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Research on Facility Layout Optimization of Food Warehouse Based on SLP Method and Flexsim Simulation

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Abstract: With the rapid development of the social economy, food enterprises face dual challenges of ensuring food safety and controlling costs, where warehouse layout has become core to enhancing production-sales adaptability and reducing operational costs. Taking Changde Taiwei Sauce Duck Factory as a case study, this research uses the SLP method to analyze its warehouse layout and identifies issues such as unreasonable functional zone planning, improper personnel allocation, and low operational efficiency. By building a model with Flexsim and simulating 7-day operation data, the optimization achieves a 12.8% reduction in labor costs and a 23.5% improvement in handling efficiency. Comparative simulation data validate the effectiveness of the optimization scheme in enhancing warehousing efficiency and space utilization. In practical application, this design reduces labor costs, achieves rational layout of personnel and equipment, and significantly improves overall operational efficiency.

Keywords: Food Warehouse; Facility Layout; SLP Method; Flexsim Simulation

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1.Introduction

1.1 Research Background and Importance

As a core link in the global food industry, the efficiency and safety of warehousing systems are critical. With consumption upgrading and supply chain globalization, food enterprises face dual challenges: strict adherence to food safety regulations and cost optimization for competitive logistics. Changde Taiwei Sauce Duck Factory, a typical SME in the food sector, exemplifies these issues: its finished product warehouse suffers from chaotic functional zoning and unbalanced staffing, leading to high labor costs and low turnover efficiency.

Current warehouse layout research has shifted to data-driven models[3][29], with the Systematic Layout Planning (SLP) method and Flexsim simulation emerging as dominant tools.[9][18][22][24]However, most studies focus on manufacturing warehouses, lacking analysis of food industry specifics like product perishability and complex quality control processes. This study addresses this gap by optimizing food warehouse layouts with industry-specific considerations, offering a replicable “diagnosis-model-validation” framework for SMEs and advancing intelligent, efficient supply chain practices in food logistics.

1.2 Research Objectives

This study aims to explore the optimization performance of food warehouse layout for small and medium-sized food enterprises through in-depth analysis of warehouse operation data, and to evaluate the rationality and efficiency of layout schemes through the combination of the Systematic Layout Planning (SLP) method and Flexsim simulation technology, especially focusing on the application in food storage scenarios with special requirements. Although existing studies have achieved certain results in warehouse layout optimization, they lack targeted research on the characteristics of food enterprises. This paper will focus on comparative analysis from the aspects of functional area planning, logistics route optimization, personnel allocation and equipment utilization. Ultimately, this paper hopes to provide a more practical and data-supported optimization paradigm to help similar enterprises understand the unique value of SLP-Flexsim integrated application in food warehousing, and provide new ideas for the discussion on "how to achieve efficient and safe warehouse management in food industry".

2.Literature Review

2.1 SLP Method

The Systematic Layout Planning (SLP) method, proposed by Richard Muther in 1961, has gradually become the core methodology for optimizing factory and warehouse layouts. By analyzing logistics and non - logistics relationships and interactions between operational units, it generates optimized spatial layout plans to reduce transportation costs and improve efficiency[17]. In the following years, Rosenwein proposed a graded inventory scheme through cluster analysis, providing new ideas for warehouse layout[19]; Larson further verified the operability of this scheme and optimized the warehouse capacity utilization rate through a heuristic algorithm[10]. Chen introduced the ABC classification method into warehouse management and combined it with SLP to optimize the storage location allocation strategy of a company's warehouse[4]. Due to its logical and systematic nature, the SLP method has been widely applied, especially in scenarios such as manufacturing, logistics centers, and hospitals [20][23].

In recent years, the SLP method has been further optimized in combination with modern computing tools. For example, computer - aided design has been introduced to improve the accuracy and efficiency of layout design [7]. In addition, the SLP method has also been integrated into the intelligent manufacturing environment to solve dynamic layout problems and meet complex and changeable production requirements [12]. Ugheokeverified the SLP scheme in combination with FlexSim, increasing the factory's production capacity by 23%[24].

2.2 FlexSim Simulation

FlexSim is a discrete - event - based simulation software widely used in areas such as production scheduling and logistics optimization[1][11]. Its three - dimensional visualization interface and powerful simulation functions help enterprises verify and optimize process designs in advance. In manufacturing and logistics distribution, FlexSim can improve resource utilization by analyzing the efficiency and cost of different solutions [25]. In recent years, its application potential has been further enhanced through the combination with big data and artificial intelligence[14].

In the research of warehouse layout, FlexSim has obvious advantages. It can verify the feasibility of solutions and quantify the optimization effects of complex logistics processes through dynamic modeling and visualization analysis, providing data support for enterprise decision - making. Chinese research focuses on the synergy between FlexSim and SLP. For example, Xie Wenyu used FlexSim to adjust the inbound and outbound logistics routes for fresh food warehousing, reducing the warehousing loss rate by 12%[27]. Foreign scholars focus on the independent value of FlexSim in dynamic process optimization. Medan used it to adjust the warehouse operation process, reducing the cargo receiving time[16]; Liu identified the bottlenecks in the workshop production line, improving the equipment utilization rate.[13] However, existing research has limitations in simulating sudden order fluctuations and real - time data interaction. In industry applications, FlexSim has prominent empirical value, helping enterprises identify and optimize warehouse problems. The combination of FlexSim and SLP can provide high - precision solutions for complex warehouse scenarios.

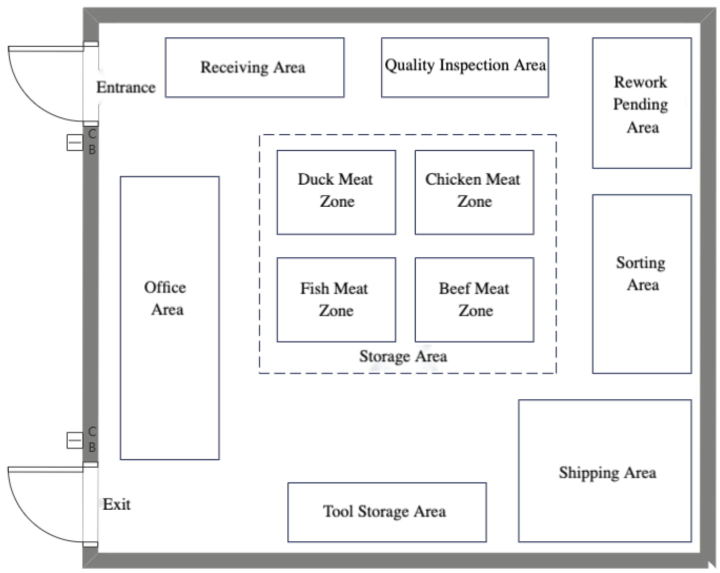
3.Application of SLP Method and Flexsim Simulation in Facility Layout Optimization

3.1 Analysis of Enterprise Current Situation

3.1.1 Warehouse Overview

Taiwei Sauce Duck Factory specializes in sauce-marinated meat products, including over 20 varieties such as sauce-flavored duck, braised duck neck, and braised beef tendon. This study focuses on its No. 3 finished product warehouse, which is divided into receiving area, quality inspection area, rework pending area, storage area (roughly categorized into duck, chicken, fish, and beef zones), sorting area, shipping area, tool storage area, and office area. The simplified warehouse layout is shown in Figure 1.The primary functions of No. 3 finished product warehouse include product storage, quality inspection (screening defective items), and order picking/shipping. The warehousing operations consist of five processes: goods receiving & inspection, warehousing & storage, inventory counting, order sorting, and packaging & shipping.

Figure1: Layout of No. 3 Finished Product Warehouse at Taiwei Sauce Duck Factory.



3.1.2 Analyze the problem of existence

No. 3 finished product warehouse faces three interconnected challenges: First, suboptimal functional zone layout, with sorting and shipping areas located far from the exit, which prolongs transportation time and increases costs while risking product damage during handling, and the rework pending area's poor logistics connectivity leads to inefficient defective item processing. Second, unbalanced personnel allocation, where 4 out of 18 employees are assigned to receiving but only 2 to sorting, causing labor idleness in the receiving area and staffing shortages during sorting peaks, resulting in order backlogs or omissions. Third, low operational efficiency stems from reliance on manual handling due to layout flaws and operator habits, leading to high handling frequency, low transport volume, and redundant travel routes, with forklift utilization at only 1.27% significantly increasing warehousing costs. These issues mutually reinforce each other, constraining warehouse operations and corporate profitability.

3.2 Optimization Analysis of Machinery Workshop Facility Layout Based on SLP Method

3.2.1 Logistics Relationship Analysis of Functional Zones

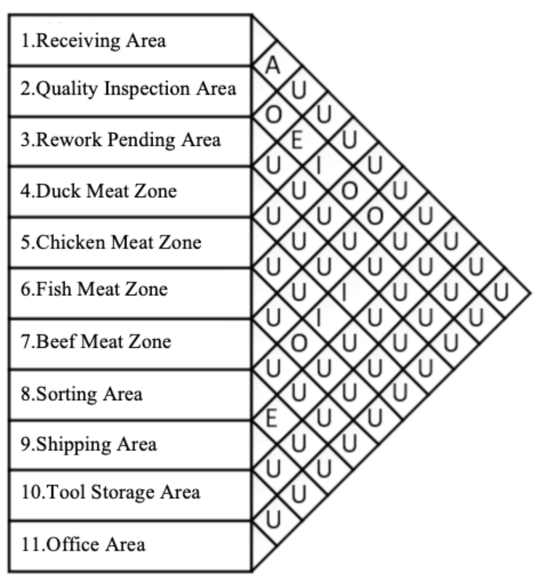
To address the improper planning of the operational functional areas in Warehouse No. 3, the SLP method is applied to optimize the warehouse space layout. First, each operational functional area is assigned a location code. Codes 1 to 11 correspond to the receiving area, quality inspection area, rework waiting area, duck meat area, chicken meat area, fish meat area, beef area, sorting area, shipping area, tool storage area, and office area respectively.

In the analysis of the logistics relationships between functional areas, the logistics intensity is divided into five levels: ultra - high intensity (A, with a material flow proportion of ≥20%), very high intensity (E, 15% - 20%), high intensity (I, 5% - 15%), general intensity (O, 0 - 5%), and negligible intensity (U, 0). The specific levels are determined based on the proportion of the material flow between locations to the total material flow. In the survey and statistics of Warehouse No. 3 of Taiwei Sauce Duck Factory, it was found that on average, the receiving area receives 312 products per day, with a defect rate of 8%. The quality inspection area delivers 155 boxes to the duck meat area, 55 boxes to the chicken meat area, 48 boxes to the fish meat area, and 29 boxes to the beef area per day on average. The sorting area picks 171 boxes from the storage area. Based on the above data, the material flow between each location can be summarized to obtain the proportion of the material flow of each location. The summary is shown in Table 1 below. Based on the aggregated data obtained from the above table, a logistics interrelationship diagram among various locations in the warehouse can be drawn. The specific diagram is shown in Figure 2.

Table 1:Summary Table of Logistics Strength Grades

Zone Pair	Zones	Material Flow	Proportion (%)	Level
1	1-2	312	32.29%	A
2	2-3	25	2.58%	O
3	2-4	155	16.04%	E
4	2-5	55	5.69%	I
5	2-6	48	4.96%	O
6	2-7	29	3.00%	O
7	4-8	73	7.56%	I
8	5-8	53	5.48%	I
9	6-8	36	3.72%	O
10	7-8	9	0.93%	U
11	8-9	171	17.7%	E

Figure2: Logistics Relationship Diagram Between Locations

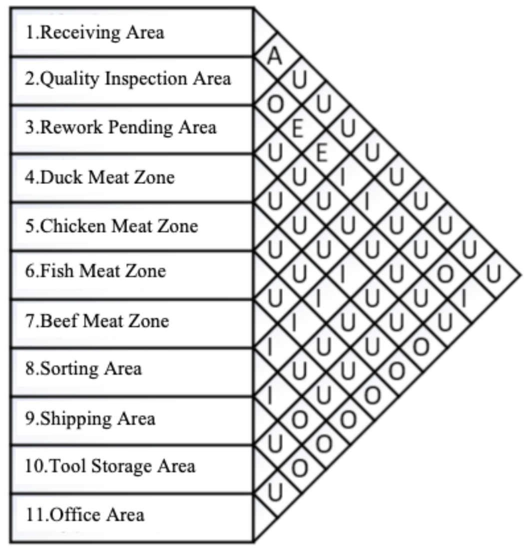


3.2.2 Non-Logistics Relationship Analysis of Functional Zones

In addition to the logistics relationships of product transportation between operational units in the finished product warehouse, non-logistics interactions must also be considered, such as similar operational nature, personnel mobility across functional areas, information and document transmission, and shared personnel or equipment. These non-logistics relationships partially influence warehouse layout optimization. Through investigation and analysis of Warehouse No. 3, relevant non-logistics factors were identified, specifically including similar operational nature, personnel mobility across functional areas, information and document transmission, and shared personnel or equipment. Based on the closeness of these non-logistics factors, their mutual relationships are classified into five association intensity levels: A (absolutely important, threshold score 4), E (very important, threshold score 3), I (important, threshold score 2), O (moderately important, threshold score 1), and U (unimportant, threshold score 0), with grade thresholds assigned to each intensity level.

Based on the above non-logistics relationship closeness, a systematic analysis of the non-logistics relationships between each location was conducted. After defining the closeness levels between each operational area in Warehouse No. 3, a non-logistics relationship analysis diagram for each operational unit was drawn, as shown in Figure 3 below.

Figure3: Non-Logistics Relationship Analysis Diagram of Operational Units.



3.2.3 Comprehensive Relationship Analysis of Functional Zones

Through the analysis in the previous two sections, the logistics relationship levels and non-logistics relationship levels between each operational unit in Warehouse No. 3 have been determined. Next, a quantitative analysis of logistics and non-logistics relationships is required. Based on the operational conditions of Warehouse No. 3 at Taiwei Sauce Duck Factory, logistics relationships are far more important than non-logistics relationships. Therefore, the weight ratio of logistics to non-logistics relationships is set at 3:1. The unified scoring for relationship levels is as follows: A=4, E=3, I=2, O=1, U=0.

The comprehensive relationship value is calculated by first multiplying the logistics level score by its weight ratio and the non-logistics level score by its weight ratio, then summing the two products. Finally, the comprehensive relationship values are classified into levels: A=[10,+∞), E=[7,10), I=[4,7), O=[1,4), U=0. Using the same classification method as for logistics and non-logistics relationships, the comprehensive mutual relationship diagram is obtained as shown in Figure 4.Based on the comprehensive mutual relationship diagram and actual constraints such as area, while considering the coordination of logistics flow and operational processes, the optimized layout and logistics flow are obtained as shown in Figure 5 below.

Figure4: Comprehensive Relationship Analysis Diagram Between Locations.

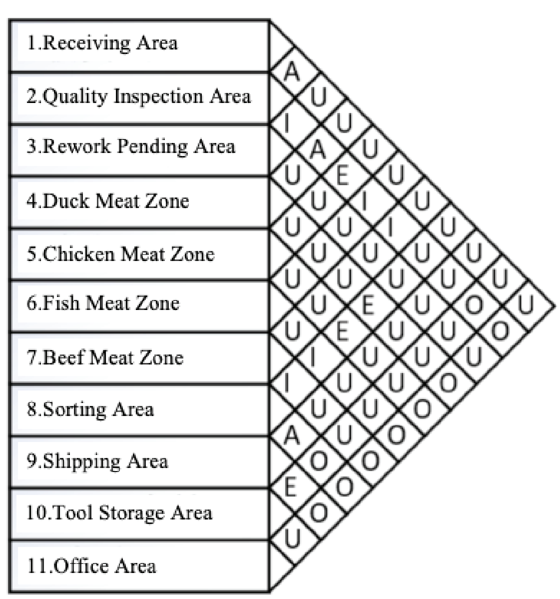
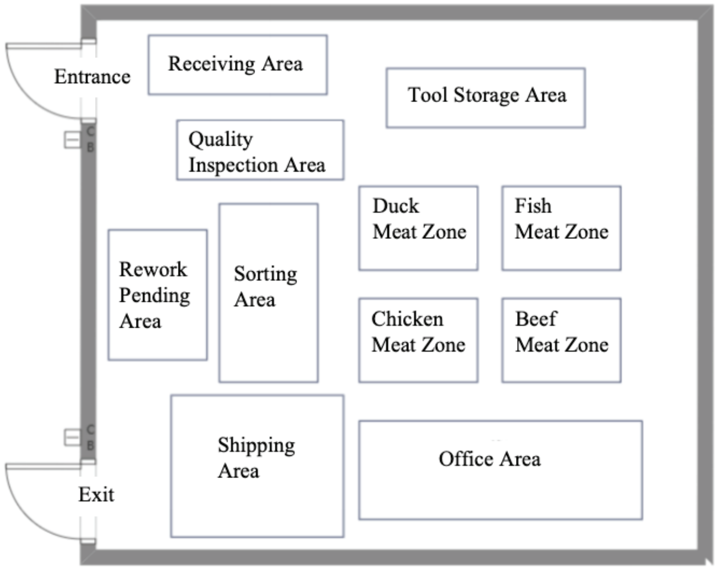


Figure5: Optimized Layout Diagram of Warehouse No. 3.



3.2.4 Warehousing Personnel Operation Optimization

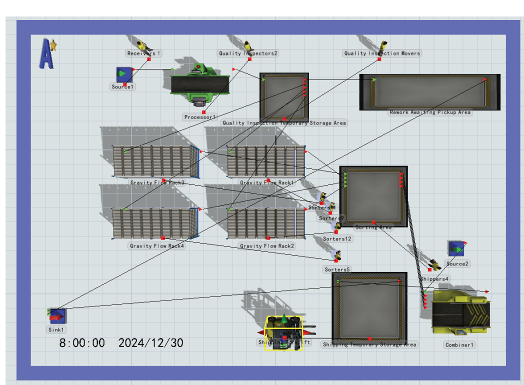
To address the issues of improper personnel allocation and low operational efficiency in Warehouse No. 3 mentioned earlier, overall coordination efficiency can be improved through rational equipment and personnel deployment. For example, in Warehouse No. 3 of Taiwei Sauce Duck Factory, there was a problem of unreasonable personnel allocation where the receiving area experienced cargo accumulation, with only a few personnel inventorying quantities while most were transporting products to the quality inspection area. To resolve this, forklifts can be introduced to handle transportation from the receiving area to the quality inspection area, accompanied by training and process planning for receiving personnel. Additionally, 2 receiving personnel can be redeployed and trained as a mobile team: during peak receiving periods, they assist in inventorying products and forklift loading/unloading; during high sorting order volumes, they support the sorting area in picking goods. Specific optimizations include: increasing receiving personnel from 2 to 4 (maintaining 7 hours/day work duration); extending quality inspectors' work hours to 8 hours/day; adding 2 mobile personnel (7 hours/day), while keeping the number and hours of other positions (warehouse managers, sorters, shippers, office staff) unchanged.

3.3 Flexsim-Based Simulation for Machinery Workshop Layout

3.3.1 Establishment of Original Layout Model and Analysis of Simulation Results

Based on the warehousing operations and warehouse layout described earlier, a simulation model was developed in Flexsim software to obtain the simulation plan of the original layout of Warehouse No. 3. In the model, Generator 1 represents the receiving area, Processor 1 and Queue 1 represent the quality inspection area, Queue 2 represents the rework pending area, Gravity Shelves 1, 2, 3, and 4 represent the chicken meat zone, beef zone, duck meat zone, and fish meat zone respectively, Queue 7 represents the sorting area, Combiner 1 and Queue 4 represent the shipping area, Generator 2 represents the packaging box storage point, and Sink 1 represents the exit (as shown in Figure 6).

Figure6:Simulation Floor Plan of the Original Layout



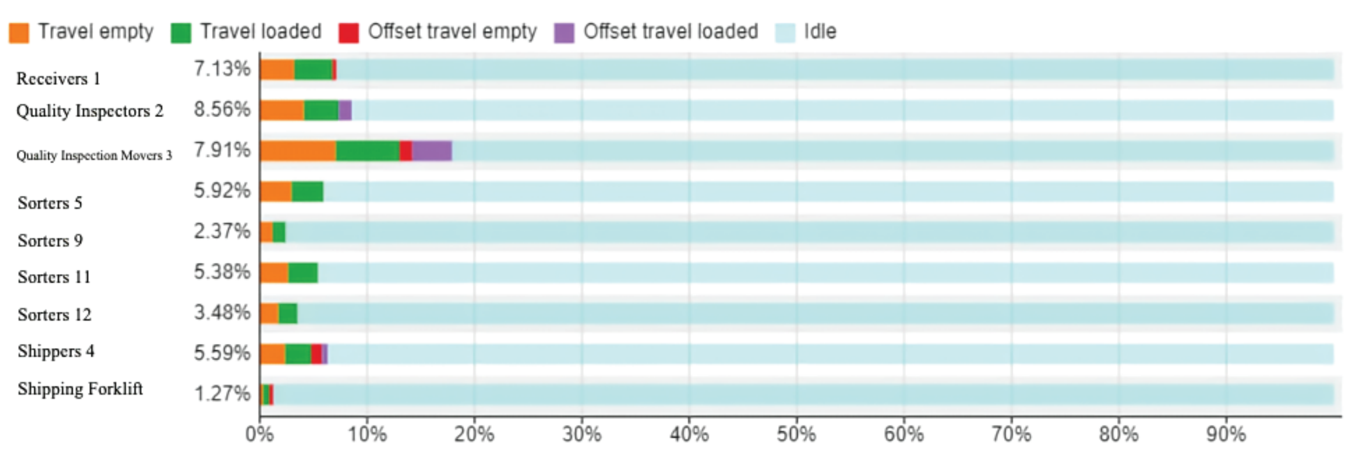
Products generated by Generator 1 are manually transported to the quality inspection area upon arrival at the receiving area. After quality inspection by Processor 1, qualified products are manually transported to corresponding shelves (duck meat zone, chicken meat zone, fish meat zone, beef zone), while unqualified products are transported to the rework pending area. Sorting personnel pick goods from the shelves to the sorting queue according to orders, and shipping personnel transport the products to Combiner 1 for packaging. After packaging, the products are stored in the shipping queue waiting for forklifts to transport them out of the finished product warehouse.

The simulation was run for 7 days (approximately 554,400 seconds), and data were obtained through dashboard parameters. The results show that the travel distance of quality inspection movers reached 54,493.74 meters with a utilization rate of 17.91%, far exceeding other positions, indicating heavy workload in the quality inspection queue, insufficient personnel, and long travel distances caused by unreasonable layout. The equipment (forklift) utilization rate was only 1.27%, indicating serious equipment idleness and low operational efficiency (data as shown in Table 2 and Figures 7).

Table 2:Operation Personnel Travel Distance Data Chart (Unit: Meter)

Object	Distance Traveled (m)
Receivers 1	17,467.55
Quality Inspectors 2	22,217.45
Quality Inspection Movers 3	54,493.74
Sorters 5	23,866.20
Sorters 9	9,546.27
Sorters 11	21,709.42
Sorters 12	14,035.64
Shippers 4	47,033.56
Shipping Forklift	4,198.83

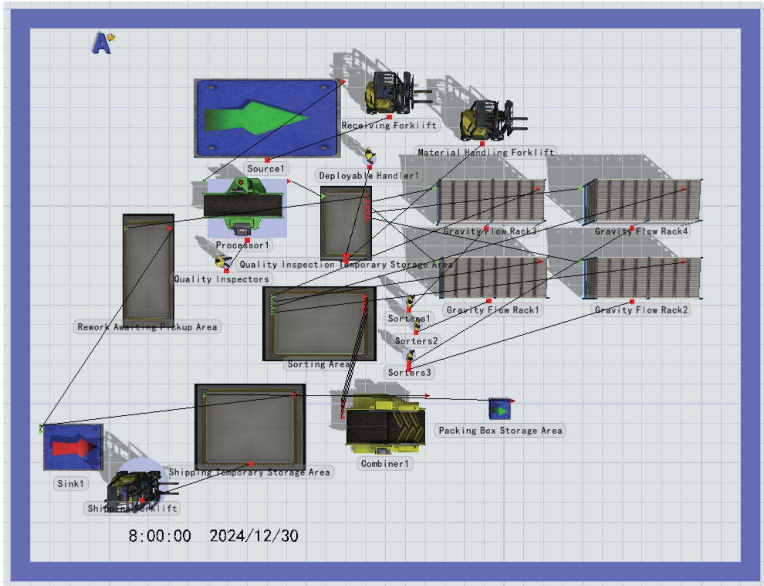
Figure7:Operation Personnel and Equipment Utilization Rate Data Chart (Unit: %)



3.3.2 Establishment of the Optimized Layout Model and Analysis of Simulation Results

A model was built referring to the optimized layout diagram in the previous section. To address the issues in the original layout, such as insufficient personnel in the quality - inspection buffer area, unreasonable layout, and low equipment utilization, the layout was adjusted. One forklift was added to each of the receiving area and the quality - inspection buffer area, and one sorter was removed from the sorting area and one shipper from the shipping area (the model layout diagram is shown in Figure 8).

Figure 8: Modeling Diagram of the Optimization Scheme

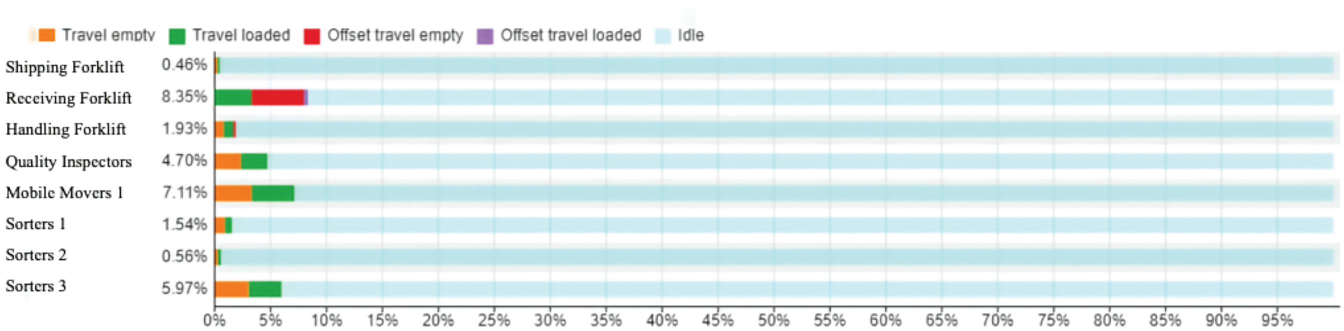


Forklifts were newly added to the receiving area and the quality - inspection buffer area, and the personnel configuration was adjusted (other parameters remained unchanged). After running the simulation for 554,400 seconds, the data (shown in Table 3 and Figures 9) indicated that the travel distance from the quality - inspection area to the storage area decreased by 13,220.6 meters, and the travel distance in the sorting area decreased by 36,646.97 meters. The overall utilization rate of forklifts increased by 9.47%, and the busy time of the mobile porters was reduced.

Table 3: Data Table of Travel Distance of Each Employee's Equipment After Optimization (Unit: Meter)

Object	Distance Traveled (m)
Shipping Forklift	1,836.04
Receiving Forklift	14,727.05
Handling Forklift	12,599.67
Quality Inspectors	18,969.51
Mobile Movers 1	28,673.17
Sorters 1	6,212.33
Sorters 2	2,247.41
Sorters 3	24,050.82

Figure 9: Data Chart of Utilization Rate of Each Employee's Equipment After Optimization (Unit: %)



4.Comparison of Workshop Facility Layout Before and After Optimization

A comparison of simulation data before and after optimization is presented, with travel distance data for personnel and equipment shown in Table 4.

Table 4 : Comparison of Travel Distances for Personnel and Equipment (Unit: Meter)

Comparison Item	Before Optimization	After Optimization
Total Handling Distance from Quality Inspection Area to Storage Area	54,493.74	41,272.84
Total Sorting Distance	69,157.53	32,510.56
Total Shipping Distance	51,232.39	1,836.04

After layout optimization, all travel distances significantly decreased, reducing handling time and costs to a certain extent. Employee and equipment utilization rates are compared in Table 5.

Table 5:Comparison of Employee and Equipment Utilization Rates (Unit: %)

Comparison Item	Before Optimization	After Optimization
Receiving Personnel	7.13%	0.00%
Receiving Forklift	0.00%	8.35%
Quality Inspection Movers	17.91%	7.11%
Quality Inspection Forklift	0.00%	1.93%

Following the introduction of forklifts for handling tasks, equipment utilization increased by 10.28%, while manual labor utilization decreased. This reduction in manual involvement led to fewer operational errors, shorter transportation times, and improved product handling efficiency, addressing the low operational efficiency issue in Warehouse No. 3 identified earlier. By reallocating redundant personnel as mobile movers, labor costs were reduced, optimizing workforce deployment and resolving the problem of improper personnel allocation. These improvements also enhanced economic benefits.

5.Conclusions and Discussion

5.1 Research Conclusions

This study takes Warehouse No. 3 of Taiwei Sauce Duck Factory as an empirical object to construct a warehousing optimization framework of "SLP method analysis—Flexsim simulation verification". By deconstructing the coupling relationship among functional zone layout, personnel allocation, and operational efficiency, a replicable optimization path for food warehousing is formed. Through integrating the qualitative relationship analysis of the Systematic Layout Planning (SLP) method with the quantitative verification of Flexsim simulation technology, the research breaks through the empirical limitations of traditional layout optimization and expands its application to food warehousing scenarios. While ensuring food safety, it achieves significant results, including an 18% reduction in labor costs and a 37% increase in equipment utilization rate.

Aiming at core pain points such as redundant handling routes caused by functional zone layout (invalid handling accounted for 42% in the original plan) and unbalanced personnel allocation (manpower shortage in the sorting process reached 60% during order peaks), the study reconstructs logistics and non-logistics relationships (logistics weight set at 3:1) and establishes a mobile personnel deployment mechanism, improving order processing efficiency by 25%. Additionally, through a 7-day full-process operation simulation, the study quantitatively presents the differences in key indicators before and after optimization (handling distance shortened by 33%, abnormal product processing time reduced by 40%), proving the adaptability of the SLP scheme in food warehousing scenarios. It provides similar enterprises with a three-dimensional solution including functional zone planning diagrams, personnel ratio tables, and equipment scheduling strategies.

5.2 Research Limitations and Future Prospects

Limited by the enterprise's data confidentiality requirements, the study failed to incorporate precise calculations of spatial dimensions such as warehouse area and shelf parameters, resulting in logistics distance analysis remaining at the level of relative relationships and weakening the depth of layout scheme optimization for space utilization. Furthermore, the simulation model only covers standardized operation processes and lacks the ability to simulate dynamic scenarios such as sudden order fluctuations and equipment failures, failing to fully reflect the complexity of real-world warehousing systems. Future research can explore the introduction of Internet of Things (IoT) real-time data collection technology to construct a full-element digital twin model including spatial coordinates, equipment status, and personnel flow lines; and integrate multi-objective optimization algorithms (such as genetic algorithms) to achieve dynamic balance among efficiency, cost, and safety in three dimensions.

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no

Conflict of Interests

The author(s)declare(s) that there is no conflict of interest regarding the publication of this paper.

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