

\begin{itemize}
  \item Initial solution $\beta=0$
  \item Model 1 $\beta=0 \rightarrow \sum_{t=1}^{p} a_{tj}x_{ktj} = d_{kj}$
  \item Model 2,3 $\beta=1 \rightarrow \sum_{t=1}^{p} a_{tj}x_{ktj} \leq d_{kj}$
\end{itemize}

$\Delta \tau(A_k,i,j) \begin{cases} 
  = \frac{1}{T_C(A_k)} & \text{if } \{i,j\} \in A_k \\
  = 0 & \text{otherwise}
\end{cases}$
4 Experiments
Experiments environment

- Computing power
  - P4 CPU / 256MB – Coding: JAVA

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$ (weighting the pheromone)</td>
<td>1</td>
</tr>
<tr>
<td>$\rho$ (evaporation rate-local)</td>
<td>0.01</td>
</tr>
<tr>
<td>$\gamma$ (evaporation rate-global)</td>
<td></td>
</tr>
<tr>
<td>$N_{ants}$ (number of artificial ant)</td>
<td>75</td>
</tr>
<tr>
<td>C (number of cycles in a trial)</td>
<td>1000</td>
</tr>
<tr>
<td>RF (number of reinforcement cycles)</td>
<td>25</td>
</tr>
</tbody>
</table>
Example and results

Results

Fig. 6. Objective function evolutions of CPGA, MAA and ILOG OPL.
Example and results

- Results

![Graph showing profit share structure for different R values.](image)

Fig. 7. Profit share structure for different R.
Conclusion

- Presented a MILP Model
- Suggested ACO approach