Design and Application of Flavors Composite Scheduling System Based On Dynamic Safety Stock

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Abstract. At present, the scheduling of flavors and fragrances based on artificial experience and using EXCEL tools for measurement and manual scheduling. During the process, it is not possible to consider the relevant factors, so that the results of scheduling cannot optimized. In view of this, this paper has constructed a composite scheduling system based on dynamic safety inventory. Based on the dynamic management of safety stocks for raw materials and semi-finished products of flavors and fragrances, multi-objective planning and modeling of production constraints and business objectives of the company carried out to realize the planning and design of plans for the production, procurement and shipping of flavors and fragrances. Through the practical application of the system, the dynamic control level of safety stocks has been improved, scientific production, procurement and dispatch plans carried out, and the overall supply chain management has been optimized.

1. Introduction
Flavors and fragrances are indispensable materials in the production of cigarettes, and its formula is one of the core technologies of cigarette companies. It plays an important role in improving the taste of cigarettes and highlighting the style of tobacco. Flavors and spices play an important role in solving the problem that the aroma components of cigarettes reduced due to the reduction of tar [1-2].

Flavors and fragrances generally not stocked on a large scale due to changes in formulations, shelf life, and storage capacity. As one of the core raw materials, flavor and fragrance are irreplaceable. Once lacking the material, it will directly lead to a complete shutdown of the entire production process, so the safety of stocks of spices and spices on production security requirements are extremely high. Cigarette companies are typical representatives of the mixed-process industry (discrete packaging workshops and process workshops). Its production characteristics determine that its production process has many characteristics such as non-linearity, randomness, and uncertainty [3], so the complexity of its scheduling and safety inventory management is getting higher and higher. At present, the flavors production and safety inventory management all performed by the business people using EXCEL tools. There are three main problems in the way of scheduling and dispatching the cigarette production plan and the flavor and fragrance material BOM based on experience:

1.1. It is difficult to predict the uncertainty of demand
Mainly reflected in the rolling forecast and package production plans, silk production schedules between the data is not high degree of coordination, reflected in the planning of the preparation time, planning
cycle, plan changes, etc., affecting the forecast of future production demand for flavors and fragrances. The order of shipments of shreds of tobacco is of great uncertainty, the delivery schedule is tight, it is difficult to predict and the delivery pressure is high.

1.2. Lack of rationality proof for safety stock level
Mainly reflected in the absence of a clear quantifiable safety inventory, there is no reasonable data support and scientific argumentation for the current maintained inventory levels. There is no effective way to optimize future inventory levels on the premise of guaranteeing supply.

1.3. High complexity of production rely on the experience of personnel
To this end, established a flavors composite scheduling system covering the entire supply chain business, managed the procurement, scheduling, and distribution, integrating the company’s overall resources. The system realized the scientific management of flavors and fragrances’ demand calculations. This system could control the dynamic safety stocks, production plans, and balance of production capacity, to solve the problems of the lag caused by manual scheduling and the unresponsiveness to changes in demand and increase the accuracy of the production plan of the flavor and fragrance and the plan of the transfer.

2. System Design

2.1. Logic business model in system
The core business of the compound dispatch system lies in the close integration of the core functions of the company’s sales management, inventory management, production management, procurement management, and dispatch management, to make the information scattered in each “island” of the company into a structured and systematic data mart, and collaboratively to integrate plans across factories and across business chains. The main links in the entire business chain include demand calculation, dynamic stock control of fragrant raw materials, semi-finished product dynamic inventory control, procurement plan, outbound plan, semi-finished product inventory monitoring, and fragrant raw material inventory monitoring. Each link involves the corresponding constraints as input and output, and the logic business model as shown in Figure 1:

![Fig.1 Logic business model for composition system](image-url)
2.2. Dynamic safety stock coverage days design

According to the company's past production and sales, to find that the establishment of the company's safety stock is affected by the level of demand, the concentration of demand, the degree of change in demand, and the frequency of changes in demand. Therefore to build a dynamic calculation model for days of security inventory, including the following steps:

2.2.1. Step 1: Calculate the days for safety stock guarantee D. The setting of the benchmark days based on the company’s constraints on multiple factors such as the order guarantee rate (timely delivery rate), storage capacity limit, inventory turnover rate, and shelf life. There are also many evaluation indicators for the number days for safety stock guarantee.

Constraint 1: The maximum stock out probability allowed by the target safety stock guaranteeing days guaranteeing safety stock:

\[ D \geq \frac{Z_{min} \cdot \sqrt{\frac{\partial d^2}{\partial L^2} + \frac{\partial d^2}{\partial d^2} \cdot \bar{d}^2}}{d} \]  

(1)

\( Z_{min} \) is the minimum value of the safety factor and it can be and calculated based on the required minimum order guarantee rate by referring to the following safety factor table.

| Safety Factor Z | Probability Shortage (%) | Guarantee Rate (%) |
|-----------------|---------------------------|--------------------|
| 1.29            | 10                        | 90                 |
| 1.34            | 9                         | 91                 |
| 1.41            | 8                         | 92                 |
| 1.48            | 7                         | 93                 |
| 1.56            | 6                         | 94                 |
| 1.65            | 5                         | 95                 |
| 1.75            | 4                         | 96                 |
| 1.88            | 3                         | 97                 |
| 2.05            | 2                         | 98                 |
| 2.33            | 1                         | 99                 |

\( \partial d \) is the standard deviation of demand during the average lead time, \( \partial L \) is the standard deviation of the lead time, \( \bar{L} \) is the average lead time, and \( \bar{d} \) is the average daily demand.

Constraint 2: The current security inventory days guarantees the security inventory is lower than the storage capacity limited alert value:

\[ D < \frac{SC}{d} \]

SC is the storage capacity of the guard stock limited by the storage capacity; \( d \) is the average daily demand.

Constraint 3: The limit of the maximum number of inventory turnover days DS<sub>max</sub>:

The difference (= DS – DC) is calculated by the number of inventory turnover days and the current number of safety stock days.

\[ D < DS_{max} - (DS - DC) \]

2.2.2. Step 2: Calculate demand level O Demand level is the use of quantitative indicators to measure the market share of a particular product in the total market demand for that category. This calculation method is applicable to the short product production line, the shorter lead-time for the production cycle relative to the market, and the delivery time for the delivery of a single product not to become the main constraint of the production plan. The demand level and safety stock coverage days positively correlated.
\[
Q_i = \frac{DM_i}{\sum_{i=1}^{m} \frac{DM_i}{m}}
\]  

Among it, \(i\) is the serial number of the product and the maximum value of the product is \(m\).

By collecting and collating historical sales data for a certain period, to obtain the demand \((DM_j)\) for each unit of the product during the period.

### 2.2.3 Step 3: Calculate demand concentration (volatility) \(C\).

Demand concentration is an indicator used to measure the volatility of market demand. It reflected in specific data calculations. Use the index of the relationship between the month average daily demands, the dynamic proportion of the annual average monthly demands, based on the annual average daily demand. The month-to-month dimension used to measure the volatility of the monthly average daily demand at the benchmark, taking one year as a statistical period, the average volatility within one year calculated as the calculation result of the demand concentration index. The specific formula is as follows:

Volatility calculations for individual products: Average daily demand for month \(j\) = demand quantity for month \(j\) divided by number of natural days per month.

Daily demand average

\[
u = \sum_{j=1}^{n} \frac{A_j}{n}
\]

Standard deviation

\[
\delta = \sqrt{\frac{1}{n} \sum_{j=1}^{n} (A_j - \mu)^2}
\]

Volatility

\[
V = \frac{\delta}{\sqrt{n}}
\]

Demand concentration

\[
C_i = \frac{V_j}{\sum_{j, i} \frac{V_j}{n}}
\]

### 2.2.4 Step 4: Calculate the degree of change in demand (change in customer orders) \(VO\).

The index of change in demand is a statistic of the number of customer orders and the adjustment of delivery dates. For example, from 100 boxes to 200 boxes, the degree of change is 100%. In the degree of change, we only consider the data of the first official order and the final shipment quantity. Changes in the process not considered in the degree of change indicator. For a period time, the rate of change of each order for a product averaged and the ROC of the individual product is calculated:

\[
ROC = AVG \frac{[\text{Final shipping order quantity} - \text{First order quantity}]}{\text{First order quantity}}
\]

Demand change indicator:
2.2.5. Step 5: Calculate frequency of changes in demand (customer order change frequency) \( R \). The index of frequency change statistic for demand is an evaluation index of the frequency of changes to the order of the customer, and the order change includes various changes, such as the quantity, delivery period, shipping conditions, and the place of receipt, which are different from the previous order requirement. For example, in the case of 10 orders, the customer changes two orders, one of which is changed three times, and the frequency of change is \( \frac{4}{10} = 40\% \).

The rate of change of a single product over a period of time \( F \) equals to the total number of order changes divided by the total number of orders.

Frequency of demand changes:

\[
R_i = \frac{F_i}{\sum_{j=1}^{n} F_j}
\]

(7)

2.2.6. Step 6: Calculate safety stock coverage days \( D \)

\[
D_i = D \times (O_i \times W_1 + C_i \times W_2 + VO_i \times W_3 + R_i \times W_4)
\]

(8)

Where \( W_i \) is the weight of each influencing factor, it is necessary to set the optimal influencing factors of each weight according to the historical demand data of each product, and the weights of the influencing factors can also be given by default, that is \( W_1 = W_2 = W_3 = W_4 = 1 \).

According to the needs of the company, to avoid changes in the dynamic security inventory too frequently, it can automatically recalculate the number of days covered by the security stock \( D_i \) according to a certain period.

2.3. System architecture design

The system is based on the ABAP (Advanced Business Application Programming) workbench as a development tool, based on SAP NetWeaver as a system support platform, using DB2 database to build. The system is integrated with the enterprise bus (ESB) [4], enterprise resource planning (ERP) system, PDM system[5], material management system, MES system [6], flavor and fragrance centering centralized control system, etc. The overall architecture design of the system as shown in Figure 2.
3. System implementation and application

3.1. The system functions’ implementation

In the first step of system implementation, basic data standardization work is required. Firstly, to classify the data related to complex scheduling into six categories of materials, customers, suppliers, BOMs, processes, and resources. Material contains the most abundant information, through the integration with the enterprise master data platform and ERP, the automatic synchronization and updating of master data is achieved, mainly involving the materials related to the scheduling of flavor and fragrance, including the cigarette raw materials, cut tobacco, and fragrant raw materials needed during the deployment of flavor and fragrance. Then, to use standard data structure to store the scheduling related configuration information, including demands for cigarette brands, package production lead time, silk production lead time, transport time matrix, standard production quantities of flavors, single batch deployment time, deployment lead time, inspection lead time, buffer lead time, etc. the minimum packaging volume, minimum purchase volume, procurement cycle, and inspection cycle. Finally, data maintenance and integration of customers, suppliers, BOMs, processes, and resource information performed in the same manner to ensure the uniqueness of the data source.

After the standardization of the basic data is completed, the design and implementation of external demand collectors and processors performed. External requirements include the company's sales goals, cigarette transportation plans for finished products, rolling sales forecasts, roll-to-roll production plans and silk production plans for cigarette factories, and production and arrival plans for co-processing plants. After the requirements collector has collected and structured storage requirements, to establish a top-down, coarse-to-fine demand system. Ultimately, through the demand management engine, external demand transformed into internal demand for flavors and fragrances through BOM deployment and lead-time planning.

The establishment of a dynamic security inventory model is an important prerequisite for ensuring that the system guarantees supply in the event of market changes. Traditional static safety stocks can meet production requirements when a fixed demand for safe stocks determined by manual experience when the demand is free from the low and peak season. However, for some materials that require long-term instability, static safety stocks may cause safety stocks at the peak of the peak season not to play a role, and low stock demand during the off-season has lot of restrictions. In the implementation of the system, we use different forecasting algorithms to predict the future market demand in terms of the different attributes of self-production, cooperative processing and external supply of shreds in various aspects of plan lead-time, transport lead-time, and mode of use. Calculate the average daily demand of each product in the future by moving average with the sales forecast provided by the sales department. For different sources of demand target subjects, according to the different levels of historical demand, the degree of change, to calculate the different safety stock satisfaction days. The average daily demand and safety stock meet the number of days to obtain a dynamically changing safety stock value, which can dynamically change according to changes in external demand in real time.

The collection of real-time inventory data and production data is the key to the effective operation of the compound dispatch system. Many scheduling systems fail to receive endorsement from users, and the main reason why they eventually return to the users’ manual scheduling is that the system's response to external abnormal factors cannot expected. Through the data access with the factory's MES system, co-production processing plant production schedule control platform, to real-time master of the production conditions of the demand for flavors and fragrances, For the change of package and wire making plan, the global availability check of the system is immediately triggered and evaluate the current flavor and fragrance production plan. Once the feedback production and demand do not match, immediate warning is given. The Integration with the centralized control system of the deployment center, mastering the deployment schedule of flavors and fragrances ensure that the scheduling system responds quickly to production anomalies. By firmly controlling the three main lines of demand, inventory, and production, we have grasped the fundamentals of efficient system operation.
Many unplanned rules need to consider in actual scheduling. For example, for some fragrant spices used incense raw materials are more viscous, in the fully automatic production line production, in the scheduling of production, the production batch arrangements need to set special rules. Because the company has realized the batch management of the smallest packaging unit material in the whole supply chain, small brands issued to co-production plants need to produce continuously on the same day in accordance with the requirements of batch management, and the batch number must to unify. These will procedurally modeled through a dedicated library of detailed scheduling rules. In the genetic algorithm for detailed production scheduling, there is a need to base on the constraints of these scheduling rules, and at the same time, to meet the needs and safety inventories, the pursuit of reducing inventory occupation, increase inventory turnover rate, and improve production continuity and stability. In the above, a feasible solution obtained, and then the optimal solution obtained by the genetic algorithm based on the feasible solution. If there is no feasible solution, the user prompted to make concessions to certain constraints. For example, reducing certain safety stocks, delaying the delivery of certain requirements, or increasing production capacity through overtime, etc., and re-arrange production until a final production plan obtained.
3.2. System application effect

Six months after the composite scheduling system put into operation, the sluggishness of flavors inventory significantly reduced without reducing the timeliness of delivery of individual products. The average inventory turnover days fell from 18 days to 15 days, and the average order demand satisfaction rate increased from 95% to 98.1%, the production plan version changed from 8 times per month to 4 times per month, and the emergency insertion rate decreased by 25%. After optimization of the product inventory structure, the longest inventory sluggish days for a small number of cigarette products decreased from 57 days to 45 days. The overall greatly improved the stability of the production of flavors and fragrance, reduced the response time of adjustment of production plans due to market changes, and effectively avoided the risk of backlogs of flavors.

4. Conclusion

The flavor composite scheduling system realized the dynamic safety stock management of semi-finished products of fragrant spices and fragrant raw materials on different time series. At the same time, based on customizable scheduling rules, genetic algorithms used to form corresponding production plans and procurement plans for flavors and fragrances. Through the production control module, the system controls the production and control system of flavors and spices center, flavor and spice deployment equipment, and obtains data in real time. Through the interaction between the material management module and the material management platform, the procurement schedule of the raw materials and inventory transfer plans are controlled. Connect the customized pre-warning devices to provide early warning of anticipated shortages of flavor and fragrance stocks and shortages of raw materials so that production planners can adjust factory calendars and change production plans in advance to ensure smooth production. With the implementation and application of the system, the company has improved the safety inventory control of flavors, and improved the management of scheduling and transportation, and can more scientifically ensure the production.

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