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Study on the Area of Waiting Space in the Old Area of a Tertiary Hospital Based on AnyLogic Simulation

Jing He*, **Haoxu Guo**

School of Architecture, South China University of Technology, Guangzhou 510642, China

Corresponding author: Jing He, hestiahj@163.com

Abstract: The waiting space is the place where patients stay the longest during the entire medical treatment process, and the adequacy of its spatial area to the number of waiting patients has a significant impact on the treatment experience. Due to the continuous expansion of the medical scale and the increasing outpatient volume, congestion in the waiting areas of the old area of tertiary hospitals in Guangzhou is common, seriously reducing patients' medical experience. Therefore, it is necessary to determine the optimal waiting area space in the old area based on the number of consultation rooms and evaluate the current situation of the waiting area to optimize the waiting area reasonably. Taking the Third Affiliated Hospital of Sun Yat-sen University as an example, this study determines the daily outpatient volume of departments under specific consultation room numbers, uses AnyLogic to simulate the medical treatment process of patients, outputs the change in the number of patients in the first waiting area. Based on the mean and peak number of waiting patients during peak hours, the study calculates the areas required for "generally adequate" and "specially adequate" waiting space respectively. These are then compared with the current area to evaluate the adequacy of the current waiting space.

Keywords: Tertiary hospital old area; Waiting space; AnyLogic simulation

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1. Introduction

In tertiary hospitals, the waiting area is an indispensable space for patients during the treatment process, with extremely high frequency and duration of use. Therefore, it is undoubtedly one of the most crucial areas within the hospital. However, the size of the waiting area is often determined by architects based on their own professional experience or by the opinions of medical consulting teams, leading to a mismatch between the waiting area size and the number of waiting patients, resulting in congestion and a decrease in patients' treatment experience. This phenomenon is particularly common in the old districts of tertiary hospitals because tertiary hospitals boast strong medical capabilities, comprehensive department settings, and convenient location conditions, making them the preferred choice for patients seeking medical treatment, thus exacerbating the contradiction between waiting area size and waiting patients.

Against this background, it is necessary to conduct a study on the adaptability of the area of waiting space in the old area of tertiary hospitals. There is limited research on waiting area size, with Luo proposing that the waiting space should accommodate 15%–20% of the daily patient volume of each department, and the area of the waiting space should be calculated based on the indicators of 1.2–1.5 square meters per adult and 1.5–1.8 square meters per child [1]. Wang used AnyLogic simulation experiments to adjust the number of people that the waiting area needs to accommodate, which should be 9.2%–25.3% of the department's daily outpatient volume [2]. The calculation methods proposed by the above studies require the design team to clearly determine the daily patient volume of each department. However, the daily patient volume of each department fluctuates seasonally and is uncertain, making it difficult to determine. Moreover, the area of waiting space calculated based on the daily patient volume cannot cover the needs most of the time and future development needs of the hospital.

Under the system of online appointment registration, hospitals typically set a relatively fixed number of appointment slots based on the available number of consultation rooms and the scheduling of doctors to ensure medical quality and reasonable work intensity for doctors. Therefore, there is a correlation between the maximum daily patient volume of the hospital and the number of consultation rooms, allowing for the calculation of an appropriate waiting space area based on the number of consultation rooms to ensure the spatial area matches the number of waiting patients, reducing congestion during the waiting process. Therefore, this paper takes the old area of the Third Affiliated Hospital of Sun Yat-sen University as an example, using AnyLogic simulation experiments to output the mean and peak number of waiting patients under specific consultation room numbers, and then calculate the areas required for "generally adequate" and "specially adequate" waiting space respectively. Finally, it compares the current area of waiting space in the old area with these two levels to determine the current adaptability level of the waiting space in the old area.

2. AnyLogic simulation

AnyLogic is a simulation software that supports modeling based on three methods: discrete event, system dynamics, and agent-based, either individually or in combination. It provides various modeling components such as a process modeling library, pedestrian library, state chart, and data analysis. Known for its rich visualization and user-friendly interface, AnyLogic is widely used in fields such as logistics, manufacturing, socio-economic systems, disease spread, urban planning, and architectural design [3]. In the simulation of the patient seeking medical treatment process, the pedestrian library provided by AnyLogic is proposed to be used for spatial environment and behavior process modeling. This enables a relatively realistic simulation of patients' queuing and waiting behaviors, and the output of changes in the number of waiting patients helps determine the required area for the waiting space.

3. Field research

3.1. Case situation

The Third Affiliated Hospital of Sun Yat-sen University was established in 1971, with its old area located in the Tianhe District of Guangzhou, Guangdong Province, China. The hospital is conveniently situated near subway stations, with a daily outpatient and emergency volume exceeding 14,000 visits, imposing a significant medical burden. The outpatient building, the subject of this study, was constructed in 1995 and features a typical internal corridor layout. Through on-site photography, observation, recording, and drawing, detailed documentation of its functional layout and facility configuration was conducted, along with an analysis of its waiting areas.

As shown in **Figure 1**, the central area of the floor plan includes vertical circulation spaces, self-service areas, payment zones, initial waiting zones, and triage counters. The self-service area is equipped with three self-service machines that integrate check-in and payment functions. Flanking these are secondary waiting corridors and examination rooms, totaling 22 examination rooms.

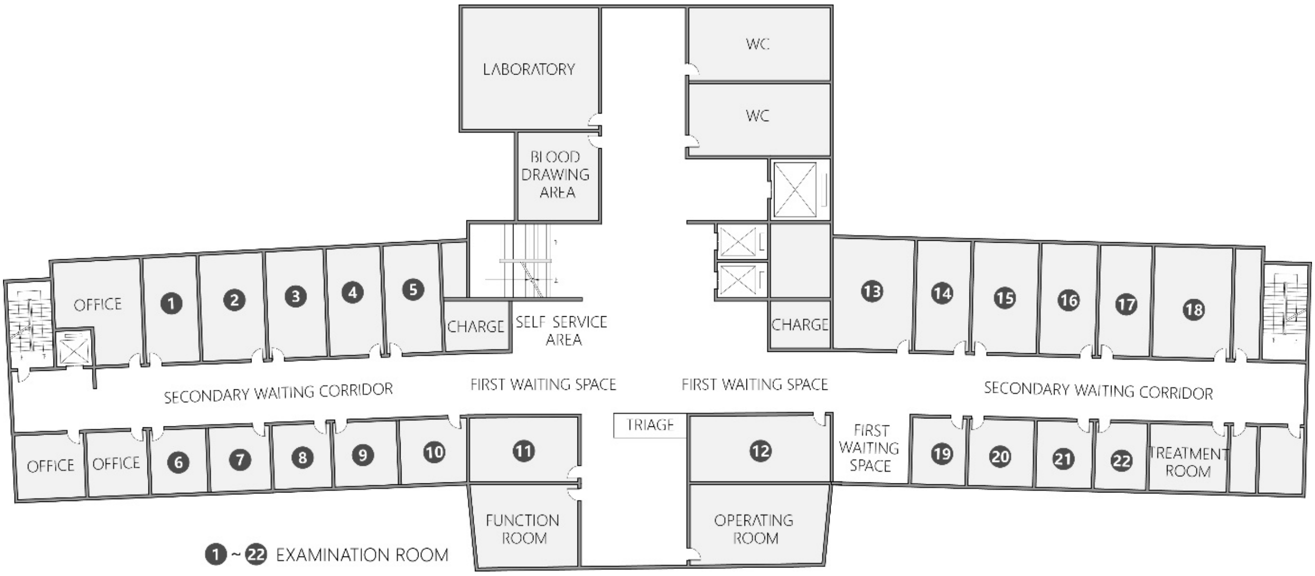

Figure 1. Layout plan of case

3.2. Medical treatment process

This study focuses on the medical treatment process occurring on a single floor. The main actions of patients and their accompanying individuals include arriving at the floor, checking in, waiting, consulting, making payments, and leaving the floor. Both the check-in and payment processes offer manual and self-service options. Additionally, some patients may check-in or make payments in the outpatient lobby or via mobile phones, collectively referred to as other methods. It is necessary to collect data on the usage probabilities and durations of the above processes and different process methods. However, since other check-in and other payment methods do not involve queuing behavior on the floor, only their usage probabilities need to be accounted for, without the need to track their durations.

The morning working hours of working days (8:00–12:00) were selected for on-site surveys and statistics. A 30-minute observation was carried out for each process method at the case site to tally the number of patients using each method, thereby calculating its usage probability. Additionally, 10 patients were randomly selected for observation in each process to record the process duration. The statistical results are shown in **Table 1**. In addition, it is necessary to research the half-day outpatient volume. Under the system of online appointment registration, the number of patients attending half-day outpatient appointments for each department can be obtained through the official website. The hospital's morning registration period is from 8:00 to 11:30, in half-hour increments, with each doctor having 5 appointment slots. This means each examination room needs to accommodate a total of 35 patients in the morning, and with 22 examination rooms, the total capacity amounts to 770 patients.

Table 1. Time consumption and usage probability of different process methods

	Manual check-in	Self-service check-in	Other check-in	Manual payment	Self-service payment	Other payment	Consultation
Process duration	28–51s	12–33s	-	79–108s	46–65s	-	300–480s
Usage probability	13%	41%	46%	17%	15%	68%	-

4. Assessment of waiting space adaptability based on AnyLogic simulation experiments

To quantify the adaptability of the waiting space, it is necessary to output the number of patients waiting during peak hours. Therefore, AnyLogic simulation experiments are conducted. The experiments include the following steps: (1) Establishing a simulation model, including setting up the spatial environment and defining patient treatment behavior processes; (2) Setting experimental parameters; (3) Running the experiment and outputting relevant data. After obtaining the data related to the number of patients waiting, the area required for the waiting area is calculated based on this data. It will then be compared with the current area of the waiting space in the research case.

4.1. Establishment of simulation model

This study imported the floor plan of the sample into AnyLogic and used the pedestrian library's space markup module to draw walls of arrival areas, departure areas, primary waiting areas, and service areas, and used line components to mark the queues for manual service, self-service, and secondary waiting area. The service point for the secondary waiting queue is located inside the examination room, serving one person at a time. The queue is located in the secondary waiting corridor outside the examination room, with a capacity of 2 people (**Figure 2**). The behavior process of patients is set as follows: Arrival at the floor, Check-in (multiple methods), Waiting, Consultation, Payment (multiple methods), and Leaving the floor (**Figure 3**).

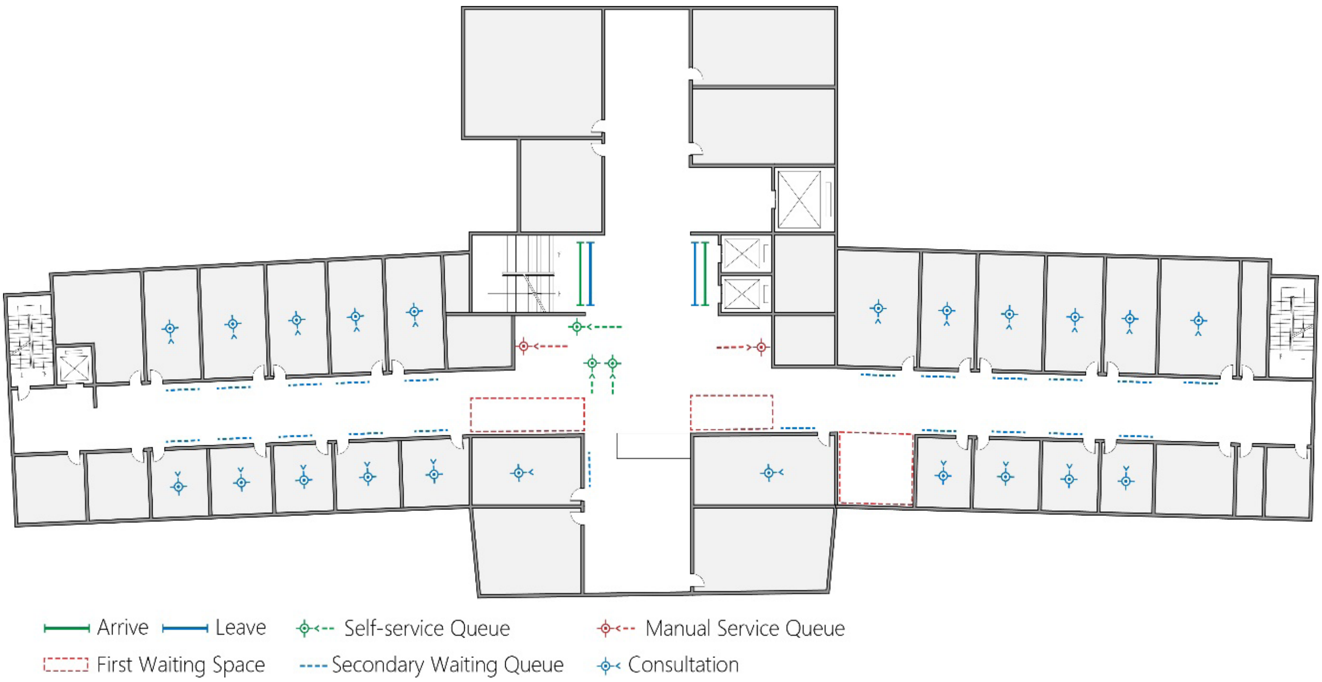

Figure 2. Simulation space environment

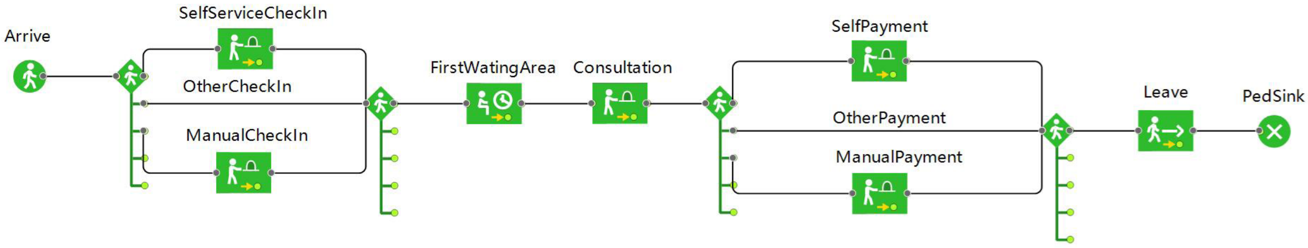

Figure 3. Simulation behavior process

4.2. Parameter settings

The parameters for the behavior process in the simulation model are set based on the on-site research statistics, while also defining the parameters for the agents. In the simulation, patients are simplified into two-dimensional circles, with the diameter of the circle representing the range of human shoulder width. Additionally, parameters for the patients' body dimensions, comfortable distance, and walking speed range are established based on literature research (**Table 2**) [4–5]. The number of patients arriving every hour is 220, following a Poisson distribution, with a total of 770 patients arriving. The time consumption of each process is assigned by a triangular random function, and its lower limit, upper limit, and time consumption with the highest probability of occurrence are determined by the previous survey.

Table 2. Simulation model parameter settings

Module	Behavior process settings							Patient settings		
	Arrival rate (p/h)	Max number (person)	Self check-in (s)	Manual check-in (s)	Consult (min)	Self payment (s)	Manual payment (s)	Body size (m)	Distance (m)	Walking speed (m/s)
Parameter	Poisson 220	770	Triangular (12, 20, 33)	Triangular (28, 30, 51)	Triangular (3, 5, 8)	Triangular (46, 50, 65)	Triangular (79, 80, 108)	0.4–0.5	0.3	0.8–1.2

4.3. Experiment execution and result analysis

Before running the simulation experiment, the Ped Area Descriptor module is used to return the number of patients in the primary waiting space and the real-time number of patients in the primary waiting space is recorded with a time-series plot. The data is set to update every minute to obtain a line chart showing the change in the number of people in the primary waiting area in minutes. The duration of the experiment is set to 240 minutes, corresponding to half a day of hospital working hours. After setting up the simulation model, the experiment is run multiple times to stabilize the simulation results. The results of 5 experiments are randomly output, as shown in **Figure 4**.

The line chart depicting the variation in the number of patients during the first waiting period across 5 simulation experiments reveals a consistent trend, indicating the stability of the simulation results. Therefore, the average values of the 5 experiments can be computed to describe the pattern of variation in the number of patients during the first waiting period for the case (**Figure 5**). Within the first hour, there are relatively few patients waiting, allowing patients arriving at the waiting area to proceed quickly to the secondary waiting process. Starting from the second hour, the number of patients waiting gradually increases, reaching a peak at around 120 minutes. The number of patients waiting during the first period then declines at around 210 minutes. Therefore, the time period from 120 to 210 minutes can be considered as the peak waiting period.

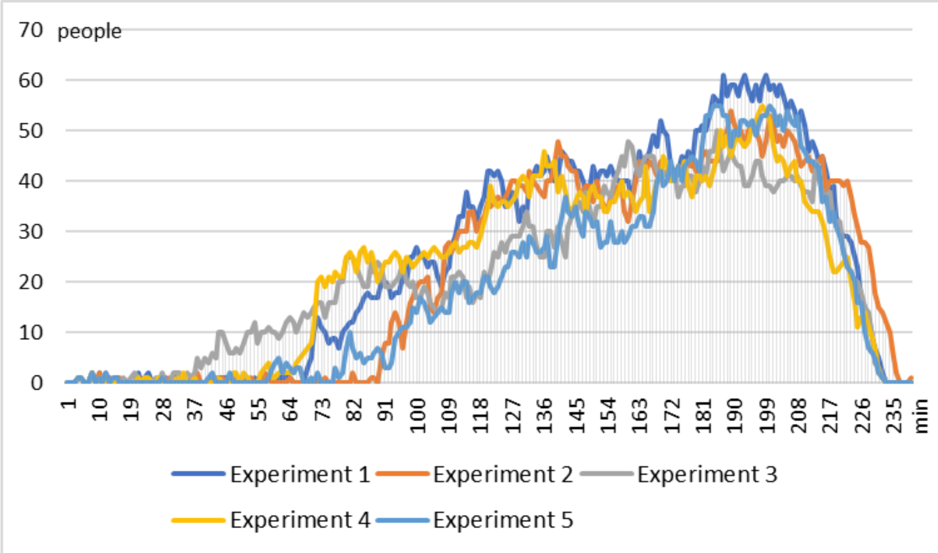

Figure 4. Line chart of changes in the number of first waiting patients for five experiments

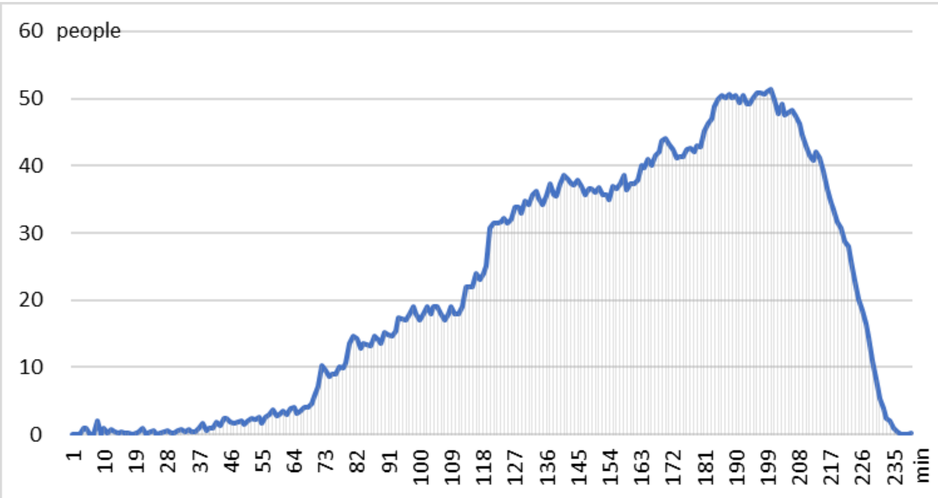

Figure 5. Line chart of mean changes in the number of first waiting patients for five experiments

After determining the peak period, the average and max number of patients in the first waiting space were calculated to be 41 persons and 51 persons. During the on-site research, interviews with some patients revealed that 30.4% of patients had one accompanying person, and 2.4% of patients had two or more accompanying persons. Since the simulation experiment is conducted based on individual patients, the average and maximum number of patients in the first waiting space in the peak period need to be adjusted according to the proportion of accompanying persons to better reflect the real situation. Considering the accompanying persons, the adjusted average and max number of patients in the first waiting space are 55 persons and 69 persons. Calculating the required area for the waiting space based on the guideline of 1.5 square meters per person shows that the required areas are 82.5 and 103.5 square meters, respectively.

The waiting area size calculated based on the average number of waiting patients can accommodate the resting needs most of the time, categorizing it as "generally adequate." On the other hand, the waiting area size calculated based on the maximum number of waiting patients can accommodate the number of waiting patients at all times, thus categorized as "specially adequate." With the current waiting area size of 75.12 square meters at the Third Affiliated Hospital of Sun Yat-sen University, which is below the standards of 82.5 and 103.5 square meters, it can be concluded that the waiting area size is categorized as “inadequate”, indicating the need for reasonable optimization of the waiting space.

5. Optimization strategy

Since the study case follows an internal corridor layout, with the waiting space primarily situated in the secondary waiting corridor, the current capacity for secondary waiting in each consultation room is 2 patients. Increasing the number of patients accommodated in the secondary waiting area can help alleviate the flow pressure in the primary waiting area. When the capacity for secondary waiting in each consultation room is increased to 3 patients, the average and maximum number of patients in the primary waiting space decreases by 22 individuals each, resulting in 33 and 47 patients, respectively. Consequently, the required area for the primary waiting space would be 49.5 and 70.5 square meters. Thus, the existing primary waiting space size can simultaneously meet both requirements, transitioning from the “inadequate” category to the “specially adequate” category.

In addition to increasing the capacity of the secondary waiting space, optimization can also be achieved by enlarging the primary waiting area. This can be done by removing walls near the central area of the floor plan, thereby expanding the primary waiting space to enhance adaptability. For instance, if consultation room 10 is replaced with a primary waiting area, the size of the primary waiting area would be 93.42 square meters, meeting the size requirement for the “generally adequate” category of waiting areas.

6. Conclusion

Under the online appointment registration system, this study used the number of consultation rooms to determine the half-day outpatient volume of the case. Subsequently, AnyLogic simulation was employed to output the variation of the number of patients in the first waiting space, thereby obtaining the average and maximum number of patients during peak hours. Based on the criterion of 1.5 square meters per person, the required areas for “generally adequate” and “specially adequate” levels of first waiting spaces were calculated. Finally, by comparing the current areas of waiting of the case with the sizes corresponding to the two levels, it was concluded that the waiting area of the case falls under the “inadequate” category. Suggestions were made to increase the number of patients in the secondary waiting corridor or to expand the area of the primary waiting space to optimize the existing waiting space, aiming to achieve a better level of adaptation.

Disclosure statement

The authors declare no conflict of interest.

Author contributions

Study idea conceptualization: Haoxu Guo
Experiment conducting: Jing He
Data analysis: Jing He
Article writing: Jing He

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