Product inventory model of iron and steel enterprises

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Abstract

As a pillar industry, iron and steel industry has made a significant contribution to China's economic development. Steel and iron inventory is a hot research issue in the supply chain management. How to make use of advanced management methods and mathematical models to obtain reasonable inventory to meet customer service and reduce unnecessary inventory-related costs, and accelerate corporate capital turnover rate, is the goal that the enterprises should pursue in the future. According to the batch production of iron and steel enterprises, and in consideration of inventory-related costs, including fixed costs, storage costs, shortage costs (including deferred delivery costs and lost sales costs), establish the model of finished products inventory cost. When calculate model, we make c + + program and do accurate calculation to the model, optimize the production cycle, production time and production quantities, and define the deferred delivery coefficients. By changing the value of the deferred coefficient, analyse the influence to the production cycle, production time and production quantities and all kinds of costs.

Keywords: Steel and iron industry; supply chain; inventory; finished products inventory; optimization

1 Introduction

In traditional inventory management, inventory was divided into two modes: Independent Demand and Dependent Demand. The problem of inventory demand was always been deal with by using Material Requirement Planning (MRP) [1], while Order Point was always been used in dealing with the independent demand problem. In general, the management of finished goods inventory was regarded as dependent demand management.

For an enterprise, if the demand of product and raw materials could be supplied on time, and the production was able to meet this demand instantly, not keeping the inventory was the most economical state in theory. However, it was always hard to predict the demand accurately, or make sure the supply of raw materials could arrive on time, and there was no way to avoid the fault of machine. All above are the causes of inventory in iron and steel enterprise. Even if the supply and demand of product tends to be exactly equal, the production also need to response quickly, requiring the transport completely reliable and without delivery time. All these are completely impossible at any reasonable range of cost. Therefore, companies should use the inventory to better balance supply and demand and the uncertainty of corresponding demand; adjust the economical production quantities and time to reduce production costs. As for iron and steel enterprises, various processes in production should be continuous, especially in continuous casting production, once out of stock, which will result in broken pouring and severe losses ,so steel companies are not allowed out of stock, and they need stock for more effective buffer. Therefore, to establish the most reasonable production inventory management model become a pivotal issue [2].

Nowadays, the management of finished products inventory was completely artificial, managers need to deal with a lot of inventory business every day, and fill a number of records, make variety of forms. Those steps make a lot of errors in information transmission, and delay seriously. Therefore, they bring great inconvenience in inventory management. Sometimes when an error, which had been caused by a functional department might contribute to more mistakes in other department, and if the error was not checked in time, might lead to very serious consequences. Since the limitation of inventory capacity, a lot of work being cut down, and the inaccurate and delay of information, the complex task become more difficult. In order to meet customers' requirements and improve the service quality, so only the increase of inventory could cover all managers' mistakes.

As it is can be seen, the control strategy of finished products inventory was very simple, this strategy was obviously not suitable to the modernize of inventory management, and inventory management should keep the balance between improving the service quality to fulfil the customers' requirements and reducing the inventory costs, That is to say, the strategy should achieve low-cost operation on the basis of quickly and efficiently get customers' satisfaction. in order to achieve a reasonable storage purposes. Therefore, the stock of finished products should be made for the goal to improve the production supply, control the inventory reasonably, reduce costs, and improve the customer satisfaction, and

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to coordinate the healthy development of iron and steel enterprises. In order to meet customers' uncertain requirements, thinking about the mechanical failure, unreliability of transportation, the limitation of inventory capacity, and the delay of information transformation, it was necessary to determine a reasonable production volume and the production time to meet customer demands and ensure continuous production in a production cycle.

An enterprise system, which was composed of interrelated subsystems: supply system, production system, inventory system, sales system, consist the feature to convert the raw materials and semi-finished products to the finished goods. Finished goods inventory system between the production system and sales system plays an important role of regulatory. In turn, production system and marketing system also directly affects the inventory system of finished goods. Therefore, the study the inventory control of finished product should be started with the view of system, the following aspects should be considered.

(1) Inventory levels should be maintained in a stable quantity as far as possible. Unlike the seasonal products, the peaks and valleys in steel product sales were relatively not very obvious. Finished goods inventory control should be not only ensured the needs of sales, so that enterprises could rely on a reasonable opportunity to avoid the loss of chance caused by the shortage of products or delaying the delivery of some products, but also avoided the condition that finished goods inventory funding was so large and velocity of money was so slow caused by product unmarketable happens. Therefore, the number of stocks should be maintained at a reasonable level in the finished product inventory control in order to achieve the lowest total cost of inventory.

(2) Considering the raw materials procurement, some bulk material was expensive and had a long purchasing cycle. Under the premise of maintaining certain stability in the production, these raw materials should be ensured the smooth supply firstly in order to prevent raw material shortages affecting production. In addition, in order to make production plans and production scheduling facilitate, maintain certain stability and management easily for production line, productivity should also be as smooth as possible.

(3) Combined with the development trend of the industry, market's competitive requirements and the need of companies' own strength, cost management level had become the core competitiveness of future success for an enterprise. Therefore, finished goods inventory control must be considered the cost factors, not only reduce inventory storage costs, but also reduce the production cost of the product as far as possible to keep it at a relatively low level.

2 Finished goods inventory model

Inventory management was the core and soul of logistics management [3], because the management process of logistics planning, control, execution, assessment was based on the flow of content to meet the demand of market-oriented customers. The charm of the inventory lies in the future demand forecasts, and forecast uncertainty, it was always necessary to balance the relationship between the demand for services and the stock investments limited in the uncertainty.

Inventory management was an important part of enterprise production and management, which was also an effective way and methods to reduce the cost and improve the economic efficiency of enterprises. Too little inventor would affect the continuity of production, while excess inventory levels would cause the backlog of funds. Therefore, a reasonable inventory management was an important condition to achieve the best combination of both. It was assumed that all the demand was delayed delivery or lost during the empty of the warehouse in general storage model.

2.1 BUILD MODEL

(1) Model assumptions

In order to simplify the research model, making the following assumptions:

1) During the patience period [4], the enterprise had no cost loss; during impatient period, some customers were lost, others would delay delivery, in the meantime, the costs include the cost of lost customer losses and delayed costs of delayed delivery.

2) Demand rate was continuous and uniform, the demand rate was denoted as *R*, the product productivity was denoted as *P*, and $P > R$.

3) When you use your own warehouse storage products, storage costs of per unit of product and per unit of time was c_2. When using leased warehouse, storage costs of per unit of product and per unit of time was c_3, and $c_2 \le c_3$.

4) The maximum capacity of own warehouse was Q_0, $Q_{\max}$ was the maximum storage capacity of products, and $Q_0 \le Q_{\max}$.

5) When the product were stored, the product should be stored in own warehouses first, and then deposited the remaining into rented warehouse; when using the product, the product of leased warehouse should be used first, and then use own warehouse products after running out of rented warehouse product.

6) During impatient period, demand rate of backordered was equal to the original demand rate R multiplied by α, $R' = \alpha R$ (R' was demand rate of backordered, $\alpha > 0$, α was backordered coefficient), m was maximum time of patience period.

(2) Establishment of model

Figure 1 showed the variation of the system inventory level with time. In order to establish a more realistic inventory cost model [5], analysis as follows: the section of [0, m] in a period T, said the patient period, customers were willing to wait, all out of stock could delay delivery, there was no case of loss of sales; in the section of [m, t_1], said the impatience period, all out of stock was composed of two parts, namely the backlogging costs and lost sales opportunities lost, then the store capacity was zero, t_1 was the time to begin production; in the section of [t_1, t_2], the products not only met the requirements of use, also needed to fill the shortage which in the section of [0, t_1]; and in the section of [t_2, t_3],in addition to met the production demand, storage capacity was increased to P - R speed, until t_3 moment to fill their warehouse; in the section of [t_3, t], storage capacity was increased to the original growth rate, the increased product was deposited in the leased warehouse; in the section of [t, t_4], using the products which stored in the leased warehouse; in the section of [t_4, t], enterprises used the storage products of its own warehouse at the demand speed of R; at the moment T, the storage capacity was zero. However, due to the iron and steel enterprises patience period was short, and the problem was more complex, the first M segment would not be considered, resulting in the figure 2.

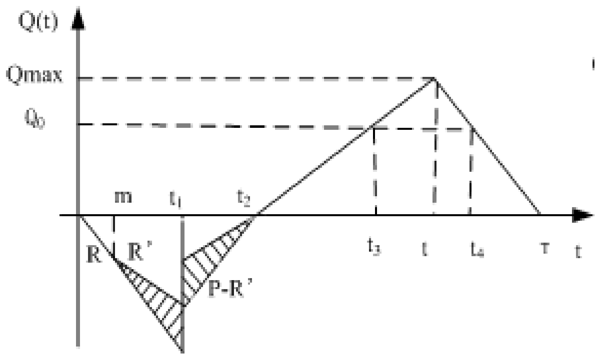

FIGURE 1 Storage capacity change chart

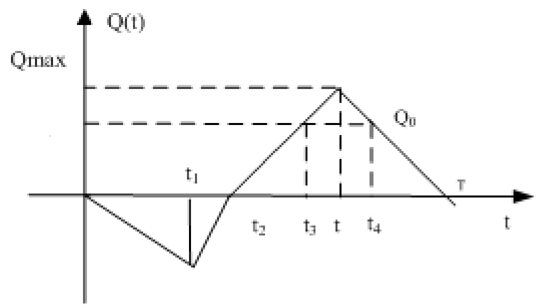

FIGURE 2 Storage capacity change chart

From the figure 1, it could be seen that: $R't_1 = (R-R')(t_2-t_1)$, then got:

$$t_1 = \frac{P-R'}{P}t_2, \tag{1}$$

$Q_0 = (t_3-t_2)(P-R) = (T-t_4)R$, then got:

$$t_3 = \frac{Q_0}{P-R} + t_2, \tag{2}$$

$$t_4 = T - \frac{Q_0}{R}, \tag{3}$$

$Q_{\max} = (t-t_2)(P-R) = (T-t)R$, then got:

$$t = \frac{t_2(P-R)+TR}{P}, \tag{4}$$

$$Q_{\max} = \frac{(P-R)R}{P}(T-t_2). \tag{5}$$

1) The shortage cost

When customers placed orders, and the goods could not be delivery by the usual designated warehouse, then it would generate the shortage cost [6]. Shortage cost had two kinds: the lost sales cost and keep the order cost. In each case, assumed that customers would make some response, however, because the customer response could not fathom, the cost was very difficult to accurately measure out.

When out of stock, if customers chose to withdraw his purchase request, it would generate lost sales cost. The cost was the sales profits, which this time should be obtained, and it might also include the negative effects on future sales caused by shortage. If the customer was willing to wait for order fulfilment, then it would not happen lose sales, there would only appear delayed order fulfilment, which produce the retention order cost.

In the section of [0, t_1], one part was tardy delivery quantity, the other part was lost sales for the customer did not want to wait, then backlogging cost was $\frac{1}{2}c_4R't_1^2$, as shown in Figure 3, the shaded area represented lost sales opportunities, therefore lost sales cost was $\frac{1}{2}c_5(R-R')t_1^2$.

In the section of [t_1, t_2], there were still some delay delivery and lost sales situations, then backlogging cost was $\frac{1}{2}c_4(P-R')(t_2-t_1)^2$, as shown in Figure 4, the shaded area represented lost sales opportunities, therefore lost sales cost was: $\frac{1}{2}c_5[(P-R')(t_2-t_1)^2-(P-R)(t_2-t_1)^2] = \frac{1}{2}c_5(P-R')(t_2-t_1)^2$

Put the formula (1) and $R'=\alpha R$ into the above equation, it could obtain backlogging cost in the section of [0, t_2] was:

$$\frac{1}{2}c_4[R't_1^2+(P-R')(t_2-t_1)^2] = \frac{1}{2}c_4\frac{(P-\alpha R)\alpha R}{P}t_2^2. \tag{6}$$

And lost sales cost was: $\frac{1}{2}c_5[(R-R')t_1^2+(P-R')(t_2-t_1)^2] = \frac{1}{2}c_5\frac{(1-\alpha)R}{P^2}[(P-\alpha R)^2+(\alpha R)]\cdot t_2^2$.

(In the formula, C_4 was the shortage backlogging cost of unit goods and unit time, C_5 was the loss caused by lost sales opportunity of unit goods.)

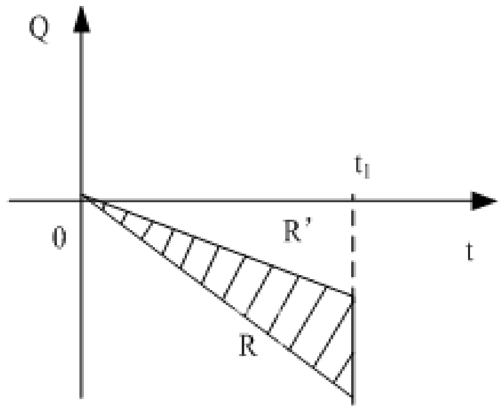

FIGURE 3 The lost sales quantity in the section of $[0, t_1]$

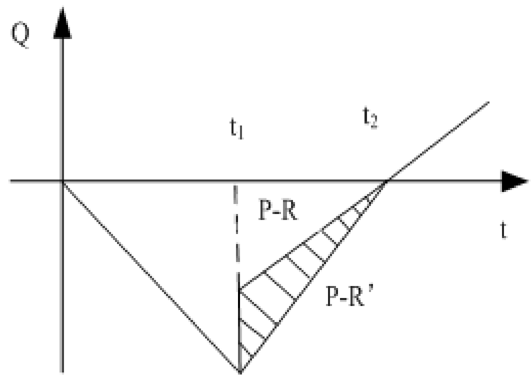

FIGURE 4 The lost sales quantity in the section of $[t_1, t_2]$

2) The storage cost

Total storage cost was composed of two parts, one part was the cost of using their own storage warehouse to store product, the other part was the cost of renting warehouse storing the product. Therefore, the total storage cost was: $\frac{1}{2}c_2Q_0(t_3-t_2)+c_2(t_4-t_3)Q_0+\frac{1}{2}c_2Q_0(T-t_4)+\frac{1}{2}(Q_{max}-Q_0)c_3(t_4-t_3)$.

Put the formula (2), (3) and (5) into the above equation, then got:

$$c_2[Q_0(T-t_2)-\frac{Q_0^2}{2A}]+c_3[\frac{1}{2}A(T-t_2)^2-Q_0(T-t_2)+\frac{Q_0^2}{2A}]. \quad (8)$$

3) The fixed cost

The fixed cost of a cycle of T was C_1 (including warehouse depreciation and workers wages etc.). Therefore, in order to simplify the model, assuming $A=\frac{(P-R)R}{P}$, the average inventory cost of a cycle of T was:

$$C(T,t_2)=\frac{1}{T}[c_1+c_2[Q_0(T-t_2)-\frac{Q_0^2}{2A}]+c_3[\frac{1}{2}A(T-t_2)^2-Q_0(T-t_2)+\frac{Q_0^2}{2A}]+ \frac{1}{2}c_4\frac{(P-\alpha R)\alpha R}{P}t_2^2+\frac{1}{2}c_5\frac{(1-\alpha)R}{P^2}[P-\alpha R^2+(\alpha R)^2]t_2^2]. \quad (9)$$

2.2 THE SOLUTION OF THE MODEL

Making that $\frac{\partial C}{\partial T}=0, \frac{\partial C}{\partial t}=0$, $B=c_4\alpha R(P-\alpha R)P+c_5(1-\alpha)R[(P-\alpha R)^2+(\alpha R)^2]$.

Solved the equations which consist of the above equation, got the optimal production cycle and the beginning of production time were:

$$T^*=\sqrt{\frac{Q_0^2}{A}(1-\frac{c_2}{c_3})(\frac{1}{A}+\frac{c_2P^2}{B})+2\frac{c_1}{c_3}(\frac{1}{A}+\frac{c_3P^2}{B})}, \quad (10)$$

$$t_2=\frac{c_3AT^*-(c_3-c_2)Q_0}{c_3A+\frac{1}{P^2}\cdot B}. \quad (11)$$

The optimal production lot size was:

$$Q^*=R'\times t_2+R(T-t_2)=R[T-(1-\alpha)t_2]$$
$$=\frac{R(\alpha c_3AP^2+B)}{c_3AP^2+B}\cdot\sqrt{\frac{Q_0^2}{A}(1-\frac{c_2}{c_3})(\frac{1}{A}+\frac{c_2p^2}{B})+2\frac{c_1}{c_3}(\frac{1}{A}+\frac{c_3P^2}{B})}+\frac{R(1-\alpha)(c_3-c_2)Q_0P^2}{c_3AP^2+B}. \quad (12)$$

The optimal production time was:

$$t^*=t-t_1=\frac{R}{P}[T-(1-\alpha)t_2]$$
$$=\frac{R(\alpha c_3AP^2+B)}{P(c_3AP^2+B)}\cdot\sqrt{\frac{Q_0^2}{A}(1-\frac{c_2}{c_3})(\frac{1}{A}+\frac{c_2P^2}{B})+2\frac{c_1}{c_3}(\frac{1}{A}+\frac{c_3P^2}{B})}+\frac{R(1-\alpha)(c_3-c_2)Q_0P}{c_3AP^2+B}. \quad (13)$$

3 Cases

3.1 THE ANALYSIS OF THE MODEL SOLUTION

(1) Model solution of different situations

1) When α＝1

$$T=\sqrt{\frac{Q_0^2}{A^2}(1-\frac{c_2}{c_3})(1+\frac{c_2}{c_4})+\frac{2c_1}{Ac_3}(1+\frac{c_3}{c_4})};$$

$$Q=\sqrt{\frac{P^2Q_0^2}{(P-R)^2}(1-\frac{c_2}{c_3})(1+\frac{c_3}{c_4})+\frac{2c_2}{c_3}\cdot\frac{PR}{P-R}(1+\frac{c_3}{c_4})},$$

$$t=\sqrt{\frac{Q_0^2}{(P-R)^2}(1-\frac{c_2}{c_3})(1+\frac{c_2}{c_4})+\frac{2c_1}{c_3}(1+\frac{c_3}{c_4})\frac{R}{(P-R)P}}.$$

Here T, Q, t were the model of the optimal production cycles, the optimal production batch and the optimal production time for the shortage of warehouse capacity was limited to allow delay.

2) When α ＝ 0

$$T\to T^*=\sqrt{\frac{PQ_0^2}{(P-R)R^2}(1-\frac{c_2}{c_3})(\frac{P}{P-R}+\frac{c_2}{c_5})+\frac{2c_1}{c_3R}[\frac{P}{(P-R)}+\frac{c_3}{c_5}]},$$

$$Q\to Q^*$$
$$=\frac{c_5P}{c_3(P-R)+c_5P}\cdot\sqrt{\frac{PQ_0^2}{(P-R)R^2}(1-\frac{c_2}{c_3})(\frac{P}{P-R}+\frac{c_2}{c_5})+\frac{2c_1}{c_3R}[\frac{P}{(P-R)}+\frac{c_3}{c_5}]}$$
$$+\frac{(c_3-c_2)Q_0P}{c_3(P-R)+c_5P}$$

$$t \to t^* = \frac{c_5 P}{c_3(P-R)+c_5 P} \cdot \sqrt{\frac{PQ_0^2}{(P-R)R^2}(1-\frac{c_2}{c_3})(\frac{P}{P-R}+\frac{c_2}{c_5})+\frac{2c_1}{c_3 R}[\frac{P}{(P-R)}+\frac{c_3}{c_5}]} + \frac{(c_3-c_2)Q_0 P}{c_3(P-R)+c_5 P}$$

Here T^*, Q^*, t were the model of the optimal production cycle; production batch and production time for out of stock all lost sales.

3) When $\alpha = 1$, $c_4 \to \infty, P \to \infty, c_2 = c_3$,

$$T \to T^* = \sqrt{\frac{2c_1}{c_2}\frac{1}{(P-R)}}; Q \to Q^* = \sqrt{\frac{2c_1}{c_2}\frac{R}{(P-R)}}.$$

T^*, Q^* were classic model of the optimal production cycle and the optimal production batch, which were not allowed out of stock storage.

(2) Stability analysis of the model solution

It was necessary to make the stability analysis for model which was not allowed out of stock storage [7], and its application was very wide .It was the foundation of other model when they were deduced.

3.2 THE MODEL OF EXAMPLE VERIFICATION

Through research, data related to inventory system was as follows: P=2000000 tons per year，R=1000000 piece per year, c_1=6000 RMB, c_2= 8.1RMB per ton•year, c_3=13.27 RMB per ton•year,c_4=20 RMB per ton•year,c_5=35 RMB per ton•year, Q_0 =78500 tons. Applying the model to calculate the optimal production cycles, the optimal inventory and a variety of cost under different the coefficient [8] of delaying pay, it was shown in Table 1.

TABLE 1 The influence of the coefficient of delaying pay to the optimal production cycles, the optimal inventory and a variety of cost

α	production cycles (year)	production lot size (ton)	Production time (year)	carrying cost (RMB)	Shortage cost (RMB)	Lost sales cost (RMB)	maximum inventory (ton)
0	0.1134	105010	0.05255	25850	0	1214	52550
0.2	0.1154	106768	0.05338	25704	212	1351	52299
0.4	0.1178	109532	0.05477	25542	605	1350	52015
0.6	0.1204	113598	0.05680	25368	1209	1169	51708
0.8	0.1235	119351	0.05968	25169	2079	788	51350
1	0.1285	128457	0.06423	24875	3602	0	50809

Table 1 showed that, as the delay coefficient alpha, shortage cost increases gradually, the storage cost and the maximum inventory had shrunk, lost sales cost was increased first and then decreases, while increasing production cycle caused by the holding cost, shortage of years lost sales cost increase was greater than the storage cost reduction, the enterprise couldn't extend the production cycle.

4 Conclusions

To summarize finished-parts storage inventory problems, and to describe the factors should be taken into consideration when the finished goods inventory was controlled, the key was to establish model ,in which iron and steel enterprise was considered allowing delayed delivery and lost sales inventory, and it obtained the most optimal production time, the production batch and production cycle within a production cycle, to achieve the minimum total inventory related products, finally, through a set of experimental data and the delay submitted the coefficient alpha effects on various fees.

This paper established model, which allowed the delayed delivery and considered the costs of inventory, and its solution and sensitivity was analysed, the analysis showed as follow:

(1) With the gradual increasing of delay delivery coefficient alpha and shortage cost, the storage cost and the maximum inventory had shrunk, lost sales cost was increased first and then decreased, while increasing production cycle in shortage caused by the holding cost, lost sales cost increase was greater than the storage cost reduction, the enterprise couldn't extend the production cycle.

(2) When the demand rate was less than 1/2 productivity, classic inventory model had good stability, and closer to the actual inventory management problem.

In a word, using a large number of advanced management was an innovative management to research inventory management in supply chain management thought [9]. Especially, to the state-owned enterprises, they had to admit that a lot of advanced management ideas and management methods, with very low success rate, being carried out in China, one of the important factors was the basic problems of enterprise management. It would be a losing battle to implement a advanced management, in enterprises with weak basic management. As strip factory finished goods inventory management [10] application of supply chain management thinking, at the same time, it should adhere to the principle of grasping both the advanced management and basic management, held "standardization construction" as the breach of the basic management, business process institutionalization, standardization of basic data .Only in this way, management strategies proposed in this paper some could play a role and had practical significance.

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