Combinatorial Optimization Model and Algorithm of Material Dispatching with Supply Priority

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Abstract: As for a company with continuous and mass production, such as T iron and steel company, its supply logistics of material has characteristics of high interspaces, multiple suppliers and complex transport scheme. It is of great significance to coordinate the trade-off between transport cost and inventory cost and thereby realize the lean supply for continuous production and cost control of the company. According to the difficulties to coordinate the supply rhythm and supply quantity when multiple suppliers provide the same material, we establish a material dispatching model and make a solving algorithm on the basis of continuous production and cost minimization. Based on the coking coal transport network of T iron & steel company, we propose a material dispatching scheme with MATLAB7.0 software compiling supply routes and dispatched quantity per batch and time for the supplier.

Key Words: Combinatorial optimization, material dispatching, supply priority, cost minimization

INTRODUCTION

As for a company with continuous and mass production, its material suppliers are numerous and its geographical location is dispersed, such as T iron and steel company whose coking coal is provided by 22 suppliers through 28 stations. Assuming that the station and the supplier is one-to-one relationship, that is, supposing that supplier has two delivery stations: Sl, and Sl2, then supplier S1 is divided into S1 and S1, where S1 delivers the goods at Sl1, S1 at Sl2. Or supplier S2 and S1 both deliver the goods at St, then the station St is divided into St1 and St2, where S1 delivers the goods at St1, S1 at St2 and other circumstances with similar treatment. The space distribution of these stations is shown in Fig. 1 and the corresponding stations of serial number can be seen in http://ewebmail.mail.163.com. Because these suppliers and T iron and steel company have signed a contract and reached strategic partnership, each supplier requires the T iron & steel company to dispatch its material with priority at least once a production cycle. Here the main problem we try to solve is: Under the constraint of the material supply priority, the company properly arranges the material supply time and quantity of suppliers and avoids the simultaneous reaching of suppliers' material which can cause higher inventory and loading and moving burden and thereby leading to cost increase while meeting the demand, or avoids affecting the production continuity from insufficient inventory and the lack of timely replenishment of suppliers.

There are many optimization methods of material dispatching, such as transportation planning, shortest path method, min-cost max-flow method etc. (Guan and Zheng, 1983; Zhao, 1996; Hu, 1993). However, the given algorithm of each optimization method is based on satisfying specific conditions and these algorithms are used for solving specific problems accordingly. Yang et al. (2011) builds a mixed integer nonlinear

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programming model of liner fleet based on improving optimal configuration level of the liner transportation system and obtains the route-deployment, frequency of dispatching and optimization scheme of fleet construction in planning period. Qin et al. (2013) establish a mixed integer programming optimizing model. Li (2012) builds a multi-objective non-linear mixed integer programming model according to the specific circumstances of coal dispatching in S Group and solves the problem by genetic algorithm. Combining with material dispatching, emergency transportation and dynamic programming, Chen and Shuai (2010) investigate the transportation optimizing problem for emergency material under time window. Yuen (2007) studies a multi-objective supply planning problem under uncertain demand through introducing CVaR method. Chen and Liu (2012) solves an allocation problem of purchasing quantity with network analysis method when multiple suppliers supply the same material. Yu et al. (2011) and Liang et al. (2010) have performed related research on dispatching field of coal.

Due to the different supply capacity of coking coal suppliers, T iron & steel company should dispatch coking coal of one or more suppliers (called supply combination) in each supply period so as to meet the demand of production. According to contract between the company and supplier, the company should give priority to certain supplier's demand of production in this supply combination. Hence, the study mainly investigates the problem of material dispatching with supply priority. In supply combinations, the supplier with supply priority is called main supplier, the rest of suppliers are called auxiliary suppliers.

In material dispatching fields, some scholars also consider the selection of different transportation modes. Taking into account different means of transportation in the whole coal transportation network, Zhou and Ding (2011) establish a multi-objective programming model based on network flow whose objective function is related to transportation cost and time of multimodal transport and optimize it with genetic algorithm. Under the premise of considering both fixed transport cost and variable transport cost, Li et al. (2012) build a mixed integer linear programming model in allusion to a transportation mode optimizing selection problem of each section for a batch of goods on transportation route. Due to the strategic partnership between T iron and steel company and 22 suppliers of coking coal, the geographical location of each supplier is changeless, that is, each supplier selects the optimal transportation mode (whether unimodal transport or multimodal transport) in a production cycle when supplying T iron & steel company with coking coal. We assume that the transportation mode of each supplier is vested.

We mainly study the material dispatching problems with supply priority. In the research fields of material dispatching, the differences between this study and above scholars' research are as follows. First, the supplier for each kind of material serves as main supplier at least once a dispatching cycle of the company. Second, the transportation mode of supplier is vested when the company establishes the dispatching scheme of material. The study considers such factors: the production schedule, material inventory of the company, supply capacity, spatial and geographical distribution, supply priority of supplier, etc., establishes the model of material dispatching with supply priority and puts forward a material dispatching scheme with MATLAB7.0 software compiling supply routes and also dispatched quantity per batch and time for the supplier.

**PROBLEM DESCRIPTION AND NOTATIONS ASSUMPTIONS**

**Problem description:** In practice, due to the restriction of production capacity or transport capacity for supplier, the material supply of single supplier often cannot meet the production demand. Hence, the single supplier should cooperatively constitute a supply combination with other suppliers and supply the company with material so as to guarantee the normal and continuous operation for production system of the company.

Supposing there are I suppliers supplying certain same material for a company. Each supplier has signed the contract with the company and the contract guarantees each supplier serving as main supplier at least one time in a dispatching cycle. These suppliers constitute different supply combination according to the vested supply routes and each supply combination supply the same material in accordance with certain rules. With the development of continuous production, the material of next supply combination just arrives when the material of the previous supply combination is consumed to safety inventory. The inventory variation with time of certain material is shown in Fig. 2, where $t_i$ denotes the time when the inventory level reaches the safety inventory. $\Delta t_i = t_{i+1} - t_i$ denotes the supply period. $\Delta j$ denotes the time when batch $j$ arrives within $[t_i, t_i + \Delta t_i]$. $M_{t_i}$ denotes the economic order quantity within $[t_i, t_i + \Delta t_i]$. $q_{t_i}$ denotes the material supply arriving at $\Delta t_i$. The total quantity:

$$\sum_{t_i} q_{t_i}$$
Fig. 2: Variation of material supply

are consumed to safety inventory after \(\Delta t\). The first batch of material supply quantity \(q\Delta t\) has just arrived with:

\[
\left[ t_{s1}, \Delta t + t_{s2} \right] \\
(k = 1, 2, \ldots, K, \ldots, i = 1, 2, \ldots, I, s \in N^r)
\]

Assumptions and notations:

- \(I\): index set of suppliers, \(I = \{1, \ldots, i, \ldots, I\}\), where \(I, i\) denotes the supplier of number \(i\). Assuming that the supplier does not change during a dispatching cycle
- \(S\): safety stock of certain material
- \(P_{si}\): average daily consumption of material within \([t_{a1}, t_{a2} + \Delta t]\)

\[
P_{si} = \left[ P_{s1}, P_{s2}, \ldots, P_{Si} \right] \\
\text{stands for production capacity set, where } P_{si} \text{ denotes the average daily production capacity for supplier } i \text{ supplying this kind of material within } [t_{a1}, t_{a2} + \Delta t].
\]

\(u_{si}\): Average daily offloading capacity for this kind of material within \([t_{a1}, t_{a2} + \Delta t]\)

- \(C_{si}\): cost set, where \(C_{si}\) denotes unit transportation cost for supplier \(i\) transporting this kind of material with certain vested transportation mode within \([t_{a1}, t_{a2} + \Delta t]\)

\(V_{si}\): the speed set, where \(V_{si}\) denotes the average transportation speed for supplier \(i\) transporting this kind of material with certain vested transportation mode within \([t_{a1}, t_{a2} + \Delta t]\)

- \(D_{i}\): The start date to consume this kind of material of the company's production. \(D_{i}\): The expiry date not to consume this kind of material of the company's production. We assume the company always consumes this kind of material in the process of production. \(D = [d_{1}, \ldots, d_{i}, \ldots, d_{I}]\) is time set, where \(d_{i}\) denotes the start time for supplier \(i\) producing this kind of material and here we also assume that the supplier always meets the demand in the process of the company's production

- \(K\): Supply times of material in dispatching cycle and \(K\) satisfies:

\[
K \leq \left[ \sum_{i} M_{i} \right] \leq D_{i} - D_{i}, \quad \sum_{i} M_{i} \equiv D_{i} - D_{i}, \quad K \in N^r
\]

- \(q\): The inventory level of this kind of material in the beginning of the company's production. \(Q = [q_1, \ldots, q_I]\) is the initial inventory set, where \(q_i\) denotes the inventory level for supplier \(i\) supplying the company with this kind of material at the first time

- \(L_{ij}\): spatial distance set, where \(L_{ij}\) denotes the spatial distance between supplier \(i\) and the company within \([t_{a1}, t_{a2} + \Delta t]\). (Since, the change of transportation mode can alter the spatial distance between)

- \(X_{si}\): Supply matrix set which is shown as follows:

\[
X_{si} = \left[ [1, m_{1}, \ldots, h_{1}], \ldots, [i, m_{i}, \ldots, h_{i}], \ldots, [1, m_{I}, \ldots, h_{I}] \right]
\]

where, \([i, m_{i}, \ldots, h_{i}]\) denotes the supply combination for supplier \(i\), \(m_{i}, \ldots, h_{i}\) in the same route and \(i\) serving as the main supplier within \([t_{a1}, t_{a2} + \Delta t]\). Each supplier is sorted in ascending order of spatial distance except for the main supplier in each supply combination and the main supplier is located in the first column of the matrix:

- \(Y_{si}\): Total dispatching batch within \([t_{a1}, t_{a2} + \Delta t]\), namely:

\[
Y_{si} = \left[ \begin{array}{c}
\text{if supplier } i \text{ supplies material and the } j \text{ batch arrives at } [t_{a1}, t_{a2} + \Delta t] \\
\text{otherwise}
\end{array} \right] \\
k = 1, 2, \ldots, K; i = 1, \ldots, I
\]

- \(J_{si}\): Total dispatching batch within \([t_{a1}, t_{a2} + \Delta t]\), namely:

\[
J_{si} = \left[ \begin{array}{c}
M_{si} \\
M_{si}
\end{array} \right]
\]

where, \(x|y\) denotes that \(y\) can be divisible by \(x\), \(y\), denotes that \(y\) cannot be divisible by \(x\), \(d_{i}\) denotes down round.

Assuming:

\[
\Delta t_{si} + \frac{S}{u_{si}} \geq \frac{L_{si}(i)}{V_{si}(i)} \\
(i \in [1, I], \quad \Delta t_{si} \in [1, \Delta t])
\]

- Supposing the unit wholesale price for all the suppliers is the same, here we don't consider the supplier's removal or dock cost at each station
DISPATCHING MODEL

A proper material dispatching scheme not only satisfies the production demand at any time but also meets the minimizing of transportation cost, namely we must consider the trade-off between transportation cost and inventory cost. Hence, dispatching model of this study obeys the following two basic rules: the continuity of production and the minimizing of transportation cost.

**Decision variables:** In each supply period, the company can select proper supplier from numerous suppliers and in order to satisfy the stability, continuity and economical efficiency. Let \( q_{akj} \) be decision variable which denotes the dispatching quantity that supplier \( i \) can supply and reach within \( \Delta t_{kj} \).

**Constraint conditions:**

- **Total dispatching quantity constraint**
  \[
  M_{ai} - \sum_{t_k=0}^{\Delta t_{kj}} \sum_{t_r=0}^{\Delta t_{jr}} q_{akr} Y_{akr} = 0, (k = 1, \ldots, K)
  \]

- **Each supplier's supply capacity constraint**
  \[
  q_{akj} \leq \sum_{t_r=0}^{\Delta t_{jr}} q_{akr} Y_{akr} (k = 1, \ldots, K; i = 1, \ldots, J)
  \]
  where, \( q_{akr} \) denotes the stocking quantity of supplier \( i \) at \( t_r \):
  \[
  q_{akr} = \frac{Q_0}{\sum_{t_k=0}^{\Delta t_{kj}}} (1 - t_k) R_{ki} (i = 1, \ldots, I)
  \]
  \[
  (k = 1, \ldots, K; i = 1, \ldots, J)
  \]

- **Continuous production constraint**
  \[
  \sum_{t_k=0}^{\Delta t_{kj}} \sum_{t_r=0}^{\Delta t_{jr}} q_{akr} Y_{akr} + (M_{ai} - t_k) P_{ai} > 0, (k = 1, \ldots, K; i = 1, \ldots, I)
  \]
  \[
  q_{akr} = \frac{Q_0}{\sum_{t_k=0}^{\Delta t_{kj}}} (1 - t_k) P_{ai} \geq S_i (k = 1, \ldots, K)
  \]

- **Average daily offloading capacity constraint:**
  \[
  (\Delta t_{k+1} - \Delta t_{kj}) d_{akr} - \sum_{t_r=0}^{\Delta t_{jr}} q_{akr} Y_{akr} \geq 0, (j = 1, \ldots, J - 1)
  \]

- **Contract constraint:**
  \[
  l_j - t_k \leq 0, (k = 1, \ldots, K)
  \]

where, \( I \) and \( L \) have the same dimension, if supplier \( m \) has already served as the main supplier before \( t_m \) then \( l_m(i) = \text{otherwise}, l_m(i) = 0, i \neq i \).

- **Transportation capacity constraint**
  \[
  q_{akj} \leq CW_{akj} q_{akj} \leq GV_{akj}
  \]
  where, \( q_{akj} \) denotes the weight of material arriving the company at \( \Delta t_{kj} \), \( CW_{akj} \) denotes the maximum weight capacity of vehicle, \( GV_{akj} \) denotes the volume of material arriving the company at \( \Delta t_{kj} \), \( GV_{akj} \) denotes the vehicle's maximum volume.

- **Non-negativity constraint of parameters:**
  \[
  q_{akr} > 0, (k = 1, \ldots, K; j = 1, l_m(i) = 1, \ldots, J)
  \]

**Optimization goal:**

- **Transportation cost C:**
  \[
  C = \sum_{t_k=0}^{\Delta t_{kj}} \sum_{t_r=0}^{\Delta t_{jr}} q_{akr} Y_{akr} C_{akr}(t_r) L(t_k)
  \]

- **Transportation time T:**
  \[
  T = \sum_{t_k=0}^{\Delta t_{kj}} \sum_{t_r=0}^{\Delta t_{jr}} q_{akr} Y_{akr} t_r L(t_k)
  \]

- **Vehicle utilization U:**
  \[
  U = \sum_{t_k=0}^{\Delta t_{kj}} \sum_{t_r=0}^{\Delta t_{jr}} \left[ \frac{q_{akr} Y_{akr}}{CW_{akj} \cdot GV_{akj}} \right]
  \]

**Dispatching optimization model:** The optimization model of material dispatching is a multiobjective optimization problem. We assume that the decision maker of the company gives priority to transport cost, then vehicle utilization and finally the transit time after satisfying the constraint conditions in section 3.2.

**Definition 1:** Let \( A \) be the decision value, \( B \) be the target value, then positive deviation variable \( d^+ \) and negative deviation variable \( d^- \) are defined as follows:

\[
\begin{align*}
  d^+ & = \begin{cases} 
  A - B, & A \geq B \\
  0, & \text{otherwise} 
  \end{cases} \\
  d^- & = \begin{cases} 
  B - A, & A \leq B \\
  0, & \text{otherwise} 
  \end{cases}
\end{align*}
\]

Then in the dispatching optimization model of section 2.4, the minimum transport cost is the first precedence level goal. We introduce the decision value g.
and generate the goal constraint $C+d'_1-d'_1 = g_c$. The objective function with positive deviation variable should be small as soon as possible, namely $d'_1$. The minimum transit time is the third precedence level goal. We introduce the decision value $g_d^r$ and generate the goal constraint $T+d'_2-d'_2 = g_d$. The objective function with positive deviation variable should be small as soon as possible, namely $d'_2$. The maximum vehicle utilization is the second precedence level goal. We introduce the decision value $g_2$ and generate the goal constraint $U+d'_3-d'_3 = g_2$. The objective function with negative deviation variable should be small as soon as possible, namely $-d'_3$. The priority coefficient denoting target precedence level $P_1, P_2, P_3, P_4, P_5$ multiply them ahead of each objective, respectively, then the dispatching optimization model can be converted to:

$$
\sum_{n=1}^{k} \sum_{i=1}^{n} q_{ni} Y_{ni}(i) + d'_1 = g_c,
$$

$$
\sum_{n=1}^{k} \sum_{i=1}^{n} Y_{ni}(i) + d'_2 = g_d^r,
$$

$$
\sum_{n=1}^{k} \sum_{i=1}^{n} \max \left\{ \frac{q_{ni} - CV_{ni}}{CW_{ni}}, \frac{CV_{ni}}{CW_{ni}} \right\} - d'_2 = g_d.
$$

Subject to:

$$
\sum_{n=1}^{k} \sum_{i=1}^{n} Y_{ni}(i) = 0
$$

$$
Q_{ni} \geq \sum_{i=1}^{k} q_{ni},
$$

$$
\sum_{n=1}^{k} \sum_{i=1}^{n} q_{ni} Y_{ni} + S - (t_{ij} - t_i) p_{nj} > 0
$$

$$
q_{ni} - \sum_{i=1}^{n} q_{ni} Y_{ni} - (t_{ij} - t_i) p_{nj} \geq 0
$$

$$
(t_{ij} - t_i) - t_{ij} + \sum_{i=1}^{n} q_{ni} Y_{ni} \geq 0
$$

$$
L_i - 1_i = 0
$$

$$
q_{ni} \leq CW_{ni}
$$

$$
q_{ni} \leq CV_{ni}
$$

$$
q_{ni} > 0, k = 1, \ldots, K; j = 1, J_{ni}; i = 1, \ldots, I
$$

MODEL SOLUTION

**Model analysis:** This study mainly solve the joint scheduling problem with contract constraint. So, we first determining of the various outlets supply combination as well as the supply of each combination of dynamic inventory according to geographic location; And then we determining supply combination and main supply by optimization goal; Finally this study propose a material dispatching scheme and dispatched quantity per batch and time for the supplier.

So, the solving algorithm for dispatching optimization model of section §2.4 can be divided into five procedures: (1) Initializing data. (2) Calculating total inventory of supply routes. (3) Classifying total inventory of supply routes. (4) Judging the opening and closing of4 supply cycle. (5) Confirming dispatching scheme of material. The algorithm structure is shown in Fig. 3.

**Algorithm design:** The specific procedures of the algorithm are as follows:

**Procedure 1: Initializing data:** When $K = 1$, let $I = [0, 0, 0, \ldots, 0]$, $IM = I_r I$, then initializing the following data: $I_o, D_o, D_s, Q_i$.

**Procedure 2: Calculating total inventory of supply route:** When the company is making dispatching decision, we get the latest departure time $T$ of supplier $i$ when $i$ arrives at the company and the company's inventory quantity is:

$$S_i = \left[ \frac{\text{datenum} (D_o) + \max \left( \frac{q_i - S_i}{p_{nj}}, \frac{L_{nj}(i)}{V_{nj}(i)} \right)}{p_{nj}} \right] = 1, \ldots, k = 1, \ldots, K$$

where, datenum x convert the character x into the numeric.

$q_i$ denotes each supplier's inventory quantity at $T(i)$ on the route that the supplier $i$ serving as the main supplier:

$$q_i = \left\{ [q_i, q_{i2}, \ldots, q_{ik}] \right\} = \left\{ [\max (T(i), T(j)) - D_{nj}(i)] \right\} = [q_j, q_{j2}, \ldots, q_{jk}]$$

Where:

$$q_i = \max (q_i, 0) + \max (\min (T(i), T(j)) - D_{nj}(i), 0) \times R_{nj}$$

$R_{nj}$ denotes the total inventory quantity of supply route where and when supplier $i$ serving as main supplier at $T(i)$.
Table 1: Coking coal dispatching scheme of T iron and steel company

<table>
<thead>
<tr>
<th>Main supplier</th>
<th>Supply combination</th>
<th>Supply quantity</th>
<th>Batch departure time</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>2013-12-01</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>[3]</td>
<td>[5]</td>
<td>2013-12-05</td>
<td>92.05</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2013-12-06</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>[6,4,3]</td>
<td>[0.6681,0.5377,3.7941]</td>
<td>2013-12-10</td>
<td>115.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2013-12-10</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2013-12-11</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>[7,4,3]</td>
<td>[0.7055,0.4344,3.8600]</td>
<td>2013-12-15</td>
<td>132.68</td>
</tr>
<tr>
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<td></td>
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<td>2013-12-15</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>[8,4,3]</td>
<td>[0.5913,0.4865,3.9222]</td>
<td>2013-12-20</td>
<td>138.86</td>
</tr>
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<td></td>
<td></td>
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<td>2013-12-20</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>[9,4,3]</td>
<td>[0.6995,0.4118,3.9787]</td>
<td>2013-12-24</td>
<td>190.29</td>
</tr>
<tr>
<td></td>
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<td></td>
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<td>2013-12-31</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2013-12-31</td>
<td></td>
</tr>
</tbody>
</table>

\[ R_T = \left\{ \sum_{[i,j]} q_{i,j} \right\}_{1 \leq i \leq I, 1 \leq j \leq K} \]

**Procedure 3: Classifying total inventory of supply routes:**
We classify the total inventory of supply routes into two types:

\[ R_1 = \{ R_{i,j} \}_{i,j} \]
\[ R_2 = \left\{ q_{i,j} \cdots q'_{i,j} \cdots q_{i,j} \right\}_{i,j} \]

For any \( S_i q_{i} \leq M_i \) for any \( S_i M_i \leq q'_{i} \). Corresponding to \( R_T, Q_T \) is also divided into two types, namely \( Q_T = \{ Q_T, Q_T' \} \).

**Procedure 4: Judging the opening and closing of supply cycle:** If any \( I (M) = 0 \), then move to procedure 1. Otherwise, move to procedure 5.

**Procedure 5: Confirming dispatching scheme of material:**

- If is empty \((R_i) \neq 0\), we can select the supply combination where \( i \) serving as main supplier in \( Q_T \) according to the principle of continuous production and cost minimization. The selection method of supply combination and the scheme design of each supplier's departure time and dispatching quantity for each batch are shown in Appendix A.

- If is empty \((R_i) = 0\), is empty \((R_i) \neq 0\), then we need continuously dispatch the supply combination from different routes. At this point, the selection method of supply combination and the scheme design of each supplier's departure time and dispatching quantity for each batch are shown in Appendix B.

**CASE ANALYSIS**

The demand of coking coal for T iron and steel company is supplied by 28 suppliers, the basic information of each supplier is shown in http://ewebmail.mail163.com. According to the supplier's geographical location and mode of transportation in Fig. 1, we obtain the supply combination X.

On the grounds of the above algorithm of dispatching model, we establish the dispatching scheme of T iron & steel company with MATLAB 7.0 software in Dec. 2013. The dispatching scheme is shown in Table 1. The other related information and MATLAB program of the numerical example can download from http://ewebmail.mail163.com. Username: study_D_F@163.com, Password: studydf.

**CONCLUSIONS**

To meet the demand of normal and continuous production, we establish a model and algorithm of material dispatching and schedule a material dispatching scheme according to the minimum standard satisfying normal production and transport cost and also combining with the factors such as production planning, material inventory quantity of the company, spatial and geographical distribution, the priority of the supplier. Finally we compile a dispatching scheme with MATLAB 7.0 software for T iron & steel company in Dec. 2013:

- T iron and steel company previously works out the dispatching scheme of material by experience. Through the model and algorithm of material dispatching in this study, we can easily make a dispatching scheme, save the labor cost and improve the work efficiency.

- The dispatching scheme compiled by model and algorithm clearly confirms the departure time and dispatching quantity per batch for each supplier and is convenient for supplier to arrange production planning.

- On the basis of supplier's priority, the dispatching scheme can save the logistics cost to a large extend for the supply system composed by T iron and steel company and suppliers.
APPENDIX

Appendix A: If isempty (R) 0, we can select the supply combination where j serving as main supplier in Q_{ij} according to the principle of continuous production and cost minimization. The scheme design is as follows:

Assuming the supply combination from R is X \{j\} = \{i-m'...h\}. The total dispatching quantity of this time is M, the transport batch is:

\[
Z = \left\lceil \frac{M}{ul_{ij}} \right\rceil \text{round}(M/ul_{ij}) + \text{Others}
\]

Let \( L_{ij} = \text{length}(Q_{ij}) \), then the supply quantity of supplier \( j, m, ..., h \) is

\[
q_{ij} = \min \left( M - \sum_{i=0}^{\theta} q_{ij}(i) \right) \text{, } i=1,2, ..., L_{ij}, k=0,1, ..., i-1
\]

Which satisfies:

\[
\sum_{x(i)} q_{ij} = M, q_{ij} = 0, x(i), i=1,2, ..., \text{length}(x)
\]

Calculating the cost \( C_{ij} \) of \( Q_{ij} \), where:

\[
C_{ij}(i) = \sum_{x(i)} C_{x(i)} \times q_{ij}(i) \times L_{ij}(i)
\]

\[
k = 1,2, ..., \text{length}(x), i=1,2, ..., \text{length}(X_{ij})
\]

Select the main supplier \( j - \text{min}(C_{ij}) \) according to cost minimization.

By ranking spatial distance between suppliers and the company in descending order, we get \( X' \{j\} \), then departure batch \( Z \) of supply \( e \) can be obtained from below:

\[
\text{Let } s_u = \frac{\sum q_u}{ul_{ij}} - \text{round} \left( \frac{\sum q_u}{ul_{ij}} \right)
\]

\[
\text{Let } s_u = \frac{\sum q_u}{ul_{ij}} - \text{round} \left( \frac{\sum q_u}{ul_{ij}} \right), \text{ others}
\]

The departure time of supply \( e \) is:

\[
T_e = \sum_{i=0}^{\theta} T_{ij} s_u = 0
\]

\[
T_e = \sum_{i=0}^{\theta} T_{ij} s_u - 1, \text{ others}
\]

and the corresponding dispatching quantity are: \( ul_{ij} s_u \) denotes the quantity at first time, \( \min(q_u - z_{ij} ul_{ij}) \) indicates the quantity at last time, \( ul \) denotes the quantity at middle time:

Where \( e = X' \{j\} (i), e' = X' \{j\} (k) \)

\[
1 = 1,2, ..., \text{length}(X' \{j\}) - 1, k = 0,1, ..., i-1
\]

Update the following data in sequence:

\[
\begin{aligned}
I \{j\} = 0, q_i = M + R_i Q_{ij} \left\{ \begin{array}{ll}
Q_{ij} + R_i \{j\} - q_e \leq X' \{j\} & D_e = D_e + \frac{q_e}{p_0} \\
Q_{ij} + R_i \{j\} - q_e > X' \{j\} & D_e = D_e + \frac{q_e}{p_0}
\end{array} \right.
\end{aligned}
\]

If \( I = 0 \), then a supply cycle is over and move to procedure 1. Otherwise, move to procedure 2.

Appendix B: If isempty (R) = 0, isempty (R) = 0 then we need continuously dispatch the supply combination from different routes. The scheme design is as follows:

Let \( \text{sum } R_i = 0 \):

- The total cost \( C_{ij} \) of each supply route can be calculated according to \( Q_{ij} \), the supply route \( [i,m',...h] \) that \( i \) serving as main supplier can be selected in accordance with the rule of minimum cost and the supply quantity of the route is \( \text{sum } R_i = \text{sum } R_i + \text{R}(i) \), then updating \( q_e \) and recalculating \( \text{r} \):
- If there exists \( R_i(i) > M - \text{sum } R_i \), then we select the supply combination according to method (1), at this point, we have \( M = M - \text{sum } R_i \)

Otherwise, continuously circulating (1), until there successively exists \( [i, j, ...v, u] \) (note that \( [i, ...v, u] \) cannot serve as main supplier.) and satisfies:

\[
\sum_{r} R_r(r) < M < \sum_{r} R_r(r) + R_r(u), r \in [i, j, ...v]
\]

Now the corresponding supply quantity for supply route that \( [i, ...v] \) serving as main supplier is \( R_r \), the supply quantity of supply route that \( v \) serving as main supplier is:

\[
R_r(u) = \min \left( M - \sum_{r} R_r(r) - R_r(u), r \in [i, j, ...v] \right)
\]

The ultimate supply combination selected from \( X_{ij} \) is:

\[
X_{ij} = \{i, m', ...h\} = \{i, m', ...h\} \neq \{i, m', ...h\}
\]

We confirm the departure time and dispatching quantity per batch for each supplier according to \([i, ...v, u]\) in sequence and the calculating method is same as Appendix A.
According to the dispatching quantity per batch for each supplier, we calculate the total dispatching cost $C_T$ for this time and the calculating method is same as Appendix A.

Update the following data in sequence:

$$I(i) = \delta, \quad q_i = M + \delta, \quad Q_i = \begin{cases} Q_i(e), & e \in \mathcal{E}_i \text{, } i = 1, \ldots, v \text{, } e \neq e \setminus q_i \text{, } e \in \mathcal{E}_i \text{, } i = 1, \ldots, v \text{, } e \neq e \\ Q_i(e) - q_i, & e \in \mathcal{E}_i \text{, } i = 1, \ldots, v \text{, } e \neq e \setminus q_i \end{cases}$$

$D_0 = D_0 + \frac{\delta}{P_0}$

If $I = 0$, then a supply cycle is over and move to procedure 1. Otherwise, move to procedure 2.

REFERENCES


