Optimization of inventory cost control for SMEs in supply chain transformation: A case study and discussion

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Abstract: With the continuous transformation of supply chains in various industries in China, the strategic landscape, industrial structure, industry rules, business models, and management logic have all changed dramatically, and the consumer market has become more demanding regarding pre-sales quality and after-sales service. Primarily for distribution companies whose primary business model is "buy and sell products and earn a profit margin," the supply chain transformation has placed higher demands on inventory cost control. In this study, we propose an integrated approach for optimization of inventory cost control of internal supply chain management. The integrated approach includes an improved ABC inventory classification method, spare parts demand forecasting, and an adapted inventory management method. We then select a small and medium-sized home appliance distribution company as the case study because the company is at its early stage of inventory transformation due to the supply chain transformation. Using the case study and field research methods, we analyzed the specific impact of supply chain transformation on the company's inventory cost control and demonstrated the efficiency of the integrated approach. This study finds that the case company can control inventory costs more efficiently and effectively after implementing the improved ABC inventory classification method. The proposed different demand forecasting plans can help improve the accuracy of spare parts demand forecasting. Finally, different inventory management methods based on different classifications of spare parts can help determine the appropriate spare parts ordering point and procurement quantity.

Keywords: Supply chain, transformation, inventory cost, spare parts, distribution company.

JEL Classification: L81, M41.

Introduction

Supply chain transformation requires the support of information technology (IT) and other innovative digital technologies such as blockchain, internet of things (IoT), big data, and cloud computing. The rapid development of these technologies has facilitated business model innovation. Among other things, digital technologies can improve the overall management efficiency of the supply chain by optimizing workflow, improving information sharing, enabling information transparency, reducing collaboration costs, and increasing the accuracy of production forecasts (AlMulhim, 2021;

Attaran, 2020; Bigliardi et al., 2022; Chowdhury et al., 2019; Guo et al., 2022; Li et al., 2023; Perano et al., 2023; Pflaum et al., 2023). Over the years, the focus of supply chain operations in various industries has gradually shifted from partners to consumers (Basu, 2023; Chapman et al., 2003; MacCarthy et al., 2016; Min et al., 2019). In the traditional consumer market, the information transmission and channel construction costs between home appliance companies and the consumer market are too high, so the channel dealers directly facing the consumer market often have a greater right to speak. However, in the e-commerce market, each node of the supply chain can directly grasp a large amount of information about the consumer market, so the rights of channel merchants are gradually weakened, and the rights of consumers are strengthened. On this basis, a consumer-centric product and service supply model is gradually formed.

A distributor is an entity or individual that provides sales or services only in a specific area and field. As an essential part of the distribution channel, dealers, especially small and medium-sized home appliance distribution companies, face serious supply chain transformation challenges. For example, fierce competition among core enterprises in the supply chain has led to increasingly thin profits in the entire home appliance industry; direct sales by manufacturers have made the market competition more and more intense; the phenomenon of annexation by large companies has also made the survival of small and medium-sized distribution companies more and more difficult. Small and medium-sized distribution companies are disadvantaged regarding business scale, capital strength, and management level. As a result, such companies have the slowest and most pronounced response to macroeconomic regulation and changes in market supply and demand and the weakest ability to cope with market fluctuations and risk crises. For this reason, small and medium-sized home appliance distribution companies urgently need to seek reliable and stable profitability and appropriate ways to survive.

Cost competition is one of the most effective means of modern competition (Kharub et al., 2019; Porter, 2008; Sui & Wei, 2000), and the primary goal of supply chain management (SCM) is to minimize the total cost of the supply chain. In this regard, inventory cost usually accounts for over 30% of the total supply chain cost (Yu et al., 2019). The purpose of companies holding inventory is to obtain more economic benefits, but holding a large amount of inventory will take up too much liquidity for companies. As a result, inventory cost control is the focus of supply chain cost management. The more mature the inventory cost control system is, the better the industry's supply chain management system will be. In this research, we will have a close study of inventory cost control using a case study of the home appliance industry in China as this industry is undergoing a significant digital transformation due to the current trend of the "digital economy" and "new retail model" based on the internet, consumer demand, data (technology) drive, and channel integration.

1. Theoretical background
1.1 Supply chain management and transformation

SCM refers to the management of the supply chain; in other words, it is the coordination, integration, optimization, monitoring, and control of the physical, information, and financial flow activities of the production, manufacturing, and marketing chain of each nodal enterprise (Basu, 2023; Christopher, 2016). Shen et al. (2000) analyzed the literature and they concluded that SCM can usually be divided into two categories: internal supply chain management (e.g., planning, procurement, production, sale) and external supply chain management (e.g., supplier, consumer). SCM has both short-term and long-term objectives. Short-term objectives are to increase production capacity, reduce various costs such as inventory, communication, financial, and logistics costs, and reduce product cycle time. Long-term objectives are to improve customer satisfaction, market share, and profitability.

Strategic transformation refers to an organization's strategies to adapt to its business environment (Cohen & Roussel, 2013; Holtström, 2022). Specifically, it refers to the upgrading or renewal of organizational characteristics that affect the long-term organizational vision at the process, impact, and outcome levels. Strategic upgrading and renewal include two types of strategic transformation: reconfiguration and incremental (Agarwal & Helfat, 2009). The main drivers of strategic reconfiguration transformation come from external technological developments, changes in consumer demand, and the degree of market

maturity or decline. Reconfiguration strategic transformation does not only refer to changes in organizational processes. It also involves renewing the business model, technology base, organizational structure, resource capabilities, and trends (Ben-Menahem et al., 2013; Holtström, 2022; Tripsas, 2010).

Supply chain transformation is a strategic upgrading behavior led by the core companies of the supply chain. Core companies need to meet three conditions to complete supply chain transformation: first, selectively use or obtain support from existing resources; second, make full use of network resources to build supply chain capabilities; and finally, complete strategic upgrading and renewal of the supply chain (Xiao, 2015). In recent years, due to the advancement of IT and other digital technologies supply chain is undergoing a rapid transformation. Ageron et al. (2020) focused on challenges and future directions in digital supply chain and found supply chain transformation research is centered on two big areas: innovative technologies and strategic, organizational and human dimensions of the digital supply chain. Preindl et al. (2020) discussed a number of supply chain transformation strategies based on the impact of Industry 4.0 and digital transformation. Ho et al. (2023) developed a framework for developing digital strategies for supply chains. Alzarooni et al. (2022) analyzed the literature and in combination with expert opinions in the United Arab Emirates, they found three significant enablers (smart warehousing, intelligence, real-time) for digital supply chain transformation in the service industry. Aamer et al. (2023) identified three main themes (technology, people and processes) and ten drivers (e.g., IT infrastructure) for assessing the readiness for supply chain digitalization. Some research is on enabling sustainable supply chain transformation using different methods such as using real-coded genetic algorithm in the cement manufacturing industry (Khan & Sinha, 2022). Rasool et al. (2023) developed several key measures for digital supply chain performance. Other supply chain transformation topics include transportation cost optimization (Muntaka et al., 2023), the role of artificial intelligence for supply chain resilience (Dey et al., 2023), IoT-blockchain for efficient warehouse management (Kumar et al., 2023), the impact of knowledge management on digital supply chain transformation (Gagliardi et al., 2023), impact of digital transformation on supply chain relationship and collaboration dynamics (Hamann-Lohmer et al., 2023), role of structural social and human capital in supply chain transformation (Lang et al., 2022), factors and pathways to achieve supply chain resilience (Yin, 2023), impact of environmental dynamism on sustainable digital supply chain transformation (Sharma et al., 2022). Different industries are also examined for supply chain transformation issues. For example, Beaulieu and Bentahar (2021) discussed a roadmap to generate more benefits for digitalization of the healthcare supply chain. Saryatmo and Sukhotu (2021) examined the digital supply chain performance in the food and beverage industry in Indonesia.

1.2 Inventory cost control

Inventory is considered to be one of the most critical parts of any company and it needs to be correctly, efficiently and accurately managed (Govindasamy et al., 2022). On the one hand, companies must fully utilize the advantages of inventory to improve service quality and customer satisfaction. On the other hand, they must strictly manage and control inventory costs. Inventory cost consists of four main categories: inventory acquisition cost (procurement cost, ordering cost, and preparation cost), inventory holding cost (capital cost, inventory service cost, storage cost, and inventory risk cost), inventory out-of-stock cost (shortage cost and replenishment cost), and inventory in transit cost (inventory capital cost, inventory service cost, and inventory risk cost in transit).

Designing and operating a cost control system with spare parts as the main inventory is a complex task because the system needs to consider many influencing factors simultaneously, such as demand quantity, criticality, product failure rate, value, importance, procurement cost, production cost, replenishment period, and so on. According to Bacchetti and Saccani (2012), cost control activities with spare parts as the primary inventory should include three aspects: spare parts classification, demand forecasting, and inventory management. Inventory management is the top priority, while classification and demand forecasting can be considered supporting activities. Boylan and Syntetos (2010) argue that spare parts classification and demand forecasting should be linked to the inventory management policy of companies

and suggest that companies should organize inventory cost control activities in a closed loop. In recent years, the role of ABC classification in inventory cost control has been discussed. For example, Hanafi et al. (2019) argue that ABC classification can help the realization of green inventory control by minimizing total inventory cost. Eraslan and İÇ (2020) developed an improved decision support system (IDSS) which is a software to obtain more accurate and fast ABC classification for inventory control. Other technologies were also adopted in ABC classification such as the use of acceptability analysis (Li et al., 2019), Pareto's principle (Kheybari et al., 2019), Gaussian mixture model (Zowid et al., 2019), multi-attribute fuzzy method (Yung et al., 2021), stochastic data envelopment analysis approach (Tavassoli & Farzipoor Saen, 2022), extended R-model, SVM and Lorenz curve (Sarkar, 2023).

Companies must first classify and manage spare parts to better control inventory costs. Based on this, companies need to adjust different demand planning and forecasting models. Then, according to the different demands for spare parts and the degree of cooperation between the internal business model and the external supply chain, companies need to establish a targeted inventory management method and finally form an inventory cost control system that can support their operations.

As the internal supply chain is a main part of the whole supply chain and in consideration of the unique inventory cost control challenges of SMEs in supply chain transformation, this paper selects a small and medium-sized distributor of home appliances in Hunan Province, China, as a case study to discuss and analyze the company's operating model at the initial stage of supply chain transformation and to optimize its inventory cost control system for internal supply chain management.

Although many issues have been discussed on digital supply chain and supply chain transformation, much research is on enablers, strategies, and impact of different digital technologies and factors on supply chain transformation. Little research has been done on the impact of digital supply chain transformation on a single SME from an internal chain perspective. In this research, we will study optimization of inventory cost control for the SME in the context of digital supply chain transformation. For this purpose, an integrated approach was developed, which includes an improved ABC inventory classification method, spare parts demand forecasting, and an adapted inventory management method. We believe the integrated approach will be able to optimize inventory cost control more effectively and efficiently.

2. Case introduction
2.1 Company profile

Company Z, located in Hunan Province, China, was established in 2006 as an SME home appliance distributor. The company has exclusive distribution rights for many brands in the region. It is located in the middle of the home appliance supply chain, connecting upward to home appliance supply groups and downward to home appliance retailers. Through field research, we learned that most home appliance companies had implemented channel-deepening transformation to "continuously improve channel efficiency and transform retail service capabilities." In order to follow the principle of separate operation of logistics and trade, many home appliance companies re-planned the functions of inventory storage, logistics management, marketing, and after-sales service in each city of the province, breaking through the original administrative division, gradually eliminating the "hoarding mechanism" of distributors, and sending home appliances directly to retailers. In addition, home appliance companies take the original warehouse in the province as the logistics and shipping center of the products, build their own logistics departments or rely on third-party carriers, gradually forming a modern logistics and distribution system with independent operation and perfect management. As a result, all the home appliances of Company Z have been transferred to home appliance companies for management.

Under the transformation trend of the supply chain and the fierce competition among home appliance distributors, Company Z needs to quickly define its positioning, continuously push new value-added category services, optimize inventory cost control, enhance and improve channel operation efficiency, and contribute to the innovation and reform of the core companies of the supply chain.

2.2 Supply chain transformation impact on inventory costs

According to the management decision, Company Z has entered into a strategic cooperation

agreement with home appliance companies to acquire businesses such as regional home appliance after-sales services. This means that Company Z's business model would be changed from a distribution nature to a service nature, and its main inventory business would be changed from home appliances to various spare parts needed for after-sales services. This is a reconfigured strategic upgrade and renewal.

After-sales service means that Company Z meets home appliance users' subsequent various service needs after the retailer sells the product. The service's main contents include inspection, repair, maintenance, and replacement of home appliances. A high level of after-sales service reflects the competitive advantage of home appliance companies. Therefore, after-sales service by home appliance companies aims to improve customer satisfaction, satisfy individual needs, and obtain maximum benefits. This paper studies the impact of supply chain transformation on Company Z's inventory cost. A comparison of Company Z's inventory cost focus before and after supply chain transformation is shown in Tab. 1.

Tab. 1: A comparison of Company Z's inventory cost focus before and after supply chain transformation

Inventory cost items	Before supply chain transformation	After supply chain transformation
Main inventory	Home appliances	Spare parts
Inventory type	Less variety	More variety
Main service targets	Home appliance retailers	Home appliance users
Warehouse area	Large area	Small area
Demand forecast basis	Consumer demand	Sales volume and failure rate
Classification indicators	Turnover rate, value, demand, and profitability	Criticality, replenishment period, and suppliers
Inventory cost management focus	Stockholding cost	Inventory acquisition cost; on-transit stockholding cost

Source: own

Based on the above comparison, Company Z should start from the organizational structure and business process reorganization, integrate the regional logistics and distribution system, optimize the spare parts storage structure, continuously reduce the inventory cost by itself, and improve the after-sales service satisfaction of home appliance users.

3. Optimization of inventory cost control system

The inventory management of spare parts differs from that of ordinary finished products. Suppose Company Z directly applies the original inventory management system to spare parts management. In that case, it may lead to the problem of spare parts inventory hoarding or shortage. It may also cause economic losses such as capital occupation or service stoppage, directly affecting the company's economic benefits (Qu & Zhang, 2006). Therefore, Company Z needs to strengthen inventory cost control according to the characteristics of spare parts required for after-sales service.

Based on the analysis of the literature review, this paper proposes a set of inventory cost control methods applicable to internal supply chain management, taking into account the actual operating situation of the supply chain transformation of Company Z.

3.1 Implementing an improved ABC classification method

In order to implement an improved ABC classification method, there are a few steps to follow, as discussed below.

(1) Establishing a two-stage model for spare parts

According to the two-stage classification model, this paper classifies spare parts into three categories in the first stage: fast-moving spare parts,

Tab. 2: Characteristics of the first stage of spare parts classification

Classification	Demand	Purchasing volume	Restocking period	Scrapping ratio	Prediction difficulty
Fast-flowing	High	High	Short	Low	Low
Slow-flowing	Low	Low	Long	High	High

Source: own

slow-moving spare parts, and infrequent spare parts. Infrequent spare parts are spare parts with zero consumption value in one year for the company, and the spare parts are still essential to support the company's operation; slow-flowing spare parts are those with an uncertain demand rate of less than 1 per year; fast-flowing spare parts are those with an uncertain demand rate of more than 1 per year (Zhao et al., 2004). According to the actual situation of Company Z, this paper summarizes the characteristics of fast-moving and slow-moving spare parts (Tab. 2).

In the second stage of the classification model, this paper adopts the improved ABC classification method to classify the spare parts of Company Z. The method is based on the basic
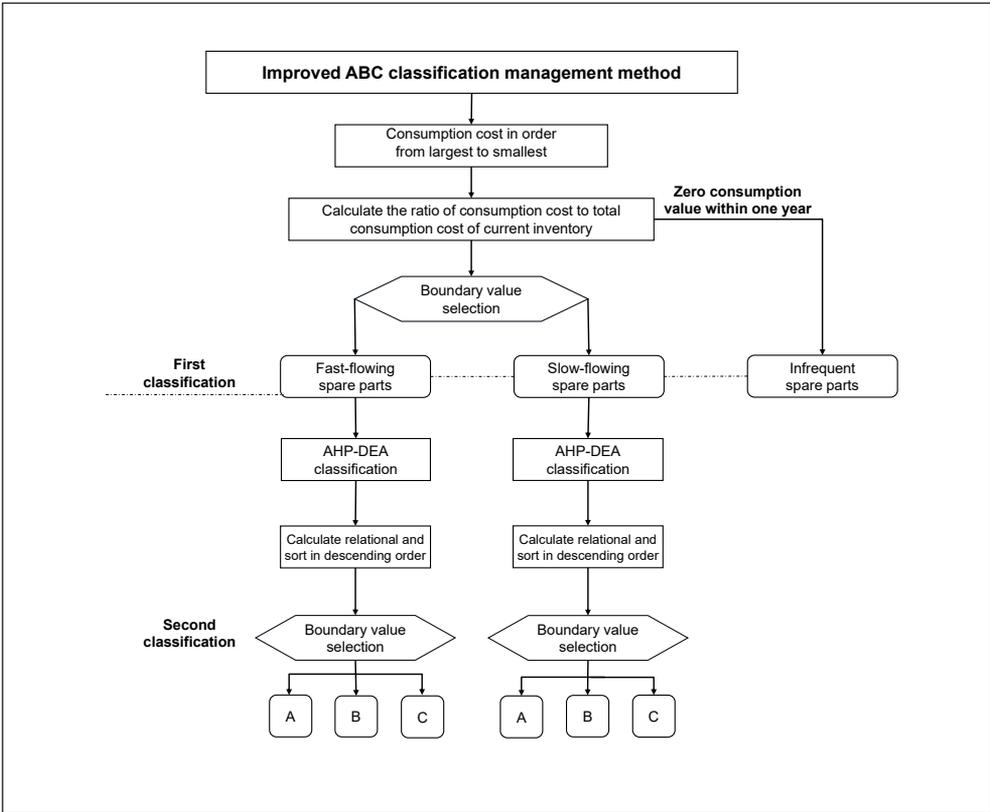

Fig. 1: The improved ABC classification management method

Source: own

logic of the ABC classification method, combines analytic hierarchy process (AHP) with super efficiency data envelopment analysis (SE-DEA), solves the total weight of spare parts by grey relational analysis (GRA), and then sorts and classifies the spare parts, classifying the spare parts with the top 20%, middle 30% and bottom 50% correlation into three categories A, B and C (Fig. 1).

Compared with the traditional ABC classification method, which only considers a single factor, and the AHP-ABC classification method, which is highly influenced by subjective factors, the classification results of the improved ABC classification management method are more comprehensive, scientific, and reasonable, which is more helpful for Company Z's spare parts management and cost control.

(2) Establishing AHP-ABC classification
The classification process of fast-flowing spare parts and slow-flowing spare parts is the same. Due to the limited space, the analysis in this paper only takes fast-flowing spare parts as an example. However, the shortage cost of slow-flowing spare parts is generally higher than the inventory cost and storage cost, and its related index weights should be slightly different from those of fast-flowing spare parts. According to the actual operation situation of Company Z,

this paper selects six classification indicators, namely, key factor (KF), replenishment period (RP), consumption cost (CC), shortage cost (SC), inventory cost (IC), and the number of suppliers (NS).

In a word, the criticality factor refers to the importance of spare parts to the company's after-sales service. The smaller the criticality factor of spare parts, the greater the impact on business operations and the more attention companies should pay. The replenishment period is the interval between when the company places an order and when the spare parts arrive at the warehouse. Consumption cost is the company's total cost of spare parts consumption in each operation cycle. Shortage cost is the loss incurred by the company due to a shortage of spare parts supply. Inventory cost is the total cost incurred by the company to store spare parts.

Since Company Z started its transformation at the end of 2020, the spare parts data covers a short time, so in this research, only the data of the first half of 2021 of the company is used to speculate the annual demand rate of spare parts and evaluate their flow rate. In the paper, the data of 20 fast-moving spare parts were randomly selected and screened from the company's spare parts information system (Tab. 3).

Tab. 3: Information sheet for random sampling of fast-flowing spare parts – Part 1

No.	Material code	KF	RP	CC	SC	IC	NS
1	B2051-001-1227	5	15	10,120	13,730	104	6
2	B2062-001-MB35	8	10	7,440	12,200	130	4
3	B2069-001-0468	3	30	560	300	58	9
4	B2065-001-0462	2	10	640	592	23	16
5	B2055-001-0723	3	10	600	296	19	19
6	B2062-G01-DF01	7	45	900	3,470	43	7
7	B2062-001-MD01	9	30	1,600	2,980	76	6
8	B2003-001-1243	2	12	1,350	1,030	38	17
9	B2051-001-1105	5	15	11,160	15,380	94	11
10	B2055-001-0723	1	10	720	630	22	13
11	X2368-001-0017	1	30	700	430	24	16
12	X2421-201-0001	1	30	800	355	13	25
13	X2362-001-0631	7	30	4,200	86,360	73	3

Tab. 3: Information sheet for random sampling of fast-flowing spare parts – Part 2

No.	Material code	KF	RP	CC	SC	IC	NS
14	X2062-001-0095	6	20	12,800	16,385	195	4
15	X2061-001-0032	5	30	240	96	12	14
16	X2114-001-0099	3	15	520	538	36	6
17	X2113-001-0051	2	30	600	683	54	6
18	X2111-001-0067	1	15	10,800	14,294	42	15
19	X2067-001-0038	4	15	1,800	824	63	13
20	X2069-001-0211	2	20	840	1,035	32	8

Note: Key factors (KF) are scored by Company Z's employees. The unit of the replenishment period (RP) is days. Consumption costs (CC), shortage costs (SC), and inventory costs (IC) are in Yuan. Suppliers indicate the number of suppliers (NS).

Source: own

Tab. 4: Characteristics of the first stage spare parts classification

	KF	RP	CC	SC	IC	NS
KF	1	2	3	3	5	5
RP	1/2	1	3/2	3/2	5/2	5/2
CC	1/3	2/3	1	1	5/3	5/3
SC	1/3	2/3	1	1	5/3	5/3
IC	1/5	2/5	3/5	3/5	1	1
NS	1/5	2/5	3/5	3/5	1	1

Source: own

Tab. 5: Weight coefficients of the judgment matrix of classification indices

	KF	RP	CC	SC	IC	NS
Weight coefficients	0.389	0.195	0.130	0.130	0.078	0.078

Source: own

After soliciting the opinions of department heads and experts, we formed a judgment matrix and calculated its statistical weights based on the provisions of the comparative quantitative values between each key factor in the AHP criterion layer (Tabs. 4–5).

The maximum eigenvalue of the matrix is calculated to be max = 6.000.

$$CI = (\lambda_{max} - N) \div (N - 1) = 0.000$$

The sixth-order stochastic consistency index is $RI = 1.24$.

$$R = CI \div RI = 0.000 < 0.01$$

Consistency check is passed.

(3) Combining SE-DEA to solve comprehensive weights

SE-DEA inherits all the advantages of the traditional DEA model and can effectively solve the problem of ranking the advantages and disadvantages of the traditional model. The calculation method of SE-DEA is shown in Equation (1).

$$\min [\theta - \varepsilon (\hat{e}^T s^- + \hat{e}^T s^+)]$$

$$\text{S. t.} \begin{cases} \sum_{j=1, j\neq j_0}^{n} X_j \lambda_j + s^- = \theta x_0 \\ \sum_{j=1, j\neq j_0}^{n} Y \lambda_j + s^+ = y_0 \\ \lambda_j \geq 0, \ j = 1, 2, ..., n \\ s^+ \geq 0, s^- \geq 0 \end{cases} \quad (1)$$

EM

Tab. 6: Schematic table of input and output indicators

Indicator	Number	Indicator name
Input indicators	X1	Key factor (KF)
	X2	Replenishment period (RP)
Output indicators	Y1	Consumption cost (CC)
	Y2	Shortage cost (SC)
	Y3	Inventory cost (IC)
	Y4	Number of suppliers (NS)

Source: own

where: θ – the super-efficiency value; $X_j = (x_{1j}, x_{2j}, ..., x_{nj})^T$ – the value of the input quantity; $Y_j = (y_{1j}, y_{2j}, ..., y_{nj})^T$ – the value of the output quantity; λ_j – the indicator weight; $s^- = (s^{1-}, s^{2-}, ..., s^{b-})^T$ and $s^+ = (s^{1+}, s^{2+}, ..., s^{b+})^T$ are the residual and slack variables, respectively.

Using SE-DEA, the two input indices and four output indices of the spare parts, as well as their residual and slack variables, can be found separately. On top of Equation (1), the preference coefficient β ($\beta = 0.6$) is introduced to solve for the combined weights, which are calculated as in Equation (2).

$$\alpha_i = \beta\omega + (1 - \beta) S_i \qquad (2)$$

According to the basic principle of DEA, the indicators with a small impact on spare parts classification are set as input indicators, and those with a large impact are set as output indicators in this research. The input and output indicators are shown in Tab. 6.

By using DEA-SOLVER Pro5.0, this study solves the input and output indicators of 20 fast-flowing spare parts, as well as the vectors of residual and slack variables of the indicators, and finally solve the composite weights.

(4) Combining GRA for classification

Using GRA for classification, this study first determines the optimal set of classification indicators for spare parts management $Q_0 = (q_{01}, q_{02}, ..., q_{06})$, where q_{0j} ($j \in [1, n]$) denotes the optimal solution for the jth indicator, and the optimal solution plays a boundary role in the classification indicators. It controls the min of the input indicators and the max of the output indicators so that the solution set matrix $G1$ can be inferred. Uniform regularization and normalization of $G1$ are performed to obtain the new matrix G, as shown in Equation (3).

$$G = \begin{pmatrix} q_{01}^* & \cdots & q_{06}^* \\ \vdots & \ddots & \vdots \\ q_{n1}^* & \cdots & q_{n6}^* \end{pmatrix} \qquad (3)$$

where: G – the correlation coefficient matrix based on GRA.

The correlation coefficient ε_{ab} can be calculated for the bth indicator in the ath spare part and its corresponding optimal indicator, as in Equation (4).

$$\xi_i = E_i \, a_i^* = [\xi_{n1}, \xi_{n2}, ..., \xi_{n6}] \begin{bmatrix} a_1^* \\ \vdots \\ a_6^* \end{bmatrix} \qquad (4)$$

ρ is the resolution ratio, taken as 0.5, and the relation coefficient matrix E composed of ε_{ab} can be solved. From the row vector E_i in the relation coefficient matrix E and the combined

Tab. 7: Results of grey relational analysis of spare parts

	KF	RP	CC	SC	IC	NS
Relatedness	0.562	0.578	0.545	0.553	0.553	0.594

Source: own

weight the correlation degree ξ_i of the ith solution is calculated, which is Equation (5).

$$\varepsilon_{ab} = \frac{\min_i \min_j |q_{ij}^* - q_{0j}^*| + \rho \max_i \max_j |q_{ij}^* - q_{0j}^*|}{|q_{ab}^* - q_{0b}^*| + \rho \max_i \max_j |q_{ij}^* - q_{0j}^*|} \quad (5)$$

Rank ξ_i in descending order. A higher value of ξ_i means that the spare part is more important. The ranking results of the relatedness are classified according to the basic principles of ABC classification. The results of the GRA of spare parts are shown in Tab. 7.

(5) Results based on the improved ABC classification method

Based on the above analysis, this study can obtain the results of the traditional ABC classification method, the AHP-ABC classification method, and the improved ABC classification

management method for 20 fast-flowing spare parts of Company Z (Tab. 8).

Different classification methods can lead to different results for the same batch of spare parts. For instance, under the ABC classification and the AHP-ABC classification, spare part 2 is classified as Class B, and spare parts 4 and 5 are classified as Class C. However, under the improved ABC classification, spare parts 2 and 5 are upgraded to Class A, and spare part 4 is upgraded to Class B. It is worth noting that spare part 14, which is classified as Class A under the ABC classification and Class B under the AHP-ABC classification, is unexpectedly downgraded to Class C under the improved ABC classification.

The improved ABC classification method considers the weight relationship between multiple indicators and reduces the influence

Tab. 8: Classification results

No.	Material code	ABC	AHP-ABC	Improved ABC
1	B2051-001-1227	A	B	B
2	B2062-001-MB35	B	B	A
3	B2069-001-0468	C	B	C
4	B2065-001-0462	C	C	B
5	B2055-001-0723	C	C	A
6	B2062-G01-DF01	C	A	C
7	B2062-001-MD01	B	A	B
8	B2003-001-1243	B	C	C
9	B2051-001-1105	A	B	A
10	B2055-001-0723	C	C	C
11	X2368-001-0017	C	C	C
12	X2421-201-0001	C	C	C
13	X2362-001-0631	B	A	B
14	X2062-001-0095	A	B	C
15	X2061-001-0032	C	B	B
16	X2114-001-0099	C	C	C
17	X2113-001-0051	C	C	C
18	X2111-001-0067	A	B	A
19	X2067-001-0038	B	C	B
20	X2069-001-0211	C	C	C

Source: own

of subjective factors in decision-making, so it has higher comprehensiveness, science, and rationality. Consequently, Company Z can analyze its inventory level by this method and achieve timely inventory warnings.

3.2 Setting up market demand forecasting plan

There are not many SMEs in China that can accurately calculate the demand for spare parts through material requirements planning (MRP). However, SMEs can use scientific forecasting methods and hire professional inventory planners to reduce operating costs, increase inventory turns, and improve inventory levels. To improve the accuracy of spare parts demand forecasting, the management of Company Z needs to abandon the empirical forecasting method. The company should adopt a more scientific forecasting method for different spare parts according to the demand pattern and characteristics. Based on the improved ABC classification management method results, this study proposes a feasible demand forecasting model for Company Z's spare parts (Fig. 2).

Using the data of fast-flowing spare parts as an example, this study measures and analyses the demand forecasting method for spare parts of Company Z.

(1) Class A for fast-flowing spare parts

Class A spare parts for fast-moving spare parts of Company Z are characterized by high importance and value. The demand for this type of spare parts is moderate, continuous, and the demand trend fluctuates up and down in some benchmarks.

In this study, the single exponential smoothing method is selected for demand forecasting of Class A spare parts, as in Equation (6). This method applies to forecasting demand without an apparent change trend.

$$S_t = \alpha \times Y_t + (1 - \alpha) \times S_{t-1} \qquad (6)$$

where: S_t – the exponentially smoothed value at time t; Y_t – the actual value at time t; S_{t-1} – the exponentially smoothed value at time $t - 1$; α – the exponential smoothing constant.

The predicted value of the single exponential smoothing is calculated as in Equation (7).

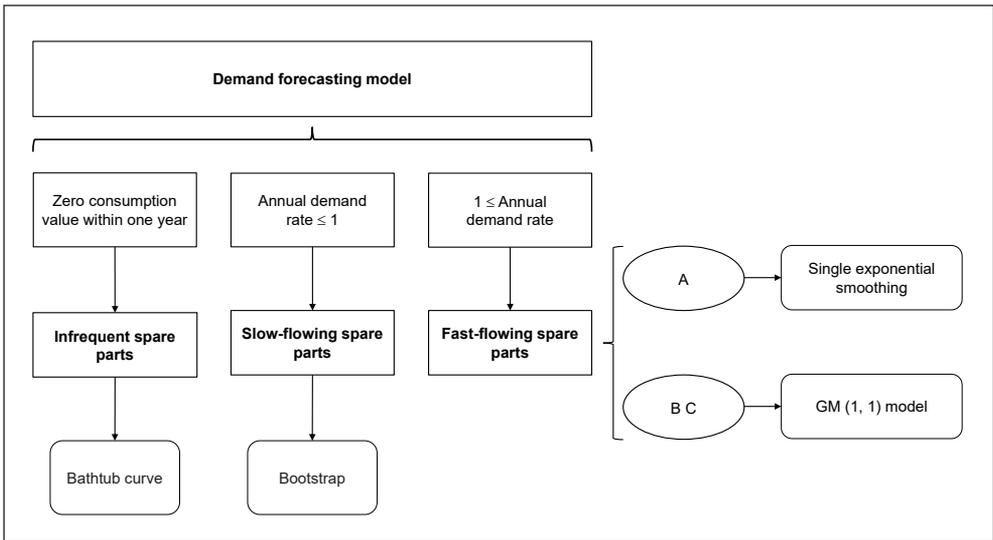$$Y_{t+1}^* = \alpha \times Y_t + (1 - \alpha) \times Y_t^* \qquad (7)$$

Fig. 2: **Spare parts demand forecasting model based on improved ABC classification**

Source: own

Tab. 9: **Historical data observation for fast-flowing spare parts Class A**

Month	January	February	March	April	May	June
Observation	5	4	5	7	6	4

Source: own

where: Y^*_{t+1} – the predicted value for time $t + 1$, which is the exponentially smoothed value for time t; Y_{t+1} – the actual value for time t; Y^*_t – the predicted value for time t, which is the exponentially smoothed value for the previous period.

Taking spare part 5 as an example, this study forecasts the demand for the first half of 2021. The historical data observations for spare part 5 are shown in Tab. 9.

Taking the smoothing index α as 0.1–0.9, the mean square error (MSE) of single exponential smoothing is obtained (Tab. 10).

Based on this, the mean square error is minimized when α = 0.1, and its spare parts prediction value, is shown in Tab. 11.

The smaller the standard error, the closer it is to the actual value. The standard error is minimized when α = 0.1 by applying the trial algorithm. Therefore, the forecast of Class A spare parts of Company Z can be made according to the solution of spare part 5.

(2) Class B and Class C for fast-flowing spare parts

Company Z's fast-moving spare parts, Class B and Class C, are mostly general spare parts with high consumption. The relevant sample data of the company is small for the time being, and the GM (1, 1) grey prediction model has the advantages of collecting few samples. Samples do not need to show regular distribution, small computational workload, and high accuracy, which can be used for short-medium and long-term prediction. The operational steps of the GM (1, 1) model are specified as follows.

Suppose there are n observations of the original series $X^{(0)}$, which is: $X^{(0)}$ = {$X^{(0)}(1)$, $X^{(0)}(2)$, ..., $X^{(0)}(n)$}, the new series X = {$X(1)$, $X(2)$, ..., $X(n)$} is obtained by cumulative summation. The differential equation of the GM (1, 1) model is as follows.

$$\mathrm{d}X \div \mathrm{d}t + \alpha X^{(1)} = \beta \tag{8}$$

Tab. 10: **List of MSE**

	α								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
MSE	1.269	1.374	1.481	1.585	1.680	1.759	1.817	1.849	1.854

Source: own

Tab. 11: **Demand forecast table for fast-flowing spare parts Class A**

	January	February	March	April	May	June
Observation	5	4	5	7	6	4
Predicted value	5	5	5	5	5	5
Error	0	1	0	2	1	1
Percentage (%)	0.00	25.00	0.00	28.57	16.67	25.00

Source: own

where: α – the development of the grey number; β – the endogenous control grey number.

Let $A = [\alpha\ \beta]^T$ and use the least-squares method to find $A = (B^T B)^{-1} B^T Y$.

$$B = \left[\left(\begin{matrix} -\frac{1}{2}\{X^{(1)}(1) + X^{(1)}(2)\} & \cdots & 1 \\ \vdots & \ddots & \vdots \\ -\frac{1}{2}\{X^{(1)}(n-1) + X^{(1)}(n)\} & \cdots & 1 \end{matrix} \right) \right] \quad (9)$$

$$Y = [X^{(0)}(2), X^{(0)}(3), \ldots, X^{(0)}(n)]^T \quad (10)$$

By substituting the required parameter values into the differential equation, Equation (11) is obtained.

$$X^{(1)}(i+1) = \left[X^{(1)}(1) - \frac{\beta}{\alpha} \right] e^{-\alpha t} + \frac{\beta}{\alpha} \quad (11)$$

The above calculation only yields one accumulation. The final predicted value of the spare parts can be obtained only through the recursive generation of data $X^{(1)}(i+1)$.

On this basis, the demand forecast is carried out for spare part 4 of Class B and spare part 11 of Class C. The forecasted results are shown in Tab. 12.

Under this model, the error rate of forecasting Class B and Class C spare parts is less than 0.1, which means the accuracy is more than 90%. This indicates that it is feasible to use the GM (1, 1) model to forecast the demand for fast-flowing Class B and Class C spare parts for Company Z.

3.3 Adopting an adapted inventory management method

Inventory management methods depend mainly on Company Z's inventory check cycle, order time, and procurement quantities. The main influencing factors are the consumption characteristics and classification of spare parts. For example, for inventory with high key factors, long replenishment cycles, high shortage costs, and few sources of supply, Company Z should not only order in advance but also maintain safety stocks. However, high purchase quantities can lead to excessive inventory levels. To some extent, this can improve Company Z's service levels, but it can also significantly increase inventory costs. Therefore, it is important for the company to balance the relationship between service levels and inventory costs. The analysis in this study continues to focus on fast-moving parts.

(1) Inventory management of infrequent spare parts

The infrequent use of spare parts does not mean that they do not support Company Z's actual operations, but rather that their demand and frequency of use are extremely low. In addition, the shortage cost of infrequently used spare parts may be high, or such parts may only serve the company internally, making it "necessary" for the company to continue to stock them for emergencies. The inventory management method for infrequent spare parts is shown in Fig. 3. For the rare spare parts located in the empty area of Fig. 3, Company Z should choose the order point

Tab. 12: Demand forecast table for fast-flowing spare parts Class B and Class C

	Spare part	January	February	March	April	May	June
4	Observation	12	15	18	22	24	28
	Predicted value	12	16	18	21	24	28
	Error	0	1	0	1	0	0
	Percentage (%)	0.00	3.56	0.11	4.99	1.03	0.45
11	Observation	8	9	10	11	13	14
	Predicted value	8	9	11	12	13	15
	Error	0	0	1	1	0	1
	Percentage (%)	0.00	4.72	5.63	7.63	2.08	6.24

Source: own
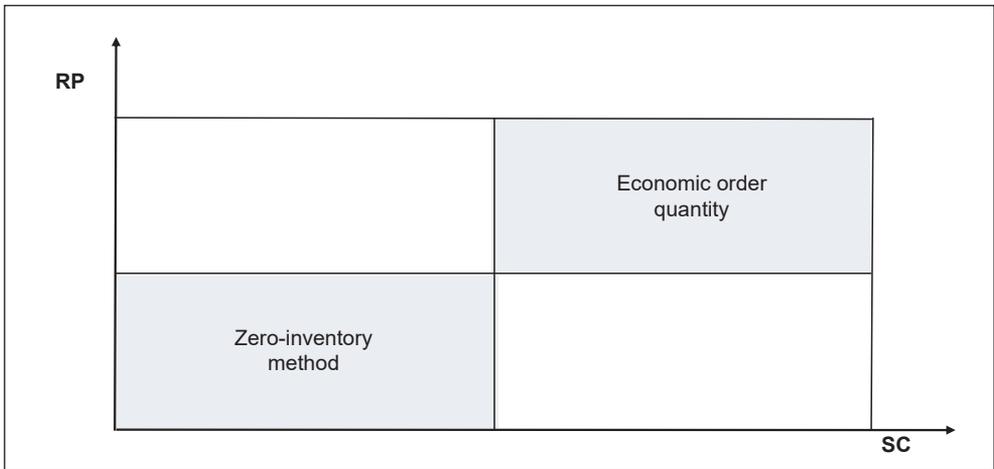
Fig. 3:   **Inventory management methods for infrequent spare parts**

method or the zero inventory method according to the actual situation.

Company Z can use the zero-inventory method for infrequent spare parts with relatively short replenishment lead times and relatively low shortage costs, which means that the company does not stock such spare parts and purchases them from suppliers when needed.
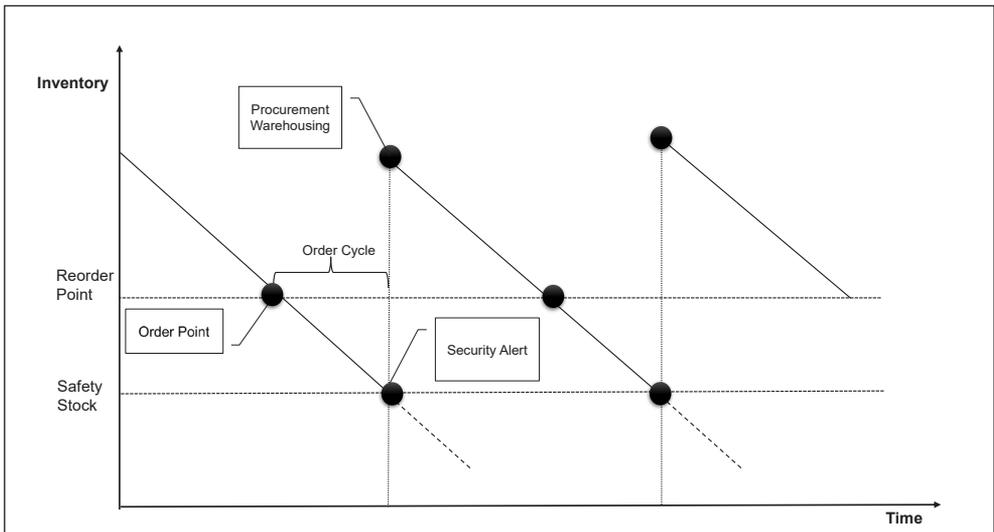

Fig. 4:   **Order point method (safety stock method) for infrequent spare parts**

Meanwhile, Company Z should use the order point method for the infrequent spare parts with long replenishment lead times and high shortage costs, which means the company maintains a safety stock for such spare parts, as shown in Fig. 4.

The purpose of safety stock at Company Z is to provide a buffer against the effects of uncertainties, such as changes in demand or delays in delivery. The level of safety stock is influenced by three factors: the uncertainty of demand for spare parts, the uncertainty of supply, and the service level (availability rate requirement). For Company Z, safety stock is also a cost of inventory that cannot be ignored. For this reason, Company Z cannot make a rough estimate of spare parts demand based only on market experience. The company should quantify the influencing factors as much as possible, based on historical data and mathematical and statistical methods, so that the order time is as close as possible to the demand time and the purchased quantity is as close as possible to the demand quantity. The company must ensure its inventory adequacy and reduce supply instability.

(2) Inventory management of slow-flowing spare parts

Slow-moving spare parts still occupy an important position in the after-sales service work of Company Z. They are characterized by high criticality, high versatility, low demand, long replenishment period, high shortage cost, high scrap rate, and tricky demand forecast. In response to these characteristics, Company Z can use the periodic inventory method, which means that spare parts are inventoried at regular intervals, and the amount of replenishment depends on the quantity in inventory after the inventory is taken. It is also worth noting that slow-moving items have a low inventory turnover rate, and management is focused on minimizing inventory. Therefore, Company Z needs to determine the order point and replenishment quantity for slow-moving items.

Slow-moving Class A spare parts are critical to Company Z's daily operations. Once the spare parts are missing, it will lead to a reduction in the company's after-sales service level and customer satisfaction. To ensure sufficient spare parts quantity, this study adopts $(S - 1, S)$ inventory management method. In order to ensure the continuous supply of spare parts, the $(S - 1, S)$ inventory management method requires Company Z to immediately replenish one spare part for every one consumed. In addition, the company's spare parts planners must regularly check the spare parts and provide an accurate picture of the inventory and storage status of the spare parts. The planners also need to record various spare parts issues and make a simple forecast of the expected useful life of remaining spare parts and market demand to determine their ordering points.

Compared to slow-moving spare parts, Class A, Class B, and Class C spare parts have lower criticality, shorter replenishment lead times, lower shortage costs, lower demand, and lower total value. By devoting too much management effort to these types of spare parts, Company Z cannot achieve more economic benefits and has limited cost savings. As a result, the spare parts inventory management in Company Z may be rough. This study considers the (t, S) inventory management method appropriate for Company Z. This method requires Company Z to inspect the spare parts at a fixed inspection interval t before ordering. And the company's order quantity at each time is the difference between the maximum spare parts inventory and the actual inventory. Adopting this method for slow-flowing Class B and Class C spare parts helps spare parts planners to focus more on managing Class A and fast-flowing spare parts to achieve accurate management. Company Z should avoid frequent reconciliation of such spare parts to reduce operational difficulties and workload. In addition, Company Z can manage logistics and transportation through order integration to save time and costs, make it easier for suppliers to arrange production storage and logistics distribution, and reduce supply uncertainty.

(3) Inventory management of fast-flowing spare parts

Company Z's most important spare parts are fast-moving spare parts, which are characterized by stable demand, rapid consumption, short procurement time, high capital consumption, and low demand volatility. Continuous inventory is a common method for managing fast-moving spare parts, which enables a quick response through accurate detection and potential shortage problems. When the quantity of spare parts falls to a certain level, Company Z should order them immediately to restore the inventory

to an acceptable level. Company Z uses continuous inventory to maintain the inventory at a reduced level, but it also incurs some labor costs. Therefore, this method is only suitable for spare parts that are consumed and circulated at a high rate.

Fast-moving Class A spare parts are the most important spare parts for Company Z. The company not only needs to minimize the shortage probability of spare parts but also needs to reduce its inventory level. For this reason, this study considers that
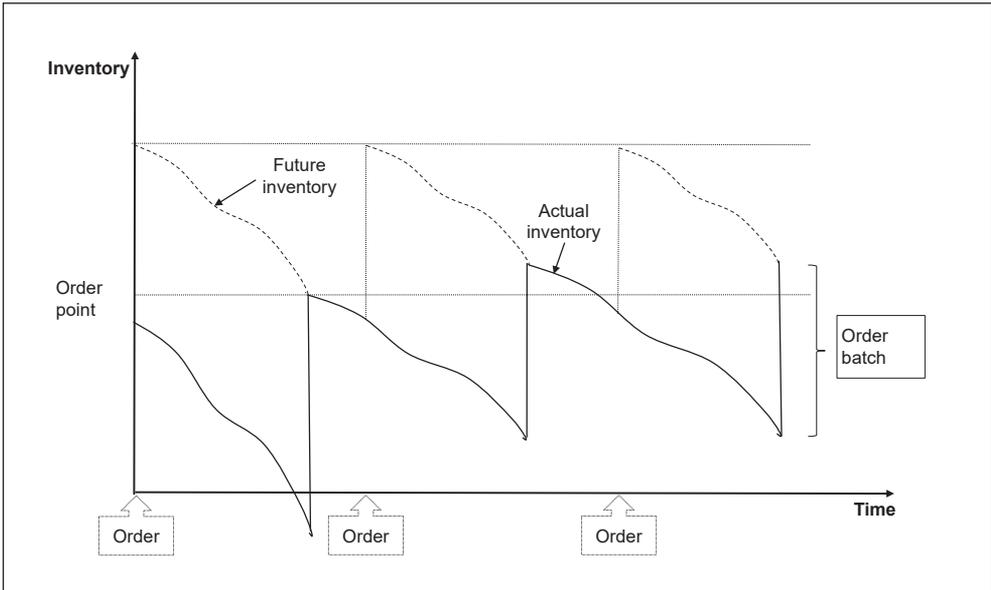

Fig. 5: **(R, Q) Inventory management method for fast-flowing spare parts Class A**

the (R, Q) inventory management method can better manage the fast-moving Class A spare parts (Fig. 5).

Thus, it is clear that the reorder point of the (R, Q) management method is R. Each order quantity Q is precisely calculated, and if the inventory quantity is found to be less than R after a continuous inventory check, an order quantity Q is immediately placed. In addition, Company Z must implement other control measures for fast-moving Class A spare parts, such as detailed and complete records of spare parts receipt, issue, and inventory, detailed procurement plans, and strict logistics control. At the same time, Company Z must establish a good cooperative relationship with spare parts suppliers to ensure the timeliness and stability of their supply, as well as the quality and quantity

of spare parts. Fast-moving Class A spare parts are characterized by relatively high demand and value, high shortage cost, and long replenishment time, which have a significant impact on the company's warehouse logistics. Company Z should ensure the procurement quantity and safety stock of such spare parts to some extent. However, the company should also try to reduce the occupied area of the warehouse to save inventory carrying costs and pay attention to the consumption of spare parts to prevent shortages.

Fast-moving Class B and Class C spare parts are of secondary importance in the spare parts management activities of Company Z. These spare parts are characterized by high demand and short replenishment time, and the service level requirement is not as high
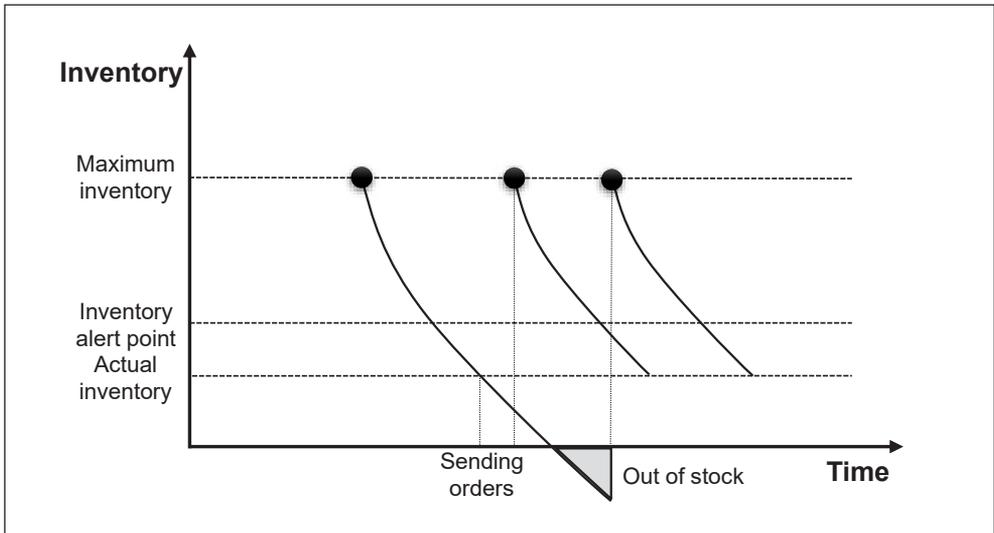
Fig. 6: **(s, S) Inventory management method for fast-flowing spare parts Class B and Class C**

as that of Class A. For this reason, this study suggests that Company Z may choose the (s, S) method for the management and control of fast-moving Class B and Class C spare parts (Fig. 6).

It can be seen that the continuous inventory cycle for fast-moving Class B and Class C spare parts can be slightly longer than for Class A. After each inventory check, the inventory is replenished to the maximum inventory level S when the inventory falls below the order points. Fast-moving Class B and Class C spare parts are generally not very valuable and have a relatively small capital footprint. Company Z can set a maximum inventory level for this type of spare part to minimize management efforts.

Conclusions

Although reducing the inventory level can reduce the inventory cost of a company to a certain extent, it may lead to problems such as the increased risk of shortage, frequent emergency procurement, lower service level, and lower customer satisfaction, and the inventory cost of the company will increase rather than decrease. Therefore, establishing a scientific and reasonable inventory cost control

system is a necessary condition for the healthy operation of the company.

For SMEs that are or will be in the supply chain transformation phase, it is important to leverage the supply chain externally to manage inventory and internally to optimize the inventory cost control system. Compared to large companies, SMEs are in a relatively disadvantaged and passive position in terms of capital size, technical resources, human resources, supply chain influence, voice, and decision-making power. However, this does not mean that SMEs are "helpless" when it comes to inventory. On the contrary, SMEs can proactively respond to the supply chain transformation, integrate resources and change their mindset in a shorter time to optimize their inventory cost control system. As the internal supply chain is considered to be a main part in supply chain transformation, this study focuses on internal supply chain management of the case company in order to propose and validate an intergrated approach for inventory cost control.

For the internal supply chain management of various spare parts required for the operation of the case company, this study proposes to first classify spare parts into three categories:

fast-flowing, slow-flowing, and infrequent, and then handle them according to the basic principles of the improved ABC inventory classification method. Then the improved ABC inventory classification method integrates three other methods, namely AHP, SE-DEA, and GRA, and considers the weight relationship among multiple indicators to reduce the influence of subjective factors in decision-making. As a result, the improved ABC inventory classification method is more comprehensive and precise; secondly, according to the different classification results of spare parts, companies are suggested to set up different demand forecasting plans to improve the accuracy of demand forecasting; furthermore, to determine the appropriate ordering point and procurement quantity, companies also need to specify different inventory management methods based on different classifications of spare parts. The integrated approach for inventory cost control is validated using the case study to prove that it is efficient and effective. A number of suggestions are also discussed to further optimize inventory cost control for SMEs in supply chain transformation.

The issues covered in this study are only a part of the inventory cost control problems of the case company. In the future other situations and factors need to be considered, such as external supply chain management cooperation, which needs to be explored in depth by future practitioners and academics.

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