Research on Order Allocation of Group Enterprise Based on Differential Evolution Algorithm

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Abstract: Aiming at the problem of procurement volume allocation of group enterprises, according to the characteristics of the internal structure of group enterprises, considering factors such as price discounts, comprehensive supplier scores, transportation costs, etc., a procurement optimization model based on internal allocation of group enterprises is established. When establishing the model, it is considered that the subsidiaries directly order from external suppliers and transfer between subsidiaries with excess inventory, so as to effectively use internal resources and balance the total inventory. When solving the model, a differential evolution algorithm with fast convergence speed, simple structure and excellent performance is selected for simulation solving. Through the example experiment, the procurement quantity and allocation amount are reasonably allocated, which effectively reduces the procurement cost of the group enterprises, and shows the effectiveness of the model.

1 INTRODUCTION

Order quantity allocation is the core strategic decision in procurement, and its scientific rationality is directly related to the high production cost of the enterprise. Therefore, it is of great significance to improve the core competitiveness of enterprises by optimizing the allocation of order quantity in order to reduce procurement costs.

Kaur et al.(Kaur, 2021) study order allocation in the context of Industry 4.0 with multiple materials and multiple cycles considering supply disruption risk; Safaeian et al.(Safaeian M, 2019) develop a multi-objective model for order allocation in a fuzzy environment considering both incremental discounts and transportation costs; Ghasemy et al.(Ghasemy Yaghin R, 2020) study an integrated model for order allocation and transportation planning in an uncertain environment considering corporate social responsibility; Alavi et al. Ghasemy et al. (Alavi B, 2021) studied an integrated model of order allocation and transportation planning considering corporate social responsibility in an uncertain environment; Alavi proposed a sustainable supplier selection method for circular supply chains based on a dynamic decision support system; Jia et al.(Jia R, 2020) proposed a new sustainable goal planning model with distributed robustness considering carbon emissions. Balakrishnan et al. developed an integrated optimization model considering both corporate volume discounts and inventory costs considering the purchasing demand preferences of each division of a large company and the requirements of centralized corporate purchasing;

In this paper, price discounts, supplier scores, transportation costs, inventory costs, etc. are taken into account, and when the demand is known, an order quantity allocation model considering both procurement and allocation is established, and a suitable differential evolution algorithm is designed to solve the problem.

2 MODEL CONSTRUCTION

2.1 Problem Description

In recent years, with the rapid development of big data, the Internet and other high-tech technologies, centralized procurement has become the most concerned procurement mode for domestic and foreign enterprise groups. Centralized procurement refers to a procurement mode in which group-type enterprises integrate the resources of their subordinate sub enterprises and centralize the management of resources. Through centralized

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procurement, the unified deployment of sub-distributed procurement resources helps optimize the optimal allocation of resources. In this paper, the procurement model combining centralized ordering, external procurement and internal redeployment is adopted, as shown in figure 1.

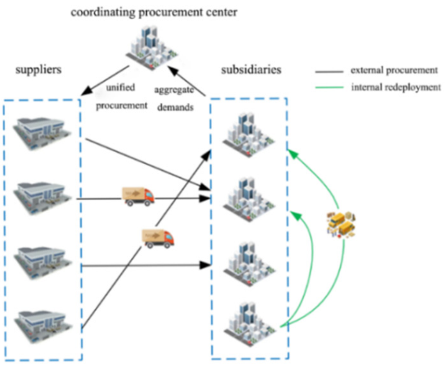

Figure 1. Schematic diagram of procurement and redeployment.

The group enterprise establishes a coordinating procurement center to aggregate the needs of subsidiaries and then conduct unified procurement. When purchasing, two sources of supply are considered: the first is direct procurement from external suppliers, and the second is transferring between subsidiaries with excess inventory. After aggregating demands, the coordinating procurement center queries subsidiaries with excess inventory on the information sharing platform of the group enterprise, takes the subsidiary as the supplier, and after comparing costs such as transportation costs and coordination costs, reasonably allocates procurement volume between suppliers and subsidiaries and formulates procurement plans to achieve cost optimization.

2.2 Model Assumptions

To simplify the model, the following assumptions are made:

Assumption 1: After the group enterprise conducts uniform procurement, it is assumed that the procurement quantity in a procurement cycle T can meet the demand of the subsidiaries, neither allowing out-of-stock.

Assumption 2: The demand of each subsidiary is determined and is known.

Assumption 3: The same supplier can supply to different subsidiaries, and the supply quantity does not exceed the maximum supply capacity.

Assumption 4: Each supplier uses the same transport vehicles, i.e. the only factor affecting transport costs is distance.

Assumption 5: The ordering cost of transferring between subsidiaries is less than the ordering cost of purchasing from suppliers.

2.3 Symbol Description

The explanation of the symbols used in the paper is shown in Tables 1, 2 and 3 below.

Table 1: Sets and Comments.

Assemblies	Note
i	Set of subordinate sub enterprises of the group, i=1,2 ....*n*
j	The set of materials to be purchased, j=1,2...*J*
k	The set of suppliers with supply capacity, external suppliers if k=1,*2....q*, and subsidiaries if *k=q+1....m*
T	Purchasing cycle
t	Discount level, t=1,2...*L*

Table 2: Variables and Comments.

Parameters	Note
Z_k	Fixed procurement costs for a single procurement activity
D_{ij}	Subsidiary's demand for material *j in* cycle *T*
E_{kj}	The maximum supply capacity of the supplier for material *j during the* cycle *T*
g	Truck vehicle loading capacity
G	Unit weight of purchased materials
d_{ik}	Distance between the supply side and the demand side of the business
C_{ik}	Supply-side transportation costs per unit distance
r_{kjt}	Price discount at level *t* offered by the supplier for material *j*
P_{kj}	The initial price of material *j* provided by the supplier
h_k	Overall supplier score
H_{kj}	Unit material storage cost of the kth subsidiary
Y_{ikt}	0-1 variable, equal to 1 means that *i is* supplied by supplier *k* at level *t*, otherwise 0

Table 3: Decision Variables and Notes.

Decision Variables	Note
X_{ijk}	Quantity of material *j* purchased by subsidiary i from supplier *k*

2.4 Model Building

The objective function is as follows:

$$\min = Z_k + r_{kjt} y_{ikt} p_{kj} + \frac{GX_{ijk}}{g} C_{ik} d_{ik} + X_{ijk} T - h_k X_{ijk} \quad (1)$$

Constraints:

$$\sum_{i=1}^{n} X_{ijk} \geq \sum_{i=1}^{n} D_{ij} \quad (2)$$

$$\sum_{i=1}^{n} X_{ijk} \leq E_{kj} \quad (3)$$

$$\sum_{t=1}^{l} y_{ikt} \leq 1 \quad (4)$$

$$D_{ij} \geq 0 \quad (5)$$

$$X_{ijk} \geq 0 \quad (6)$$

The objective function (1) is the minimum total procurement cost, which is the fixed ordering cost, procurement cost, transportation cost, subsidiary storage cost and supplier comprehensive performance merit score, respectively. Since the supplier comprehensive merit score is the larger the better, and the objective function is the smaller the cost function, the negative sign is taken here. Constraint (2) indicates that the subsidiary's procurement quantity must be greater than the demand quantity, i.e., no shortage is allowed; constraint (3) indicates the supply capacity constraint; constraint (4) indicates that the group enterprise enjoys at most one level of price discount at the supplier; constraint (5)(6) indicates that the demand quantity and procurement quantity can only be positive values.

3 SOLVING ALGORITHM

For the linear programming model of this multivariate and multi-constraint condition, its solution is an NP problem, so a differential evolution algorithm is designed to solve it in this paper. In general, differential evolution algorithms mainly include four main steps: population initialization, mutation, crossover, and selection.

3.1 Initializing the Population

Let N and D be the population size and the dimension of the search space, respectively, and the initial population is generated in the form of a uniform distribution according to the given range of variables.

$$\vec{X}_i = \left\{ X_{i,1}, X_{i,2} \ldots X_{i,D} \right\}; i = 1,2\ldots N, j = 1,2\ldots D \quad (7)$$

$$X_{i,j} = LB_j + (UB_j - LB_j) \times rand \quad (8)$$

where LB_j, UB_j denotes the upper and lower bounds of the jth dimension, respectively, and rand is a random number uniformly generated between (0,1).

3.2 Variant Operation

At generation t, a variation vector corresponding to the parental vector $\vec{V}_i$ is generated by the variation strategy, and the classical variation strategy is as follows:

$$V_{i,j} = X_{r1,j} + F \cdot (X_{r2,j} - X_{r3,j}) \quad (9)$$

where $X_{r1,j}, X_{r2,j}, X_{r3,j}$ is a random selection of three mutually dissimilar individuals from the population, F is a mutation proportionality factor that controls the differential variation of $X_{r2,j} - X_{r3,j}$ and $F \in [0,2]$.

3.3 Cross-Operation

After generating the variance vector, it enters the crossover phase, which produces a candidate solution at $\vec{U}_i$, operating as follows:

$$U_{i,j} = \begin{cases} V_{i,j}, if\ rand < CR\ or\ j = j_{rand} \\ X_{i,j}, otherwise \end{cases} \quad (10)$$

Where, $rand_j$ is the jth solver of the uniform random number generator, $rand_j \in [0,1]$, CR is the given crossover probability, $CR \in [0,1]$, $rand_j$ is the number of randomly selected numbers from dimension D ensuring that $\vec{U}_i$ gets at least one parameter from $\vec{V}_i$.

3.4 Evaluation Options

Using the greedy rule to compare the objective function values of $\vec{U}_i$ and $\vec{V}_i$, the individual with the lowest function value for the minimization problem will be selected to be passed to the next generation, with the following expression:

$$\vec{X}_{i,t+1} = \begin{cases} \vec{U}_{i,t}, if\ f(\vec{U}_{i,t}) \le f(\vec{X}_{i,t}) \\ \vec{X}_{i,t}, otherwise \end{cases} \quad (11)$$

The above is the basic steps of the differential evolutionary algorithm, run iteratively through the above steps, and stop when the optimal solution is reached to get the optimal solution

4 NUMERICAL CALCULATION EXAMPLE

Suppose there are 3 subsidiaries out of stock, namely E_1, E_2, E_3, and they are supplied by 3 external suppliers selected after evaluation, namely S_1, S_2, S_3, and the subsidiary with internal transfer capability is S_4, S_5, S_6, only one kind of material is purchased, the unit weight of the purchased material is G=1 ton, the vehicle load is g=100 tons, the transportation cost per unit distance of each transport vehicle is \$20, the ordering period is T=30 days, the demand for material 1 from E_1, E_2, E_3 is 135 pieces, 500 pieces and 280 pieces respectively. The unit inventory cost of E_1, E_2, E_3 for material 1 is \$1.5/per piece per day, \$1.8/per piece per day, and \$1.2/per piece per day, and the initial prices offered by the supplier S_1, S_2, S_3, S_4, S_5, S_6 are \$1600, \$1650, \$1750, \$1600, \$1700, and \$1500 per piece, respectively, and the fixed order costs are 1000, 1000, 1000, 300, 300 , 300 yuan/piece, the maximum order capacity is 950, 800, 1000, 300, 500, 550 pieces, and the comprehensive evaluation scores are 9.3, 9.0, 9.1, 10, 10, 10, 10, and the different price discount levels of suppliers and the transportation distance between supply and demand enterprises are shown in tables 4 and 5 below.

Table 4: Supplier discount levels for different prices.

Discount Level	(0,300)	(300,700)	(700,1000)	(1000,)
S_1	1	0.95	0.85	0.75
S_2	1	0.94	0.85	0.74
S_3	1	0.9	0.78	0.71
S_4	1	1	1	1
S_5	1	1	1	1
S_6	1	1	1	1

Table 5: Transportation distance between supply and demand enterprises.

Transportation distance (km)	E_1	E_2	E_3
S_1	48	35	18
S_2	25	15	40
S_3	20	40	45
S_4	30	25	18
S_5	20	28	30
S_6	20	35	21

The above examples were solved by using the differential evolutionary algorithm, setting the parameters as follows: variance proportionality factor F=0.9, crossover probability CR=0.8, 100 iterations, population size N=20, and using python software to perform the operation, and the results are shown in table 6.

Table 6: Optimal Purchase Volume.

Purchase volume (pieces)	E_1	E_2	E_3
S_1	0	118	132
S_2	4	0	44
S_3	72	181	0
S_4	54	7	120
S_5	6	56	5
S_6	0	140	82

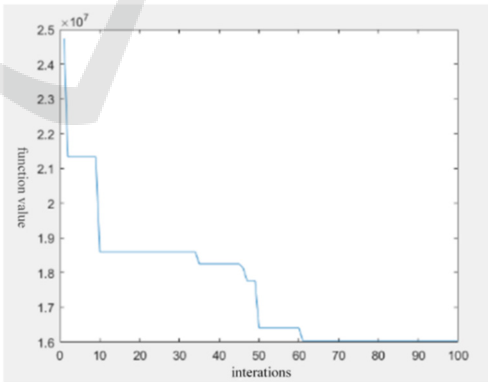

Figure 2: Convergence diagram of the algorithm.

The optimal procurement volume of the group enterprise is shown in table 6, and the total procurement cost is 16.128 million. After 100 iterations, the convergence curve of the differential evolutionary algorithm is shown in figure 2, which has good convergence and indicates the effectiveness and feasibility of this algorithm.

5 CONCLUSION

The allocation of order quantity is an important part of the enterprise in making purchasing decisions, and a scientific and reasonable allocation can effectively reduce the production cost of the enterprise. In this paper, combining the characteristics of group enterprises, the procurement considers two ways: direct ordering from suppliers and transferring among subsidiaries with excess inventory, and establishes a procurement optimization model based on internal transfer for group enterprises by considering factors such as price discount, comprehensive rating of suppliers, full truck transportation and inventory cost. Through the experiment of arithmetic cases, a differential evolutionary algorithm is designed for simulation solution with the help of python software, and the procurement volume of each subsidiary with procurement demand is calculated between suppliers and subsidiaries with transfer capability, which effectively reduces the procurement cost of the group enterprise and illustrates the effectiveness and feasibility of the model.

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