Optimization research of material inventory management based on genetic algorithm

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Abstract

Inventory management is an indispensable part in supply chain management. On the one hand the important position it has in the enterprise competitiveness. It has a direct impact on the cost of the products, respond speed to the market, delivery date and other indexes; On the other hand, the inventory system is a dynamic system, which involves huge inventory and wide area. The paper first under the influence of the uncertain factors does certain analysis to the raw material inventory issues, establishes minimum model of raw materials inventory cost in the iron and steel enterprises. Among them, the raw materials inventory cost includes fixed cost, procurement cost and storage cost. By making each purchase amount and raw materials inventory as the decision-making variables, it adopts the corrected genetic algorithm and uses MATLAB to get the optimal solution and get the most optimized raw materials procurement and inventory. The optimization model of raw materials inventory control which presents in this paper mainly applies to iron and steel enterprises of continuous production process, and can also be extended to other types of the enterprises in raw materials inventory control.

Keywords: material inventory, iron and steel industry, optimization, genetic algorithm, MATLAB

1 Introduction

For the characteristics of continuous production of iron and steel enterprises, the problem of material inventory is worthy of studying: on the one hand, raw material inventory takes up a lot of money, impacting on the speed of capital turnover; on the other hand, the uncertainty exists in the procurement, such as not timely supply, a shortage of raw materials, etc., and raw material purchasing cost accounts for 60% to 70% of the total cost of the iron and steel production enterprise, it is crucial to determine reasonable the material inventory and purchasing quantity in order to ensure the normal and continuous production of enterprise.

Iron and steel industry is the foundation of the industrial economy, undertaking the important task of providing raw materials to other industry sectors, which has made a significant contribution to promoting the development and progress of the industrial economy [1]. At present, the type of iron and steel enterprise is converting from the extensive type to technology-intensive type with the intense competition of global steel market and the influence of limited resources, in order to improve the competitiveness of products and grab a bigger share of the market, steel enterprises must constantly compress production costs, improve product quality, improve the level of customer service, speed up the turnover of funds and make the whole supply chain coordination. However, raw material inventory and purchasing problem of iron and steel enterprise has some characteristics, such as kinds of varieties, large purchase quantity and high cost, which increases the difficulty of the problem and make it more difficult to solve.

Raw material inventory control is one of the cores of production enterprises, especially one of the cores of enterprise logistics management for the continuous production [2-3]. Under the pressure of reducing the production cost continuously, the managers of iron and steel enterprise have to focus on inventory. Although inventory can make up for the damage caused by the uncertain factors and maintain the continuity of production, but also increase the inventory cost of the enterprise and lead to a large backlog of funds at the same time. Therefore, how to meet the iron and steel enterprise capacity constraints to optimize the balance between inventory and production requirements is a problem worthy to be discussed. Appropriate inventory is necessary to ensure the normal continuous production of enterprise, too little and too much can cause unnecessary economic losses. Inventory is too large, which will need extra storage places and increase the stock fee and transportation fee so as to slow capital turnover occupied. It may reduce the quality of raw materials or make the material deterioration because of the change of storage condition and the passage of time; If too little inventory, it may cause work being held up for lack of materials,

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and even force to stop production, thus losing customers and sales opportunities, reducing profit or losing their entitlement. The main purpose of material inventory control is that, under the condition of normal and continuous production, inventory takes up the least amount of money and less procurement costs in order to achieve the minimum total inventory cost. How to maintain in the best of our inventory and purchase quantity is the research questions this chapter [4-5].

2 Characteristics and consider factors of iron and steel enterprise raw material inventory

This chapter aims at raw material inventory problem in the process of the continuous production of iron and steel enterprise. For this type of enterprise, features are as follows:

a. Source of raw materials is extensive and raw material in inventory is multifarious so that the determination of safety inventory is difficult;

b. The demand of raw material is very big, and the order in advance is longer than the other;

c. There are a lot of subcontractors to provide the raw material for continuous production enterprise so that the number of received goods is uncertain. There are three forms of the contract signed with enterprises: their annual contract, quarterly contract and monthly contract. If the contract be enforced strictly, the arrival amount of goods each month is certain, but under the current situation in our country, due to transportation problems or imperfect delivery system, some subcontractors may provide the goods beyond the contract amount the goods and some others may only perform the part of contract, or even not. Hence it is brought certain problems to determine the arrival amount of goods;

d. The inventory cost is high; the raw material takes up more funds;

e. The shortage of the goods is not allowed, certain insurance reserve is stored;

f. Parts of the raw materials have a shelf life.

The inventory problem of raw material has features, such as many varieties, large quantity, high cost and long order time and so on, these features increase the difficulty of the problem to make it more difficult to solve. Considering the characteristics above, I put forward an inventory optimization model to determine the best inventory level and the best purchasing for all kinds of raw materials in a planning period in order to realize the minimization of inventory cost. What the inventory optimization should solve is: how to determine the single batch purchase quantity makes the total cost at least about the purchasing cost and storage cost [6].

The scale of the raw material inventory has a great influence on the production coordination and capital flow, therefore, the size of the raw material inventory should be generally considered from three aspects:

a. The production: from the perspective of production, enough inventory of raw material is in the hope. So, when some unplanned orders make the production increase temporarily or purchasing encounters the unexpected accident and long order time can't purchase raw materials in time, if there is enough raw material inventory, production can be continued so that the forced shutdown caused losses owning to the shortage of stock. So from taking the production into consideration, of course, the more reserve of raw material is better;

b. The capital flow: inventory of raw materials accounts for most of flow capital, the raw material is stored in the warehouse to produce collateral damage, namely the holding cost. The fee includes: interest, the storage of raw material loss, warehouse workers wages, warehouse handling fee, depreciation, repair, ventilation, lighting, rent and other fees of warehouse. These costs increase as the quantity and time increases. Therefore, in liquidity ways, the storage of raw materials is less as far as possible;

c. The procurement: considering from procurement, raw material need various fees from order into the library, such as communication fee of purchasing department, travel expenses for acceptance, handling fee, warehouse department acceptance fee. These costs are mostly related to the number of orders, which will increase with the increase of order number. So from the aspects of order, the less number of orders is better, it also requires more quantity each time.

From different point of view, therefore, the requirement of storage material is different. In these factors, there is a contradiction between the order and the storage. Less batches and large number of orders means low purchasing cost and the high cost of storage, while more batches and small number of orders will make the low storage cost and the high cost of purchase. Therefore, how to obtain the balance of contradictions through the reasonable optimization and achieve the lowest total inventory cost is the key to the inventory control.

3 The establishment of the optimize inventory model

3.1 THE ESTABLISHMENT OF THE MATERIAL INVENTORY MODEL

This chapter studies the raw material inventory problem of continuous production process of iron and steel enterprise. Inventory control problem is an optimization problem with multiple variables and complex constraints, which is difficult to solve through the traditional optimization method and is very suitable to solve by genetic algorithm. Genetic algorithm is a kind of adaptive random global search algorithm based on the biological evolution and natural genetic mechanism, which is suitable for solving complex problems such as global optimization, large-scale, multivariable, nonlinear. Inventory optimization unit is the core of the whole system; its main function obtains needed data from the database to optimize procurement and inventory with certain optimization algorithm. The optimization results are applied to guide the procurement and inventory of raw materials and store a variety of data related to the inventory. Some of these data come from the actual production process, and some come from other optimization of logistics management and the output of forecasting subsystem [7].

In practical production, the comprehensive decision-making of inventory management is affected by various dynamic factors, such as macroeconomic factors, raw material and product market and the condition of the supplier [8]. If all these factors are taken into consideration, it will make the problem complex, and some of the values cannot be obtained directly. In order to simplify the problem, when optimizing raw material purchasing and inventory, we should mainly consider the production planning of manufacturer according to the sales situation and the actual production situation, the forecast value of raw material purchase prices in the coming year and inventory parameters prediction [9-10].

Inventory optimization model for the considerable scale enterprise, the total quantity of raw material purchasing and the total quantity of consumption monthly roughly equal [11-13]. Inventory model is set up in a month for a period with the monthly purchase quantity and inventory as control variable. Inventory optimization saves money to maximize, at the same time meet the needs of continuous production for the purpose.

The description of raw material inventory problem is as follows.

The objective function:

$$C_{\min} = \sum_{i=1}^{N} \left\{ k_i + C_i X_i + \frac{1}{2}\left[Y_i(j) + Y_i(j+1)\right] \cdot h_i \right\}. \quad (1)$$

Constraints:

a. The balance constraints of raw material

Balance is as follows before and after the period of raw material inventory:

$$X_i + Y_i(j) - Y_i(j+1) - \sum_{i \in R}(1+\delta) q_i = 0, \quad (2)$$

b. The balance constraints of product sale

Before and after the period, on the basis of considering inventory change, the same material meet the following relation on the quantity from raw material to finished product:

$$Y_i(j+1) = Y_i(j) + X_i - U_i, \quad (3)$$

c. Procurement constraints

The total procurement budget:

$$\sum_{i-1}^{N} C_i X_i \le C, \quad (4)$$

(In the type C is the total procurement budget.)

d. The matching constraint of ability to inventory

In actual production, it's hard to maintain completely the material inventory within the scope of the safety stock level, and it is often more than safety stock, so the matching of inventory capacity meets the following constraints:

$$S_i \le Y_i \le X_i, \quad (5)$$

e. The constraint of total supply capacity

The amount of material purchase should not be larger than the biggest supply of material in the period of time:

$$X_i \le Z_i, \quad (6)$$

k_i is the fixed startup cost of raw material i purchasing;

C_i is the procurement price of raw material i in month j;

X_i is the purchasing quantity of raw material i in month j;

$Y_i(j)$ is the inventory quantity of raw material i at the beginning of month j;

$Y_i(j+1)$ is the inventory quantity of raw material i at the end of month j;

U_i is the consumption of raw material i in month j;

h_i is the storage cost of unit goods of raw material i;

N is the kinds of raw materials;

S_i is the safety inventory of raw material i;

δ is the average coefficient of waste;

q_i is the number of raw material for production products.

3.2 THE SIMPLIFICATION OF MATERIAL INVENTORY MODEL

TABLE 1 The relevant parameters and values of calculation model

Parameter	Material		
	Iron ore	*Llimestone*	*Coal*
The unit price (RMB/t)	730	60	541
Unit inventory cost (RMB /ton)	14.0	5.0	18
Safety inventory (t)	50000	50000	50000
Monthly consumption (t)	444882	102851	5554
The maximum annual material supply (t)		3000000	2200000

$$C_{\min} = 737X_1 + 62.5X_2 + 550X_3 + 14Y_1 + 5Y_2 + 18Y_3 - 34152875 \,. \tag{7}$$

Constraints:

$X_1 \geq 2Z = 340000$

$0 \leq X_2 \leq 250000$

$0 \leq X_3 \leq 183333$

$50000 \leq Y_2 \leq X_1$

$50000 \leq Y_2 \leq X_2$

$50000 \leq Y_3 \leq X_3$

$730X_1 + 60X_2 + 541X_3 \leq 100514224$

3.3 THE SOLUTION OF MATERIAL INVENTORY MODEL

Recently, Genetic Algorithm (GA) is widely applied to the optimization problems in different fields, which arouses more and more people's interest of study and application due to its good characteristics that the Genetic Algorithm is not dependent on the problem model, along with global optimality, implicit parallelism, high efficiency and solution of the nonlinear problem.

GA is applied to the problem of constrained optimization; the constraint processing has become a very important link [14]. There are two kinds of solutions: one adopts the changed operator in the operation, producing always the legitimate offspring from the legal parent satisfying the constraint conditions and making the search in the legal and valid space all the time; Another is to apply the corresponding punishment to the objective function in the adaptive function according to each individual to satisfy the different constraints so that the constrained problems are converted into unconstrained problems. The main steps of genetic algorithm are as follows [15]:

a. Establish the initial group composed of a string at random;

b. Calculate the fitness of each individual.

c. According to the genetic probability, the following operations is applied to generate new group:

Copy: The existing excellent individual copied is added to the new group, and the bad individual is removed;

Hybridization: Two individuals picked out are exchanged, and the new individual is added to new groups;

Variation: One particular character is changed randomly in an individual; the new individual is added into new groups;

d. The steps of (2), (3) are carried out repeatedly to reach the termination conditions, and the best individual is chosen as a result of the genetic algorithm. It is the key to practical application to choose the encoding strategy and convert the parameters into a string and the accurate fitness. The initial population $N = 200$, the crossover probability $P_c = 0.95$, the mutation probability $P_m = 0.01$, the function of minimum inventory cost is as the objective function, namely $F(X) = C_{\min}$, the objective function is as fitness function directly, namely. The optimal purchase quantity and inventory is obtained in the following table with iterations of 53 times.

TABLE 2 The results of optimization model

	X_1	X_2	X_3	Y_1	Y_2	Y_3
The optimal value (t)	339930	50340	50550	50260	50270	50250

$$C_{\min} = 2.7947e + 008, \text{ (RMB)}. \tag{8}$$

The inventory of raw material is one of the cores of logistics management, on the one hand, the raw material inventory takes up a lot of money; on the other hand, the reasonable inventory is essential. In the process of enterprise management, Inventory items take up a lot of money. Iron and steel enterprises cost 20% to 40% of the profits every year to maintain its all inventory, enterprises set out to the material inventory to reduce the production cost and improve enterprise's capital turnover and return for the survive and development in the fierce market competition. Inventory management has become the important link in the production and management of iron and steel enterprise, and raw materials inventory accounts for most of the iron and steel enterprise, so now it is the important content of the inventory management that many iron and steel enterprises have to reduce raw material inventory levels and benefit from it.

4 Conclusions

With analysing the characteristics of the raw materials inventory and other factors, the optimization model of raw material inventory of iron and steel enterprise is established. The optimal purchase quantity and inventory is obtained by optimization analysis for the main raw materials such as iron ore, limestone and coal, the result makes the raw material inventory take up the least amount of money. The optimization control model of raw material inventory, being put forward, is mainly for the iron and steel enterprises with continuous production process, can also be extended to other type control of raw material inventory of the enterprise.

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