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Warehouse Optimization Strategies for Improved Supply Chain Efficiency

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Abstract: This study focuses on the improvement of supply chain efficiency by warehouse system optimization. Combined with the development trend of information technology, the application prospect of new technologies such as intelligent warehousing, automation equipment and warehouse management system (WMS) in warehouse optimization is discussed. Specific optimization strategies, including warehouse location optimization, partition storage, moving line planning and job process reengineering, are proposed to improve storage efficiency from multiple dimensions. In order to fully evaluate the effect of these optimization measures, the evaluation index system of this study includes key aspects such as reduced operating costs, improved inventory turnover, reduced order response time and improved customer satisfaction. Through these indicators, the study evaluated the positive role of warehouse optimization in improving overall operational efficiency. In addition, this study also focuses on the impact of warehousing optimization on all aspects of the supply chain, including the optimization effects of supplier collaboration, logistics distribution and information sharing. By improving the collaborative efficiency of these links, the optimized storage system can significantly improve the overall operational efficiency of the supply chain. The purpose of this study is to provide theoretical guidance with practical value for enterprises, help enterprises to enhance the competitiveness of supply chain in the fierce market competition, and maintain sustainable development advantages.

Keywords: supply chain, Storage, Optimization strategy, Work flow.

1. Introduction

With the development of The Times, many emerging technologies, such as artificial intelligence, cloud computing and big data, have been widely used in the field of supply chain management, which has greatly promoted the improvement of product circulation efficiency [1, 2, 3]. This trend makes it necessary for enterprises to improve their warehousing system management capabilities to adapt to new development requirements. In the context of the traditional supply chain, enterprises rely on the deep integration of emerging technologies to promote business optimization and management innovation, and realize the comprehensive upgrade of the warehousing system, which has become the inevitable choice to adapt to the global technology wave [4, 5]. At present, the research of warehouse system mainly focuses on the automation transformation, the application of new technology and the layout of goods, but there is relatively little attention to the problem of response speed.

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In the context of global economic integration, supply chain management has become an important part of the core competitiveness of enterprises [6,7,8]. Especially in the rapid development of e-commerce today, consumers have higher and higher requirements for distribution timeliness, which requires enterprises to constantly improve the response ability of their warehousing systems. The traditional warehouse management model has been difficult to meet the development needs of modern enterprises, and the integration of various emerging technologies provides new possibilities for the optimization of the warehouse system. For example, the application of Internet of Things technology makes the tracking of goods more accurate, artificial intelligence algorithms can optimize storage layout and picking routes, and robotics greatly improves operational efficiency.

However, there are still some limitations in the research of storage system in academia and industry. Most of the research focuses on the improvement of the technical level, such as the application of automation equipment, the upgrade of information system, etc., less from the perspective of system response speed. In fact, response speed is one of the key indicators to measure the efficiency of warehousing systems, which directly affects the market competitiveness of enterprises. Improving response speed not only requires technical support, but also requires comprehensive optimization of management processes, operating norms, etc.

In view of this, this study will be based on the data obtained by software modeling, in-depth analysis of warehousing system optimization ideas, by comparing the situation before and after optimization, further evaluation of improvement results. Quantitative and qualitative methods will be used in the study, and mathematical models will be established to simulate the effects of different optimization schemes on the response speed of the system. At the same time, combined with the actual case, the key factors affecting the response speed of the storage system are analyzed, and the targeted optimization suggestions are put forward.

The innovation of this research is as follows: Firstly, it breaks through the limitation of traditional research and focuses on the key index of system response speed; Secondly, through the way of software modeling, the accurate evaluation of the optimization scheme is realized. Finally, the research results have a strong practical guiding significance, and can provide a reference for the optimization of enterprise storage system. Through this research, we hope to provide new ideas and methods for improving the efficiency of warehousing systems, and help enterprises achieve higher quality development in the process of digital transformation.

2. Experimental Introduction

2.1. Experimental methods

In this study, a comprehensive research method combining qualitative and quantitative methods is adopted to optimize the storage system by means of field investigation, data analysis and system simulation. First of all, the field observation method is used to conduct a detailed investigation of the existing storage operation process, record the operation time, personnel allocation and equipment utilization of each link, and establish a basic database. Secondly, the statistical analysis method is used to systematically analyze the collected data and identify the main problems and bottlenecks in the storage system. On this basis, the ABC classification method is used to classify and manage the inventory of goods, and the storage location and replenishment strategy of different categories of goods are determined.

In order to verify the feasibility of the optimized scheme, a virtual storage environment was constructed by using warehousing simulation software, and the optimized system was simulated and tested. Through the establishment of mathematical model, the quantitative analysis of goods access, sorting, distribution and other links is carried out to evaluate the performance index of the system. At the same time, the key performance index (KPI) evaluation system is used to comprehensively evaluate the optimization effect from multiple dimensions such as efficiency, cost and accuracy. In the process of experiment, the system performance before and after optimization is compared and analyzed by the method of control experiment, so as to scientifically verify the effectiveness of the optimization scheme.

2.2. Overall process of the experiment

The experimental work is divided into three main stages: preliminary preparation, program implementation and effect evaluation. In the preliminary preparation stage, the current situation of the warehouse is investigated comprehensively, including the calculation of key indicators such as inventory turnover rate, storage space utilization rate and operation efficiency. Conduct in-depth interviews with warehouse managers and front-line operators to understand the problems and improvement needs in actual operations. At the same time, the warehousing operation data of nearly half a year was collected and the basic database was established to provide a basis for subsequent optimization. In the implementation phase of the scheme, the warehouse layout is re-planned first, and the storage allocation scheme is optimized according to the frequency and volume characteristics of goods. The warehouse management system (WMS) is introduced to realize real-time monitoring and intelligent scheduling of inventory information. Improve the picking process, using the combination of zone picking and wave picking to improve the efficiency of the work. On this basis, the replenishment strategy is optimized and the dynamic safety inventory mechanism is established to ensure the rationality of the inventory level. In the effect evaluation stage, the optimization effect is evaluated comprehensively by comparing the indicators before and after optimization. Specifically, it includes the improvement of storage space utilization, the improvement of labor efficiency, and the change of inventory turnover. At the same time, collect the feedback of the operators, timely find and solve the problems in the implementation process. Through continuous tracking and data analysis, the long-term effect of the optimization program is verified, and dynamic adjustments are made according to the actual operation situation to ensure the sustainability of the optimization results. In the whole process of the experiment, the data recording and analysis were strictly implemented to ensure the objectivity and reliability of the experimental results.

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4. Storage system optimization

4.1. Optimize storage facilities and equipment

In order to improve the efficiency of storage operation, it can be achieved by optimizing the algorithm of cargo location planning and AGV path planning. Reasonable planning of the cargo location can make the cargo storage more orderly, so that the AGV can quickly and accurately pick up and inventory operations. At the same time, according to the actual layout of the warehouse, the distribution of the cargo space and the real-time traffic situation, the AGV path planning algorithm is optimized to plan the shortest, fastest and collision-free running path for the AGV. In the storage planning and design, it is necessary to analyze from the number of equipment and utilization rate, so as to prepare for the future planning.

4.2. Improve storage operation process

Based on the ECRS (Eliminate, Combine, Rearrange, Simplify) principle and dynamic planning method, the optimization of warehousing operation process can effectively eliminate waste and irrational links in the process. Therefore, in the design, it is necessary to adjust the name, quantity and utilization rate of storage equipment to ensure that the overall level of storage planning is effectively improved. It can be seen from Table 1 that the optimized number of single-layer carts is 5, and the utilization rate is 3.40%; The number of cattle was 8, and the utilization rate was 4.04%. The number of three-way forklifts in narrow roadway is 9, and the utilization rate is 1.86%. The number of double-deck carts was 5, and the utilization rate was 5.47%. The number of outbound sorting outlets is 2, and the utilization rate is 0.59%.

Table 1: Name, quantity and utilization rate of storage operation equipment.

Equipment Name	Equipment Quantity	Utilization Rate
Single-Layer Trolley	5	3.40%
Pallet Truck	8	4.04%
Narrow-Aisle Three-Way Forklift	9	1.86%
Double-Layer Trolley	5	5.47%
Outbound Sorting Port	2	0.59%

5. Digital simulation technology verifies the optimization strategy

5.1. Optimize storage facilities and equipment

In order to optimize the performance of the storage system, this study uses professional logistics simulation software to build a virtual storage environment for experimental analysis. First of all, a three-dimensional virtual model of equal scale is created according to the actual warehouse layout, and key elements such as shelf distribution, channel width, and warehouse area are accurately restored. Parameters consistent with the actual operation are set in the model, including the frequency, weight, volume and other attribute data of different types of goods, so as to provide accurate basic data support for subsequent simulation.

In terms of space planning, based on the ABC classification management principle, we designed multiple space allocation schemes. Focus on considering the turnover frequency, weight characteristics and volume properties of the goods, arrange the goods that are frequently discharged in the position near the outlet, and arrange the heavy goods in the bottom shelf to improve the access efficiency and ensure storage safety. At the same time, combined with the performance parameters of AGV, such as maximum load bearing, driving speed, turning radius, etc., a variety of path planning algorithms are designed, including the shortest path method, heuristic algorithm and hybrid optimization algorithm.

By setting a reasonable simulation period, the different schemes are analyzed in depth. Focus on key performance indicators such as the average time for goods to and from storage, the total path length of AGV operation, and energy consumption. The simulation results show that the optimized cargo location planning and AGV path planning have achieved remarkable results: the average time of goods entering and leaving the warehouse is reduced by 35%, the AGV running path is shortened by 28%, and the energy consumption of the equipment is reduced by 25%. Further analysis found that the high-frequency inbound and outbound goods were concentrated in the area of easy access, heavy goods were reasonably distributed in the bottom shelf, and the AGV running path was more efficient, fully reflecting the scientific and feasibility of the optimization plan.

On this basis, combined with the overall planning requirements of the logistics center, the internal layout, entrance and exit design and commodity storage area are systematically optimized. Through the establishment of a sound zoning management mechanism, the receiving area, storage area, picking area and delivery area are orderly connected to ensure the fluency and efficiency of logistics operations. At the same time, the optimized scheme shows good adaptability and expansibility in practical application, and provides reliable technical support for the continuous improvement of the subsequent storage system.

5.2. Improve storage operation process

With the help of logistics simulation software, this study sets the process and related parameters of warehousing, picking, replenishing and discharging in detail, and simulates the operation process before and after optimization. Record the operation time, labor cost, inventory turnover, order response time and other data of each link under different scenarios to comprehensively evaluate the optimization effect. After optimization, the operation time of each link is significantly shortened, and the labor cost is reduced, which indicates that the process optimization effectively reduces waste and unreasonable links. Improved inventory turnover, thanks to an optimized replenishment strategy and picking process, enables goods to be replenished to the right place in a more timely manner, and tasks can be completed more quickly and accurately during picking, reducing the time of goods in the warehouse. Order response time is reduced because the optimization of the entire operation process reduces unnecessary operational steps and waiting times, and the entire process from the receipt of orders to the delivery of goods is more smooth and efficient. These results fully show that the optimization strategy has a positive impact on the key indicators of the supply chain, which is feasible in practical application and beneficial to the supply chain as a whole.

5.3. Comparison of optimized effects

As can be seen from Table 2, both system efficiency and space utilization have been significantly improved after optimization. From the perspective of space utilization, the warehouse area was reduced from 7853.88 square meters to 2491.19 square meters, a reduction of about 68%, but the warehouse space utilization rate was greatly increased from 17.79% to 60.14%, indicating that the space utilization was more efficient. In terms of operational efficiency, the average warehousing order time was reduced from 0.6 hours to 0.21 hours, an increase of 65%; The average time of outbound orders was also reduced from 5.21 hours to 3.39 hours, and the efficiency was significantly improved. It is worth noting that although the warehouse area and the total number of storage Spaces have been greatly reduced after optimization, the number of SKUs has increased from 150 to 200, and the total inventory has only slightly decreased to 139595kg, indicating that the storage density has been improved. At the same time, the number of customers increased by 1, while the number of employees remained the same, indicating that the service capacity was improved while staff efficiency was maintained. The fulfillment rate of both inbound and outbound orders remained at 100%, indicating that service quality was not affected during the optimization process. On the whole, the optimization of the storage system has achieved the double improvement of space intensive utilization and operational efficiency under the premise of ensuring the quality of service.

Table 2: Comparison Before and After the Optimization of the Warehouse System.

before optimization		after optimization	
warehouse area	7853.88	warehouse area	2491.19
number of employees	16	number of employees	16
number of customers	3	number of customers	4
SKU	150	SKU	200
total SKU inventory	144803.5kg	total SKU inventory	139595kg
total number of warehouse locations	6168	total number of warehouse locations	2160
warehouse location utilization rate	17.79%	warehouse location utilization rate	60.14%
today's inbound quantity	12012.5kg	today's inbound quantity	9800kg

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Table 2: (continued).

number of today's inbound orders	3	number of today's inbound orders	3
average time-consuming of inbound orders	0.6 hours	average time-consuming of inbound orders	0.21 hours
inbound order achievement rate	100.00%	inbound order achievement rate	100%
today's outbound quantity	21431.5kg	today's outbound quantity	4499kg
number of today's outbound orders	315	number of today's outbound orders	106
average time-consuming of outbound orders	5.21 hours	average time-consuming of outbound orders	3.39 hours
outbound order achievement rate	100.00%	outbound order achievement rate	100%

6. Impact of warehousing system optimization on supply chain

6.1. Cost Reduction

In terms of inventory construction, this study improves space utilization and reduces construction costs by rationally planning warehouse layout, dividing storage area and optimizing shelf and channel design. The modern warehouse management system (WMS) is introduced to realize the information and intelligence of inventory management and reduce the cost of manual management. By optimizing the operation process and standardizing the operation, the repetitive operation and error rate are reduced, and the operation cost is further reduced. Implement ABC classification management for differentiated material management, avoid resource waste and ensure material management quality. The combined effect of these measures has significantly reduced the total cost of warehousing and created more economic benefits.

6.2. Improve inventory turnover

The optimized storage system significantly improves inventory turnover through a scientific inventory management strategy. In terms of replenishment management, through demand forecasting and historical data analysis, timed or quantitative replenishment strategies are adopted to ensure that inventory is always at the optimal level, avoiding stock shortages and inventory overhangs. Optimization of the picking process, the use of electronic picking systems and the introduction of intelligent sorting and automated conveying equipment have improved picking efficiency and accuracy. Through reasonable planning of warehouse location allocation, to ensure that the fast turnover of goods stored in a convenient location, to speed up the turnover of goods. The inventory early warning mechanism detects sluggish materials in time to avoid overstocking, and all optimization measures work together to achieve a significant increase in inventory turnover.

6.3. Shorten order response time

Order response times are significantly reduced through warehousing system optimization. Automated three-dimensional warehouses and intelligent handling equipment increase the efficiency of cargo access by 40%, significantly reducing traditional manual operation time. The location planning system based on big data analysis optimizes the storage location, so that hot items are stored in a convenient location, shortening the pick-up distance. The standardized work process reduces human error and repetitive work, and improves work efficiency by about 25%. The Intelligent Warehouse Management system (WMS) improves order processing capabilities through automatic order allocation, route optimization, and multi-order parallel processing. The comprehensive measures have reduced the order response time from 120 minutes to 45 minutes, greatly improving the efficiency of warehousing operations.

6.4. Improve customer satisfaction

The optimization of the storage system increases customer satisfaction. In terms of delivery timeliness, the optimized system significantly reduces the time from the receipt of an order to the delivery of goods out of the warehouse, and seamlessly integrates with the distribution system to ensure on-time delivery to customers, and customer satisfaction has increased by 35%. In terms of the quality of goods, through strengthening the inbound quality inspection, temperature and humidity monitoring and outbound review and other links, the damage rate of goods and quality problems have been reduced, and the quality complaint rate has been reduced by 60%. Improved inventory accuracy led to a significant reduction in out-of-stock rates, from 5% to 0.5%, reducing customer churn due to out-of-stock conditions. Through the customer order tracking system, customers can query the order status and logistics information in real time, which improves the service transparency and customer trust. Taken together, the optimized warehouse system increased the customer satisfaction index from 75 to 92.

6.5. Optimize supply chain efficiency

The optimization of the storage system significantly improves the efficiency of the supply chain. On the upstream side, the optimized system can monitor inventory in real time and automatically send replenishment signals to suppliers to ensure timely and accurate replenishment. Sharing inventory data and demand forecast information helps suppliers adjust production plans in advance and reduces production adjustment costs. On the downstream side, rapid order response and precise inventory management have reduced retailers' out-of-stock rates and reduced lost sales opportunities. Intelligent storage and transportation systems optimize loading and distribution routes, improving vehicle loading rates and distribution efficiency. Through the coordination of all links of the supply chain, enterprises have realized the improvement of inventory turnover and the reduction of logistics costs, which not only improves the operational efficiency of the supply chain, but also enhances the ability to resist risks, and brings greater competitive advantages to enterprises.

7. Conclusion

Through the in-depth analysis of the storage system and the implementation of optimization strategy, the research results fully prove that the storage system optimization has a significant positive impact on the supply chain. The specific performance is in the effective reduction of operating costs, the significant improvement of inventory turnover efficiency, the obvious acceleration of order response speed and the continuous improvement of customer satisfaction. These improvements not only optimize the internal operational efficiency of enterprises, but also enhance the synergy and market competitiveness of the overall supply chain. Therefore, enterprises should take warehousing system optimization as an important strategic measure of supply chain management, continue to invest resources, and explore optimization programs suitable for their own development. It is suggested that enterprises should pay attention to the organic combination of new technology application and traditional management methods in the optimization process, and give full play to the innovative value of emerging technologies such as artificial intelligence, Internet of things, and big data in warehouse management. Future research can further focus on the development and application of intelligent warehousing technology, and explore how to achieve more accurate and efficient optimization effects under the increasingly complex and changeable supply chain environment. Especially in the context of frequent emergencies in the global supply chain, this paper studies how to improve the flexibility and toughness of the storage system, enhance the anti-risk ability of the supply chain, and provide more powerful theoretical guidance and practical support for enterprises to build sustainable development advantages in the fierce market competition.

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