 doi: 10.54517/vfc.v3i2.2603

Original Research Article

Research on the Improvement of University Restaurant Service Capability: Based on IE and Flexsim Simulation

HAN Jing-yuan, XING Cong-cong, SUN Zhi-cong

School of Economics and Management, Hebei University of Science and Technology, Shijiazhuang 050018, China

Abstract: According to the example of University restaurant, in order to improve the service ability, the industrial engineering method is used to optimize the meal purchasing process and restaurant layout. Considering the process random events, queuing, popular routes and other factors, the simulation model is established by using Flexsim software. The data are collected by field measurement and random sampling, and the data distribution is verified by maximum likelihood estimation method and goodness of fit test method, and the simulation parameters are calculated. The simulation results show that the optimized model can serve 124 people more than the current model in one hour, and the working rate of the four checkout counters has been improved, which proves that the optimized scheme can effectively alleviate the crowd congestion, improve the service ability, and provide data support for the implementation of the optimization scheme.

Keywords: Restaurant optimization; Service capability; Modeling and simulation; Industrial engineering; Flexsim.

1. Introduction

With the expansion of the scale of higher education in our country, the number of college students is increasing year by year. Due to multiple factors such as layout, process and staff, overcrowding and long queuing time of students often occur in university restaurants during the peak period after school.

How can we effectively alleviate the problem of passenger congestion and improve service efficiency? Many scholars have carried out research and put forward countermeasures, such as using SLP to plan layout[1,2], using queuing theory to optimize queuing system, etc[3-7]. In addition, Industrial Engineering (IE)[8-10] method was used to analyze the process and layout, combined with Flexsim software modeling and simulation to find the bottleneck, and then improve and verify the optimization effect[11-13]. However, most scholars lack the consideration of random events in process analysis. Flexsim modeling lacks the influence of the random route of the flow of people. The movement direction of the temporary entity only depends on the connection of A, and the route of the personnel is all straight.

According to the actual case, considering the conditions of random events in the process and random routes of people traveling, aiming at the situation that it is impossible to make significant changes in the layout, the food purchasing process and restaurant layout are analyzed and optimized by IE method from the perspective of food buyers, and Flexsim software is used to simulate, providing data support for the implementation of the optimization plan in reality.

2. Status of the Issue

School A is a key undergraduate university in a province, with four independent restaurants, which can basically meet the needs of students to buy food. During the COVID-19 pandemic, the campus has been closed, students can not go out to buy food, and the campus restaurant has seen a surge in customers. In the peak period of class, the campus restaurant often has different degrees of crowded people and low efficiency of buying meals.

Received: 12 October 2023 Accepted: 27 October 2023 Available online: 11 December 2023

The third restaurant located at the intersection of the teaching area and the living area is more serious. Through the observation and analysis of the current situation of restaurant food purchasing, it is found that there are some places to be improved in the process and layout of food purchasing.

2.1 Current Status of Restaurant Layout

The third restaurant is located in the middle of the road from the student dormitory to the teaching building, with the south, north and west doors as the entrance and exit. The restaurant is equipped with a food purchase area, plate pickup area, chopsticks pickup area, etc. The plane layout is shown in Figure 1.

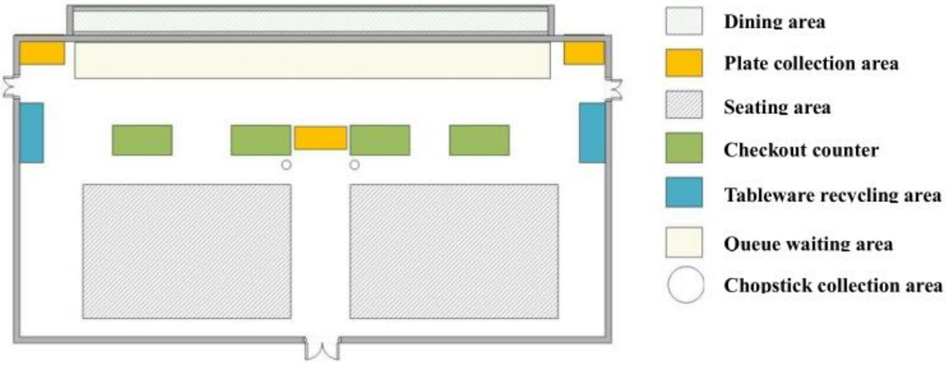

Figure 1 Restaurant Layout Plan.

2.2 Current Status of the Meal Purchase Process

The process begins with entering the restaurant and ends with leaving the restaurant. After entering the restaurant, students will get their plates in the plate collection area, and some students will occupy the seats, then look for the food they want to buy, go to the target food purchase area, order the food and pay at the checkout counter, after the checkout, go to the chopsticks collection area to get chopsticks, look for the table to eat, after the meal, put the plate chopsticks in the recycling area, and finally leave the restaurant, the entire food purchase process is completed. The flowchart of food purchase is shown in Figure 2.

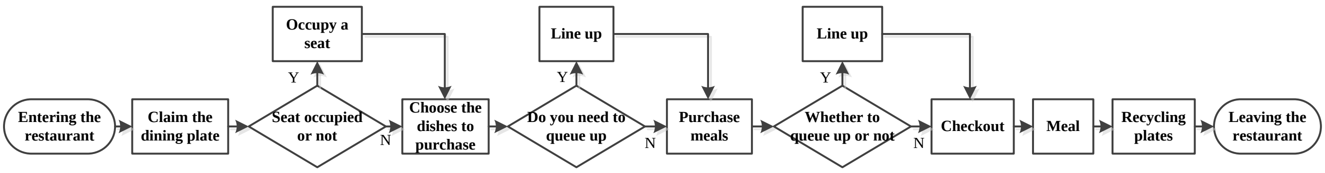

Figure 2 Meal Purchase Flowchart.

3. Process, Route Analysis

3.1 Current Situation

Using the process analysis, layout and route analysis in industrial engineering, the current meal purchase process is recorded, so as to further analyze whether there are unreasonable places. The students' meal purchase process is shown in Figure 3.

The route of students' food shopping was recorded and analyzed using the roadmap. According to the sequence recorded in the process diagram, each process activity was marked with symbols and numbers. The roadmap of students' food shopping through the north gate of the restaurant was shown in Figure 4.

3.2 Problem Analysis

The restaurant has three entrances and exits (north gate, South gate and West gate). During the peak hours of classes and classes, the personnel in the restaurant will move along a complex path, and the number of round-trip movements will be many, which will often cause crowded people in the restaurant and low efficiency in buying meals. Combining the process diagram of food purchase with the roadmap analysis, it can be found that the reasons leading to this phenomenon are:

Job description / Statistical table	Assignment Content	Number of times
Job description: Meal Purchase Process	**Operate ○**	**6**
Object: Food purchasing personnel	**Inspect □**	**1**
Location: Restaurant of a certain university	**Transport →**	**8**
Method: Current	**Wait D**	**2**
	Storage ▽	**0**

Illustrate	○	□	→	D	▽
1. Enter the door and proceed to the dining plate			●		
2. Claim the dining plate	●				
3. Move to the seating area and occupy a seat			●		
4. Find the food items you want to purchase		●			
5. Move to window			●		
6 queues				●	
7. Purchasing Meals	●				
8. Move to checkout counter			●		
9. Queuing				●	
10. Checkout	●				
11. Move to the chopstick area			●		
12. Take chopsticks	●				
13. Move to dining table			●		
14. Meals	●				
15. Move to the tray recycling area			●		
16. Recycling plates	●				
17. Go out, leave			●		

Figure 3 Procedural Diagram of the Current Meal Purchase Process.

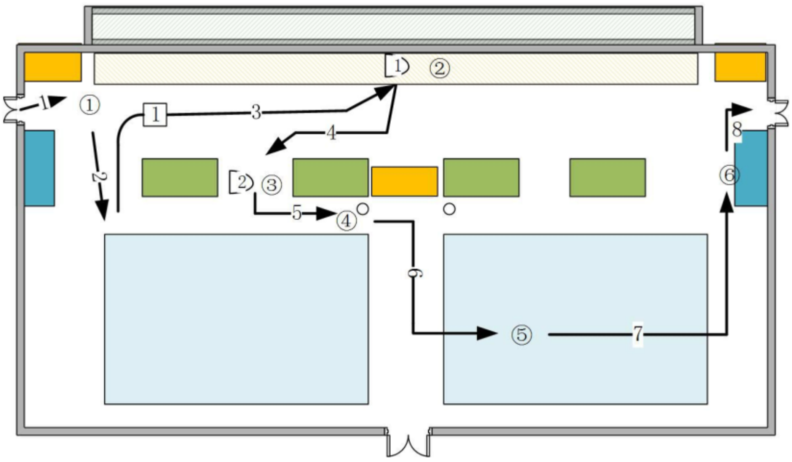

Figure 4 Current Route Map for Meal Purchases.

(1) After the students receive the dinner plate, most of them will first go to the seating area to occupy a

seat, and then return to the queue to buy food, and the flow of people to and from the North-South channel is easy to hinder the travel of the food purchase personnel during the peak period.

(2) During the peak period, there are too many people to buy meals, the service staff service intensity is large, the queue to buy meals and the checkout queue exceeds the waiting area, causing the flow of people to hinder, and the flow of people in the restaurant decreases.

(3) The checkout counter and the tray collection area block the west gate pedestrian passage.

(4) The chopsticks pick-up area is close to the seating area and checkout desk, which is too narrow and crowded, causing road congestion.

(5) Due to the tray recycling area at the north and south gates, the personnel flow is dense and often blocked, but the personnel flow at the west gate is sparse.

4. Optimisation Programme

4.1 Improvement Based on IE

Using industrial engineering 5W1H questioning technology and ECRS principles, suggestions for optimization of current processes and layouts:

(1) The plate pickup area and chopsticks pickup area are merged to reduce the path of personnel moving back and forth.

(2) Taking into account the behavior of occupying seats, the tray collection area and the seating area should be as close as possible to reduce the reciprocating distance of students occupying seats.

(3) The tray collection area in the middle of the checkout counter will be repositioned so that the tray collection area is adjacent to the west gate, and the middleman circulation channel will be opened to speed up the flow of personnel.

(4) The four checkout counters are arranged in an “L” shape to prevent checkout queues from blocking the flow of people.

(5) Add a tray recycling area and arrange it near the West gate to ease the congestion of people in the north and south gates.

(6) Add electronic kanban in each meal purchase window to make the price and variety of dishes at a glance, and reduce the time to think about the choice.

4.2 Optimised Food Buying Process and Layout

The optimized food purchase process program diagram and layout diagram are shown in Figure 5 and Figure 6. Compared with the current situation, the optimized food purchase process reduces 3 processes: operation, inspection and movement. Compared with the current situation, the mobile route of food shopping in the optimized scheme reduces the round-trip route, and the layout of the “L” checkout desk is more flexible, which can alleviate the obstruction of the queue on the passenger flow channel and effectively improve the food shopping environment.

The layout scheme is shown in Figure 6.

5. Flexsim Simulation

Simulation is the process of establishing the actual activity event model and conducting experimental research on it. Flexsim 2017 simulation software was used to establish a restaurant meal purchase simulation model before and after optimization, and comparative observation was made to evaluate whether the optimized meal purchase process and layout scheme were effective.

5.1 Simulation Element

Flexsim is a discrete event simulation software that uses 3D virtual animation to simulate processes and output data reports to easily identify problems and help users make decisions and optimize solutions.

As shown in Table 1, relevant simulation elements can be used to simulate the meal purchase process of university restaurants, further helping to make program evaluation and decision. Considering that the flow of people will travel randomly instead of in A straight line, the A* module and the A* algorithm navigation can reasonably plan the walking path of personnel to achieve the purpose of collision avoidance and automatic optimization.

Job description: Meal Purchase Process
Object: Food purchasing personnel
Location: Restaurant of a certain university
Method: After optimization

Statistical table	
Assignment Content	**Number of times**
Operate ○	**5**
Inspect □	**0**
Transport →	**7**
Wait D	**2**
Storage ▽	**0**

Illustrate	**Symbol**				
	○	□	→	**D**	▽
1. Enter the door and proceed to the dining plate			●		
2. Collect plates and chopsticks	●				
3. Move to the seating area and occupy a seat			●		
4. Move to window			●		
5. Queuing				●	
6. Purchasing meals	●				
7. Move to checkout counter			●		
8. Queuing				●	
9. Checkout	●				
10. Move to dining table			●		
11. Meals	●				
12. Move to the tray recycling area			●		
13. Recycling plates	●				
14. Go out, leave			●		

Figure 5 Optimised Meal Purchase Process Flow Diagram.

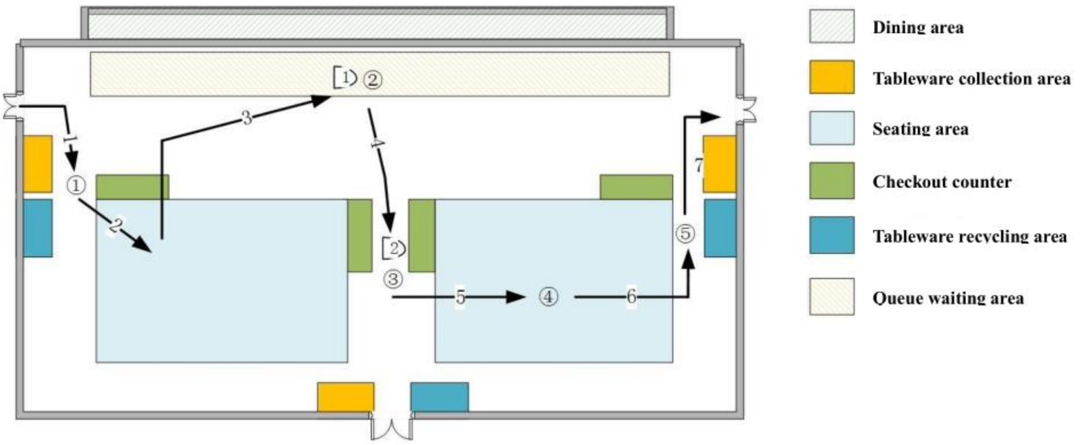

Figure 6 Optimised Route Map.

5.2 Simulation Parameters

The simulation object is the food shopping process during the peak period of lunch shopping. In order to create a simulation model that is consistent with the realistic conditions, the simulation parameters need to be collected: the arrival time interval of food buyers at each entrance, the time required for picking up plates, the probability of occupying seats, the service time of the food shopping window, the service time of the checkout desk, the time required for picking up chopsticks, and the time required for recycling tableware.

Table 1 Simulation Model Elements.

Functional elements	Flexsim simulation elements	Function
Entrance	Source	Food shoppers entering the restaurant
Export	Sink	Food shoppers leaving the restaurant
Food shoppers	Task Executer Flow Item	Food shoppers walking along the path
Plate collection area	Processor	Picking up plates
Occupying a seat	Queue	Buyers have a chance of occupying seats
Catering queue area	Queue	Waiting in line to purchase meals
Meal purchasing window	Processor	Purchase meals
Checkout counter	Processor	Checkout
Checkout queue area	Queue	Waiting in line for checkout
Chopstick collection area	Processor	Take chopsticks
Seating area	Rack	Find a seat and have a meal
Plate recycling area	Processor	Recycling plates
Tableware collection area	Processor	Picking up plates and chopsticks
Chopstick queue area	Queue	Waiting in line to collect chopsticks
Restaurant layout	Visual	Distribute entities according to the actual layout of the restaurant
Mobile Path	AStar	Random flow of people to avoid entities and collisions
Wall	Barriers	Prevent personnel from walking through restaurant walls

5.2.1 Meal Purchaser Arrival Intervals

Poisson process is also called Poisson flow, which can fit many practical problems in real life, such as the process of food buyers arriving at the restaurant[14]. It is generally believed that if the arrival rate per unit time follows the Poisson distribution, the arrival time interval follows the negative exponential distribution[15].

During the peak period of people flow (11:00-12:00), the number of people arriving in the restaurant was collected and counted. In the unit of time, 300 data samples were collected from the south gate (Entrance 2) through field research from Monday to Friday, and the average number of people arriving per minute was obtained, as shown in Figure 7.

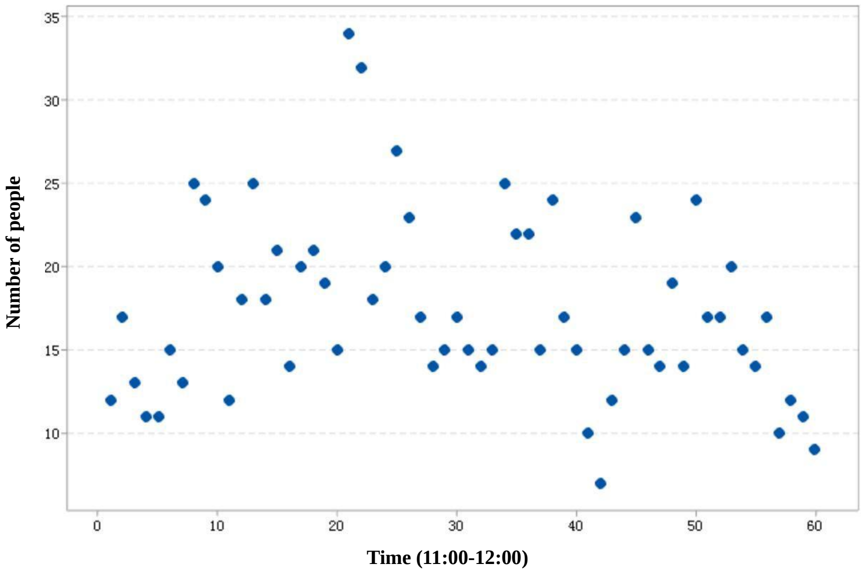

Figure 7 Entrance 2 Distribution of the Number of Arrivals of People Who Purchased Meals.

It is assumed that the arrival process of the purchaser obeys a Poisson distribution with parameter λ, i.e:

$$P(X=k)=\frac{(\lambda)^k}{k!}e^{-\lambda};k=0,1,2,\cdots,\lambda>0 \tag{Eq.1}$$

In order to verify the hypothesis, the maximum likelihood estimation method is used to estimate the parameter λ, and then the goodness test method of X^2 fitting is used to test it.

(1) Maximum likelihood estimation method.

Suppose $X1,X2\cdots Xn$ are samples of the population Xd, then the likelihood function of the sample they constitute is:

$$L(\lambda)=\prod_{i=1}^{n}P(X=xi)=\prod_{i=1}^{n}\frac{\lambda^i}{i!}e^{-n\lambda} \tag{Eq.2}$$

Taking the logarithm of the above formula and taking the derivative with respect to λ yields:

$$\frac{\partial InL(\lambda)}{\partial\lambda}=\frac{\sum_{i=1}^{n}X_i}{\lambda}-n \tag{Eq.3}$$

If the above formula is 0, it can be found that the maximum likelihood estimate of the parameters of the Poisson distribution is the average value of the sample:

$$\lambda=\frac{\sum_{i=1}^{n}X_i}{n}=\overline{X} \tag{Eq.4}$$

According to Eq.4, the parameter λ=17.33 can be calculated according to Table 2.

Table 2 Number of Simulation Model Inputs and Outputs before and after Optimisation.

	Status	After optimization
Entrance 1	708	705
Entrance 2	1039	979
Entrance 3	558	533
Output (number of people purchasing meals)	2305	2217
Export 1	600	472
Export 2	594	521
Export 3	273	598
Input (number of departures)	1467	1591

(2) X^2 goodness-of-fit test

After calculating the parameter λ=17.33, goodness of fit test is needed. The significance level was set at 0.05, and the following hypothesis was proposed: The original hypothesis H_0: the number of food buyers arriving at 2 inlet per minute followed the Poisson distribution with parameter λ=17.33; Alternative hypothesis H_1: The number of arrivals per minute at entry 2 does not follow the Poisson distribution with parameter λ =17.33.

According to X^2 goodness of fit test theory, Minitab software was used to calculate the goodness of fit test results of Poisson distribution, as shown in Table 3.

The calculated result from Table 4 is X^2=8.2055, and the degree of freedom is k-r-1=9-1-1=7. The significance level α =0.05, and $X^2_{0.05}(7)$ =14.07 through inquiring card square distribution table.

$X^2 < X^2_{0.05}(7)$, so the original hypothesis H_0, “The number of arrivals per minute at entry 2 follows the Poisson distribution of parameter λ=17.33” is valid.

Table 3 Entry 2 Arrival of Meal Buyers X^2 Goodness-of-Fit Test Results.

Number of arrivals per minute	Observation Count	Poisson probability	Observation Count	Contribution
<=10	4	0.041965	2.5179	0.8724
11-12	7	0.077083	4.625	1.21965
13-14	8	0.135923	8.1554	0.00296
15-16	10	0.181017	10.861	0.06826
17-18	10	0.188394	11.3037	0.15035
19-20	6	0.157384	9.443	1.25537
21-22	4	0.107832	6.4699	0.9429
23-24	5	0.061675	3.7005	0.45633
>=25	6	0.048726	2.9236	3.23728
Total	60	1	60	8.2055

Similarly, the number of food buyers arriving per minute at entry 1 and entry 3 follows parameters 12.26 and 8.98 as Poisson process.

If the customer arrival process is Poisson flow, then the customer arrival time interval follows a negative exponential distribution, and the mathematical expectation is: E (T) =1/λ, so the mathematical expectation of the customer arrival time interval at entrance 1, entrance 2 and entrance 3 is 0.081 minutes, 0.057 minutes and 0.111 minutes. In Flexsim software, second is set as the unit of time, and after unit conversion, the customer arrival interval of the three entrances follows the negative exponential distribution of the expected value of 4.89 seconds, 3.46 seconds, and 6.68 seconds.

5.2.2 Other Data

Due to the characteristics of “small space and dense crowd” among restaurants in reality, it is difficult to statistical the data of the meal purchase process, and it is easy to cause omissions. Since students have similar food shopping habits, random sampling is adopted to carry out random sampling in the peak period of food shopping. By tracking the purchasing process of food buyers and observing the time and law of each process, the flow of people between nodes can be reflected and the cost is low. Relevant data are shown in Table 4.

Table 4 Purchase Process Parameters.

Meal purchasing process parameters	numerical value
When taking the plate	2.97 seconds
Meal purchase time	30-60 seconds (set to random within the range due to large fluctuations)
Checkout time	4.78 seconds
When picking up chopsticks	2.31 seconds
Recycling time for tableware	2.19 seconds
Dinner time	600 for 900 seconds (due to significant fluctuations, set to random within the range)
Seat occupancy probability	60%

The number of fixed resource entities is shown in Table 5.

Table 5 Number of Fixed Resource Entities.

Fixed resource entity type	Current value	Optimized value
Plate collection area	3	0
Number of food purchase windows	30	30
Checkout counter	4	4
Chopstick collection area	2	0
Seating capacity	500*2	500*2
Tableware recycling area	2	3
Tableware collection area	0	3

5.3 Simulation Model

Considering the fact that some food buyers pack up and take away in reality, the probability of customer pack up and take away event is set as random in Flexsim modeling. Consider the food purchase flow chart in the case of customers taking food away, as shown in Figure 8.

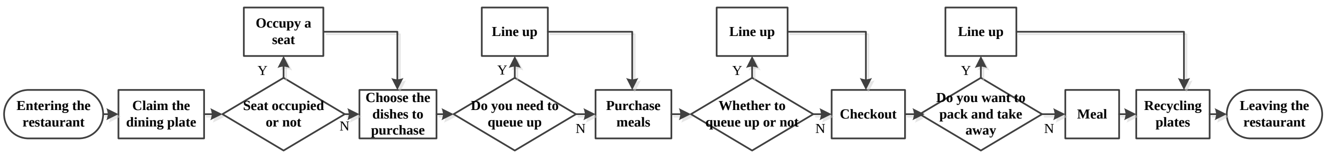

Figure 8 Existing Meal Purchase Processes Considering Pack-and-Go Situations.

5.3.1 Current Restaurant Meal Purchase Simulation Model

According to the current process and relevant parameters, Flexsim was used to create a simulation model of restaurant meal purchase during the school peak period (11:00-12:00), as shown in Figure 9 and Figure 10.

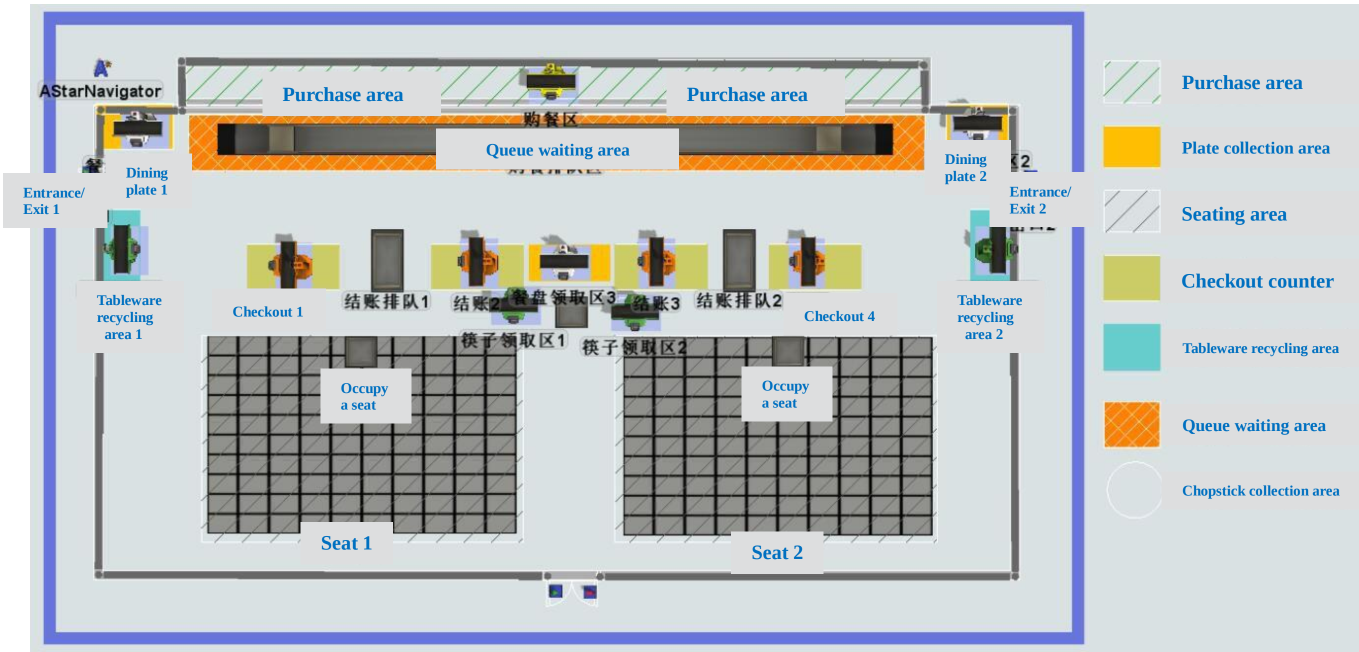

Figure 9 Current Restaurant Meal Purchase Simulation Model.

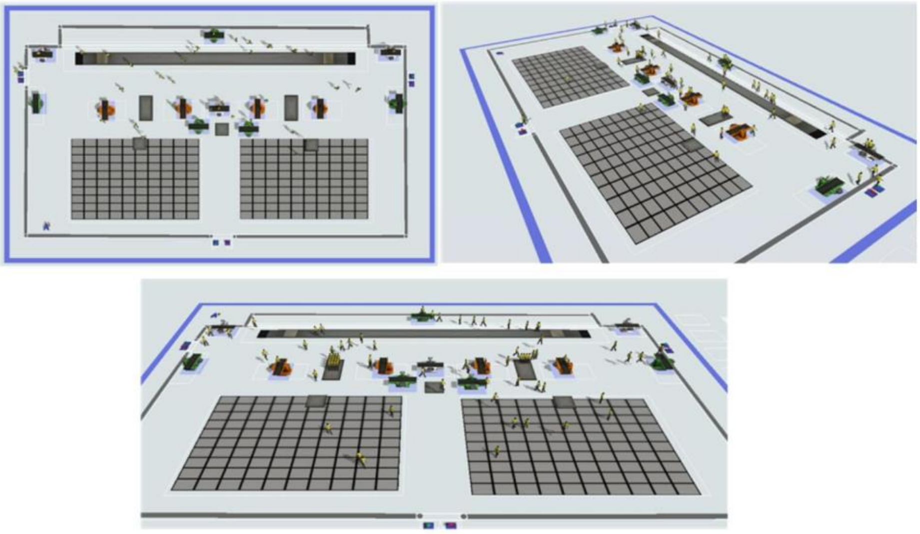

Figure 10 Running Effects of the Current Meal Purchase Simulation Model.

5.3.2 Optimised Restaurant Food Purchase Simulation Model

Flexsim was used to create the simulation model of restaurant meal purchase after optimization, as shown in Figure 11 and Figure 12.

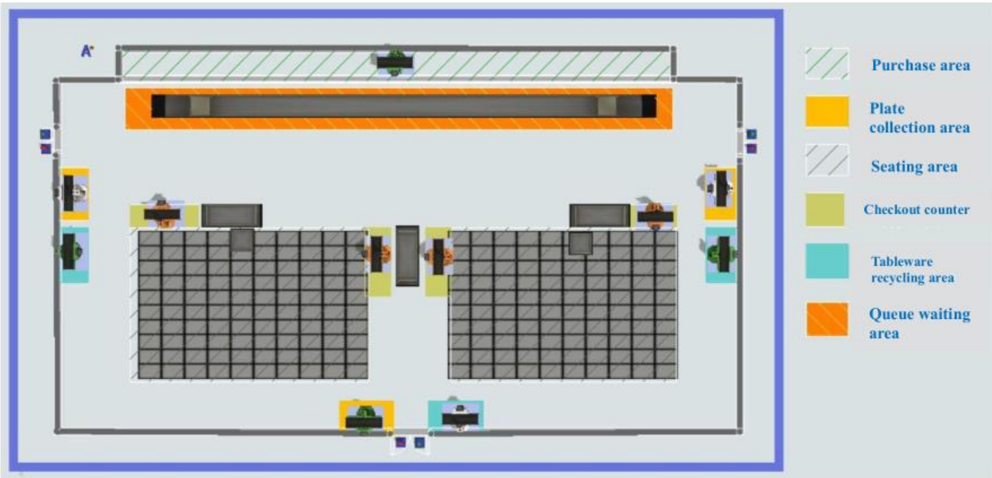

Figure 11 Optimised Restaurant Food Purchase Simulation Model.

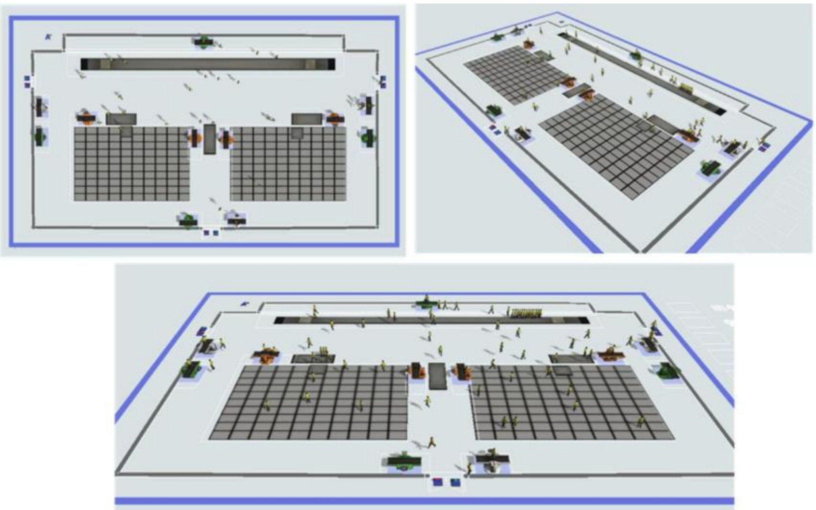

Figure 12 Running Effect of the Optimised Meal Purchase Simulation Model.

5.4 Data Analysis

After running the current meal purchase simulation model and the optimized simulation model for 3600 seconds respectively, the Dashboard tool is used to collect and output the data in Table 4.

According to the simulation results, the number of people who purchased meals and the number of people who left the meal were 2305 and 1467 in 3600 seconds. After optimization, the number of people buying meals in the simulation model is 2217, and the number of people leaving is 1591. Compared with the current model, the number of people leaving in the optimized model is 124 more, and the number of people leaving in the entrance 3 (west gate) has increased by 325 compared with the current simulation model, which can effectively alleviate the crowded situation of the entrance 1 (north gate) and the entrance 2 (South gate). (Figure 13)

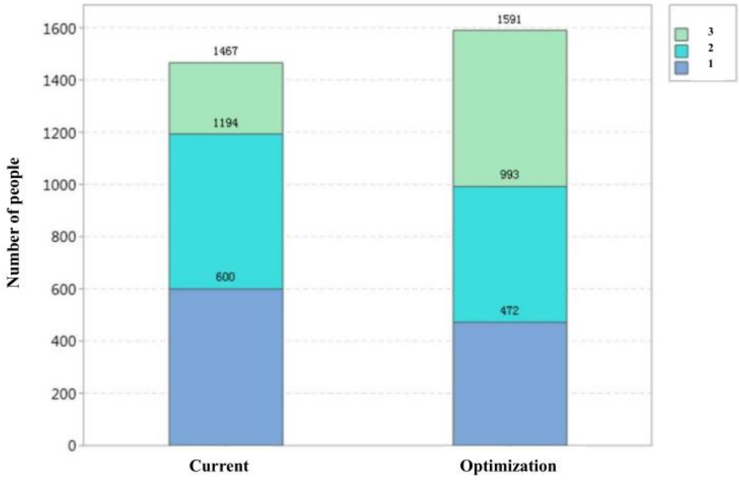

Figure 13 Number of People Exported and Exported by Each of the Meal Purchase Simulation Models before and after Optimisation.

The working rates of the four checkout stations in the current simulation model are 46.5%, 45.8%, 45.8% and 47.1%, respectively. After optimization, the working rate of the four checkout stations is 51.6%, 50.1%, 46.7% and 49.0%, respectively, and the working rate of the four checkout stations has been improved. (Figure 14)

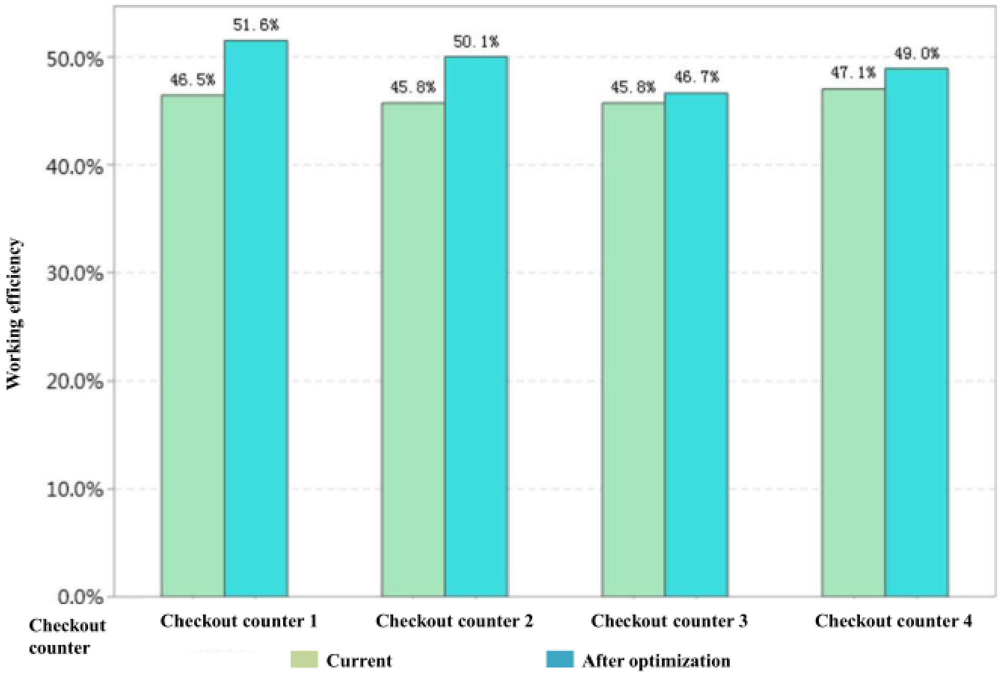

Figure 14 Simulation Model Checkout Desk Work Rate before and after Optimisation.

As shown in Figure 15 and Figure 16, the number of queues in the checkout area of the current food purchase model has a large variation, and the fluctuation of the number of queues is concentrated in 2-4 people. After optimization, the number of people in the three checkout queuing areas of the simulation model has a small variation, and the fluctuation range of the number of people in the queue is concentrated in 1-2 people, which proves that the optimized scheme can effectively alleviate the queuing situation at the checkout counter.

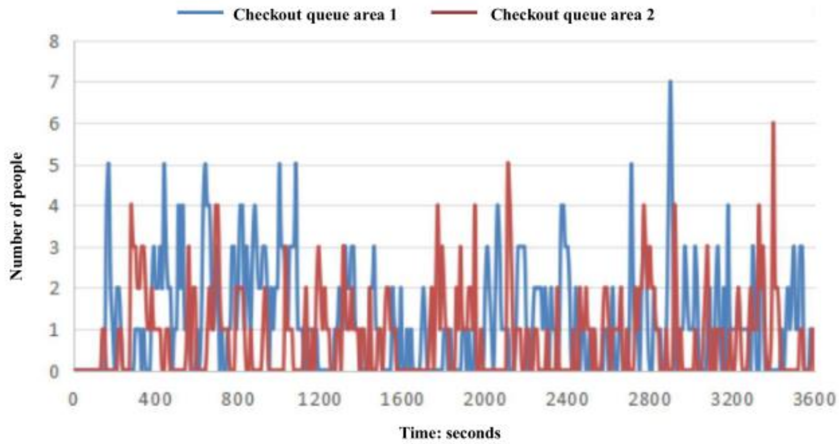

Figure 15 Number of People in the Checkout Queuing Area of the Current Meal Purchase Simulation Model.

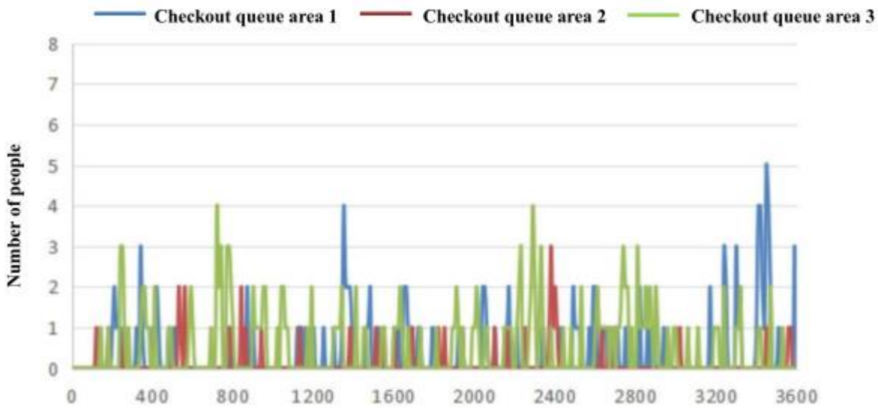

Figure 16 Number of People in the Checkout Queue Area of the Optimised Meal Purchase Simulation Model.

To sum up, compared with the current model, the optimized simulation model has been improved in terms of service number, checkout counter working rate and checkout counter queue arrangement.

6. Conclusion

By using IE analysis methods and tools, the layout of university restaurants and the food purchasing process were improved. Under the consideration of factors such as random events in the process, queues and people flow routes, Flexsim software was used to establish a simulation model of restaurant food purchasing that was close to reality. The output data proved that the optimized restaurant food purchasing plan could effectively improve the current food purchasing service ability. And alleviate the crowded situation in the restaurant, which is helpful to improve the service ability of universities.

References

1. Zhou Bin. Optimization design of facility layout of a cafeteria based on SLP [J]. Logistics Engineering and Management, 2014,36 (04) : 137-139.
2. YU Dunwu. Canteen Layout design optimization based on SLP [J]. Wireless Internet Technology, 2014 (07) : 121-122.

3. Xie Fuchun, PENG Kola, Wang Juan, Tang Qian, QING Shangle, Wang Xian 'an. Analysis and improvement of supermarket Cash register System based on queuing theory [J]. Industrial Engineering, 2019, 23 (02) : 142-149. (in Chinese)
4. Wang Hui. Application of queuing Theory in the performance analysis of bank service window [D]. Yanshan University, 2019.
5. LI Yanan. Research on Table Configuration and Layout Optimization of W Restaurant [D]. Nanjing University of Aeronautics and Astronautics, 2019.
6. Jia Shuyuan, Huang Li, Tan Juan, Li Shungang. Optimization design of fast food restaurant catering Process [J]. Industrial Engineering, 2019,22 (06) : 127-134. (in Chinese)
7. Cao Qian, Gu Yuyao. Optimization of window facilities layout in University dining halls based on queuing Theory: A case study of Shanghai Electric Power University [J]. University Logistics Research, 2020 (01) : 31-33.
8. Jia Shuyuan, Huang Li, Tan Juan, Li Shungang. Optimization design of fast food restaurant catering Process [J]. Industrial Engineering, 2019,22 (06) : 127-134. (in Chinese)
9. Yuan Yujiao, Li Junxiang, Ye Chunming. Research on Optimization of service assembly line layout in University canteen [J]. Shanghai Management Science, 2014,36 (04) : 105-109. (in Chinese)
10. Yang Haiqi, Zhang Guohui, Banknotes Yufei. Research on Industrial Engineering Optimization of University Restaurant [J]. Management Engineer, 2016,21 (06) : 71-74.
11. Li Weiwei, Wang Zheng, Tao Yang. Simulation of University restaurant queue based on Flexsim [J]. Value Engineering, 2019,38 (22) : 26-29. (in Chinese)
12. Hu Zhongmin. Research on Measurement and Improvement of Fast Food restaurant service Providing Ability based on Flexsim Modeling and Simulation [D]. Guangxi University of Science and Technology, 2019.
13. Chen Ning, Zong Yi, Liu Huashuo, Ma Xin. Layout simulation and efficiency optimization of a snack food warehouse based on Flexsim [J]. New Industrialization, 2020,10 (03) : 115-118.
14. Wang Dongsheng, Liu Yutang. Application of Poisson Process in Queuing Theory [J]. Journal of Henan Mechanical and Electrical College, 2007 (04) : 121-122,125.
15. Yu Chuntian, Li Fachao, Hui Hongqi. Operations Research [M]. 2nd Ed. Beijing: Science Press, 2011:294-295.