Investigation on Panel Material Picking Technology for Furniture in Automated Raw Material Warehouses

Yiting Niu and Xianqing Xiong *

The integrated development of the global economy has prompted the manufacturing industry of China to enter the era of intelligence, and manufacturing in the furniture manufacturing industry has gradually realized the transformation and upgrading from manual or semi-automation to automation and informatization. The traditional storage mode of receiving materials has been unable to coordinate and match the efficiency of its upstream supply and downstream processing. In order to coordinate production, reduce management costs, and achieve zero inventory, this paper integrates the common needs of the market, enterprises, actual production, and storage conditions. In addition, it designs a technical solution for the collection of sheet materials in furniture enterprises based on the environment foundation of automated three-dimensional warehouses. The research results show that the collation algorithm proposed in this study can reduce the amount of sheet material collated by 152 sheets, improve the pallet utilization rate by up to 21.6%, and increase the storage space utilization rate by up to 22.7%.

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Keywords: Panel furniture enterprise; Raw material bin; Collation scheme design

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INTRODUCTION

The traditional furniture industry is a passive enterprise, which has lower sensitivity to market trends and lower responsiveness to market changes (Xiong *et al.* 2021a). The business model of production before selling directly leads to the probability that raw materials, some in-process products, and finished products become long-term backlog inventory for the enterprise as slow-moving items. This increases the material management cost of the enterprise and becomes the primary risk source limiting the capital flow of the company (Zhang *et al.* 2021b; Xiong *et al.* 2021b).

Inventory management is the management and control of material resources at a safe and economically reasonable level in order to ensure the stable operation and business of a company. The following studies have been performed on inventory management in domestic and foreign studies: Yu (2019) analyzed the maximum influencing factors of raw material inventory through the ABC classification method based on the current situation of raw material inventory. They developed a reasonable method of purchasing, classification, and management by using the fuzzy random number theory. The results showed that the approach could effectively reduce the inventory level of raw materials and reduce the cost of enterprises in terms of material management. Chen *et al.* (2021) combined the multiple linear regression and grey theory model to form a Bayesian combination forecasting model to predict the optimization of raw material inventory for order cancellation with the goal of minimum management costs.

The experimental model was validated and analyzed with the actual data of the enterprise, and it can effectively reduce the inventory management cost of the enterprise for raw materials. Zhang (2013) used the ABC classification method combined with cov. analysis to reclassify and integrate the types of raw materials and optimize the management of raw materials inventory from both data and process aspects, which resulted in improving the efficiency of the inventory management department and optimizing the raw materials inventory structure. Shekari *et al.* (2020) designed a decentralized grid-based picking system based on a multipurpose GridHUB system for boredom processing, which improved the average throughput of the storage system by 14% to 20%, thus improving the results of throughput variation due to system congestion. Lakhwinder and Ravi (2016) validated the nonlinear customer demand forecasting method under a hierarchical supply chain structure with real data by using the discrete wavelet theory and artificial intelligence techniques, including an artificial neural network (ANN) and fuzzy inference systems based on adaptive networks, to control order amplification and bullwhip at each stage of the enterprise supply chain The method can control the order amplification and bullwhip effect at each stage of the supply chain. Thus it can control the net inventory and cost. By analyzing and summarizing the research results of scholars at home and abroad, it was not difficult to find that the research on inventory management primarily focuses on the raw material pool itself. In the field of panel furniture manufacturing, research related to collaborative production, planning, and receiving has not been involved.

In order to comply with the market development trend, the furniture manufacturing industry in China has gradually changed to the mode of sales before production (Zhu *et al.* 2019; 2021a). With the structural reform policy of "three removal, one reduction, and one compensation" as the development goal, the inventory management mode was changed to a combination of automation and information technology to achieve Zero-Inventory. The proper picking of materials constitutes the necessary conditions and prerequisites for raw material warehouses to realize all functions (Xu and Wu 2009; Xiong *et al.* 2020; Qin *et al.* 2021). The primary purpose is to realize the transfer of raw materials from the plate production department to the plate raw material warehouse, to provide the raw material warehouse with storable materials, and to realize the static storage function of the raw material warehouse. Furthermore, the purpose is to realize the dynamic self-regulation of the raw material warehouse and coordinate the upstream and downstream functions by reasonably controlling the time, period, and quantity of material collection. In a narrow sense, the material collection process, as the only factor affecting the inventory of sheet materials, indirectly becomes an important reason affecting the capital flow, inventory management, production cost of enterprises, *etc.* (Yang and Liao 2019; Zhu *et al.* 2020; Xiong *et al.* 2022).

Based on this, this paper analyzes the necessity of material collection management based on the above and downstream processes and specifically analyzes and designs the material application basis and key technologies. According to the production and actual storage status and requirements, the paper designs a material collection process, the specific calculation scheme of the quantity claimed, and a material collection sequence for panel furniture enterprises based on the application of automated three-dimensional warehouse and information technology. It aims to help customized home furnishing enterprises improve the automation and informatization of a raw material warehouse, realize the dynamic circulation and control of panels in a raw material warehouse, reduce the circulation time of panels in a raw material warehouse, reasonably coordinate the number of panels, realize the zero inventory of a raw material warehouse, and provide theoretical and practical data guidance.

CURRENT SITUATION OF PANEL MATERIAL PICKING OF FURNITURE ENTERPRISES

Through the actual investigation of panel furniture enterprises, *i.e.*, the traditional storage mode, they were primarily based on the production batch and according to the color of two kinds of material collection modes.

Among them, batch-based material collection is based on a single batch of all batches planned by the production demand, where each batch may include 1 to 6 kinds of color plates, and the quantity of each color plate may have some differences. The color-based material collection is based on the production demand; firstly, all batches are consolidated, then all batches are classified according to the color of the material, and the material is collected according to the color of the material.

Poor Coordination between Supply and Demand

In the traditional mode, the storage and management of sheet materials are too loosely associated with the production and processing departments, and the demand for automated three-dimensional raw material silos in the two processes is completely independent. In other words, the functionality of the panel material silos cannot be comprehensively applied (Zhang *et al*. 2020; Zhu *et al.* 2021b).

Poor Coordination of Production

For the panel production department, the functional demand for the automated raw material silo is primarily storage; for the plate processing department, the functional demand is primarily supply (Guo *et al.* 2020; Zhu and Wang 2021). The former requires the raw material bin to have sufficient storage space, while the latter requires sufficient inventory in the panel raw material warehouse. As such, the traditional collation mode cannot achieve coordination between the supply and demand quantities.

Low Utilization Rate of Storage Space

The automation and informatization degree of a panel raw material warehouse in the traditional furniture industry is low, and the utilization rate of vertical space in the storage area is extremely low (Zhen 2021). At the same time, the traditional picking mode, the number, and category of plate material picking integration is not high, which is conducive to later production and processing. As such, there may be a small number of materials of a certain kind, but they need to occupy separate spaces (Shao 2017).

Low Efficiency of Material Supply

The traditional method of receiving materials cannot be performed to accurately calculate the demand for plate materials for plate processing processes, according to the production efficiency of enterprises to achieve the storage of materials. This may cause downtime caused by the lack of the timely supplying of materials during the production and processing of enterprises, while increasing the frequency of storage in the automated warehouse, increasing the operating costs of equipment and time costs (Zhang *et al.* 2021a).

COMPOSITION AND MANAGEMENT OF WAREHOUSING

A warehouse refers to any form of place that can play a role in the storage and protection of materials, including buildings, containers, shelves, *etc*. Storage refers to the need and requirements for the standard, in a certain period of time, for the storage of materials for production or other activities for spare materials. For manufacturing enterprises, warehousing is the process of temporarily storing materials required for production or finished products needed by consumers in the warehouse, according to the specific needs of consumers, the market, and production, within a specified period of time and according to certain rules.

Based on the type of stored materials and their functional location, the warehouse can be divided into three types: raw material warehouses, semi-finished product warehouses, and finished product warehouses. For panel furniture enterprises, the inventory management of raw material warehouses is crucial. The primary reason is attributed to the factors that affect the personalization of the products of panel furniture enterprises, including the plates, hardware, shape, function, and modular design, *etc*. As the primary raw material for panel custom furniture, panels occupy the main vision of this study and are the primary factor affecting panel furniture diversity. Based on the structure and material characteristics of man-made panels, it is not difficult to find that panel finishing material is the primary factor in determining the diversity of panels, including the material, texture, color, and pattern of the finished material. The renewal of finished products primarily depends on the renewal of the raw material bin sheet material. The renewal frequency must be kept in sync in order to achieve the goal of a short delivery cycle for mass customization furniture (Wang and Zhang 2011).

RENOVATION DESIGN OF PANEL MATERIALS PICKING FOR PANEL FURNITURE

Through theoretical research combined with practical investigation, this paper proposes an automated and information-based raw material warehouse receiving process, which can coordinate the supply and demand relationship between plate production and processing. In addition, this can help solve a series of unreasonable inventory problems, *e.g.*, saturation, overstock, and understock, caused by unsynchronized information, and reasonably optimize the storage space.

The material receiving process can provide a detailed and reasonable production list for the plate production department, including the processing time, color, thickness, width, size, and quantity requirements of the material. This takes into account the production plan of the processing department, as well as the rush order, return order, and change order in the sales process as well as the replacement order and change order due to material damage and material loss in the production and logistics process. It coordinates the supply-demand relationship between panel production and the processing department.

Material management can ensure that the inventory of sheet materials in storage is in the best condition, and the frequency of materials in storage is approximately equal to the frequency of materials out of storage, so that the materials can be processed within the best shelf life, completely avoiding unnecessary costs caused by material quality problems.

Flow Design of Panel Material Picking

When the panel processing department has requirements for a panel, the warehouse manager needs to send the material request through the warehouse management system software system (WMS) of the automated three-dimensional raw material warehouse (as shown in Fig. 1). Then, the WMS system and enterprise ERP (enterprise resource planning) realize the sending and receiving of information through the information interaction and sharing function. When ERP receives the panel picking request sent by the WMS, the planner gets the material list, which needs to be collected and put back to the WMS system. At the same time, it gets the paper version *via* printing and transmits it to the warehouse manager, who transfers the material list according to the color and quantity of the material from the production department to the automated three-dimensional material warehouse in order. The warehousemen transfer the materials from the production department to the automatic three-dimensional raw material warehouse according to the color and quantity of the material list and complete a material claiming plan.

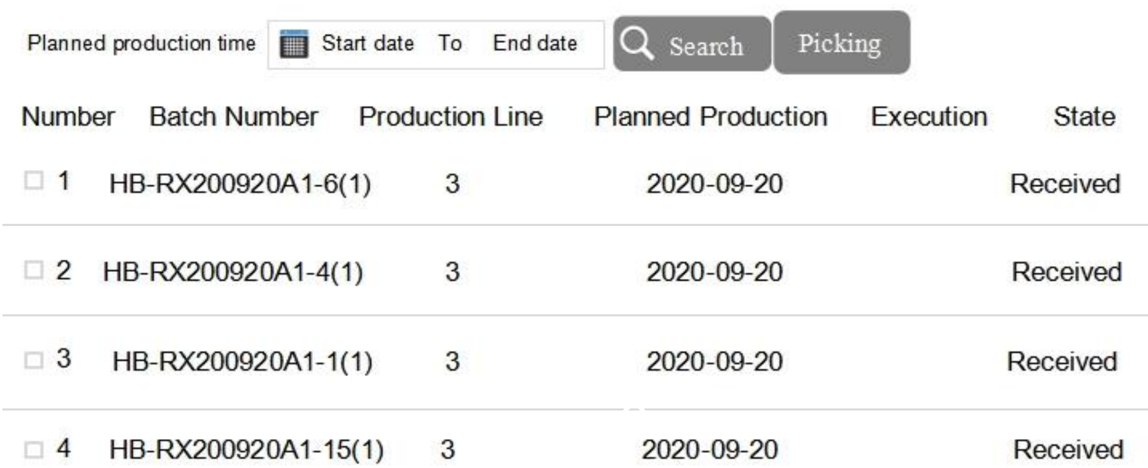

Fig. 1. The operation of panel picking planning (source: the authors, 2022)

Arithmetic Design of Panel Material Picking

Principle of arithmetic design

Panel picking requires comprehensive consideration of the production efficiency of the panel raw material, consumer order quantity, order cycle, stereo warehouse storage space, plate processing process cycle, equipment operation cost, labor cost, and other aspects. The picking plan primarily covers the total picking quantity, color type, and picking sequence of different colors (as shown in Fig. 2).

Specifically, the synchronization of the supply of the plate production processes and the workload of the equipment in the best processing state is based on the limitation of the plate capacity of the three-dimensional warehouse, the purpose of reducing the delivery cycle and the frequency of operation of the collection and storage equipment, the decision of the total number of batches and the type of colors of the single collection, taking into account the specific data of all batches to be collected, the inventory of plates in storage, the optimal stacking value of the individual bins in the three-dimensional warehouse, and finally the decision of the different patterns. The final decision is made on the total number of batches of different colors.

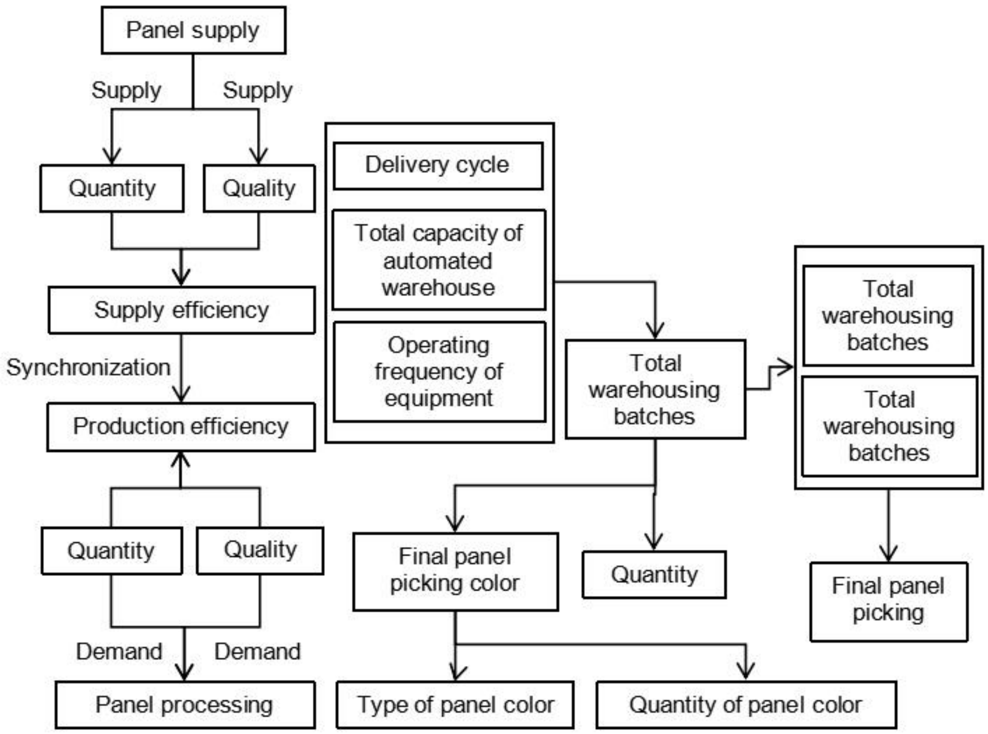

Fig. 2. Basis for panel picking (source: the authors, 2022)

Determination of parameters

The parameters related to the collation algorithm can be divided into three categories with reference to the data sources, *i.e.*, production data related parameters, product library related parameters, and the best stacking values of individual bins, with the following specific parameter settings.

Production data related parameters include the production date (S), the production batch (P), and the number of panels in demand (N), corresponding to a single color in a single production batch.

The parameters related to the product warehouse include the plate color type (Q), and the number of different plate colors in the warehouse (X).

The optimal stacking value (θ) of a single warehouse space is determined by the optimal bearing weight of a single warehouse space, the appearance size of the warehouse, the weight of individual sheets, and the overall dimensions of the sheets.

Calculation process of the quantity of panel material picking

According to the production date, the production related data is obtained. Corresponding to the panel color library, the production batch corresponding to the production order, and the production demand quantity of the panel of different colors are obtained. Corresponding to the panel color library, the number of panels of different colors in the library are obtained. From this, the warehousing demand of the panels of different colors is calculated. The optimal panel storage capacity of a single warehouse space is obtained, the final warehousing demand of panel of different colors is calculated, and the final picking quantity and total picking quantity of the panels of different colors is obtained. The calculation process is shown in Fig. 3.

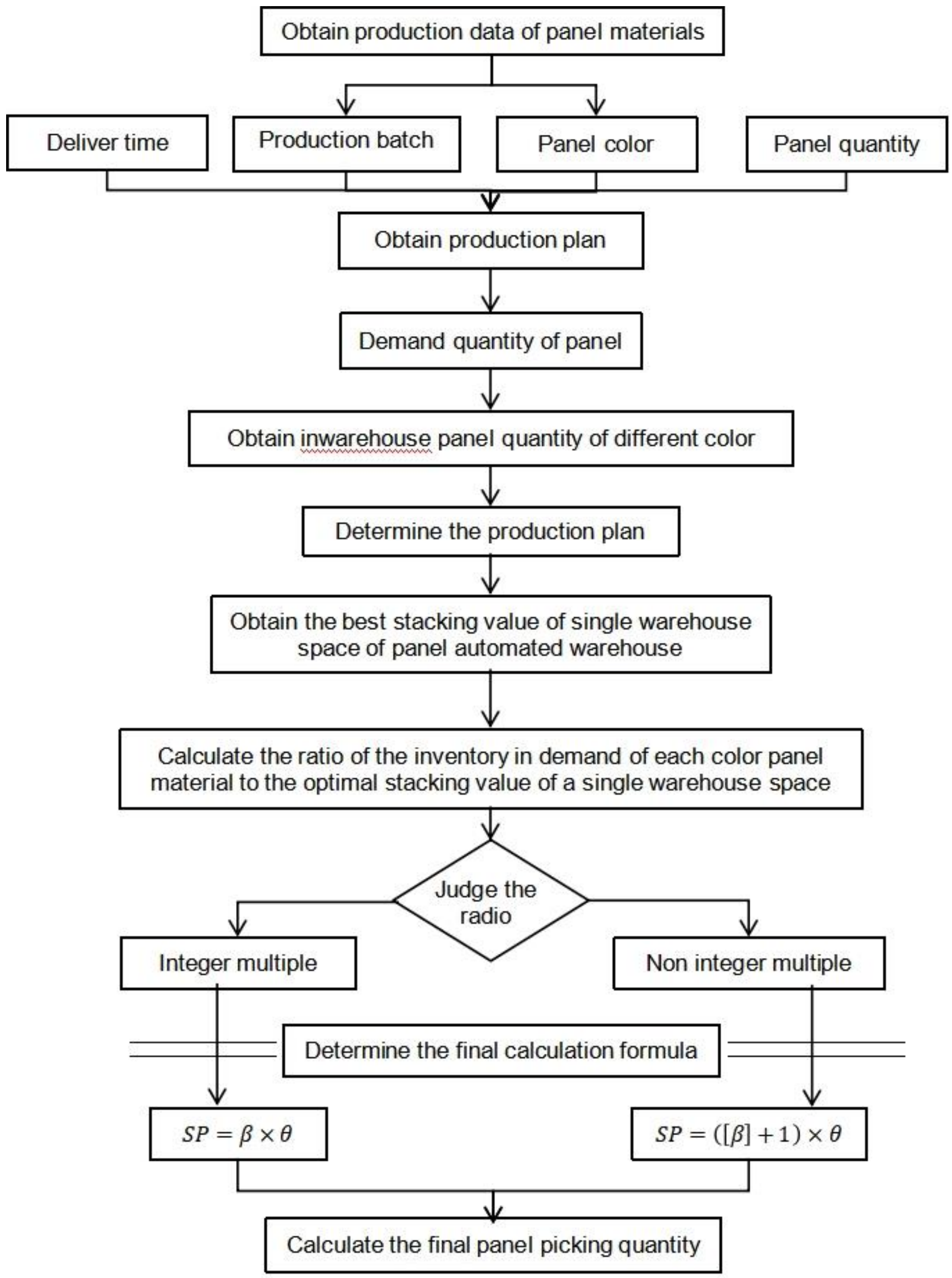

Fig. 3. Flow chart for calculating the quantity of panels (source: the authors, 2022)

The specific process for the calculations is as follows:

Calculation of production requirements

Firstly, the corresponding batches are coded and sorted according to the determined shipping date as $\{P_1, P_2, P_3 \cdots\cdots P_n\}$. Then, all the color types in the product library of the warehouse management system are coded and sorted as $\{Q_1, Q_2, Q_3 \cdots\cdots Q_m\}$. Finally, the production demand quantity of plates corresponding to all colors in a single production batch is coded and processed as $\{N_1, N_2, N_3 \cdots\cdots N_m\}$. Among them, N_j belongs to a non-negative integer including 0. Then, when the color is Q_j, the total production demand of the panel corresponding to the color in all batches can be expressed as Eq. 1,

$$S_{Qi=} = \sum_{j=1}^{m} N_j \quad (1)$$

Inbound demand calculation

The number of plates in storage corresponding to all the colors in the warehouse management system is coded as $\{X_1, X_2, X_3, \cdots\cdots X_m\}$; when the color is Q_j, the total quantity of the plates in storage demand corresponding to the color in all batches can be expressed as Eq. 2,

$$SP_{Qi} = S_{Qi} - X_j \quad (2)$$

Calculation of the final collateral volume

The ratio β between the incoming demand SP_{Qi} and the optimal stacking value (θ) of a single warehouse space can be expressed as Eq. 3:

$$\beta = \frac{SP_{Qi}}{\theta} \quad (3)$$

When it is a positive integer of β, the final quantity of material received for all batches of plates of color Q_j can be expressed as Eq. 4:

$$SP = \beta \times \theta \quad (4)$$

However, when it is a non-positive integer of β, the final picking quantity of panel with color Q_j in all batches can be expressed as Eq. 5,

$$SP = ([\beta] + 1) \times \theta \quad (5)$$

where $[\beta]$ represents the largest integer that does not exceed the real number β.

Design of panel material picking principles

The order of the receiving materials determines the order of the panel materials in the automated warehouse. This is done according to the material receiving algorithm to obtain the need to claim material details, the number of principles in accordance with the color of the plate materials for classification. The greater the material demand, the higher the demand of the production and processing process for this color. When the production and processing processes indicate a higher demand for a certain color, the color of the material in the processing of the warehouse will have a higher frequency than the other colors. The principle of nearby storage will be used for different colors of the plate for centralized storage, and a large number of colors will be used to minimize the frequency of operation of the automated three-dimensional warehouse, thus reducing the material in and out of the automated three-dimensional warehouse time.

CASE PRACTICE AND EFFECT ANALYSIS

Case Practice

In this paper, the data verification of the above collation scheme was carried out with the data of the plate production demand of the S custom furniture enterprise with a shipment date of July 27 as an example.

The panel production batches included in this production plan demand data are shown in Table 1.

The types of plate colors being produced by the company are shown in Table 2. The production demand for different color types in different production batches is shown in Table 3.

Table 1. The Batches of Panels (source: the authors, 2022)

Number	Batch number (Batch)			
1	RX200727A1-1(1)	RX200727A1-1(10)	RX200727A1-1(19)	RX200727A1-1(28)
2	RX200727A1-1(2)	RX200727A1-1(11)	RX200727A1-1(20)	RX200727A1-1(29)
3	RX200727A1-1(3)	RX200727A1-1(12)	RX200727A1-1(21)	RX200727A1-1(30)
4	RX200727A1-1(4)	RX200727A1-1(13)	RX200727A1-1(22)	RX200727A1-1(31)
5	RX200727A1-1(5)	RX200727A1-1(14)	RX200727A1-1(23)	RX200727A1-1(32)
6	RX200727A1-1(6)	RX200727A1-1(15)	RX200727A1-1(24)	RX200727A1-1(33)
7	RX200727A1-1(7)	RX200727A1-1(16)	RX200727A1-1(25)	RX200727A1-1(34)
8	RX200727A1-1(8)	RX200727A1-1(17)	RX200727A1-1(26)	RX200727A1-1(35)
9	RX200727A1-1(9)	RX200727A1-1(18)	RX200727A1-1(27)	RX200727A1-1(36)

Table 2. The Types of Panels (source: the authors, 2022)

Number	1	2	3	4	5
Color	PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S

The total production demand for different color plates in all batches is calculated according to Eq. 1, as shown in Table 4. The quantity of the different color plates in stock is shown in Table 5.

The total storage demand of different color plates is calculated according to Eq. 2, as shown in Table 6.

Table 3. The Number of Panels of Different Types in Different Batches (source: the authors, 2022)

Batch number	1	2	3	4	5
	PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S
RX200727A1-1(1)	0	0	38	0	115
RX200727A1-1(2)	143	0	0	70	0
RX200727A1-1(3)	0	0	27	0	0
RX200727A1-1(4)	0	199	33	0	0
RX200727A1-1(5)	0	0	0	0	0
RX200727A1-1(6)	0	0	0	0	116
RX200727A1-1(7)	160	0	27	0	0
RX200727A1-1(8)	0	0	17	0	131
RX200727A1-1(9)	0	0	35	0	93
RX200727A1-1(10)	0	0	3	0	76
RX200727A1-1(11)	0	0	49	0	0
RX200727A1-1(12)	0	0	29	0	0
RX200727A1-1(13)	145	0	6	34	0
RX200727A1-1(14)	149	0	26	11	0
RX200727A1-1(15)	98	0	0	2	0
RX200727A1-1(16)	1	0	0	21	0
RX200727A1-1(17)	110	0	0	8	0
RX200727A1-1(18)	121	0	61	77	0
RX200727A1-1(19)	0	154	57	0	0
RX200727A1-1(20)	0	154	38	0	0
RX200727A1-1(21)	0	0	24	0	135
RX200727A1-1(22)	0	0	20	0	8
RX200727A1-1(23)	0	0	0	0	134
RX200727A1-1(24)	0	0	31	0	112
RX200727A1-1(25)	0	0	33	0	83
RX200727A1-1(26)	0	0	26	0	140
RX200727A1-1(27)	161	0	51	0	0
RX200727A1-1(28)	0	0	0	0	157
RX200727A1-1(29)	0	0	39	0	92
RX200727A1-1(30)	0	0	31	0	0
RX200727A1-1(31)	119	0	9	27	0
RX200727A1-1(32)	0	189	25	0	23
RX200727A1-1(33)	81	0	0	6	27
RX200727A1-1(34)	99	0	19	32	0
RX200727A1-1(35)	104	0	16	9	0
RX200727A1-1(36)	0	0	0	0	0

Table 4. The Total Number of Panels of Different Types in All Batches (source: the authors, 2022)

Color	PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S
Quantity (piece)	1491	696	770	297	1442

Table 5. The Number of Panels of Different Types in the Automated Warehouse (source: the authors, 2022)

Color	PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S
In warehouse quantity (piece)	23	16	9	17	42

Table 6. The Number of Warehousing Requirements for Each Type of Panel (source: the authors, 2022)

Color	PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S
Warehousing demand quantity (piece)	1468	680	761	280	1400

The optimal number of plates stored in a single bin of the automated three-dimensional warehouse of the company, *i.e.*, the optimal stacking value of 40 plates, and the ratio between the optimal stacking value of different color plates and a single bin, which was calculated according to Eq. 3, is as shown in Table 7. The final picking quantity of the panels of different colors was calculated according to the above ratio and Eqs. 4 and 5, as shown in Table 8.

Table 7. The Ratio of the Warehousing Requirements to the Stacking Value of the Panels in Each Type (source: the authors, 2022)

Color	PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S
Warehousing demand quantity/optimal stacking value	36.7	17	19.025	7	35

Table 8. The Final Warehousing Quantity of Panel of Different Types (source: the authors, 2022)

Color	PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S
Final warehousing quantity (piece)	1480	680	800	280	1400
Corresponding demand of pallet (torr)	37	17	20	7	35
Space utilization of a single warehouse	100%	100%	100%	100%	100%

According to Table 8, the total picking quantity of the panels received for the shipment date of July 27 was 1480 + 680 + 800 + 280 + 1400 + 600 = 5240 (pieces), and the total demand of pallets was 37 + 17 + 20 + 7 + 35 + 15 = 131 (pallet). At the same time, the order of receiving different color plates was adjusted according to the quantity of the different color plates, as shown in Table 9.

Table 9. The Final Warehousing Quantity of Panel of Different Types (source: the authors, 2022)

Color	PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S
Final warehousing quantity (piece)	1480	1400	800	680	600
Picking sequence	First batch	Second batch	Third batch	Fourth batch	Fifth batch

Effect Analysis

By analyzing the survey data, the final picking quantity, pallet utilization rate, and warehouse space utilization rate of different picking scheme panels were summarized, as shown in Table 10.

Table 10. Data Summary of Different Panel Picking Programs (source: the authors, 2022)

Color		PA-18-029S	PA-18-716S	PA-18-903S	PA-18-905S	PA-18-981S
According to picking method of this study	Final picking quantity (piece)	1480	680	761	280	1400
	Pallet demand (torr)	37	17	20	7	35
	Warehouse space utilization (%)	100%	100%	100%	100%	100%
According to picking method of batch	Final picking quantity (piece)	1491	696	770	297	1442
	Pallet demand (torr)	44	18	29	13	40
	Warehouse space utilization (%)	84.72%	96.67%	66.38%	57.12%	90.13%
According to picking method of color	Final picking quantity (piece)	1491	696	770	297	1442
	Pallet demand (torr)	38	18	20	8	37
	Warehouse space utilization (%)	98.09%	96.67%	96.25%	92.81%	97.43%

Comparative analysis of panel picking quantity

Table 10 summarizes the final picking quantity of the panels of different colors in different collation schemes and the total final quantity of plates in stock for different collation schemes, as shown in Figs. 4 and 5.

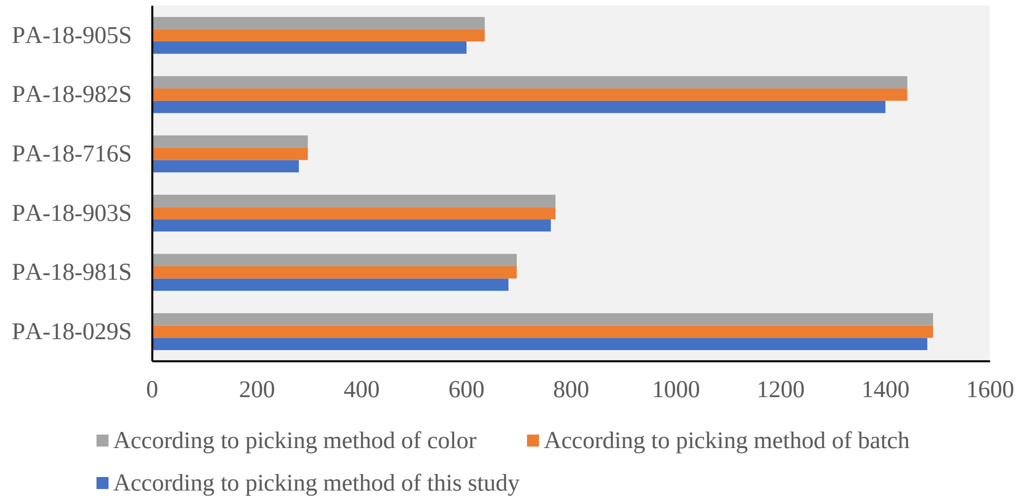

Fig. 4. Picking quantity of the panels of different colors (source: the authors, 2022)

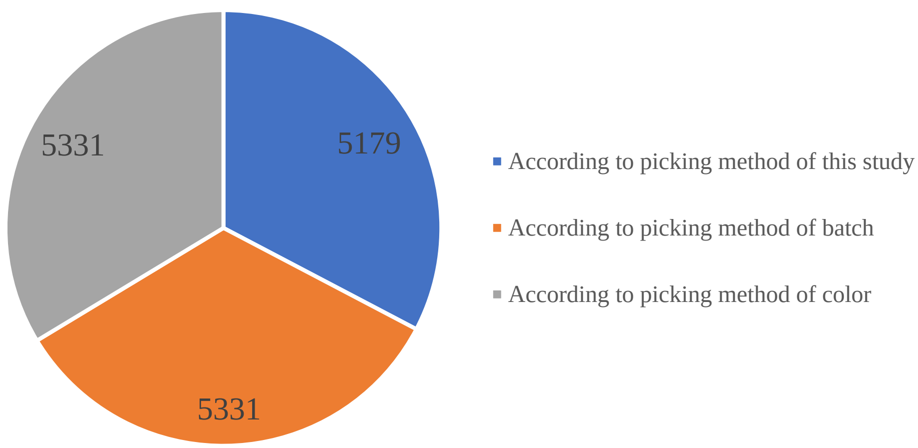

Fig. 5. Total picking quantity of the panels of different picking principles (source: the authors, 2022)

As shown in Figs. 4 and 5, compared with picking and warehousing only according to batch and color, the picking scheme proposed in this study can reduce the number of sheets in storage by 152, which is a 2.85% reduction in the number of sheets in storage. The number of sheets received is the same according to the production batch and color type. By consulting the literature, it can be seen that Winkelhaus *et al.* (2022) reached basically the same conclusion by studying the different characteristics and parameters of hybrid order picking systems. The results showed that the throughput and total costs can be improved generally compared with the picking method of traditional pure manual (Winkelhaus *et al.* 2022).

Comparative analysis of the pallet utilization rate

Table 10 summarizes the pallet requirements for different color types of plates in different collation schemes and the total pallet requirements for different collation schemes, as shown in Figs. 6 and 7.

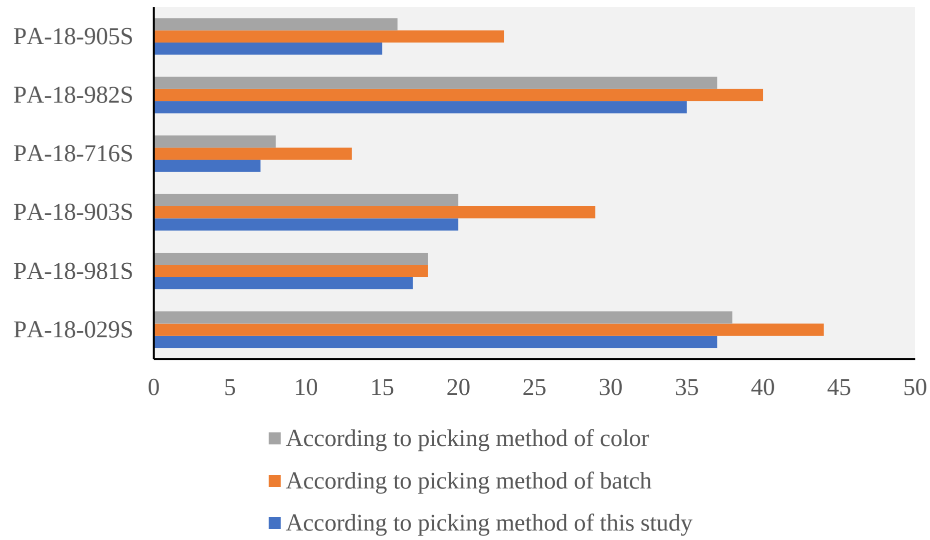

Fig. 6. Demand for pallets of panels of different colors (source: the authors, 2022)

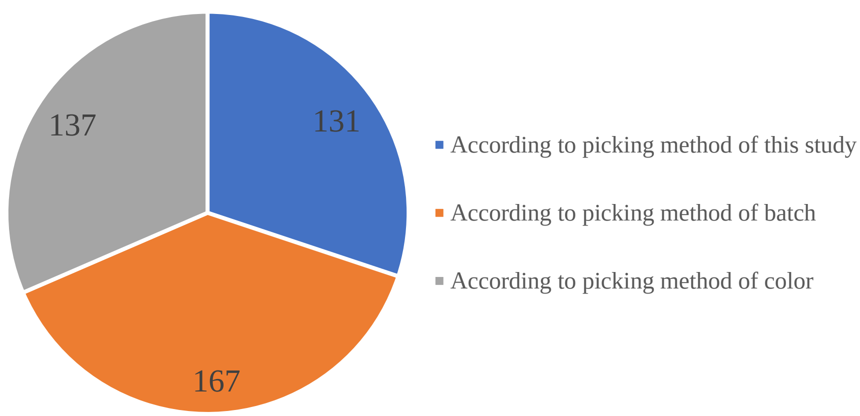

Fig. 7. Total demand for pallets of different picking principles (source: the authors, 2022)

The analysis in Fig. 6 and Table 7 shows that the picking scheme proposed in this study can reduce the required number of pallets. At the same time, one pallet represents one entry operation; the less the pallets that were used, the lower the operation frequency of the automated warehouse system. Compared to batch-based picking, the pallet usage was reduced by 36 torrs and the frequency of operation of the automated warehouse was reduced by 21.6%. When compared to picking by color type, the pallet requirement was reduced by 6 torrs and the frequency of operation of the automated warehouse was reduced by 4.4%.

Comparative analysis of the bin space utilization rate

Table 10 summarizes the bin space utilization rate of different color types of plates in different collation schemes and the bin space utilization rate of different collation schemes, as shown in Figs. 8 and 9.

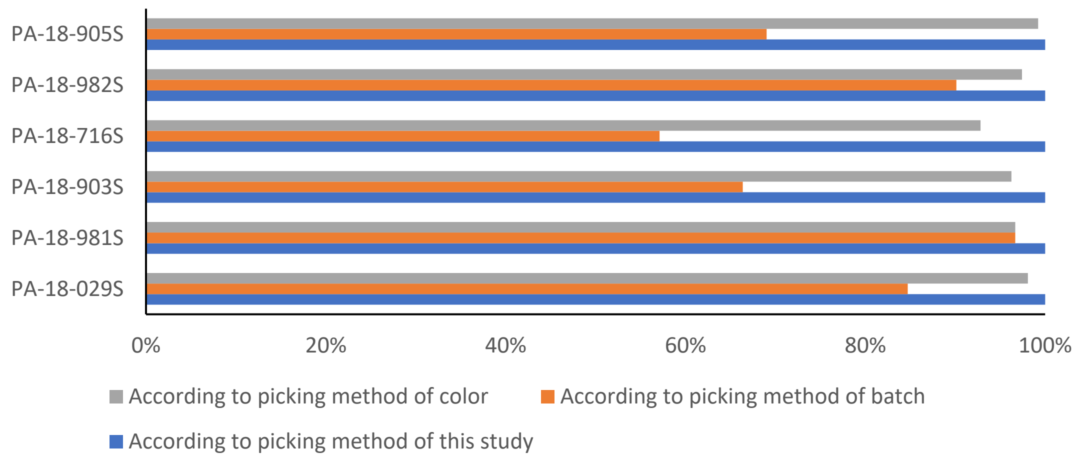

Fig. 8. Warehouse space utilization rate of panel of different colors,(source: the authors, 2022)

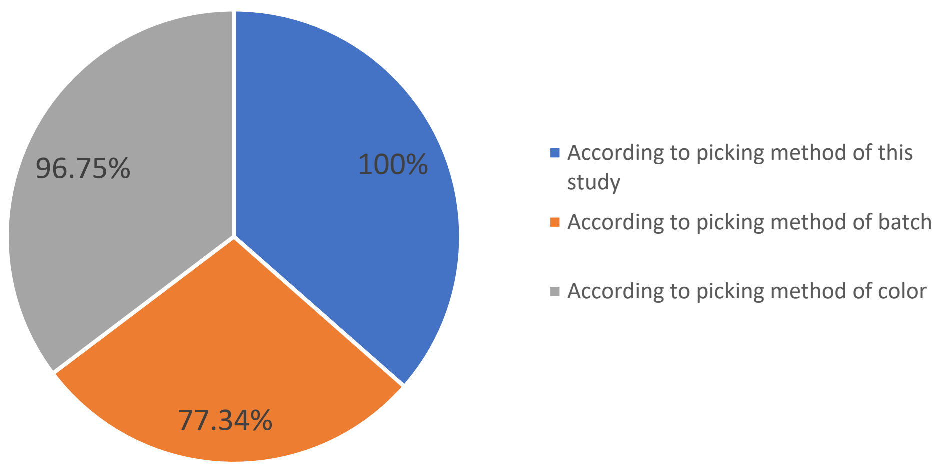

Fig. 9. Warehouse space utilization rate of different picking principles (source: the authors, 2022)

Based on the optimal stacking value for a single bin in a panel raw material warehouse of SFY panel custom furniture enterprise was determined in the chapter of the "*Calculation process of the quantity of panel material picking*". When the number of sheets inbound to a single bin is the same as the optimal stacking value, the space utilization rate of this warehouse is set to be 100%. As shown in Figs. 8 and 9, the material collection scheme proposed in this study was able to achieve 100% space utilization of the bins in the automated three-dimensional material bin for all types of panels in the incoming storage. This is a 22.7% increase in space utilization compared to batch-based pickup and a 3.3% increase in space utilization compared to color-based pickup.

CONCLUSIONS

1. A comparative study was conducted between the traditional picking method and the picking algorithm proposed in this study from three aspects: panel picking quantity, pallet occupation, and warehouse space utilization.
2. Assuming that the number of plates in a single bin reached the optimal stacking value, the space utilization rate was 100%. The algorithm proposed in this study can maximize the utilization rate of storage space to 100%.
3. Compared with picking according to batch or color, the collation scheme proposed in this study can reduce the picking quantity of panels to a certain extent.
4. In terms of pallet and warehouse space utilization, the proposed solution has the most obvious advantages, with the highest pallet usage and the lowest storage space utilization based on batch collection.
5. This paper was based on the actual production situation of S customized furniture enterprises and the control requirements for panels raw materials. It was not necessarily applicable to all furniture manufacturing enterprises. The authors will continue to improve the research and reflect it in the next article.

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