A Study of Green Smart Inventory and Dynamic Programming Algorithm of SBS Modified Asphalt Based on Industrial Internet of Thing

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Abstract. Start Based on the Industrial Internet of Things, this paper discusses the smart inventory management mode under the thermal storage of SBS modified asphalt, and preliminarily explores the smart inventory mode under the trend of smart logistics through the dynamic programming method, which provides a reference for the development direction of smart inventory of unconventional storage materials such as chemical and energy. At the same time, with the promotion and application of the Industrial Internet of Things, the dynamic, visual and intelligent development of each link in the logistics process brings a new round of intelligent reform to the logistics industry. As a kind of inventory management concept, smart inventory has gradually become one of the important links of smart logistics through measures such as Internet of Things technology, intelligent information management technology and visual management technology. The study proves that the dynamic programming method is suitable for the inventory cost optimization problem of SBS modified asphalt thermal storage. Finally, this paper uses the dynamic programming method to calculate the monthly data of a chemical raw material manufacturing enterprise in Liaoning province, and formulates the inventory management plan to optimize inventory costs.

1. Introduction

From the first formal proposal of Germany at the Hannover Messe in 2013 to the official publication of the "Made in China 2025" by the State Council of China in 2015, which deployed the comprehensive implementation of the strategy of manufacturing power, to the rapid development of artificial intelligence, 5G and blockchain technology in 2021, Industry 4.0 has enabled people to step into the era of the Industrial Internet of Things. At the same time, in the context of the upsurge of environmental protection policies in China's "13th Five-Year Plan" and the development of ICT technology, "smart + environmental protection" has become a new direction for the development of the industrial production industry. Based on the development of the Industrial Internet of Things, green production and smart inventory of chemical materials, energy materials and fuels in the industrial production industry can avoid resource waste and energy consumption, and greatly reduce industrial carbon emissions.

As a newly developed asphalt mixture, SBS modified asphalt has been popularized and applied in China's highway transportation construction. However, due to its stability in thermal storage, there are also stricter requirements in the process of mixing, transportation and storage. With the promotion and application of the Industrial Internet of Things, the dynamic, visual and intelligent development of each link in the logistics process brings a new round of intelligent reform to the logistics industry[2]. Therefore, it is of great significance to break the intelligent barriers and implement intelligent
measures in the inventory scene of the industrial production process to meet the needs of industrial Internet of Things for thermal storage of SBS modified asphalt.

2. Related Work
Smart inventory is an inventory management concept, which is one of the smart logistics links based on IoT, intelligent information management, visual management and other measures[3]. It can effectively improve the inventory turnover rate and reduce inventory cost. In the context of the rapid development of the Industrial Internet of Things, intelligent devices such as RFID tags, actuators, sensors, and GPS have been widely used in the management of smart inventory. The essence of smart inventory is to realize the JIT model through integrated intelligent technology, that is, to produce suitable products at a suitable time, neither in advance nor postponement, in order to achieve a balanced inventory level to reduce inventory costs. The goal of zero inventory is to eliminate any inventory in the production process [6], and aims to achieve the ideal minimization of inventory by implementing accurate production strategies and inventory control strategies.

Green inventory is derived from the concept of green logistics. Compared with the traditional inventory model, green inventory pays more attention to sustainable development [7] and integrates the concept of environmental protection into the whole supply chain [8]. Therefore, the development and implementation of green logistics technology can be promoted to ensure the green and environmental protection of the supply chain from the source [9]. However, "emphasis on production, light on logistics" is an inherent ideology of many chemical manufacturing companies. Therefore, with the application of industrial Internet of Things technology, a sustainable development of green logistics system should be established.

3. The Problems
Based on the above social background and analysis, the intelligent development model of the inventory of unconventional storage of chemical or energy materials such as asphalt and petroleum is rarely mentioned, and its storage standards and storage equipment have certain particularities, which are not easy to compare with conventional inventory. Commodity inventory development model for joint discussion. Based on the intelligent level of SBS modified asphalt thermal storage, this article is still in the initial stage of the industrial Internet of Things, and uses dynamic programming to initially explore its smart inventory mode under the trend of smart logistics, which is for unconventional storage of materials such as chemical or energy Provide reference for the development direction of smart inventory.

4. Model Presentation And Analysis Of SBS Modified Asphalt

4.1. Dynamic Programming
Dynamic programming can be regarded as a dynamic multi-stage decision-making process that is interconnected and interdependent, and the division of each stage is generally expressed by time. The change of state for a period of time will immediately cause the transition of another state, so it can reflect the dynamic change process of this series of problems. Proposing the optimal strategy not only establishes scientific and advanced management concepts for business managers, but more importantly, it has strong application operability and can efficiently guide production practice.

4.2. Model Description Of SBS Modified Asphalt
Let H denote the storage capacity limit of SBS modified asphalt. Assuming that the construction period is divided into stages, k is the stage number, which means the ordinal number of the week; xk is the decision variable, which represents the amount of asphalt raw material purchased in each stage; sk is the state variable, representing the inventory of asphalt raw materials (before the asphalt raw materials are released from the warehouse at this stage, and after the asphalt raw materials are stored in the previous stage); dk indicates the demand for asphalt raw material production at each stage; αk
indicates the consumption of each ton of asphalt raw materials stored in each stage. Unit heat storage cost.

Suppose the state variable \( s_k \) represents the beginning of the stage \( k \), which is the asphalt raw material at this stage is not out of the warehouse and is before production; the previous stage asphalt raw material has been purchased and put into the warehouse.

The decision variable \( x_k \) represents the amount of asphalt raw materials purchased in the stage \( k \).

State transition equation:

\[
\begin{align*}
    s_{k+1} &= s_k + x_k - d_k, \quad (k = 0, 1 \ldots n) \\
    d_k &\leq s_k \leq H \\
    D_k(s_k) &= \{s_k; s_k \geq 0, d_{k+1} \leq s_k + x_k - d_k \leq H\}
\end{align*}
\]

Let the optimal value function \( f_k(s_k) \) denote the minimum inventory cost from the stage \( k \) to the last stage when the stock quantity from the stage \( k \) is \( s_k \). Therefore, under the above constraints, the recurrence relation of dynamic programming can be listed as:

\[
\begin{align*}
    f_k(s_k) &= \min_{x_k \in D_k(s_k)} \{a_k x_k + f_{k+1}(s_k + x_k - d_k)\}, \quad k = 0, 1, \ldots, n \\
    f_n(s_{n+1}) &= 0
\end{align*}
\]

4.3. Model Solving

In the reverse equation of the dynamic programming equation established above, the stage \( k \) (\( k=0, 1, \ldots, n \)) is expressed as stage \( n \), and the inverse method is used to reverse inversely from the last stage \( k=n \). The recurrence process is as follows:

When stage \( k=n \), due to the condition of the target problem, it is assumed that the ending inventory is 0, which is 0. As of the last stage, raw materials no longer need to be purchased and put into storage.

\[
\begin{align*}
    x_n &= 0 \\
    f_n(s_n) &= 0 \\
    s_n &= d_n
\end{align*}
\]

When stage \( k=n-1 \), find the optimal solution \( x_{n-1}^* \)

\[
\begin{align*}
    s_n &= s_{n-1} + x_{n-1} - d_{n-1} \\
    f_{n-1}(s_{n-1}) &= \min_{x_{n-1} \in D_n(s_{n-1})} \{a_{n-1} x_{n-1}\}
\end{align*}
\]

\( x_n^* \) is the value of the optimal solution at the initial stage of the goal problem at stage 0. Reverse substituting the relational expression to derive the corresponding optimal decision value of each stage, and the objective function value of is the optimal solution of the target problem.

5. Example Solution

A chemical material manufacturer in Liaoning needs to formulate an inventory plan for SBS modified asphalt in a certain month, and supply a certain amount of asphalt raw materials for production at the end of the month. Table 1 shows the actual production demand and unit inventory cost data at each stage.

| Production Stage | Production Demand (ton) | Unit Inventory Cost (yuan/ton) |
|------------------|-------------------------|------------------------------|
| 0                | 0                       | 1.26                         |
| 1                | 312                     | 0.67                         |
| 2                | 330                     | 0.63                         |
| 3                | 390                     | 0.54                         |
| 4                | 297                     | —                            |
Using 500 tons of asphalt tanks for thermal storage, the proposed inventory capacity is \( H = 500 \), the initial inventory is 78, and the ending inventory is 0. It is now required to formulate an inventory plan that not only meets the production needs of this month’s asphalt mixture and inventory capacity restrictions, but also minimizes the total inventory cost.

Suppose the decision variable \( x_k \) represents the quantity of asphalt raw materials stored in stage \( k \).

\[
s_{k+1} = s_k + x_k - d_k, \quad (k = 0, 1, 2, 3, 4) \quad (11)
\]

\[
D_k(s_k) = \{ s_k; s_k \geq 0, d_{k+1} \leq s_k + x_k - d_k \leq H \} \quad (12)
\]

\[
f_k(s_k) = \min_{x_k \in D_k(s_k)} \{ \alpha_k x_k + f_{k+1}(s_k + x_k - d_k) \}, \quad k = 0, 1, 2, 3, 4 \quad (13)
\]

Given that the ending inventory is 0, when \( k = 4 \), 0. The inventory of each stage meets the production demand of the next stage, \( x_4 = 0 \).

\[
f_4(s_4) = 0 \quad (14)
\]

\[
s_4 = d_4 = 297 \quad (15)
\]

when stage \( k = 4, 3, 2, 1, 0 \). Reverse substituting the relational expression to derive the corresponding optimal decision value of each stage, and the objective function value of \( f \) is the optimal solution of the target problem.

\[
f_0(s_0) = \min_{x_0 \in D_0(s_0)} \{ d_0 x_0 + f_1(s_0 + x_0 - d_0) \}
\]

\[
= \min_{x_0} \{ 1.26 x_0 + 836.22 - 0.67 (s_0 + x_0) \}
\]

\[
= \min_{x_0} \{ 0.59 x_0 - 0.67 s_0 + 836.22 \} \quad (16)
\]

\[
312 - s_0 \leq x_0 \leq 500 - s_0 \quad (17)
\]

According to the above recursive calculation sequence, the optimal decision value of each stage is obtained as follows: \( x_0^* = 234, x_1^* = 312, x_2^* = 330, x_3^* = 390 \).

6. Conclusion
Based on the Industrial Internet of Things, this paper discusses the smart inventory management mode of SBS modified asphalt thermal storage, and uses the dynamic programming method to initially explore the smart inventory mode under the trend of smart logistics. At the same time, some monthly data from a chemical raw material manufacturer in Liaoning were used to conduct calculation examples to formulate inventory plans and optimize inventory costs.

Research shows that the dynamic programming method is suitable for the inventory cost optimization problem of SBS modified asphalt thermal storage. It can calculate the optimal inventory demand of asphalt raw materials according to the actual demand for production in different periods. Through continuous inventory demand decision-making, the basic equation of dynamic programming under the problem of minimizing inventory cost can be constructed, and then a suitable SBS modified asphalt thermal storage mode can be selected, and the cost verification after inventory can be carried out.

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