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Study on Inventory Management of LCD TV Manufacturing Enterprises--Taking BPD Company as an Example

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ABSTRACT*: LCD TV manufacturing enterprises aim to effectively control and scientifically reduce inventory costs, a critical factor for enhancing overall profitability and market competitiveness. This study focuses on BPD Company, a manufacturer of LCD TVs, conducting an in-depth analysis of the current inventory management (IM) challenges and proposing an optimized IM strategy tailored for television manufacturing companies. Given the short product lifecycle and rapid turnover of LCD TVs, which entail higher potential risks compared to traditional industries, it is imperative to avoid excessive stockpiling of finished goods. The specific components of the proposed IM optimization strategy include: employing advanced demand forecasting techniques, transitioning to an order-driven production model, enhancing the knowledge and skills of supply chain personnel, refining existing IM systems, and advancing information technology integration. The findings of this study offer valuable insights for both the focal case and similar enterprises.*
KEY WORD*: Inventory management (IM), Supply chain management (SCM), Demand forecasting model*

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I. INTRODUCTION

1.1 Background

As Chinese-style modernization progresses successfully and expands, manufacturing enterprises find themselves in a period of favorable development amid a tumultuous and intensely reformative market economy. Rising consumption levels and diversified market demands prompt these enterprises to respond swiftly to changes, leading to more refined production processes. Retailers are imposing stricter requirements on television manufacturers. Many high-tech manufacturing enterprises are rapidly adopting SCM models. Consequently, many television enterprises have come to realize that relying solely on products and services is insufficient to establish a superior competitive edge; instead, they should leverage SCM as the source of their competitive advantage.

The television industry, being largely a nascent sector, has a shorter operating history compared to other industries with longer-established supply chains. The number and scale of suppliers are often significantly lower than those in less technologically advanced sectors. The inventory characteristics within the supply chain of the television industry are as follows:

(A) Strict Inventory Control: In the intensely competitive technology market, uncertainty is on the rise. Televisions are characterized by easy replication at low cost, short product life cycles, and high market uncertainty. In terms of the market, once users invest in specialized training and complementary measures for using technology products, they develop a certain level of consumption rigidity, making them reluctant to switch to other similar products. Companies may end up with long-term inventory due to poor sales or product redesign. Therefore, television production is typically carried out in small batches to prevent the increase in product costs associated with large inventories.

(B) Supply Scarcity Leading to Increased Inventory Uncertainty: Due to the sensitivity of the technology market and technological advances, technology suppliers often conceal core technologies and sensitive business secrets to protect themselves, sometimes even controlling output to monopolize the market. High-tech products are generally characterized by advanced technology and complex functions, making qualified suppliers scarce. To maintain good relationships and ensure smooth supply, downstream companies passively choose to overstock inventory to achieve stable production, respond quickly to the market, and deliver promptly to customers,

emphasizing the responsiveness and flexibility of the supply chain.

These characteristics of the supply chain in high-tech enterprises determine the significant uncertainties present among suppliers, producers, and customers. As a result, the supply chain of television enterprises is highly vulnerable, posing significant challenges for IM.

BPD Company (BPD) was founded in 1996 and is a company dedicated to the research, development, production, sales, and service of multimedia products, including LCD TVs. The company has established a comprehensive digital TV industrial chain spanning R&D, production, sales, and service. Unlike traditional labor-intensive and capital-intensive goods, technology products exhibit distinct characteristics: they follow the principle of marginal returns, have a short product life cycle, require significant research and development investment, and are targeted at specific market segments. These characteristics mean that the supply chain IM for technology products differs from that of traditional commodities, and the risk factors and intensity are also distinct. Improving the quality of supply chain services and identifying new profit growth opportunities have thus become crucial strategies for the company.

II. LITERATURE REVIEW

Inventory theory emerged in the 1970s and has since garnered significant attention from both academic and business communities, becoming a vital area of research. Before the 1970s, inventory theory was considered an idealized management model, focusing on the relationship between corporate inventory levels and economic order quantities, with the assumption that lower inventory levels and larger order quantities would lead to higher profits for the company. It was not until the late 1970s and early 1980s, with the evolution of SCM and the appearance of various complexities, that a new understanding of safety stock theory developed.

The fundamental role of inventory is to serve as a resource held in reserve for future use, functioning as a buffer against disruptions. IM is closely tied to warehousing, with most IM activities occurring within warehouse facilities. Inventory can be classified based on different functions and purposes into cycle stock, safety stock, in-transit stock, speculative stock, seasonal stock, and idle stock. Setting inventory levels involves balancing two aspects: high inventory levels can lead to low shortage costs and high on-time delivery rates for customers, but also high inventory holding costs; conversely, low inventory levels can lead to high inventory holding costs and low on-time delivery rates for customers, but lower inventory holding costs. A scientifically and reasonably determined inventory level not only maintains a high customer delivery rate but also reduces the company's inventory expenses and promotes inventory turnover.

Since the beginning of the century, international scholars have conducted more in-depth and practical research on inventory theory, considering various factors influencing the setting of safety inventory levels, and tracking and continuously revising these levels in practice, thereby enhancing the operability of safety inventory theory. Di Fan (2018) studied the impact of supply-demand mismatch on corporate safety performance from a novel perspective. Based on a sample set of fashion and textile-related manufacturers, a systematic method was proposed to determine the optimal parameters of a stochastic IM system under economically feasible deficit conditions. This method allows for rapid response to fluctuations in demand and dynamic changes in inventory status, and it was validated using real-world data. The analysis indicated that supply-demand mismatch is associated with a higher likelihood of safety incidents.

Xiaolin Sun (2020) utilized big data to establish an XGBoost model to accurately forecast the trends of red blood cells (RBC) and predict the demand for red blood cell units (REBC) from one day to one week in advance. By investigating the usage and inventory levels of the company and analyzing the rules for RBC usage, an alert range was added to the prediction values to cope with emergency needs. The study found that the XGBoost model offers predictive advantages over other state-of-the-art methods. It demonstrates that the model can adapt to the trends in daily RBC usage. The alert range can manage the demand for emergency patients or surgical accidents.

Yang Hui (2017) explored the concept of a "pull supply chain" and incorporated it into the broader reform of supply chains, focusing on optimal choices under a supply chain construction system centered around "customers and orders." Hu Ruodun (2019) emphasized that in addressing common material inventory issues, material managers should design a scientific material IM plan based on the role of inventory and the principles of inventory models. Additionally, strict adherence to each aspect of general material safety IM and the considerations involved is necessary to enhance cash flow and utilization efficiency, making general material management products more competitive.

Kang Huifei (2018) discussed the basic theory and criteria of ABC classification and provided detailed explanations. She delved into the basic principles and specific calculation methods of safety stock, combining

practical cases to detail the application of this method, aiming to provide reference value for Chinese enterprises in managing their inventory. Jiang Aiping (2014) noted that computer companies, facing multiple uncertainties, often rely on large inventories or emergency production to meet customer requirements. If non-critical component distributors are unwilling to hold inventory, the delay rate will inevitably be higher. To address this, she recommended using a safety stock strategy to increase order accuracy and reduce delivery delays. Ultimately, after implementation, this approach significantly increased inventory turnover and reduced inventory costs.

Sheng Qiang (2020), using a manufacturing enterprise as an example, addressed the problem of overall high inventory levels and partial material shortages. He used four criteria – criticality, availability, economics, and space occupancy – to classify materials, applying (S, s) and (r, Q) strategies to formulate inventory control models for different types of materials, solving for various model parameters and safety stock. He established a material control system simulation process, targeting inventory costs and using Anylogic software for simulation, comparing the simulation results with current inventory costs. In the example, average inventory costs and shortage costs were significantly reduced. The material classification and inventory control methods proposed in this study can help manufacturing enterprises improve material response efficiency and reduce material management costs.

Summary: In recent years, numerous scholars have conducted multi-dimensional and multi-perspective discussions and research on SCM direction and IM optimization. Currently, manufacturing companies worldwide have conducted relatively thorough research on problems in the IM process and achieved many results. However, due to the different characteristics of different types of enterprises, specific problems still need to be analyzed specifically.

Focusing on the operational model of Chinese home appliance companies, particularly those that integrate R&D, production, sales, and service, this paper aims to implement optimization under the existing IM situation at BPD. The research will combine theory with practice, adopting methods suitable for the company's own development. The planned research includes exploring and validating demand forecasting methods, linking them with the company's historical data, and using the second-order exponential smoothing method for simulation to determine a demand forecasting method suitable for the company's products. This will improve the company's forecasting accuracy for its products, thereby achieving the goal of reducing inventory and optimizing inventory structure.

III. METHODS

This paper employs literature research methods, survey analysis methods, statistical analysis, and quantitative analysis methods. Focused on enhancing Company B's market competitiveness, we apply mainstream IM theories and commonly used methods and models.

3.1 Literature Research

We gathered extensive research results through libraries, the Internet, electronic resources, databases, and other channels. We gained an understanding of supply chain IM, traced the development history and current research status of the ABC classification method for procurement scale, and learned about mainstream IM theories. We also collected relevant research information on enterprise management plans, which provided ideas and references for designing this study.

3.2 Fieldwork Method

This study utilized departments involved in BPD's inventory control activities, such as logistics and warehouse personnel, to conduct in-depth interviews and surveys. We collected data related to IM practices, including inventory reports and forecast accuracy reports. This allowed us to gain a clear understanding of every aspect and the entire process of the company's IM, thereby obtaining first-hand data for research and analysis. In addition, we also collected secondary data through a comprehensive review of IM literature for data processing. This study will provide important data for identifying issues in B's IM practices and seeking feasible solutions.

3.3 Statistical Analysis and Quantitative Research

Using historical data and company statistics, we investigated and analyzed BPD's current inventory situation and the inventory structure and dynamics of the previous year, as well as the actual IM challenges faced. We conducted a deep and thorough "inside-out" analysis, identified the root causes of the problems, determined the aspects of the IM process that need optimization, and used prediction models and other quantitative research methods to optimize the company's IM.

3.4 Second-Order Exponential Smoothing Method

3.4.1 Basic Concept

Quantitative forecasting involves using historical data, statistical methods, and mathematical models to simulate the development patterns of the research subject to predict the future. Among these methods, the exponential smoothing method is frequently used. This method combines the advantages of both full-period averaging and moving averaging. Its characteristic lies in the fact that it still considers past data, but the influence of past data on the future gradually decreases; as historical data become more distant, they are assigned progressively smaller weights.

3.4.2 Main Algorithm

The basic formula for single exponential smoothing is: $St=\alpha yt+(1-\alpha)St-1$

From the above formula, it is evident that the size of the smoothing constant α determines the degree of influence of yt,St-1,and St. When α is high, the weight of the most recent actual demand (AD) increases, resulting in a more sensitive forecast. When α is low, the weight of the most recent ADdecreases, while the weight of earlier demand increases, leading to a less sensitive forecast result.

The formula for second-order exponential smoothing is: $S^{t(2)}=\alpha S^{t(1)}+(1-\alpha)S^{t-1(2)}$

The mathematical model for second-order exponential smoothing prediction is: $Y^{t+T}=\alpha^{t}+\beta^{t}\cdot T$

$\alpha_t=2S_t^{(1)}-S_t^{(2)}$

In exponential smoothing, the key to successful prediction is the selection of the smoothing constant α . A larger α value means a greater weight for new data and a smaller weight for the original prediction. Conversely, a smaller α value means a smaller weight for new data and a greater weight for the original prediction. Typically, α can be selected according to the rules shown in Table 1. In practice, various values of α are often tried, compared, and analyzed to select the one with the highest forecasting accuracy. An important metric for evaluating forecasting accuracy is the product demand forecast accuracy (Forecast Accuracy).

Table 1 Time Series Characteristics and Selection of α Values

Time Series Characteristics	α Value
Stable, level changes	0.1-0.3
Large changes in long-term trend	0.3-0.5
Obvious decline	0.6-0.8

The calculation formula for forecast accuracy (FAFA) is as follows:

$FA=1-\sigma_{i=1}^{n}|Ai-Fi|\times 100\%$

$\sigma_{i=1}^{n}Ai$

Here, Ai represents the actual sales quantity for period i; Fi represents the predicted quantity for period i, and n is the total number of periods being considered.

In practical applications, the most commonly used method to measure the forecast error is the mean absolute deviation (MAD).

The calculation formula for the mean absolute deviation (MAD) is as follows: $MAD=\sigma_{t=1}^{n}|At-Ft|$

Here, At represents the actual value for period t; Ft represents the forecast value (FV) for period t; and n is the total number of periods in the time series.

After using the prediction model to forecast future sales, it is essential to regularly monitor the difference between the forecast and actual demand, identify the reasons for any discrepancies, and adjust the prediction model accordingly to continuously improve its accuracy. This is where the tracking signal (TS) becomes useful.

The tracking signal is the ratio of the cumulative error in a time series between predictions and actuals to the mean absolute deviation (MAD) for the same period. The formula is as follows: $TS=\sigma_{t=1}^{n}(At-Ft)\ MADt$

Here, At represents the actual value for period t; Ft represents the FV for period t; n is the total number

of periods in the time series; and MADt is the mean absolute deviation at period t.

From the above formula, it can be seen that the tracking signal can be greater than zero or less than zero. The sign of the tracking signal relates to the relationship between the ADand the FV, which can be summarized (as shown in Table 2). If the tracking signal exceeds the upper or lower limit set, it indicates that the chosen forecasting method is not reasonable.

Table 2 Relationship Between Tracking Signal and AD and FV

Tracking Signal	Relationship Between AD and FV
>0	AD> FV
=0	AD= FV (ideal prediction model)
<0	AD< FV

IV. BPD IM STATUS

4.1 Case Introduction

BPD was established in 1996 and specializes in multimedia products like LCD TVs within the home appliance manufacturing sector. It is a high-tech company that integrates research and development, production, sales, and service. With strong support from the provincial government, BPD has become one of the few technology companies in the industry that produce a diverse range of audio and video digital products. Its product lineup includes Bluetooth headphones, LCD TVs, smart speakers, Bluetooth speakers, karaoke entertainment devices, mobile phones, amplifiers, and various 3C accessories. Its business encompasses the entire industry chain, including product customization, design and research and development, production, sales, and after-sales service. Since its inception, the company has grown to employ thousands of people and achieve annual sales in the billions RMB. As it maintains a high growth rate each year, BPD has always kept pace with the times. Today, the company has transitioned from a traditional offline sales model to an online e-commerce model.

4.2 Company Inventory Situation

Through in-depth interviews and field surveys with relevant departments, inventory data have been collected. In 2022, the direct logistics costs amounted to 89.7 million RMB. The specific structure of BPD's inventory costs is shown in Figure 1: From Figure 1, we can see that raw materials account for 41.4% of the direct inventory costs, while finished goods inventory accounts for 58.6%. Given the company's relatively stable supply chain and steady supply of raw materials, the inventory level can be maintained within a reasonably appropriate range. However, since finished goods make up a larger portion of the inventory costs, this study will focus on analyzing the finished goods inventory

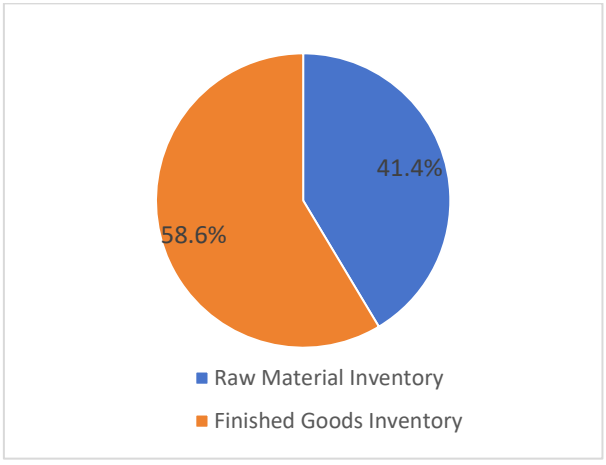

Figure 1 Structure of BPD's Inventory Cost Ratio

From the sales situation of BPD in Guangzhou in 2022, it can be seen that the main hot-selling product is the 4K Full Screen Himax HD LCD TV, with sales of this product line accounting for 38% of the main business revenue. To respond more quickly to the market, BPD stocks a large quantity of this product to meet customers' timely delivery needs, which occupies a significant portion of the warehouse inventory cost. The inventory cost

of the Guangzhou store in 2022 was 165 million RMB, with the inventory cost of Himax TV products being 73.35 million RMB, accounting for 44% of the company's inventory costs. Therefore, reducing the inventory cost of Himax LCD TVs could potentially save on inventory costs.

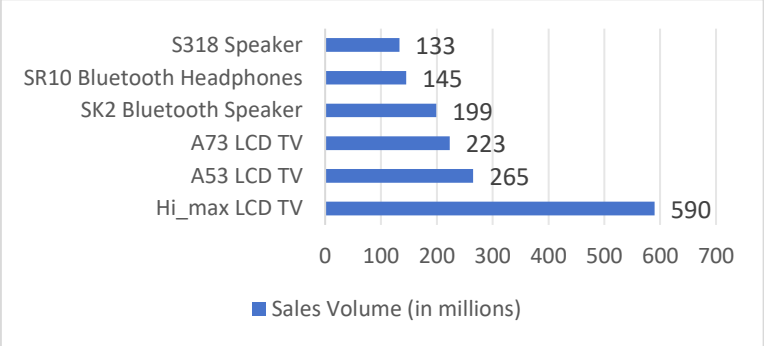

Figure 2 Sales Situation of BPD Products in 2022

4.3 Current Status of BPD's IM

The finished products of BPD mainly consist of high-value-for-money daily household appliances, which have a high degree of substitutability and a short product life cycle. To maintain and continuously increase its market share, and to meet customer requirements for products, BPD primarily adopts the Make-to-Forecast (MTF) production model. The specific process (as shown in Figure 3) is as follows:

(A) In the middle of each month, the sales department is responsible for entering N+1 to N+4 customer forecast data into the SAP system.

(B) The S&OP (Sales and Operations Planning) department downloads the forecast data from SAP, checks it, arranges meetings with the sales team to communicate the forecast data, makes necessary adjustments, and reloads the final version of the forecast back into the SAP system.

(C) The factory production planner adjusts the production plan in the PPDS (Production Planning and Detailed Scheduling) module of SAP based on the newly entered forecast data to ensure that inventory and new production orders align with the customer forecast data.

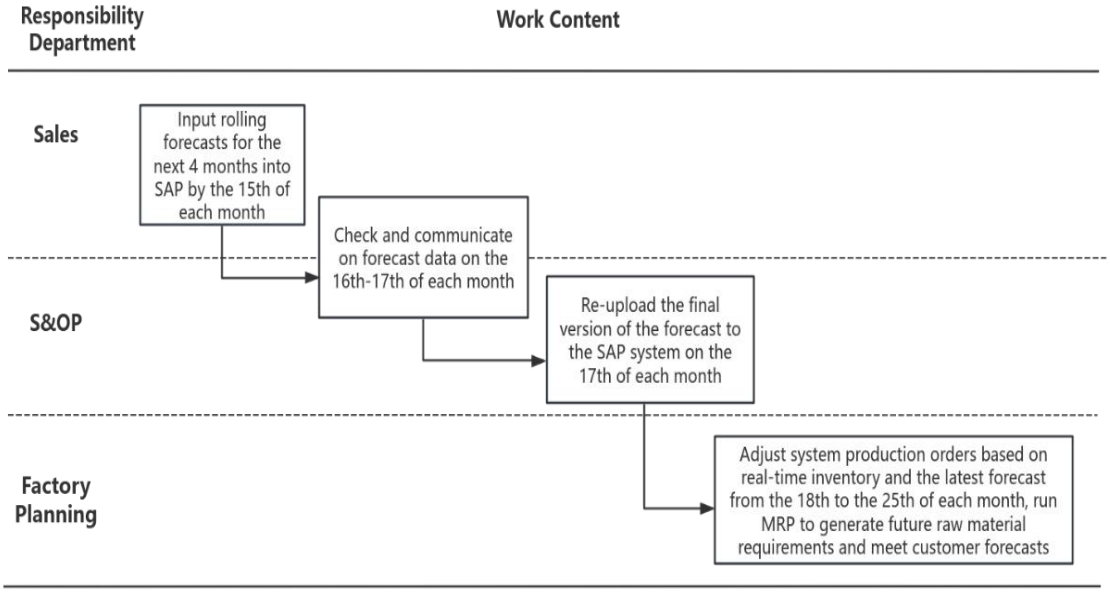

Figure 3 BPD Finished Goods Planning Process Diagram

BPD's forecasts are updated monthly, and production is planned monthly as well. Therefore, production in month N is primarily to meet the demand in month N+1. If customers provide forecasts for months N+1 to N+4 in month N, it is not possible to specify the exact time range for the demand in month N+1, such as the beginning or end of the month. When the demand for a product is high, customers often start to adjust their production pace

to control inventory levels. Customer orders are typically forwarded to the Customer Service Representative (CSR) one or two days in advance. The production planner adjusts the next month's (N) production plan based on the new forecast input in this manner, taking into account the forecasts for months N+1 and N+2. The production plans for months N and N+1 are mainly adjusted according to the production plan for month N+1 and immediately leave room. This is mainly to make the customer forecast for month N+2 match the production plan for month N+1.

4.4 IM Issues

4.4.1 Traditional Forecasting Methods

BPD's current forecasting method is primarily a traditional qualitative approach. Company production managers and relevant personnel base their forecasting opinions on past production experience. They combine historical production and sales data with recent quarter or half-year actual production data (including capacity, supply capability, sales volume, inventory, etc.) and conduct analysis and calculations to form a material demand plan for procurement actions. As an example, using Table 3, given the sales forecast and actual sales data, we can calculate the absolute difference between actual sales and forecasts for each product, and thus further derive their forecast accuracy rates.

Table 3 TV Forecast Accuracy Rates

Month	Rates %	Month	Rates %
2021.1	41	2022.1	28
2021.2	33	2022.2	29
2021.3	30	2022.3	31
2021.4	37	2022.4	12
2021.5	12	2022.5	34
2021.6	25	2022.6	22
2021.7	50	2022.7	45
2021.8	26	2022.8	52
2021.9	12	2022.9	20
2021.10	27	2022.10	15
2021.11	47	2021.11	24
2021.12	35	2021.12	37

In reality, the annual forecast accuracy rate for Himax LCD TVs exhibits significant volatility. For instance in August, the forecast accuracy rate tends to show a regular decline. The overall annual forecast accuracy rate is below the target value, indicating considerable room for improvement.

BPD primarily relies on qualitative forecasting, a method that is highly subjective and does not guarantee accuracy or scientific rigor. Inaccurate demand forecasting is essentially an issue of information asymmetry. BPD invests substantial funds in product development and technological innovation but lacks sensitivity in responding to consumer demand, leading to information asymmetry. During the execution of procurement strategies, changes in front-end demand impact the supply chain, preventing it from effectively filtering and screening relevant information. Suppliers often face conflicting demands for different products with varying urgency, making it difficult to plan and operate efficiently. Additionally, suppliers encounter last-minute order increases or cancellations, such as fluctuating order quantities, which causes dissatisfaction with the company's procurement strategy and leads to increased inventory of raw materials and finished goods at the supplier level.

4.4.2 Severe Inventory Accumulation

In the first half of 2022, with the tightening of pandemic control measures, there was a period when the factories supporting production were shut down entirely, leading to an inability to provide normal supplies of TV peripheral equipment. Customers abandoned purchasing BPD's products because they couldn't enjoy complete services. However, BPD still adopted a relatively traditional IM model. Stores maintained a relatively high level of inventory for various products to avoid stockouts, resulting in a certain amount of merchandise being stranded

in store warehouses and logistics distribution centers, unable to be sold, causing severe inventory accumulation. The book value of BPD's inventory (millions) and its proportion for 2021-2022 are shown in the following Table 4:

Table 4 Book Value of BPD's Inventory (Millions)

Year	Value of Inventory	Proportion (%)
2021	824	46.78
2022	855	48.98

It can be seen that the book value of BPD's inventory as a proportion of the company's current assets has been increasing year by year. However, inventory is a type of asset with poor liquidity, posing potential risks to the company's cash flow and hindering the company's operational development. The detailed structure of the inventory (318 Speaker (IV1), SR10 Bluetooth Headphones (IV2), SK2 Bluetooth Speaker (IV3), A73 LCD TV(IV4), A53 LCD TV(IV5), Hi max LCD TV(IV6).) book value proportions for 2021-2022 is shown in the following Table 5:

Table 5 Composition of Inventory Book Value

Inventory	2021	2022
IV1	41%	51%
IV2	23%	24%
IV3	13%	14%
IV4	8%	6%
IV5	6%	4%
IV6	4%	2%

From Figure 4, it can be seen that due to the production shutdown, the total value of BPD's inventory rose, and the composition of the inventory book value tended towards TV series with higher production costs. In 2022, the proportion of TV series inventory values increased by 8% compared to the previous year, leading to severe inventory accumulation. Therefore, reducing inventory levels can address the issue of low inventory turnover and solve the problem of high inventory costs. In recent years, the impact of the pandemic has exacerbated inventory turnover delays and extended inventory turnover times due to business shutdowns. Taking the inventory turnover period of the finished product, Hi Max LCD TVs, as an example:

The formula for calculating Days on Hand (DOH) for finished goods is as follows: FG DOH = Sm × Cm+1÷ Fm+1

This indicator is typically used to calculate how many days the end-of-month inventory can supply the next month. To maintain inventory at a reasonable level and minimize operating costs, a high DOH alone is not sufficient. If the focus is on providing timely service and maintaining or improving customer satisfaction, a low DOH alone is also insufficient. However, since DOH is a very broad and vague concept, it must be considered in conjunction with other factors when measured in practice. The Days on Hand (DOH) for finished goods of BPD in 2021 and 2022 are shown in the following Table 6:

Table 6 BPD's Finished Goods DOH (Days) for 2021-2022

Month	2021	2022	Target
Jan	62.5	58.7	40.0
Feb	48.7	47.7	40.0
Mar	57.1	44.4	40.0
Apr	49.2	41.5	40.0
May	48.3	44.0	40.0
Jun	42.4	42.9	40.0
Jul	31.1	47.9	40.0
Aug	25.5	43.3	40.0

Table 6 BPD's Finished Goods DOH (Days) for 2021-2022(continue)

Month	2021	2022	Target
Sept	37.0	30.5	40.0
Oct	36.0	33.5	40.0
Nov	42.3	32.5	40.0
Dec	32.5	39.5	40.0
Annual	42.7	38.2	40.0

The data in Table 5 is transformed into Figure 4, showing that the overall level of BPD's finished goods DOH for the whole year is relatively high, with particularly high inventory levels in the first half of this year. In the second half of this year, especially in the fourth quarter, there was a sharp drop in DOH, indicating a potential shortage of inventory, and there is still significant room for improvement.

In terms of DOH, BPD's finished goods and raw materials fluctuate significantly throughout the year, with DOH being much higher than the target value in the first half of the year; however, after entering the second half of the year, especially in the fourth quarter, there is a sudden drop in DOH. This is closely related to fluctuations in customer expectations, as 90% of BPD's products are domestically produced. During the first few months of the year, which are typically the peak sales season for the television industry, customer expectations fluctuate greatly. ADis often much lower than forecasted, leading to an overreliance on customer forecasts during actual production planning and raw material procurement, resulting in a significant increase in finished goods and raw materials. With the arrival of the peak sales season for televisions in the second half of the year, because the actual purchase volume is sometimes greater than expected, and there are many additional orders and urgent orders during the peak season based on market reactions, the DOH is usually below the target value, making product supply very tight, which poses considerable challenges to timely delivery to customers.

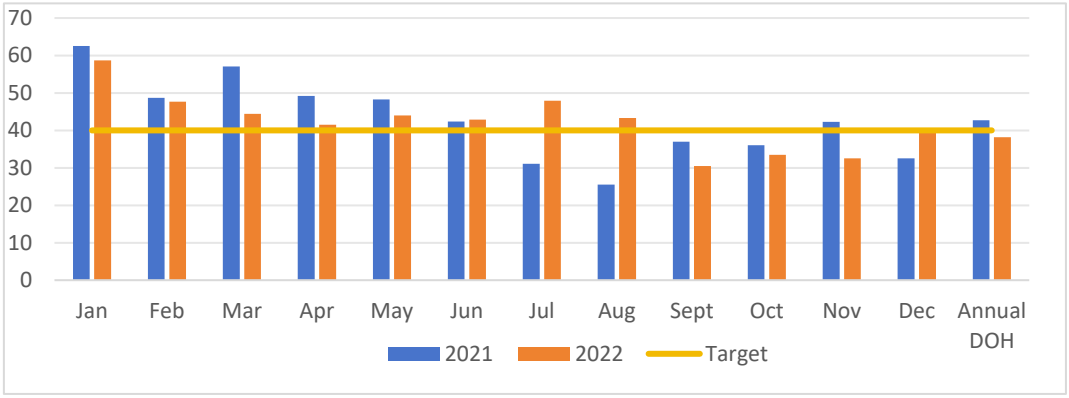

Figure 4 BPD's Finished Goods Days On Hand (DOH) for 2021/2022

4.4.3 Under forecasting Leading to Stockouts

The uncertainty in the home appliance market is influenced by various factors, including promotions, consumer responses, government stimulus policies, and competitor actions, among others, which can lead to significant fluctuations in demand forecasts. For instance, in the second half of 2022, major TV sales events on June 18th and Singles' Day, alongside a shift in pandemic control policies that favored the home appliance market's recovery, directly stimulated a substantial increase in appliance sales. However, due to underforecasting by BPD, the production department and distribution center faced supply shortages in certain months, resulting in stockouts at various store warehouses in Guangzhou.

V. BPD IM OPTIMIZATION SOLUTION AND IMPLEMENTATION

5.1 Design Principles

(A) Scientific Handling of Inventory Uncertainty: In the supply chain context, one of the key challenges in optimizing IM is dealing with inventory uncertainties. Given the current technological and theoretical limitations, these uncertainties cannot be easily resolved. It is essential to adopt a scientific approach and appropriate methods to manage these uncertainties effectively.

(B) Holistic View of IM Optimization: The focus should be not only on minimizing costs within the supply chain but also on maximizing the overall benefits. Through collaborative efforts among supply chain partners, we can strive for a comprehensive perspective that considers the best interests of the entire supply chain.

5.2 Specifics of the Optimization Plan

5.2.1 Scientific Use of Forecasting Methods

The forecasted sales volume for BPD's flagship product, Himax TV, in 2022 showed a significant discrepancy compared to the actual sales volume. Therefore, it is recommended to employ scientifically sound forecasting methods to enhance the accuracy of demand predictions. BPD's Monthly Sales Volume and Forecasted Volume in 2022 see Figure 5:

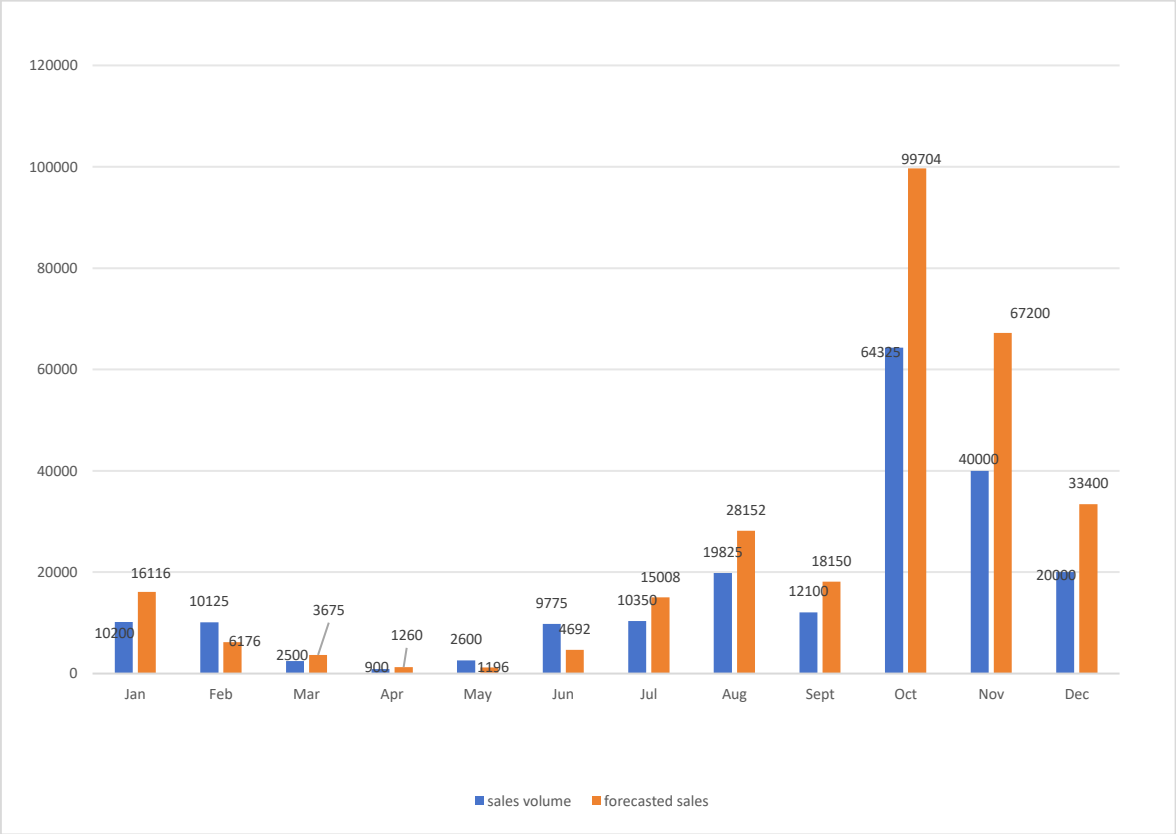

Figure 5 BPD's Monthly Sales Volume and Forecasted Volume in 2022

5.2.1 Scientific Use of Forecasting Methods

The predicted sales volume for BPD's Himax TV for the whole of 2022 showed a significant discrepancy compared to the actual sales volume. The single-month demand prediction accuracy rate dropped as low as 39%, and the difference between the single-month FV and actual sales volume reached up to 35,379 units. Thus, there is considerable room for improvement in the demand prediction aspect.

When significant fluctuations appear in the trend of the time series, this study employs the double exponential smoothing method for quantitative demand prediction. This involves conducting primary exponential smoothing followed by secondary exponential smoothing to establish a mathematical model for prediction. Therefore, primary exponential smoothing is performed first, in preparation for the secondary exponential smoothing.

Based on only 12 observations, the initial values are defined as the average of the first three months, i.e., F1=F4=(A1+A2+A3)/3=7,458. Combined with the demand variations from January to December, smoothing constants α(0.3,0.4,0.5) are selected respectively. According to the formula for first-order exponential smoothing in this paper, by selecting different values of α, it was found through testing that when α=0.53, the mean absolute deviation reached its minimum value (see Table 7).

Table 7 Quadratic Exponential Smoothing (α = 0.53)

Month	Actual Sales	F1	F2	β	Prediction	Absolute
Jan	10,200	7,458	8,641	6,275.21	-1,334.16	
Feb	10,125	8,911	8,785	9,038.3	143.08	4,941.05
Mar	2,050	9,555	9,193	9,916.55	408.14	9,181.38
Apr	900	5,577	7,276	3,877.88	-1,916.22	10,324.7
May	2,600	3,098	5,062	1,134.52	-2,214.44	1,961.66
Jun	9,775	2,834	3,881	1,787.11	-1,180.75	10,855
Jul	10,350	6,513	5,276	7,749.65	1,394.72	606.36
Aug	19,825	8,547	7,009	10,083.68	1,733.38	9,144.37
Sept	12,100	14,524	10,992	18,056.05	3,982.81	11,817.06
Oct	64,325	13,239	12,183	14,295.49	1,190.99	22,038.86
Nov	40,000	40,315	27,093	53,536.57	14,909.73	25,486.48
Dec	20,000	40,148	34,012	46,283.79	6,919.16	58,446.3
Code: Actual Sales (A); Primary Exponential Smoothing Value (F1); Secondary Exponential Smoothing Value (F2); Prediction Value (F^); Prediction Error (E); Absolute Prediction Error (|E|)				Total	39,181.71	112,664
				MAD (Mean Absolute		9,389
				TS (Tracking Signal)		4.42

Based on the primary exponential smoothing, the secondary smoothing was carried out according to the formulas in the text, yielding the prediction results of the secondary exponential smoothing. Using the formulas for the second-order exponential smoothing method in the text, the calculation with $\alpha = 0.53$ from the first-order exponential smoothing was continued. After testing, it was found that the Mean Absolute Deviation (MAD) decreased to 9,389, and the Tracking Signal (TS) remained at 4.42. Therefore, this algorithm can effectively improve the accuracy of BPD's demand prediction for the Himax LCD TV product, thereby optimizing the company's inventory structure (see Table 8).

Table 8 Analysis of Monitoring Indicators Under Various Demand Forecasting

Demand Forecasting Method	MAD	TS	Annual Prediction Accuracy (%)
Sales Forecast	15,381	NA	16.35
Simple Moving Average	12,510	4.47	42.33
Weighted Moving Average	11,782	3.48	43.57
Double Exponential Smoothing	9,389	4.42	44.29

Data analysis from the table indicates that the tracking signals (TS) for the three demand forecasting methods are all within 5, suggesting no significant bias. When comparing the mean absolute deviation (MAD) and prediction accuracy, we find that the double exponential smoothing method produces the lowest deviation and the highest prediction accuracy.

Therefore, for future demand forecasting at BPD, this study recommends using the double exponential smoothing prediction method. Additionally, considering various constraints, it is suggested that the planning department regularly review products with lower prediction accuracy and dynamically adjust the prediction model based on real-world conditions to achieve more accurate demand forecasts.

5.2.2 Transition to an Order-Oriented Production Model

The management of BPD focuses more on managing sales performance rather than recognizing the critical role of IM in overall business operations. Neglecting demand forecasting has resulted in consistently high inventory levels at BPD, leading to increased IM costs. This has also left the inventory structure in an unhealthy state, ultimately affecting timely delivery to customers (Dec Figure 6).

Figure 6 BPD's Sales Volume of the Same Period Dec 2022

For example, in January 2022, it can be seen that the sales volume of the same period last year fluctuated significantly, with a difference of 5,263 units in just one month. BPD has relevant departments that overly depend on information reports from the sales department, thus overlooking the relevance of timeliness and other market factors. This demonstrates that BPD's sales-oriented management approach significantly impacts the accuracy of demand forecasting. Therefore, improvements can be made to the MTO (Make-to-Order) management and processes. The specific optimization process is illustrated in Figure 7:

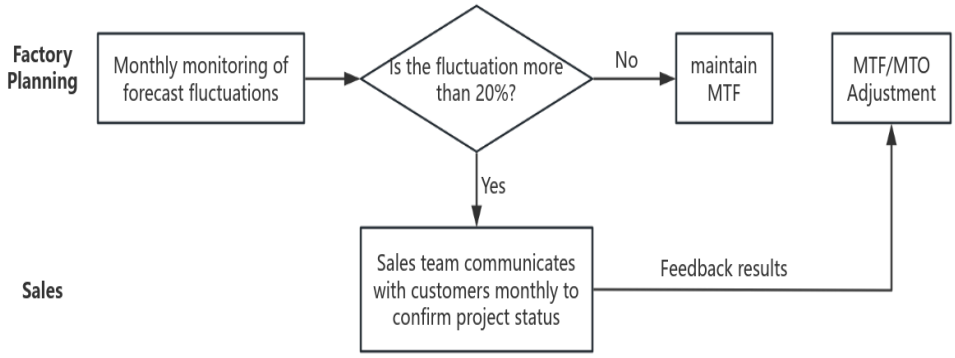

Figure 7 MTO/MTF Optimization Process

First, after the factory planner receives updated sales forecasts each month, they conduct a volatility analysis (focusing on the part where the forecast declines). If the volatility is below 20%, then MTF (Make-to-Forecast) can continue unchanged; if the volatility exceeds 20%, all abnormal lists must be promptly compiled and sent to the sales team. Secondly, it is recommended that the sales team hold regular meetings with customers each month to discuss project status, including the list of abnormal forecast fluctuations reported by the factory planner. Finally, the sales team will convert the latest project information collected from customers into MTF/MTO feedback to the factory planner for timely adjustments.

5.2.3 Strengthen Knowledge Training for Supply Chain Department Employees

In BPD, employees responsible for inventory control primarily include planners, buyers, and warehouse keepers. Most planners and buyers have a college degree or above, meeting the requirements for their positions, whereas the quality of warehouse keepers is relatively lower. First, the company's management should place greater emphasis on the position of warehouse keepers, recognizing the crucial role they play in IM. The position of warehouse keeper should be classified as a key position in the company's operations, and the pay and status of warehouse keepers should be improved. The company should establish stringent requirements for warehouse keepers concerning their skills, abilities, and physical health, and recruit qualified personnel through open recruitment. After recruitment, comprehensive training on warehouse management should be provided to all warehouse keepers to ensure they can master the fundamental theories and skills of warehouse management, as well as knowledge of production technology, materials, and goods, thereby enhancing their professional level.

To improve professional standards, the supply chain department must maintain training for its employees on IM and SCM, divided into at least three parts: new employee orientation, standard operating procedure (SOP) internal review, and learning group sessions.

(A) The new employee orientation phase involves learning the SOP and pairing new employees with

experienced ones. New employees work under the guidance of experienced employees to become familiar with all aspects of IM and all operational procedures.

(B) The SOP internal review phase involves internal reviews to continuously improve operational procedures while deepening the IM knowledge of SCM department employees.

(C) The learning group sessions primarily consist of specialized training and experience sharing, where senior employees provide in-depth introductions to the logic behind IM processes and parameters, the management tools used, etc., and the head of the SCM department introduces the logic behind inventory-related indicators, industry trends, etc., including some experience sharing and discussion sessions.

5.3 IM Optimization Implementation Guarantee

5.3.1 Optimize Existing IM System

BPD's traditional inventory system included separate systems for ordering, receiving, transferring, and returning goods, as well as product sales reporting. To check the real-time inventory of a product, one needed to query the incoming, returned, transferred, and sold quantities for the day, and then combine these with the initial inventory to calculate the total. The newly upgraded IM system consolidates these previously complex systems into a single, integrated platform. Tasks such as receiving goods, returning goods, transferring goods between stores, checking real-time inventory levels, and placing orders, which used to require separate operations, are now integrated features of the system. This streamlined system makes daily inventory maintenance more efficient and convenient.

5.3.2 Gradually Deepen Information Management

Enterprise information construction is a process in which businesses enhance the development and utilization of information resources, leveraging advanced technologies like computers and networks, to continuously improve the efficiency and effectiveness of production, operations, management, and decision-making, thereby enhancing the economic viability and competitiveness of the enterprise. For inventory optimization and SCM, information construction is particularly significant. Firstly, by creating batch input/output interfaces corresponding to the ERP system, the maintenance of material parameters, forecasting, and order placement can be performed through batch entry via reports, improving the efficiency of system maintenance. Secondly, standardizing the format of inventory reports and enabling one-click creation of required inventory reports improves the efficiency of inventory managers' work. Finally, storing data through cloud storage facilitates simultaneous multi-user access, reduces duplicate work, and improves work efficiency.

VI. CONCLUSION

Optimizing IM is a critical component of logistics management, particularly in the technology manufacturing sector. Companies that refine their IM practices can reap benefits such as increased efficiency, profitability, and customer satisfaction. By implementing the proposed solutions, a television manufacturing company can achieve a balance between minimizing holding costs and effectively meeting customer demand. In summary, this study focuses on BPD's finished goods inventory, using relevant IM theories and knowledge to analyze the challenges faced in the company's IM and offers targeted improvement strategies. The successful implementation of these strategies will contribute to the effective management of BPD's inventory, improve the company's operational efficiency, and enhance its market competitiveness.

In theoretical terms: This study optimizes the mathematical model for demand forecasting, building on existing mature IM theories and combining them with the characteristics of the technology industry and market rules to propose inventory optimization solutions suitable for the home appliance manufacturing industry.

In practical terms: In the highly competitive technology market, market uncertainty is increasing, and companies may find that temporarily stored inventory becomes long-term due to poor product sales or product redesign. Accurate demand forecasting to reduce inventory can lower operational costs and enhance BPD's market competitiveness in the technology industry. High-tech enterprises emphasize the responsiveness and flexibility of the supply chain in their competitive models. Due to market uncertainties, it is difficult for various departments within high-tech enterprises to make accurate judgments and forecasts about consumer demand types, service levels, and market growth rates. Therefore, optimizing the IM model benefits effective connections and collaboration between upstream and downstream entities, allowing all links in the industrial chain to gather and interact flexibly and efficiently.

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