Logistics Cost Minimization and Inventory Management Decision for Yarn Manufacturers in China

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Summary: Replenishing adequate cotton with high quality at the best time from the spot market is a challenging task to yarn manufacturers. Given the high seasonality of some superior cotton types such as the extra-long staple cotton (ELS), purchasing late in the season runs the risk of material shortage while purchasing early results in additional storage cost as well as opportunity cost of work capital and warehouse spaces. By formulating the cotton mixing strategy to correlate the cotton requirements with the product demand and the industrial specific constraints and policies with the logistics network in MILP, yarn manufacturers can find the optimal economic replenishment and inventory management decision based on the received orders and forecast demand. Our case study shown that a 23% of saving could be gained through this quantitative approach.

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KEY INSIGHTS

1. **The seasonality of raw material and fluctuation of spot price can lead managers to replenish material inventory as early in the season as possible.**
2. **Replenishing materials too early has a huge cost implication to the supply chain in warehousing and maintenance.**
3. **Adjusting the replenishment decision can yield major benefits in overall logistics cost savings. 23% of savings can be obtained in our case studies.**

Introduction

Sourcing and replenishing diverse properties of cottons and ensuring their availability for manufacturing consumption is critical for the spinning mill business. The conventional practice in the yarn manufacturing industry is to hold a least 3 months safety stocks plus the forecasted consumption during the out-of-the-season period.

The crucial factor affecting the replenishment policy of cottons attributes to the high seasonality of some superior cotton types such as the extra-long staple cotton (ELS). Their availability is usually last within the first half of the season or even shorter. On the other hand, as an agricultural commodity, the price of cotton is subjected to a high level of uncertainty in spot markets. In 2011, the price of cotton raised from 78 cents per pound to 2.27 dollars in one year due to the national reserve policy of China government. Many spinning businesses ran into bankruptcy during the season due to the difficulties to remain profitable without reserving cotton at reasonable prices. These uncertainties lead managers to replenish their cotton inventory for the consumption of the whole year as early as possible when the season began. This approach provides the easiest way to secure the needs of cotton for production at the cost of storage and other opportunity cost in work capital and warehouse spaces of owned warehouses. With the continuous increase of warehouse prices and operation costs, how can the sourcing manager better adjust the replenishment time and quantity for cottons with different properties, seasonality, demand and prices change to minimize the overall logistics expenses? In this research, we formulate the cotton mixing strategy to correlate the cotton requirements with the product demand and the industrial specific constraints and policies with the logistics network in MILP. The model helps yarn manufacturers in China to find the optimal economic replenishment and inventory management decision based on the received orders and forecast demand.

Methodology

The methodology of this research is divided into four steps. In step one, we understood the end-to-end business process of the cotton and yarns lifecycle in the spinning mill operations and identified the key constraints and considerations of the stakeholders in the chain. Interview sessions were conducted with the corresponding department managers to obtain the key operational and tactical decisions in six aspects: (i) the forecast of cotton consumption; (ii) the cotton procurement practice and considerations; (iii) the transportation and warehouse operations; (iv) the order processing practice; (v) the cotton mixing techniques with relevancy to the cotton sourcing; (vi) the transportation and delivery of cotton and yarn.

In step two, we obtained the list of costing drivers and their corresponding unit rate at the study period. We gathered basic information about the logistics network and facilities such as the storage capacities of warehouses and production capacities of spinning mills, types of cottons and yarn product categories. Current statistics about yarn orders, consumption of cotton, inventory level of cottons and yarn products, operation expenses of logistics facilities and services were obtained as well.

In step three, we defined the MILP model of the logistics network with the obtained business constraints and implemented the model with python for Gurobi optimizer. The mixing recipes and yarn product catalogs were re-grouped and consolidated into 17 product items to minimize the problem space. All data were formatted into csv file for program execution.

In step four, we analyzed the optimization result of the case study by comparing the total logistics cost and inventory levels with the current performance. To understand the impact of cotton prices to the logistics cost, we ran sensitivity analysis with different degree of price increase for the two key cottons, namely ELS and upland.

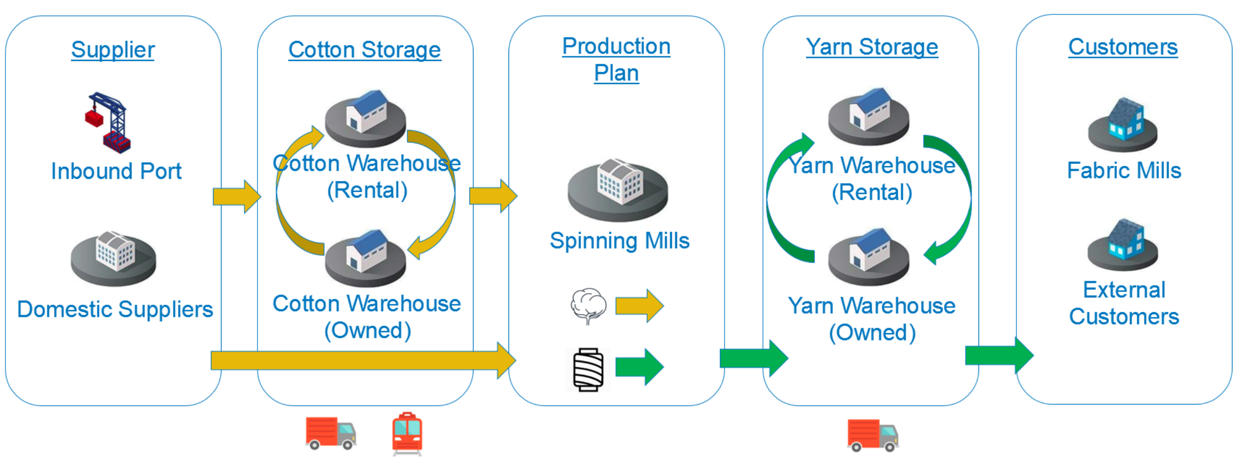


Figure 1 - Five layers logistics network of yarn manufacturing

Model Formulation

The objective function was defined in figure 2 includes the relevant cost of the logistics network to be minimized. The terms in the first row defines the purchase and ordering cost of cottons. The terms in the second row defines the storage cost and fix cost of the warehouses. The terms in the third row defines the opportunity costs to occupy the cotton and yarn. The terms in the fourth row defines the transportation cost of cotton while those in the fifth and sixth row defines the transportation cost of yarn.

$$
\begin{aligned}
\text{Min } Z = & \sum_{\substack{c\in C, s\in S,\\ t\in T}} \sum_{g\in G} \Big(\sum_{a\in A, l\in L} xc\_sw_{tgcsla} + \sum_{\substack{r\in R, m\in M,\\ l\in L}} xp\_sm_{tgrcslm} \Big) \times p_{cst} + \sum_{c\in C, s\in S} \sum_{t\in T} OF_{tcs} \times oc_{cs} \\
& + \sum_{a\in A} \sum_{t\in T, c\in C} IC_{atc} \times hc_a + \sum_{b\in B} \sum_{t\in T, y\in Y} IY_{bty} \times hy_b + \sum_{a\in A} OA_a \times hcf_a + \sum_{b\in B} OB_b \times hyf_b \\
& + \sum_{a\in A} \sum_{t\in T, c\in C} IC_{atc} \times oppc_a + \sum_{b\in B} \sum_{t\in T, y\in Y} IY_{bty} \times oppy_b \\
& + \sum_{\substack{a\in A, m\in M,\\ g\in G, t\in T}} \sum_{c\in C, r\in R,} xp\_wm_{tgrcam} \times tc\_wm_{tagm} + \sum_{\substack{a\in A, l\in L,\\ g\in G, t\in T}} \sum_{c\in C, s\in S} xc\_sw_{tgcsla} \times tc\_sw_{tlga} \\
& + \sum_{\substack{l\in L, m\in M,\\ g\in G, t\in T}} \sum_{\substack{r\in R, c\in C,\\ s\in S}} xp\_sm_{tgrcslm} \times tc\_sm_{tlgm} + \sum_{\substack{a, a1\in A,\\ g\in G, t\in T}} \sum_{c\in C} xc\_ww_{tgcaa1} \times tc\_ww_{taga1} \\
& + \sum_{\substack{m\in M, b\in B,\\ g\in G, t\in T}} \sum_{y\in Y} xe\_mw_{tgymb} \times ty\_mw_{tmgb} + \sum_{\substack{m\in M, f\in F,\\ g\in G, t\in T}} \sum_{y\in Y} xe\_mf_{tgymf} \times ty\_mf_{tmgf} \\
& + \sum_{\substack{b\in B, f\in F,\\ g\in G, t\in T}} \sum_{y\in Y} xe\_wf_{tgybf} \times ty\_wf_{tbgf}
\end{aligned}
$$

Figure 2 - Minimize the total logistics cost of cotton and yarn in the 5-layered network.

<u>Definitions</u>

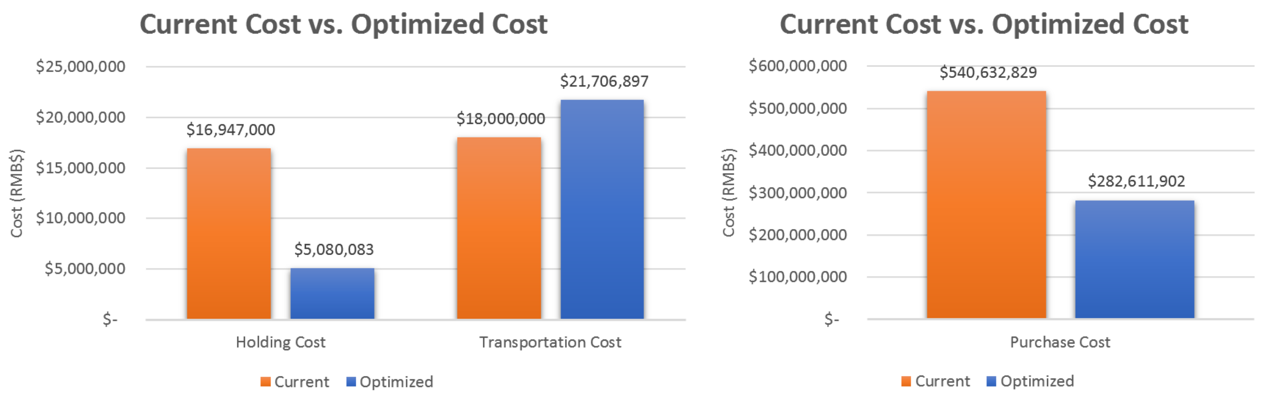
c = cotton types
y = yarn types
s = cotton suppliers
l = inbound ports
m = spinning mills
a = cotton warehouses
b = yarn warehouses
f = fabric mills
g = mode of transportations
t = time period
r = cotton properties required
p = price of cotton
oc = ordering cost of cotton
hc/hy = holding cost of cotton/yarn in warehouse
hcf/hyf = fix cost of cotton/yarn warehouse
xc_XX = amount of cotton transport between warehouses and suppliers
xp_XX = amount of cotton input to spinning mills for production
tc_XX = the transportation cost of the transfer
IC/IY = storage cost of cotton/yarn
oppc/oppy = opportunity cost of occupying the owned cotton/yarn warehouse
OF = linking variable of cotton purchase
OA/OB = linking variables flags warehouses in service

Optimization Result

The table in figure 3 compares the key cost drivers between the current and the optimized replenishment and logistics decisions. The optimized solution saves RMB $8.16m (23%) of the total logistics cost. The two bar charts in figure 3 shows the comparison of the total cost of inventory, transportation and purchased cotton before and after optimization. We see that the optimized solution expense higher in transportation cost but has much saving in inventory and cotton purchase. Less cotton is purchased in the optimized model shows that the historic inventory level is more than it needs. Notes that both the historic practice and optimization model also carries 5-months safety stocks to ensure the sourcing department has plenty of time for cotton replenishment in case a certain cotton type is fall under the re-order point. Normal lead-time to order cotton is 3 months.

Conclusions

In this project, we developed a multi-period logistics optimization model for a group of spinning mills. The main contribution of this work is to fill the gaps between the prior optimization research in logistics and the spinning industry in China by formulating the industry-specific policies and business considerations in practice to make the optimization result more valuable for business decision making. These gaps include the spot prices of cotton, the import quota of the Chinese government, the rules of cotton mixing in spinning process and the opportunity costs of cotton inventory. Industry-specific constraints including the international import quota of cotton, yarn production capacities, cotton mixing strategies and seasonality of cotton supplies are introduced to adopt the real business situations in the China spinning industry. The optimization framework can be used as a tool to guide the replenishment decision of the cotton sourcing personnel in practice.



Season 16/17	Current Cost (RMB$,000)	Optimized Cost (RMB$,000)
Ordering Cost	1.9	2.9
Holding Cost		
- Cotton	16,947	4,000
- Yarn		1,080
Transportation Cost		
- Cotton	18,000	7,400
- Yarn		14,306
Total Logistics Cost	34,948.9	26,788.9

Figure 3 - Comparison of current and optimized logistics cost

The model was applied to a company to find how the replenishment time of cotton can be fine-tuned based on the seasonality of different types of cotton to optimize the total logistics cost for the spinning mills. We demonstrated that a company can obtain 23% logistics cost saving every year by different replenishment strategies. The conventional practice in the industry attempted to source cotton at the beginning of the season for the whole year consumptions. While the current practice provides extra amount of time for sourcing personnel to purchase high quality cotton, in this quantitative study, we reviewed the economic implications of this practice and showed that different replenishment options can be taken according to the scarcity of the cotton types. For high quality ELS cotton, its availability in the market is limited and replenishment can be made with two to three months before it ran out in the first half of the season. For upland cotton which is available throughout the year, maintaining a five-month safety stock of the forecast demand would be enough to ensure the manufacturing needs.