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Simulation Design of Automobile Spare Parts Storage and Warehousing

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Abstract

With the rapid development of the automobile industry, global car ownership has been increasing. The increase in car ownership has put forward higher requirements. With the requirements for an auto repair, maintenance, logistics, and other related industries, auto parts logistics is an essential part of auto parts logistics. How to efficiently control the cost management of auto parts warehouse is now a widely studied problem at home and abroad. Now the most commonly used data collection technology and information identification technology at home and overseas are barcode technology and RFID technology. The combination of barcode technology and RFID technology applied to auto spare parts warehouse management can optimize the management mode of the whole auto spare parts supply chain. This paper will use the modeling tool Arena to apply barcode technology and RFID technology to the auto spare parts factory for the storage process of incoming spare parts. This paper will use the modeling tool Arena to simulate the stochastic inventory system and analyze the optimal combination of worker allocation to reduce the total warehousing time and improve the operational efficiency of the warehousing process when the total number of worker resources is determined.

Keywords

Arena simulation software, automotive parts, inventory management, RFID.

1. Introduction

With the flourishing development of the automobile industry, global car ownership has been steadily increasing. By November 2011, China surpassed Japan to become the second largest car owner in the world, just below the United States. The increase in car ownership has put forward higher requirements for automobile repair, maintenance, logistics, and other related industries, but it also provides more opportunities. Auto spare parts logistics are vital to ensure auto after-sales and manufacturing. While spare parts warehousing is at the core of spare parts logistics, achieving efficient and cost-controlled auto spare parts warehousing management is a concern for most auto companies. Nowadays, the most widely used data collection technology and information identification technology at home and abroad are barcode technology and RFID technology. Combining barcode technology and RFID technology in auto spare parts warehouse management can optimize the whole auto spare parts supply chain's management mode and thus improve the entire industry chain's operation efficiency.

The barcode-based automotive spare parts warehouse management and the light vehicle spare parts warehouse management are based on the integrated application of RTD and barcode. The application conditions of both in the storage process are different, the storage efficiency is different, and the number of operators to be equipped is also different. In this paper, we will use the modeling tool Arena to simulate the stochastic inventory system for storing spare parts in an automotive spare parts factory using bar code technology and RFID technology. And analyze how the number of workers specializing in different types of spare parts can be allocated to minimize the time spent on the storage process to improve the operational efficiency of the whole storage process under the condition that the total number of worker resources is determined.

2. Automotive spare parts warehousing inbound system description

System description

Auto spare parts warehousing is the process of providing a storage place for auto spare parts, storage, storage, and control of auto spare parts. Proper storage can provide more liquidity for auto manufacturing companies and auto repair shops to meet customer needs. It also provides the backbone for the production and development of the enterprise and creates profits for the enterprise. This paper divides spare parts into three categories to facilitate the application of barcode and RFID technology in warehouse management: Category A, Category B, and Category C. Among them, category A includes spare parts that are commonly used, perishable, fast turnover, and high maintenance usage. Category B refers to general pieces and the balance of imports and export to avoid a backlog. Category C refers to slow parts in small demand, relatively expensive, and slow turnover. Of these three spare parts categories, category A focuses on management, needs strict inventory, tries to compress the stock to the minimum, and reduces unnecessary inventory. Category B can be used in quantitative order, according to the theory of storage reasonable reserve. Category C spare parts do not need inventory and can simplify the management, using the way of the purchase at any time. According to these three classifications, the reasonable layout of the storage according to the principles of automotive spare parts storage design, such as the layout of the cargo space, the distribution of shelves, etc. The inbound link can be divided into four steps: preparation work, receiving goods, goods on the shelves, and data synchronization. The workflow is shown in Figure 1.

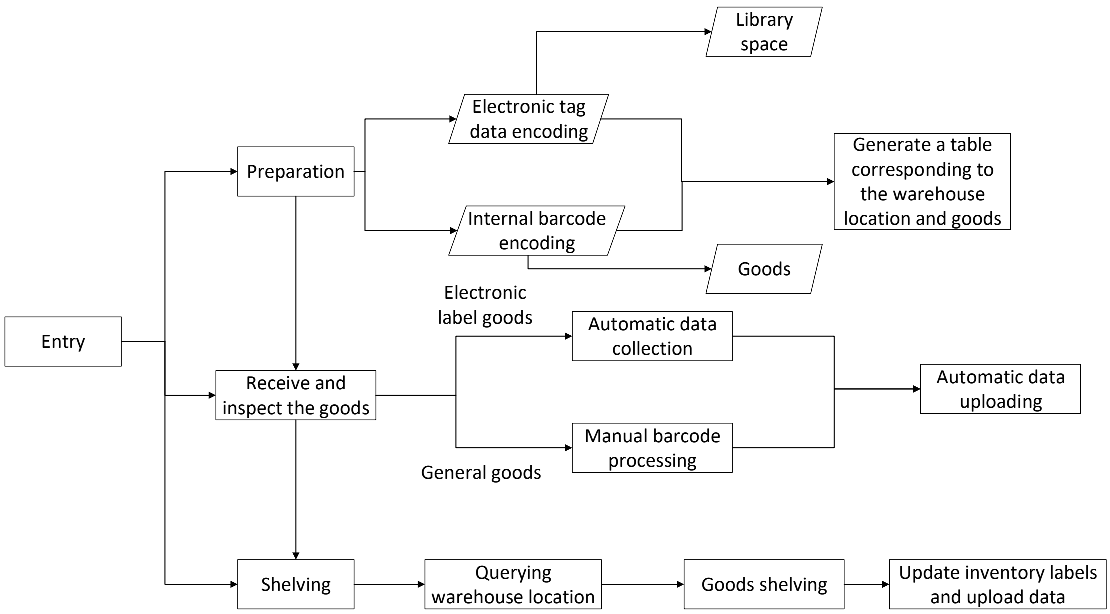

Fig.1 Inbound workflow chart

Scenario design

To analyze how the number of workers handling different types of spare parts can be allocated to minimize the time spent on the warehousing process to improve the operational efficiency of the whole warehousing process under the condition that the total number of worker resources is determined. The following three simulation scenarios are set up in this paper.

Option 1: Specialized personnel to handle different orders

The 12 inspectors are divided into 4 checkers a, 4 checkers b, 4 checkers c.12 workers spare parts shelves, update inventory information of the staff into 3 workers a, 3 workers b, 3 workers c, 3 workers rfid.

Option 2: Optimize the number of staff allocation by applying OptQuest to option 1 while the total number of staff remains unchanged.

Option 3: For different orders are handled by all workers together. That is 12 inspectors, 12 workers who put spare parts on the shelves and update inventory information to handle different types of spare parts together.

Parameter setting

The model data of automobile spare parts inbound system are as follows:

The arrival of spare parts: obey the exponential distribution with the mean value of 1, 2 spare parts arrive each time, and the time unit is minutes.

Simulation time: 2 working days according to the daily working time of 8 hours.

Inspection of spare parts: the mean value of inspection time is 5 minutes per piece, obeying the triangular distribution with the minimum value of 3 and the maximum value of 8, and the time unit is minutes.

Barcode processing: the average value of the spare parts' posting and scanning time is 15 seconds, obeying the triangular distribution with the minimum value of 10 and the maximum value of 20, and the time unit is seconds.

Storage processing: the average value of time to store goods on shelves and update inventory information is 4.5 minutes, obeying the triangular distribution with the minimum value of 3 and the maximum value of 6, and the time unit is minutes.

Data on the classification of spare parts: 75% of the total number of spare parts of category A, 20% of the total number of spare parts of category B, 5% of the total number of spare parts of category C, and 20% of the total number of spare parts configured with electronic sticky notes. Spare parts inspection pass rate: 95%.

Warehouse staff: 12 inspectors, 2 barcode operators, 12 shelf operators, workers take a 30-minute break for every 4 hours of work, 26 people in total.

3. Model building and simulation

Introduction of Arena Simulation Software

Arena simulation software is a new generation of a visualized general-purpose interactive, integrated simulation environment that uses object-oriented technology and hierarchical system structure and can run in connection with programs written in common programming languages. You can directly select graphical modules in the software, set up randomly distributed time parameters, entity attributes, and service resources, prioritize help desk queue processing, perform animation demonstrations, and have automatic report generation functions. According to the report's data, you can analyze the model's performance advantages and disadvantages.

Analysis of the main simulation function modules of the model

Auto spare parts warehousing system model mainly includes the following modules: spare parts arrival module, spare parts classification module, spare parts qualified and scrap classification module, spare parts inspection, barcode processing, shelf, update inventory module, define the number of spare parts module, spare parts statistics module and other operation modules, this model needs Create, Decide, Assign, Process, Dispose, Record six kinds of modules. The implementation process of each module is briefly described below. The simulation model is shown in Figure 2.

Create module. The role of Create module is to generate the arrival of spare parts, the arrival of spare parts obeys the exponential distribution with parameter 1, the time unit is set to minutes, and the number of arrivals of each entity is set to 2.

Process module. The delayed type accepts the default value TRIA (3, 5, 8) triangular distribution, the time unit drop-down box selects minutes, and the Report Statistic check box is selected. Due to the characteristics of category A spare parts, the inspection of its priority is higher than other categories of spare parts, so the module occupies the resources of the Priority selected as advanced high (1). Check B spare parts module priority of the occupied resources selected as medium (2) and check C spare parts module parameters are set similar to the check A module. Among them, in the inspection B spare parts process module, the module name is modified to check B, inspection C spare parts module priority is selected as low (3), and other parameters are set the same as check A. Then edit the shelf storage, and update the inventory data module. The name of the category A spare parts shelf storage module is the store and update A. Module activity type select seize delay release, resource occupation priority set to high (1). New resource worker, each entity occupies the number of resources set to 1. Delay type to accept the default value TRIA (3, 7, 8) triangle distribution corresponding to category B spare parts and category C spare parts process settings similar to store and update A.

Assign module. There are five Assign modules in this model. Which are to record the time of entity generation, count the number of variables of category A spare parts, category B spare parts, category C spare parts, and count the number of rejects that fail the inspection. Set up the first assigned module first: define the entity quantity variables. The module's name keeps the default value without changing, the type of Assignments is selected as a variable, a variable name is modified as stay time, and the new Value is filled in TNOW, which means the time value at this moment. Next, set up the dialog box of the statistical quantity of spare parts of category A. Change the module name to quantity A, click add button to create a new variable, change the variable name to num A, and fill in the value field to numA+1. Whenever an entity (spare parts of category A) flows through the module, the value of this variable increases by 1. Save the parameter settings of this module. The sets of the category B spare parts, category C spare parts, and scrap spare parts statistics module are similar to quantity A.

Decide module. There are four decide modules in this model, and their roles are to control the flow of spare parts classification, to control the flow of inspection results of category A spare parts, category B spare parts, and category C spare parts. The decide module to control the flow of spare parts classification selects N-way by chance in the type' drop-down box, fills in the proportion of category A spare parts 75%, category B spare parts 25%, and the remaining one export else defaults to 5%. The next step is to edit the remaining three decided modules: set the inspection pass rate block for each type of spare part. Modify the category A spare parts inspection result triage module, triage type selected as 2-way by chance, fill in the text box of the actual value of the percentage of 95, that is, the spare parts inspection pass rate of 95%. The test result triage module for category B spare parts and the test result triage module for category C spare parts are set up similarly to check result A.

Record module. There are eight record modules in this model. Their function is to record the time consumed by the entire process of arrival of various spare parts (entities) in the inventory. They include A, B and C qualified parts and A, B and C scrapped parts. Firstly, set up the incoming time record module for category A spare parts and select Time Interval for the record type, that is, the time interval between the properties of the record control and the properties of this module. And in the drop-down box, select Dwell Time for the control properties, which is the moment of arrival of each entity. The parameters of the other three record modules are set similarly to Record A. The record module name of incoming time for category B spare parts is edited as Record B. The name of the record module for recording the time of incoming spare parts of category C is Record C. The spare parts of the scrap module are Record F. Then, set the

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incoming quantity record module for spare parts of category A. Select count as the record type, and the other three record module parameters are arranged similarly to A.

Dispose module. The last is the dispose module, which is used to undo the generated entity. The parameter settings of the module do not need to be modified, keeping their default value.

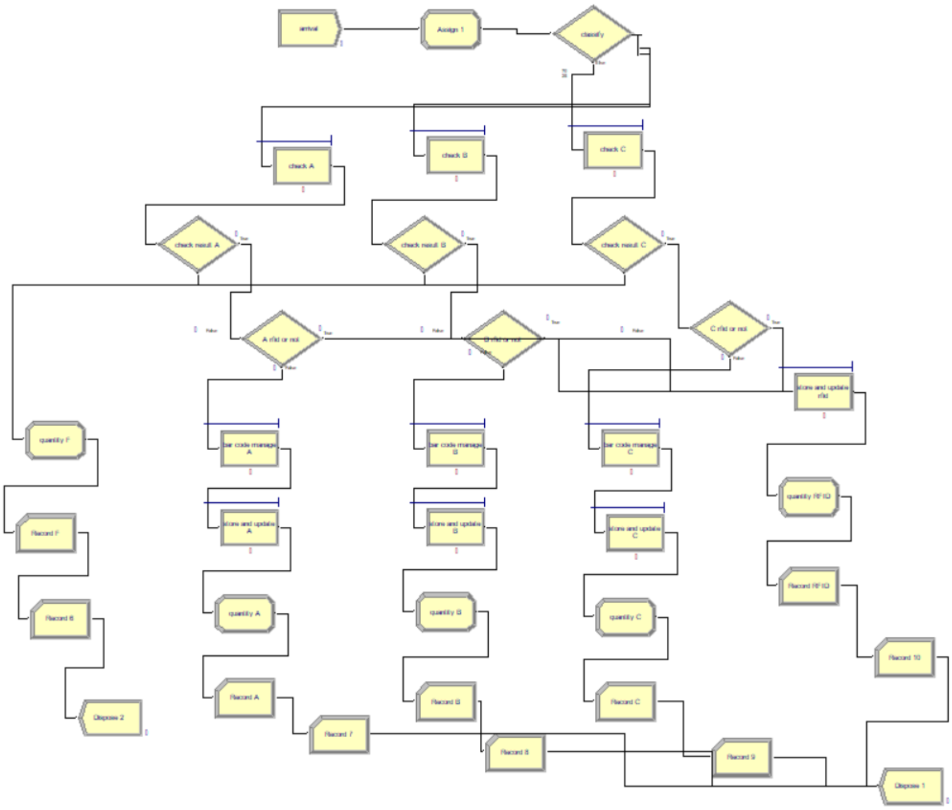

Fig.2 Simulation model diagram

4. Experimental results and analysis

Specialized staff for different orders

The 12 inspectors are divided into 4 checkers a, 4 checkers b, 4 checkers c. The 12 staff who work on the shelves and update the inventory information are divided into 3 workers a, 3 workers b, 3 workers c, 3 workers rfid.

The Entities reported in the simulation results are shown in Figure 3. The report shows the average entry time of each spare part, the number of spare parts arriving at the warehouse, and the number of spare parts completed in the warehouse. Among them, the number of spare parts that arrived at the warehouse was 1944, while the number of spare parts that completed the warehousing operation was 1259. The average time spent on warehousing each spare part was 151.29 minutes (the average effective operation time was 9.5642 minutes, and the average queuing time was 142.72 minutes, as shown in the category overview report).

The resource report is shown in Figure 4. The report contains statistics on the effective efficiency of warehouse staff. 12 inspectors: checker a, checker b, checker c, the effective work ratio is 99.84%, 62.87%, 12.93%, checker a's work intensity is more excellent, checker b's work intensity less, checker c's work intensity is minimal. The effective work ratio of worker a, worker b, worker c, and worker rfid among the 12 staff of spare parts shelving and updating inventory information is 84.88%, 53.23%, 9.76%, and 30.98%. The work intensity of worker a is moderate, the work intensity of worker b and worker rfid is low, and the work intensity of worker c is minimal. The effective work ratio of the two workers who pasted and scanned bar codes was only 12.44%, and about eight-ninths of the time were idle.

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	9.5642	0.085260903	3.2733	13.4643

NVA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	141.72	(Correlated)	0.00	473.77

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Other Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	151.29	(Correlated)	3.2733	485.08

Other

Number In	Value
Entity 1	1944.00

Number Out	Value
Entity 1	1259.00

Fig.3 Option 1 Entities Report

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
bar worker	0.1244	(Correlated)	0.00	1.0000
checker a	0.9984	(Insufficient)	0.00	1.0000
checker b	0.6287	0.076488342	0.00	1.0000
checker c	0.1293	(Insufficient)	0.00	1.0000
worker a	0.8488	(Insufficient)	0.00	1.0000
worker b	0.5326	0.077585674	0.00	1.0000
worker c	0.0976	(Insufficient)	0.00	1.0000
worker rfid	0.3098	(Correlated)	0.00	1.0000

Fig.4 Option 1 resource report

Tally

Interval	Average	Half Width	Minimum Value	Maximum Value
Record A	260.49	(Correlated)	7.6547	485.08
Record B	16.3880	3.17528	7.0118	43.1181
Record C	11.9374	(Insufficient)	7.5596	39.1484
Record F	150.53	(Insufficient)	3.2733	469.75
Record RFID	130.46	(Insufficient)	6.1207	475.82

Counter

Count	Value
Number A	545.00
Number B	337.00
Number C	62.0000
Number F	57.0000
Number RFID	258.00

Fig.5 Option 1 User Specified Reports

The report in Fig. 5 shows the quantity statistics of each type of spare part and the average storage time for each kind of spare part. Among them, the average storage time of category A spare parts, category B spare parts, and category C spare parts are 260.49 minutes, 16.388 minutes, and 11.9374 minutes respectively. The quantities were 545,337 and 62, respectively. The number of scrap spare parts that failed inspection was 57 pieces, and the average storage time was 150.53 minutes. The average warehousing time was 130.45 minutes, and the quantity was 258.

Optimization for the case of different orders handled by specialized personnel

The staff allocation is optimized using OptQuest for the 12 inspectors and 12 workers for shelving and updating inventory information in Section 3.1. The optimization results divide the 12 inspectors into 8 checkers a, 3 checkers b, and 1 checker c, and the 12 workers for shelving and updating inventory information into 7 workers a, 2 worker b, 1 worker c, 2 worker rfid.

The entities report is shown in Figure 6. The report shows the average entry time of each spare part, the number of spare parts arriving at the warehouse, and the number of spare parts completed in the warehouse. Among them, the number of spare parts arriving at the warehouse is 1974, while the number of spare parts that have completed the inbound operation is 1861. The average inbound time per spare part is 30.6767 minutes (the average effective operation time is 9.6018 minutes, and the average queuing time is 21.0749 minutes, as shown in the category overview report).

The resource report from the simulation results is shown in Figure 7. The information records the idle and busy situation of the warehouse staff. The report data shows that the effective work ratio of 12 inspectors: checker a, checker b, and checker c is 90.36%, 95.05%, and 52.71%. Checker a and checker b has high work intensity, and checker c has less work intensity. The effective work ratio of workers a, b, c, and rfid among the 12 staff members who shelve and update inventory information is 65.73%, 84.06%, 31.53%, and 64.06%. The work intensity of workers a and rfid is moderate, and the work intensity of worker b is slightly higher. And the work intensity of worker c was minimal; the effective work ratio of the two workers who pasted and scanned the barcode was only 18.78%, and about 80% of the time was idle.

The quantity statistics and average storage time for each type of spare parts are shown in the statement in Figure 8. Among them, the average storage time for category A, B, and C spare parts was 29.08, 44.8556, and 20.9587 minutes, respectively. The quantities were 982, 360, and 68, respectively. The number of scrap spare parts that failed the inspection was 92, and the average storage time was 20.6909 minutes. The average time consumed for entering the warehouse is 25.2041 minutes, and the quantity is 359 pieces.

Time

VA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	9.6018	0.078849937	3.2653	13.4475

NVA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	21.0749	(Correlated)	0.00	81.3326

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Other Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	30.6767	(Correlated)	3.8131	91.0632

Other

Number In	Value
Entity 1	1974.00

Number Out	Value
Entity 1	1861.00

Fig.6 Option 2 Entities Report

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
bar worker	0.1878	0.020903264	0.00	1.0000
checker a	0.9036	(Correlated)	0.00	1.0000
checker b	0.9505	(Insufficient)	0.00	1.0000
checker c	0.5271	(Insufficient)	0.00	1.0000
worker a	0.6573	0.095132436	0.00	1.0000
worker b	0.8406	(Insufficient)	0.00	1.0000
worker c	0.3153	(Insufficient)	0.00	1.0000
worker rfid	0.6406	(Insufficient)	0.00	1.0000

Fig.7 Option 2 resource report

Tally

Interval	Average	Half Width	Minimum Value	Maximum Value
Record A	29.0879	(Correlated)	7.8723	71.0370
Record B	44.8556	(Correlated)	9.0394	91.0632
Record C	20.9587	(Insufficient)	8.0738	45.0661
Record F	20.6909	(Insufficient)	3.8131	53.5504
Record RFID	25.2041	(Correlated)	6.3748	69.7168

Counter

Count	Value
Number A	982.00
Number B	360.00
Number C	68.0000
Number F	92.0000
Number RFID	359.00

Fig. 8 Option 2 User Specified Reports

Joint processing by all workers for different orders

The Entities report, which records the average inbound time, and the number of parts arriving at the warehouse and completed inbound, is shown in Figure 9. The number of spare parts arriving at the warehouse is 1934, and the number of spare parts conducting the inbound operation is 1910. The average inbound elapsed time for each spare part is 16.06 minutes (the category overview report shows that the average effective operation time is 9.58 minutes, and the average queuing time is 6.488 minutes).

Figure 10 shows the resource report of the simulation results. The information records the idle and busy situation of the warehouse staff. The report indicates that the effective work ratio of 12 inspectors checker is 88.96%, and the work intensity is moderate. The effective work ratio of 12 staff who shelve spare parts and update inventory information is 67.71%, and the work intensity is easy. The effective work ratio of 2 staff who paste and scan bar codes is only 18.73%, most of the time idle.

The User Specified report is shown in Figure 11. The word counts the average time consuming of each type of spare parts in the warehouse and the number of spare parts completed. Among them, the average storage time for category A, B, and C spare parts was 14.5756, 24.0592, and 28.4721minutes, respectively. The quantities were 1013, 344, and 79, respectively. The number of scrap spare parts that failed the inspection was 101, and the average storage time was 7.2810 minutes. The average time consumed for entering the warehouse is 12.5049 minutes, and the quantity is 373 pieces.

Comparison of Simulation Results

The comparison of the simulation results of the three options is shown in Table 1. It can be seen that option 3 handles slightly more spare parts than option 2, and the number of spare parts handled by option 1 is one-third less than the number of spare parts handled by options 2 and 3. In this case, the average inbound elapsed time for option 3is 135.0159 minutes less than option 1, a reduction of about 89.2465%, and 14.6084 minutes less than option 2, a decline of approximately 47.6205%. The average spare parts queuing time is 135.232 minutes or 95.42% less than option 1 and 14.5869 minutes or 69.21% less than option 2, increasing warehousing efficiency. Then look at the efficiency of warehouse staff and the effective work of inspectors as a percentage of total work hours from checker a's 99.84%, 90.36%, checker b's 95.05% to checker's 88.96%. The effective work efficiency of spare parts shelving and updating inventory information decreased from 84.88% for the worker a and 84.06% for worker b to 67.71% for worker. It can be seen that Option 3, in which all workers work together for different orders, takes less time for the operation of inspecting spare parts and updating inventory. Correspondingly the effective working time of the staff is reduced, making the work less intensive.

VA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	9.5803	0.099226187	3.0845	13.6093

NVA Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Wait Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	6.4880	(Correlated)	0.00	111.03

Transfer Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Other Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	0.00	0.000000000	0.00	0.00

Total Time	Average	Half Width	Minimum Value	Maximum Value
Entity 1	16.0683	(Correlated)	3.1691	119.24

Other

Number In	Value
Entity 1	1934.00

Number Out	Value
Entity 1	1910.00

Fig. 9 Option 3 Entities Statement

Usage

Instantaneous Utilization	Average	Half Width	Minimum Value	Maximum Value
bar worker	0.1873	(Correlated)	0.00	1.0000
checker	0.8896	0.033694064	0.00	1.0000
worker	0.6771	0.081057944	0.00	1.0000

Fig. 10 Option 3 User Specified report

Tally

Interval	Average	Half Width	Minimum Value	Maximum Value
Record A	14.5756	2.99728	7.3597	53.1435
Record B	24.0592	8.04417	8.1325	91.7573
Record C	28.4721	(Insufficient)	8.0379	119.24
Record F	7.2810	(Insufficient)	3.1691	31.3388
Record RFID	12.5049	1.88455	6.1382	40.7910

Counter

Count	Value
Number A	1013.00
Number B	344.00
Number C	79.0000
Number F	101.00
Number RFID	373.00

Fig.11 Option 3 User Specified Reports

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Table 1 Comparison of Simulation Results

Statistical volume (eight hours of work per day, simulating two working days)		Option 1	Option 2	Option 3
Number of spare parts arriving at the warehouse (pieces)		1944	1974	1934
Number of completed incoming spare parts (pieces)		1259	1861	1910
1	Number of category A incoming spare parts (pieces)	545	987	1013
2	Number of category B incoming spare parts (pieces)	337	386	344
3	Number of category C incoming spare parts (pieces)	62	90	79
4	Number of spare parts in scrap storage (pieces)	57	95	101
5	RFID inbound spare parts quantity (pieces)	258	372	373
Average time spent in storage		151.284	30.677	16.068
1	Effective operation elapsed time (minutes)	9.564	9.602	9.580
2	Waiting time in line (minutes)	141.72	21.0749	6.488
Average storage time for category A spare parts (minutes)		260.49	29.088	14.576
Average storage time for category B spare parts (minutes)		16.388	44.856	24.059
Average storage time for category C spare parts (minutes)		11.937	20.959	28.472
Scrap spare parts elapsed time (minutes)		150.53	20.691	7.281
Average RFID spare parts warehousing time (minutes)		130.46	25.204	12.505
Warehouse staff efficiency				
1	checker a	99.84%	90.36%	
2	checker b	62.87%	95.05%	
3	checker c	12.93%	52.71%	
4	worker a	84.88%	65.73%	
5	worker b	53.26%	84.06%	
6	worker c	9.76%	31.53%	
7	worker rfid	30.98%	64.06%	
8	bar worker	12.44%	18.78%	18.73%
9	checker			88.96%
10	worker			67.71%

5. Conclusion

Three indexes are selected to measure the effect of strategy optimization comprehensively. The simulation model is used to detect the improvement of different staff allocation optimization strategies on the efficiency of auto spare parts warehousing inbound to select the optimal method. The conclusion is that the optimal design for various orders to be handled by all workers is optimal. This can significantly reduce the waiting time in the queue for all spare parts warehousing processes. And at the same time, it reduces workers' work intensity to achieve the best working condition and comprehensively improves the efficiency of auto spare parts warehousing.

Based on the process of auto spare parts warehousing, the simulation modeling of an auto spare parts factory is carried out using Arena simulation software. The indicators and effect graphs reflecting the auto spare parts warehousing situation are output in real-time when the system runs. The optimal results of the simulation model system are obtained through multiple index tests, which provide a basis for the auto spare parts warehousing process research.

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