Simulation and optimization of university canteen service under the situation of epidemic prevention and control based on queuing theory

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Abstract. In this paper, according to the randomness of students ' arrival in the canteen and the randomness of dining time, a queuing model of canteen service is established. The students ' arrival rate and service time are randomly simulated, and the students ' multi-queue dining service is dynamically simulated. So got the queuing time, busy rate of dining windows and other factors. Considering the waiting cost of students and the operating cost of canteen, and effectively combining the epidemic prevention, the optimal number of canteen windows is obtained. It puts forward the optimization scheme for students to eat, and provides feasible suggestions for canteen managers and schools.

Keywords: Student flow, Canteen window, Dynamic simulation, Random number, Epidemic prevention and control.

1 Introduction

Before the global epidemic situation has not been completely controlled, it is a very typical queuing phenomenon that all services should be carried out under the premise of limiting current and maintaining social distance due to the needs of epidemic prevention and control.

In the school canteen queuing system, on the one hand, students hope that the shorter the waiting time is, the better. This requires the canteen to set more canteen windows to improve service efficiency, which will increase the operating cost of the canteen. The number of canteen windows is too short, the service efficiency is too low, and even can not meet the service requirements.

Epidemic prevention and control may become normal. How to scientifically and reasonably set the number of canteen windows to improve service efficiency is a queuing problem that needs to be solved in canteen halls.

2 Dynamic simulation method

Dynamic simulation is based on the actual data, using random system simulation method,

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from the actual probability distribution of random variables, through random number selection method, as input variable sequence simulation. In the application of this method, the required random number sequence should conform to the specific probability distribution of the random variable. The basic steps are as follows:

(1) The mathematical model is established. According to the actual situation of the school, a probability model of student arrival and service time is constructed.

(2) To generate a set of random numerical sequences which conform to the probability distribution characteristics of random variables in school;

(3) The random numerical sequence is used to simulate the arrival and service time of students, and the service simulation test is carried out to obtain the simulation test value.

(4) The simulation test results are statistically processed to make a scientific explanation for the problems studied.

3 Dynamic simulation model based on queuing theory

3.1 Canteen canteen queue model (M/M/C)

The canteen window service is a random service system, which has the following characteristics:

(1) The number of students is limited, and the time interval between students ' arrival and service is random and independent.

(2) Multiple windows in the canteen are independent of each student's service time.

(3) Multi-queue parallel, follow the principle of first to first service.

(4) There are student queues in front of each window, and students choose shorter queues to wait, thus forming a single queue with multiple windows queuing system (M/M/C). Student queuing system structure is as follows:

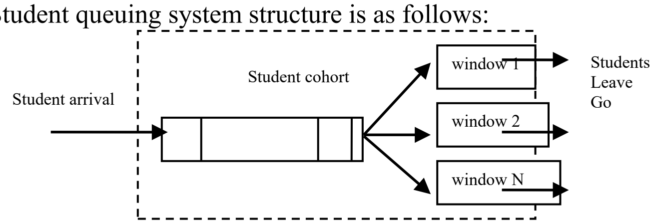

Fig. 1. Canteen queuing system.

3.2 Generating random numerical sequences

The arrival time interval and service time of students obey negative exponential distribution. The distribution density function and distribution function of random variables with negative exponential distribution are respectively:

$$f(x) = \lambda e^{-\lambda x} (x \geq 0)$$

$$F(x) = \int_0^x \lambda e^{-\lambda x} dx = 1 - \lambda e^{-\lambda x} (x \geq 0)$$

The random variable of negative exponential distribution is:

$$x = -\frac{1}{\lambda} \ln u$$

As a result, students arrive:

$$\lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = \cdots = \lambda$$

Window average service level:

$$\mu_1 = \mu_2 = \mu_3 = \cdots = \mu$$

Window service strength: $\rho = \dfrac{\lambda}{\mu}$

Probability of students not waiting: $P_0 = 1 - \rho$

Number of students staying in the system:

$$L = \rho + \rho^2 + \cdots = \frac{\rho}{1-\rho} = \frac{\lambda}{\mu - \lambda}$$

Number of waiting students in the queue:

$$L_q = 1 - P_0 = \frac{\lambda^2}{\mu(\mu - \lambda)}$$

Average stay time of students:

$$W = \frac{L}{\lambda} = \frac{1}{\mu - \lambda}$$

Average waiting time of students:

$$W_q = \frac{L_q}{\lambda} = \frac{\lambda}{\mu(\mu - \lambda)}$$

According to statistics on student arrivals and window service levels in canteens, two random sequences can be generated: student arrival intervals $t\_inter(i)$ and window service time $t\_service(i)$, This numerical sequence input for dynamic simulation.

3.3 Model establishment and symbolic description

$t\_arrive(i)$: The i-th student arrival time

$t\_inter(i)$: The time interval arrival of the i-th student

$t\_service(i)$: The length of service of the i-th student

$t\_start(i)$: Start service time of the i-th student

$t\_leave(i)$: The departure time of the i-th student

$t\_leal(j)$: Last student departure time in the j-th queue

$t\_leall(i)$: The minimum value of the last student leaving time in each queue

$t\_free(i)$: The average idle time of the i-th waiter

$t\_wait(i)$: The waiting time of the i-th student after entering the system.

So there are the following relationships:

$$t\_arrive(i+1) = t\_arrive(i) + t\_inter(i+1)$$

$$t\_start(i) = \max(t\_arrive(i), t\_leall(i))$$
$$t\_wait(i) = \max(0, t\_leall(i) - t\_arrive(i))\ t\_leall(i) = \min(t\_leal(j))$$

4 Simulation system

4.1 Simulation of canteen window service

To solve the problem of canteen queuing, the key is to calculate the number of the best canteen window under normal. According to the statistical data of student flow and service efficiency of canteen window, we can calculate the service rate and student arrival rate of canteen window, and then calculate the optimal number of canteen windows by simulation method. The basic steps are as follows:

Model construct:

(1)The system is stable after a long time of operation.

(2)According to statistical data, the number of students arriving per unit time and the time served for each student are obtained.

According to statistics, the service intensity of single canteen window is 3.1 per minute, that is $\mu = 3.1$, Rate of arrival 19.3 per minute, that is $\lambda = 19.3$.

4.2 Emulation programming

The arrival law of students and the service time of the window are both a random process. According to the statistical data of arrival and service time, two realistic random sequences are generated first. The arrival students choose the shortest queue to wait. At the same time, the service time, departure time, waiting time and stay time are calculated, and the queue length and window busy rate are calculated to change the number of windows to recalculate. In order to make the simulation data closer to reality and avoid contingency, the same simulation is repeated for 2000 times, and the average value of each simulation result is taken.

4.3 Simulation results and analysis

Table 1. Dynamic simulation results.

S	4	5	6	7	8	9	10	11
P	99.3	99.1	97.5	82.3	77.1	72.1	67.7	55.4
W	1376	669	313	15	9	5	1	1

Note: S- Number of windows p- Window busy rate (%) W- Average waiting time (Seconds)

Results analysis: Through the data in the table, it can be found that when students arrive at 19.3 people / min and the service intensity of single window is 3.1 people / min, when 4 – 6 windows are opened, the busy rate of the window is close to 100 %, and there is little leisure. The waiting time of the students is up to 23 minutes recently, which obviously cannot meet the normal canteen of the students, resulting in a large waste of time. While opening10-11windows, students almost don ' t have to wait, the average free rate of the window contest, even close to half of the time in idle, obviously caused the canteen operating costs ; when the canteen opens seven windows, the window busy probability is 82.3 %, and the average waiting time of each student is only 82.3%, which is significantly lower than that of six windows. However, when the canteen opens eight windows, the continuous decline is not obvious. Comprehensively weighing the operating cost of the canteen and the waiting time of the students, the canteen and the students are acceptable when the canteen opens seven windows.

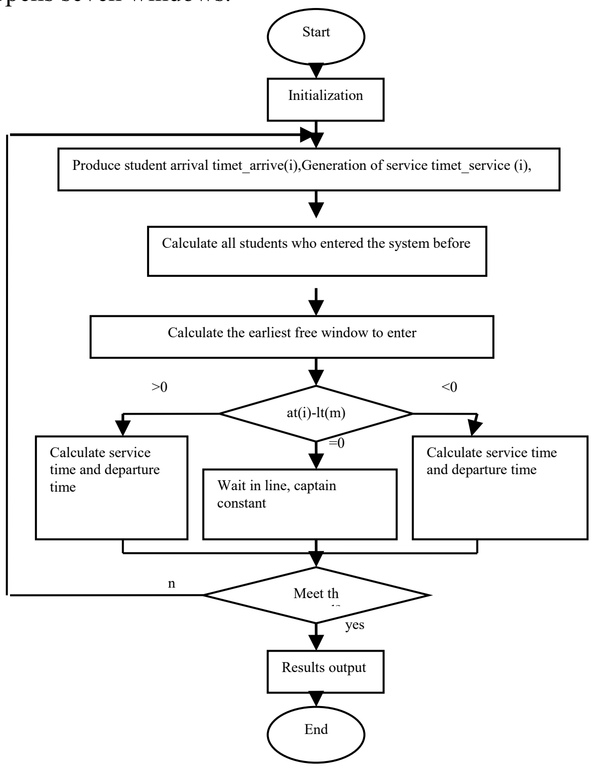

Fig. 2. Flow chart of canteen queuing simulation.

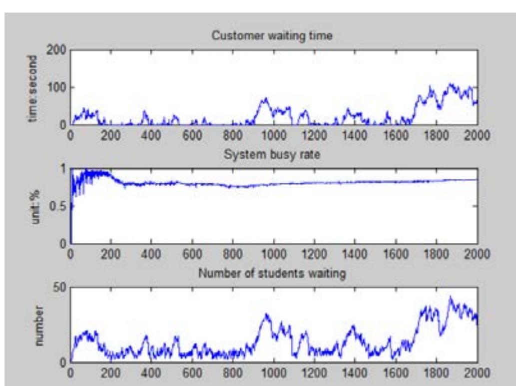

Fig. 3. Student waiting time, system busy rate, waiting number.

According to the same idea and method, and according to the changes of student flow and window service level in different periods, the dynamic simulation can get the best number of windows in different periods and different student flows to adapt to various changes and effectively improve service quality.

5 Conclusion

Because of the characteristics of random service system, it is very difficult to deal with a complex random problem by analytical method, and computer random simulation has good operability and adaptability, which can effectively solve this problem.

The simulation method introduced in this paper has certain universality, portability and popularization. Other large supermarket settlement platforms, accounting detection and hospital drug payment can learn from this model to optimize service efficiency and benefit, which has important practical significance for guiding work and life.

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