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BASED ON SIX SIGMA ANALYSIS: ON THE LEAN STRATEGY OF PARK QUEUING IN BEIJING ZOO

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Abstract: The purpose of this report is to use industrial engineering and lean management methods to improve the queuing congestion in scenic spots, solve the problem of long waiting time, and improve the efficiency of tourist experience and scenic management. At present, the long queue waiting in popular scenic spots has become a problem that seriously affects the tourist experience and the operation efficiency of scenic spots. We analyze the current situation of queuing through Six Sigma, and then optimize the queuing process, aiming to reduce the waiting time, improve the tourist experience, increase the service quality of the scenic spot and improve the competitiveness and management efficiency of the scenic spot.This report will elaborate on the background of the topic selection, the improvement process, and the expected results. Through this study, we expect to provide a feasible queuing management scheme for tourist attractions to improve the tourist experience and improve the overall operational efficiency of scenic spots.
Keywords: Scenic spot queuing; Process optimization; Tourist experience; Lean improvement

1 INTRODUCTION

In modern society, with the rapid development of the tourism industry, an increasing number of tourists are flocking to various tourist attractions, making the issue of queuing at these sites increasingly prominent. Long waiting times in queues can cause inconvenience to visitors, not only reducing their travel experience and satisfaction but also potentially having a negative impact on the image and economic benefits of the attractions. Therefore, optimizing the queuing management at tourist attractions has become an urgent problem to be addressed.

This report takes Beijing Zoo as a case study and applies industrial engineering and lean management methods to optimize the queuing process at the attraction, aiming to enhance visitor experience, reduce waiting times, increase the attraction's appeal, and simultaneously improve management efficiency. This not only helps to improve the travel experience for visitors but also enhances the competitiveness and sustainable development capabilities of the attraction.

Through in-depth research and analysis, we propose a series of improvement measures to enable visitors to tour the zoo more smoothly and fully enjoy the fun and educational significance it offers.

Firstly, we conducted an analysis of the current situation and background investigation. Data from the Ministry of Culture and Tourism's official website revealed that the willingness of residents to travel, business confidence, and the comprehensive index of tourism economic operation have all reached the best levels in the past three years. However, the significant increase in tourist numbers and the concentrated peak tourism season have led to insufficient reception capacity at various attractions, making the queuing issue at these sites increasingly prominent. Long waiting times in queues have become an inescapable problem in many popular attractions, with Beijing Zoo, which ranks among the top three in total visitor reception during the "May Day" holiday according to data released by the Beijing Park Management Center in 2023, facing an even more severe issue.

Secondly, we analyzed the identified problems and improved the process. After identifying the problem, we proceeded to analyze and resolve it. The first step was to clarify the scope, objectives, and key project details. The second step involved collecting and recording the initial data required to establish a foundation for the problem. The third step was to analyze the obtained data using various Six Sigma tools, processing the data and visualizing it to identify the causes of long queues at tourist attractions. The fourth step was to formulate various methods based on the previously identified causes and implement them, which effectively improved the situation of long queuing times at the attraction. The fifth step was to develop a control plan to monitor and manage the process, ensuring that the solutions to the problem are maintained in the long term to achieve lasting improvements.

2 BACKGROUND OF THE TOPIC

According to data from the official website of the Ministry of Culture and Tourism, the number of domestic tourism trips in the first half of the year reached 2.384 billion, a year-on-year increase of 63.9%; domestic tourism revenue was 23 trillion yuan, a year-on-year increase of 95.9%. Whether it is the willingness of residents to travel, business confidence, or the comprehensive index of tourism economic operation, they have all reached the best levels in the past three years. The China Tourism Academy forecasts that the number of domestic tourists for the whole year of 2023 will be 5.5 billion, and domestic tourism revenue will exceed 50 trillion yuan, respectively recovering to more than 90% and 80% of the levels in 2019 [1].

According to data from China Unicom, the number of tourists nationwide during this year's "May Day" holiday reached 200 million, an increase of 26.65% compared to the same period in 2019 (Figure 1).

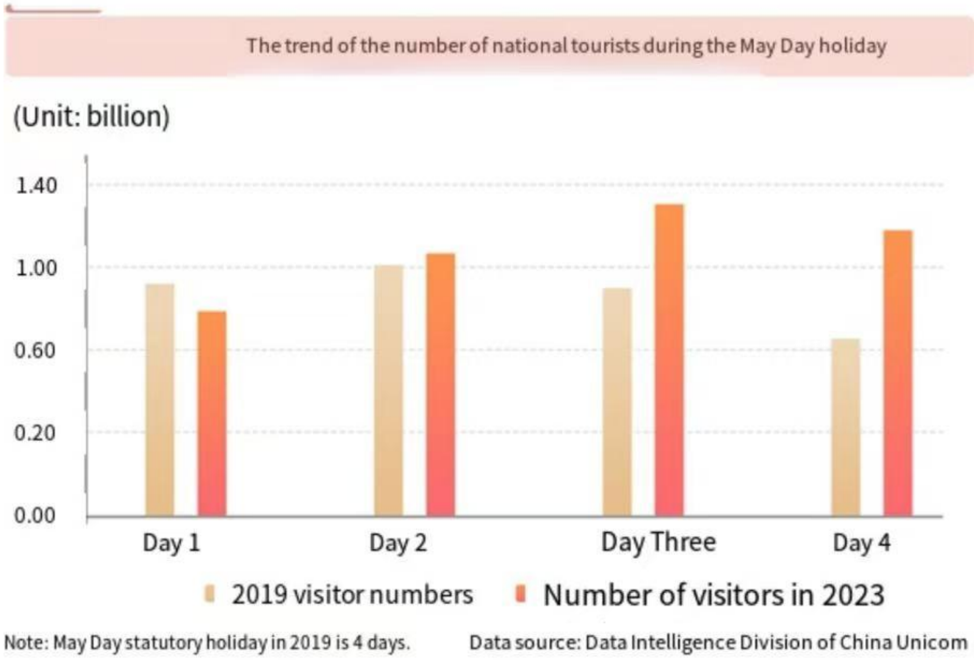


Figure 1 Trend of National Tourist Numbers during the "May Day" Holiday

After more than three years of pandemic control, the public is in urgent need of a trip to release their long-suppressed enthusiasm for travel. Data from China Unicom shows that long-distance travel was more popular during this holiday, with the average travel distance in cities across the country reaching 441.69 km (Figure 2).

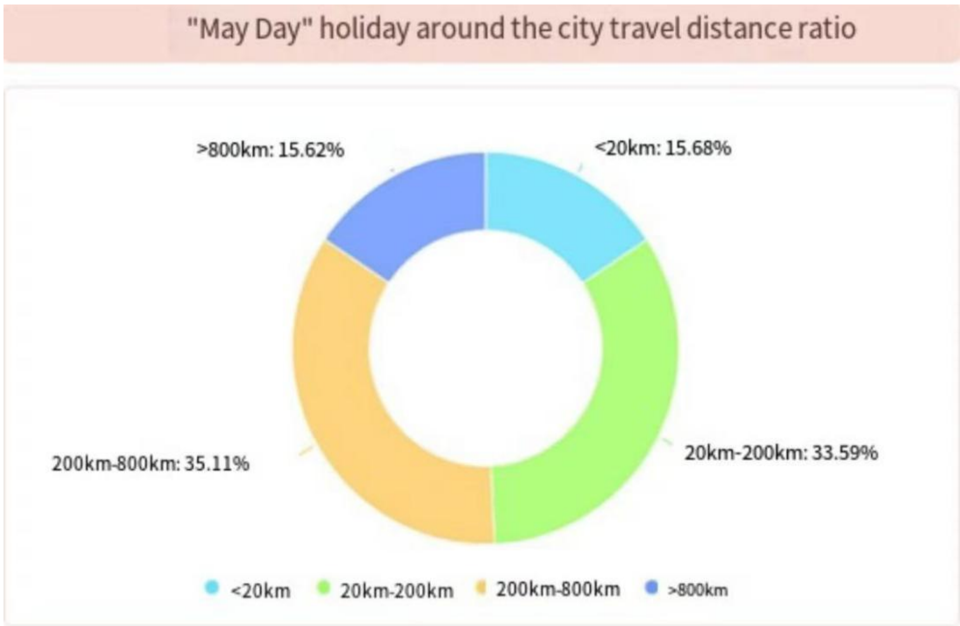


Figure 2 Proportion of Travel Distances during the "May Day" Holiday

The above data indicates that China's tourism economy has reached a strategic turning point and has entered an irreversible new channel of recovery and upward momentum. Therefore, we have reason to be more optimistic about the tourism economy in the second half of the year and even over the next three years.

However, with the recovery of the tourism economy, the significant increase in tourist numbers and the concentration of the peak travel season have led to insufficient reception capacity at various attractions, making the queuing issue at these sites increasingly prominent. Long waiting times in queues have become an inescapable problem in many popular attractions. Excessive queuing times may cause inconvenience to visitors, not only reducing their travel experience and satisfaction but also potentially leading to visitor loss, affecting the image and economic benefits of the attractions.

The official website shows that Beijing Zoo is located on Xizhimen Outer Street, Xicheng District, Beijing, China, adjacent to the Beijing Exhibition Center and the Moscow Restaurant, covering an area of about 86 hectares, with a water surface of 8.6 hectares. It was established in the 32nd year of the Guangxu period of the Qing Dynasty (1906) and is the earliest zoo in China to open and exhibit the most types of animals. It houses over 500 species of 5,000 animals and over 500 species of 10,000 marine fish and marine life. It receives more than 6 million visitors from China and abroad each year and is one of the largest zoos in China, as well as one of the world's renowned zoos (Figure 3).

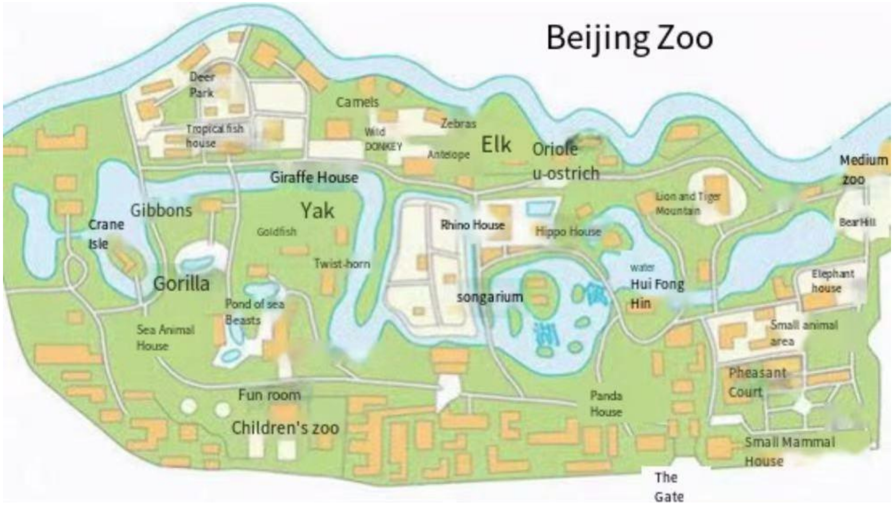


Figure 3 Beijing Zoo Tourist Guide Map

Data released by the Beijing Park Management Center shows that during the "May Day" holiday in 2023, the city-owned parks in Beijing welcomed a peak flow of visitors, with a total of 2.9537 million visitors, a year-on-year increase of 173.47%, and an increase of 21.03% compared to the same period in 2019 before the pandemic. Among them, the Summer Palace received 575,900 visitors, the Temple of Heaven received 517,800 visitors, and Beijing Zoo received 467,800 visitors, ranking in the top three in total visitor reception.

Therefore, Beijing Zoo must take certain measures to improve the queuing phenomenon at the entrance of the scenic spot (Figure 4).

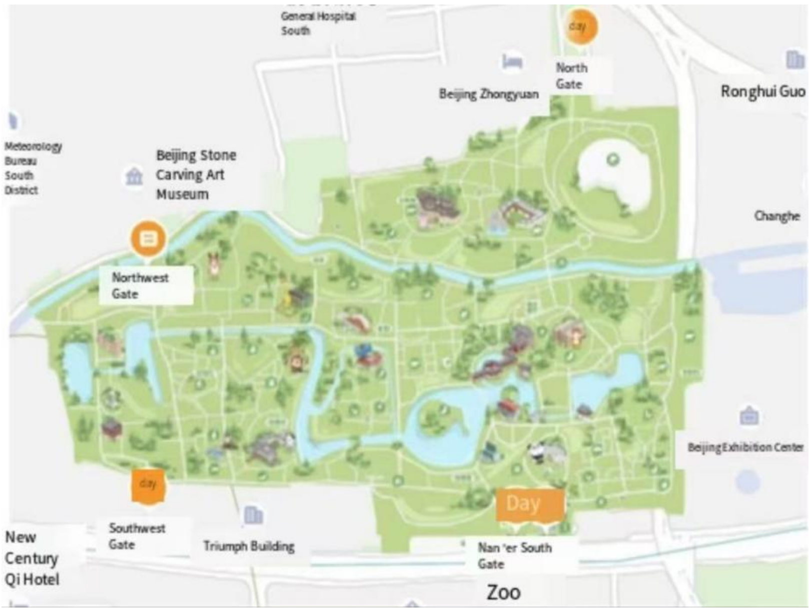
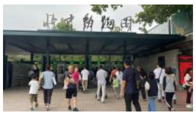


Figure 4: Beijing Zoo Entrance and Exit Guide Map

From Figure 4: Beijing Zoo Entrance and Exit Guide Map, it can be seen that Beijing Zoo has a total of 5 gates, namely the South Gate, South Second Gate, Southwest Gate, Northwest Gate, and North Gate (Oceanarium Entrance) (Table 1).

Table 1 Comprehensive Analysis of the Current Situation of Each Entrance at Beijing Zoo

Entrance	South Second Gate	Southwest Gate	Northwest Gate	North Gate (Oceanarium Entrance)
Main Mode of Transportation	Public transportation is the majority, followed by private cars, bicycles, or walking	No direct subway within 500 meters	There is a waterway in front of the gate, occasionally boats pass by, mostly walking	Mainly by car, some visitors also use public transportation
Visitor Type	Usually parents with children and the elderly, also a significant number of individual visitors	Usually parents with children and the elderly, mostly surrounding residents	Mostly local residents for leisure walks, few tourists from other places	Mainly group tours, mostly parents with children and grandparents, also couples
Number of Channels and Turnstiles	4 wider channels for wheelchairs and strollers, 5 ordinary channels, 1 group channel	One channel for vehicle traffic and one small door for pedestrians	One small door with one turnstile inside	A total of 4 turnstiles, with a dedicated group ticket inspection entrance
Parking Lot	Yes, but parking congestion occurs when there are many people	The parking lot of the nearby Fangyuan Building is open to the public, no parking pressure	No parking lot found	The parking lot is relatively crowded, which can easily cause traffic jams
Visitor Volume	High	Low	Low	High
Field Scene				

The team members' field investigation found that the South Gate is currently under construction and closed. The South Second Gate, which is close to the subway station and has convenient transportation, is currently the entrance with the most visitors [2].

3 IMPROVEMENT PROCESS

The team members utilized Six Sigma for analysis, a management method aimed at improving process quality and efficiency within an organization. It emphasizes the improvement of various processes by reducing variability and defects.
The Six Sigma methodology typically includes five major steps, commonly known as DMAIC, which stands for "Define - Measure - Analyze – Improve - Control". This framework is the core of the Six Sigma approach.

3.1 Define

We first clarified the scope, objectives, and key project details to better understand the background, scope, and significance of the problem, providing clear guidance and a foundation for the subsequent DMAIC process.

3.1.1 Problem statement

Some visitors to Beijing Zoo have reported that the queue time exceeded their expected waiting time and the queue order was chaotic, affecting their visiting experience. This has become an increasingly prominent issue among various tourist attractions, necessitating measures for improvement.

3.1.2 Project scope

Before project analysis, the scope of the project must be determined, including which aspects will be affected and the areas that need improvement. The scope of the project in this issue includes: waiting time in queues, queue lines and layout, staff allocation, and communication of queue information.

3.1.3 Stakeholders and customers

Identify the stakeholders and customers of the project, including: visitors (customers), the tourist attraction management team, staff, and surrounding communities (which may be affected by the queue). This project can improve the queue situation, enhance customer experience and satisfaction, facilitate the management of the tourist attraction team, make the work of staff smoother, and reduce congestion in surrounding communities.

3.1.4 Impact and importance of the problem

The actual impact of long queue times on the operation of tourist attractions and visitor experience may include: visitor loss, affecting the revenue of the attraction; visitor dissatisfaction, causing a negative impact on the reputation of the attraction; increased work pressure on staff, affecting the quality of service.

3.2 Measure

In the second step, Measure, the team collects and records initial data related to the problem to establish a baseline for the issue. This is used to quantify the extent and impact of the "long queue waiting times at tourist attractions" problem.

3.2.1 Data collection plan

Firstly, to assess the problem of long queue times, we identified the types of data needed, including: observing peak and off-peak visitor volumes, the distribution of visitor types, and the waiting time for visitors to enter the attraction.

3.2.2 Data collection execution

Secondly, according to the data collection plan, we began to collect relevant data. The team conducted on-site field investigations at the main entrance (South Gate) of Beijing Zoo from 7:00 AM to 4:00 PM, collecting data every 25 minutes (data collection duration was 5 minutes) [3]. We obtained a series of related data, such as the time visitors spent entering the attraction, queue length, and waiting time, and conducted visitor satisfaction surveys to obtain feedback.

The data we obtained is as follows:

(1) Time spent by visitors entering the attraction:

① 7:00-8:00, fewer visitors, smooth queues, approximately 2 minutes

② 8:00-9:00, increasing visitor numbers, slightly longer waiting times, approximately 4 minutes

③ 9:00-10:00, many visitors, long queues, increased waiting times, approximately 10 minutes

④ 10:00-11:00, slightly fewer visitors, approximately 8 minutes

⑤ 11:00-14:00, visitor numbers gradually decrease, from 8 minutes to around 5 minutes

⑥ 14:00-16:00, fewer visitors, smooth queues, approximately 2 minutes

(2) Visitor Satisfaction:

We randomly selected a total of 270 visitors and conducted a survey on their satisfaction with the queue waiting experience, with the following results (Figure 5):

[redacted]

Score A									
1 point	2 points		4points	5points	6points	7points	8points	9points	Total
	[illegible]	5	10	38	48	78	58	25	270

Figure 5 Visitor Satisfaction Statistics

3.2.3 Data analysis

The team members then analyzed the collected data to understand the severity of the queue time problem. We calculated the following metrics:

Average queue time is approximately 5 minutes

Visitor satisfaction is approximately 6.6

Satisfaction-related data (Figure 6):

effective	270
Missing	0
Mean	6.589
Median	7
Mode	7
Standard deviation	1.626
Variance	2.644
and	1779

Figure 6 Satisfaction-Related Data

3.2.4 Data presentation

Present the analysis results in the form of charts, graphs, and reports to support further decision-making. After calculating the metrics, the team members created a line chart of the number of visitors to Beijing Zoo to show the trend of average queue times (Figure 7):

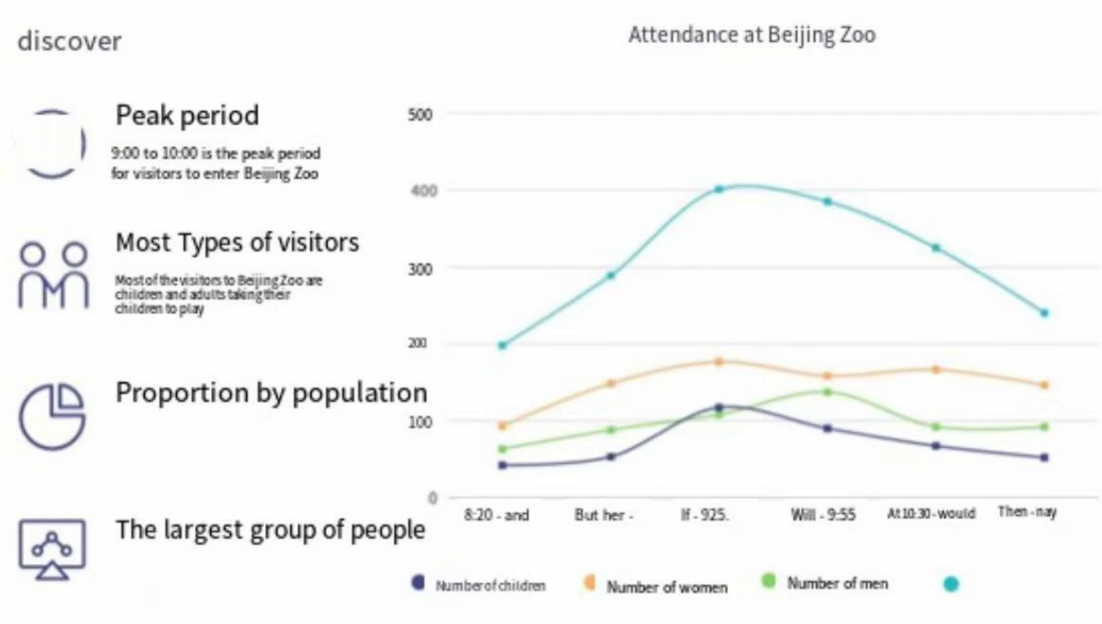


Figure 7 Line Chart of Visitors to Beijing Zoo

Through these steps, we obtained quantitative information about the problem of long queue times and provided strong support for the subsequent analysis and improvement steps in the DMAIC process [4].

3.3 Analyze

Before analyzing, we reviewed the data collected in the second step, Measure, which included average queue times, visitor numbers, satisfaction scores, etc.

3.3.1 Data visualization and exploration

We have visualized the above data using charts and graphs to better understand the distribution and trends of the data.

3.3.2 Possible cause analysis

We also conducted a cause-and-effect analysis of the long queue times at tourist attractions and created the following Ishikawa Diagram to identify possible causes of long queue times (Figure 8).

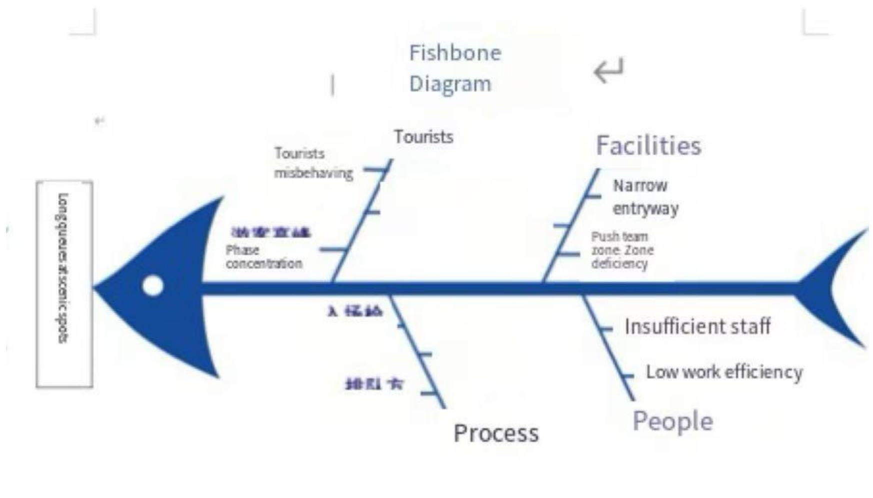


Figure 8 Ishikawa Diagram of Long Queue Times at Tourist Attractions

In Figure 8, we see that the problem of long queue times at tourist attractions is mainly caused by four major factors: visitor factors, process factors, facility factors, and personnel factors. These four factors contain many minor issues that together contribute to the congestion at tourist attractions. Therefore, we should address the issue of long queue times at Beijing Zoo from these four perspectives [5].

3.3.3 Main cause analysis

Based on the Ishikawa Diagram and the survey data, we created a fault tree analysis chart to explore the main reasons and solutions for the issue of queue times exceeding expected waiting times. Here is the chart we made (Figure 9).

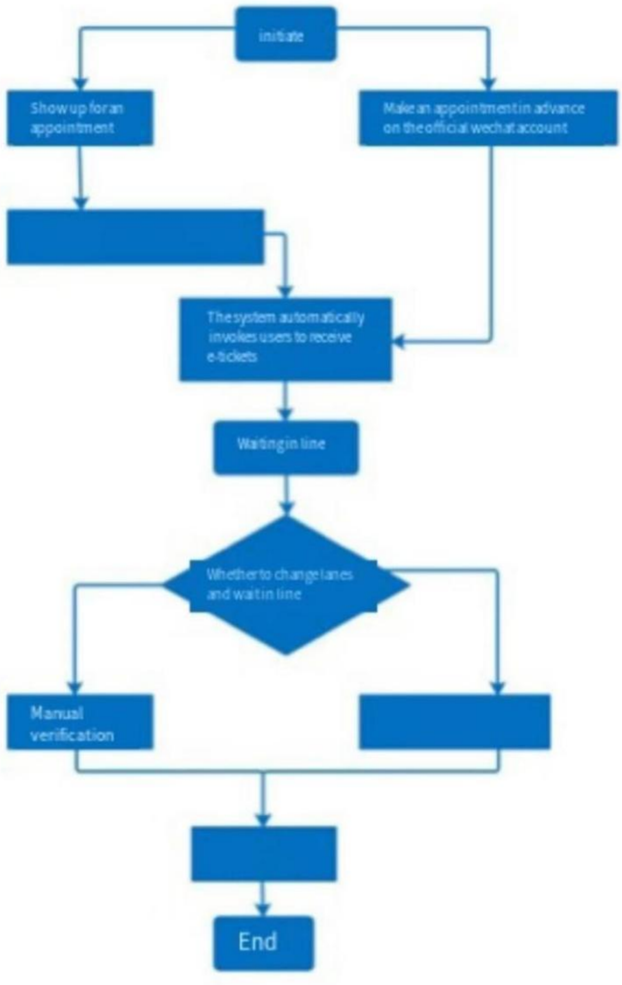


Figure 9 Visitor Entry Process Flowchart for Beijing Zoo

According to Figure 9 and on-site observations, team members found that during the queue waiting process, there were people who ordered on-site while queuing, which affected the speed of the line; and when the queue changed from a single line to multiple channels, many visitors would leave the queue to take photos, which not only disrupted the order but also caused channel congestion; during ticket inspection, some visitors would encounter issues such as slow QR code loading and slow response from the turnstiles, leading to long ticket inspection times and slow queue movement.

We can conclude that "poor queue order" and "long ticket inspection times" are the two main reasons for queue times exceeding expected waiting times.

we denote the top event of long queue times at the attraction entrance as T, the intermediate event of poor queue order as M1, and the intermediate event of long ticket inspection times as M2. The basic events are visitors not following rules as X1, insufficient service staff capabilities as X2, slow response of ticket inspection machines as X3, and few ticket inspection channels as X4. Thus, we can deduce that:

$$\begin{gathered} T = M1 + M2 \\ M1 = X1 + X2 \\ M2 = X3 + X4 \\ T = X1 + X2 + X3 + X4 \end{gathered} \tag{1}$$

Therefore, we can see that visitors not following rules, insufficient service staff capabilities, slow response of ticket inspection machines, and few ticket inspection channels are all minimal cut sets for the top event of long queue times at the attraction entrance. These four factors have a greater impact on queue times and are the most influential factors in causing queue times to exceed expected waiting times [6]. Hence, when addressing the issue of long queue times at the attraction entrance, we must not ignore these factors.

We now have a comprehensive understanding of the main causes of the problem of long queue times. This will provide a basic direction for the subsequent improvement measures, and we now move on to the next stage, Improve.

3.4 Improvement

Based on the data analysis results from previous steps, we have formulated the following improvement measures to address the issues identified in our analysis, utilizing methods such as queuing theory, category management, and visual management.

3.4.1 Solution identification

From the main cause analysis in step three, we have identified "visitors not following rules," "insufficient service staff capabilities," "long response times of ticket inspection machines," and "few ticket inspection channels" as the main factors. After discussion, the feasible solutions include the following:

(1) Based on our on-site observations, we found that even when some individuals had prepared their QR codes or ID cards in advance, they were still unable to pass through the turnstiles quickly, leading to increased queue waiting times and congestion, requiring additional manpower to resolve issues, which is a waste of resources.

After inquiring in detail with visitors who failed to scan their codes and the staff dealing with these issues, we discovered that the turnstiles could not read or verify the ticket provided by some visitors, which is the root cause of the problem.

Therefore, we decided to improve the turnstile system to address this issue [7]. First, we need to improve the information admission module of the turnstile to fill in the gaps where it could not previously admit some visitors' ID cards or QR code information. Secondly, we also need to improve the information verification module so that the turnstile can accurately recognize visitors ticket and quickly allow passage.

To achieve these improvements, we plan to take the following steps: First, technically upgrade the turnstile system to ensure it can read various types of IDs and QR codes. Second, we will establish a comprehensive database to store all legitimate visitors' identity information and ticket data, so that the turnstile can quickly verify and recognize them. At the same time, we will also strengthen the maintenance and monitoring of the turnstile system to ensure its stability and accuracy.

After these improvements, we believe that the turnstile system will be able to handle visitors ticket more efficiently and accurately, thereby reducing congestion and manpower waste, and enhancing the overall visitor experience.

(2) Through on-site observations, we found that Beijing Zoo has a serious congestion problem, especially during peak seasons and holidays. Visitors often gather in large numbers at the entrance in a short period, leading to excessive queue times and even congestion. This not only causes inconvenience to visitors but also affects the image and operational efficiency of the zoo. At many times, there are not many visitors gathering at the zoo entrance, and it is clear that there is a problem with this situation. We want to improve some functions to make the arrival time of visitors more even, thus solving the queue congestion problem.

To address this issue, we propose some improvement plans: Utilize Beijing Zoo's WeChat public account and mini-program to analyze data from entry and exit turnstiles, cameras, and visitor feedback to assess the density of visitor numbers in real-time and synchronize the results on the WeChat platform, allowing visitors to reasonably arrange their arrival and entry times to alleviate congestion. In addition, we can expand this plan to collect the density of visitors at different gates to provide a basis for visitors to choose the appropriate entrance. These improvement plans will effectively enhance the visitor experience and the operational efficiency of the zoo.

The common formula for calculating pedestrian flow is as follows:

$$\begin{gathered}\text{Pedestrian flow} = \text{Area per person} \times \text{Activity area} \times \text{Activity frequency} \times \text{Activity time} \\ \text{Area per person} = \text{Venue area} \\ \text{Activity area} = \text{Size of the activity area} \\ \text{Activity frequency} = \text{Number of activities} \\ \text{Activity time} = \text{Duration of the activity}\end{gathered} \tag{2}$$

For the analysis of pedestrian flow in the queue at Beijing Zoo, we use cameras to record the total number of people in the venue and calculate the flow of visitors in a fixed area within a unit of time. The activity area is the total area provided for queuing at the entrance of Beijing Zoo, and the area per person is the activity area divided by the total number of people within a unit of time. The activity of opening the scenic area occurs once a day, and there are generally no other special activities affecting pedestrian flow, so it is not considered. The activity time is 20 minutes, and the data is updated every 20 minutes to show visitors the current flow of people and explain the flow situation (not congested, moderately congested, severely congested) to ensure that visitors understand the real-time data.

To implement the above improvement plans, we need to first establish a comprehensive data collection and analysis system, and at the same time, strengthen the interface with the WeChat platform to ensure the accuracy and timeliness of the information. At the same time, before promoting these functions, we also need to fully publicize to visitors, guide them to use the WeChat public account and mini-program, in order to further improve the coverage and practicality of this service [8].

We believe that through the above improvement plans, Beijing Zoo will be able to better meet visitor needs, enhance its image and operational efficiency, and lay a solid foundation for future sustainable development (Figure 10).

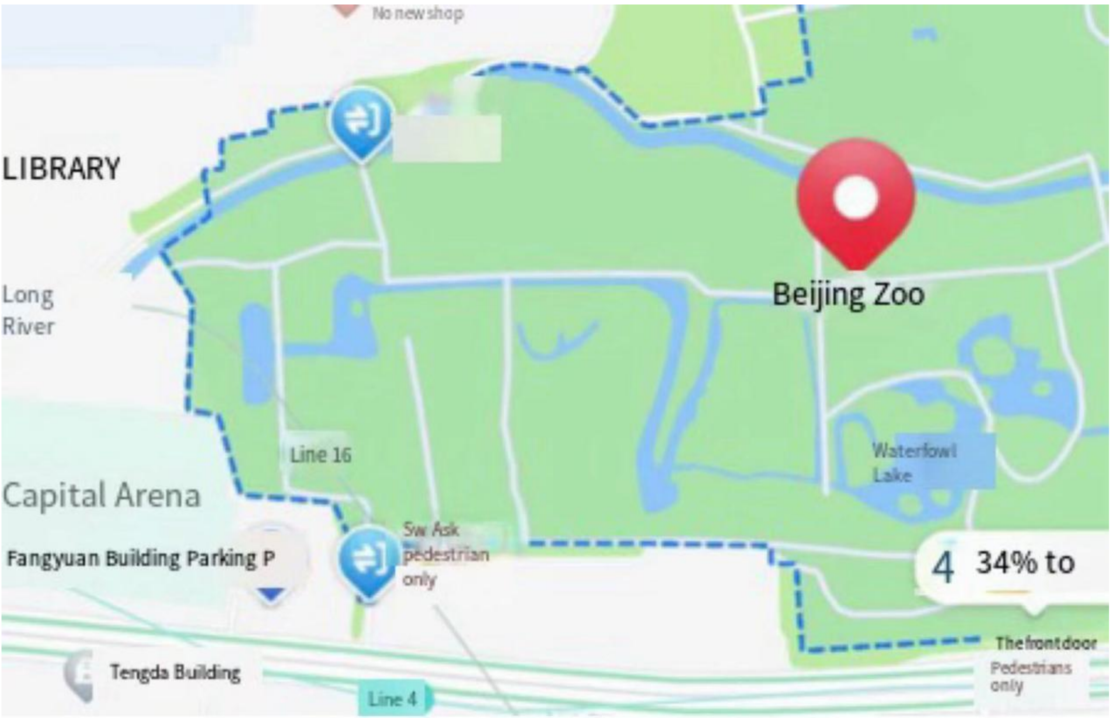


Figure 10 Location of Fangyuan Building, Southwest Gate, and Main Gate

(3) Due to the limited number of parking spaces in the zoo's parking lot and the large number of visitors traveling by car, there are always a large number of vehicles congested on the roadside near the zoo, waiting to enter the parking lot, causing interference with road traffic. To solve this problem, during our field investigation, we found that there are a large number of vacant parking spaces in the building near the southwest gate of Beijing Zoo, and the visitors entering from the southwest gate are basically nearby residents, so the number of visitors entering from the southwest gate is relatively small, which can alleviate the congestion problem at the south gate of Beijing Zoo (Figure 11).

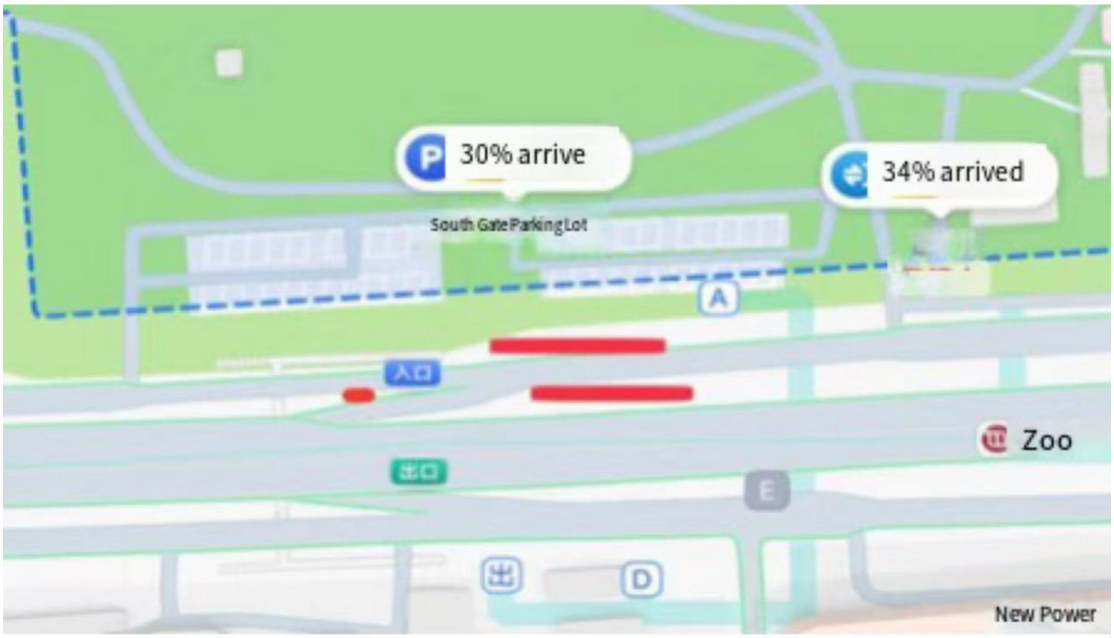


Figure 11 Road Conditions at the Entrance of the South Gate Parking Lot and the Location Where Signs can be Placed

We can set up signs at the entrance of the parking lot and on the roadside, indicating that visitors should park in the parking lot ahead, reducing the queue time for vehicles. Moreover, the parking fee standard of Fangyuan Building is similar to that of Beijing Zoo, which will not bring too many additional costs to visitors. This is of great importance for alleviating road congestion.

(4) Based on our field investigation, we found that some families with infants and the elderly have difficulty traveling and need to bring strollers or wheelchairs when entering the park, which is slower than ordinary adults when queuing; in addition, scanning QR codes may be affected by temporary machine errors, dark phone screens, and other unexpected failures, affecting the progress of the entire queue. Moreover, during the waiting process, visitors may become anxious, affecting their travel experience.

Firstly, based on the relevant knowledge of queue psychology, our team has adopted a series of measures to reduce queue times and improve visitors' psychological experience. We guide visitor diversion and improve service efficiency to minimize queue times as much as possible. Secondly, we have added double-sided electronic exhibition boards in the middle of the two channels. These exhibition boards play exciting animal videos and knowledge about living habits, aiming to improve visitors' psychological experience and alleviate their anxiety. In this way, visitors can not only be entertained and gain knowledge during the queuing process but also enjoy a more comfortable and pleasant waiting environment.

Secondly, we have also used category management methods. During the improvement process, team members made new divisions of the queuing route: utilizing the space in front of the south gate, which is under maintenance, to plan a fast track for visitors with physical passes such as ID cards and annual cards to pass quickly, reducing the time wasted by mistakes, and also freeing up more space for regular channels for family visitors and others, improving the overall efficiency of visitor entry to the park (Figure 12).

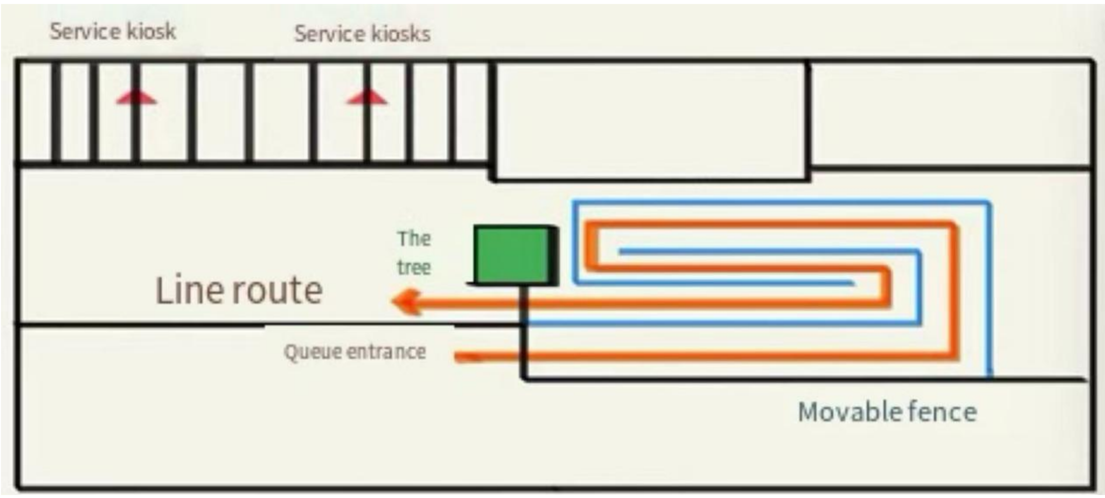


Figure 12 Current queuing route at the South Second Gate of Beijing Zoo

Finally, we also use visual management methods, adding ticket purchase procedures next to the mini-program code to reduce the input of guidance personnel, and we will also increase signs at visitor diversion points to achieve more accurate diversion.
We will consider the comprehensive effect and feasibility, combine the actual situation and resource limitations, and comprehensively adopt the above measures to determine the best solution, so that the scenic area can better solve the problem of long queuing times and improve visitor satisfaction and experience.
(5) We use the knowledge of queuing theory to solve the problems that arise, queuing theory is a discipline that studies queuing phenomena using mathematical methods such as probability and statistics.
The multi-queue multi-server model is a complex model composed of multiple single-queue single-server models combined according to certain rules. This model mainly has the following two different situations:
Customers come to a service system independently, different service desks handle different types of business, and customers choose the corresponding service desk to queue according to their own business needs, that is, multiple queues and multiple service desks are arranged in parallel, such as queuing for meals in a canteen, there are multiple windows, each with a queue, and students choose the queue according to the food they need.
Customers come to a service system independently, different service desks handle the same type of business, and customers choose a shorter queue to wait for service, which is also multiple queues and multiple service desks arranged in parallel, such as queuing for checkout in a large supermarket, customers choose the checkout counter with fewer queues after selecting goods.
The processes in both situations are shown in the figure below (Figure 13):

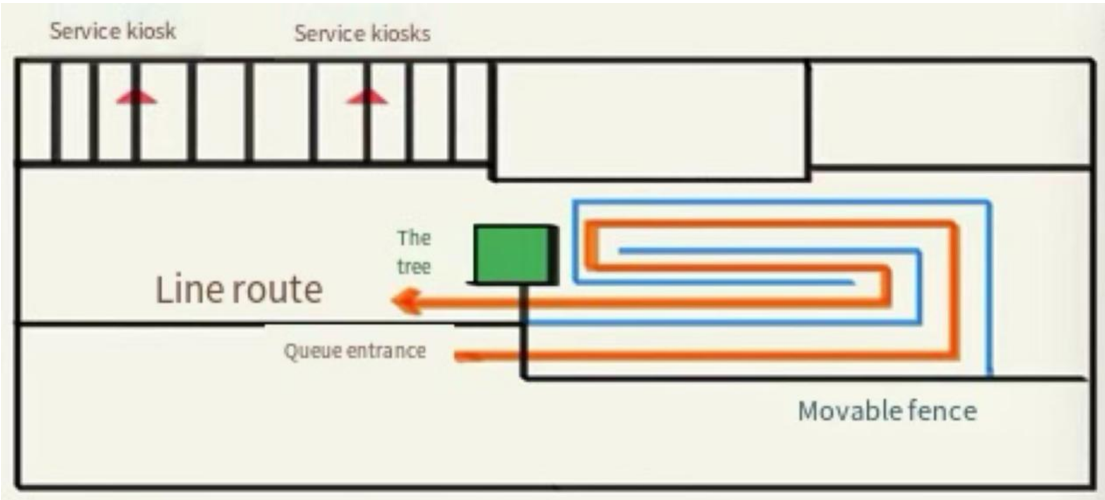


Figure 13 Improved queuing route at the South Second Gate of Beijing Zoo

This paper considers a system with n service desks, equivalent to n queues, where different service desks may provide different or the same services. These are treated as multiple parallel single-server queues. The system is modeled as n independent queues: customers form n separate queues, do not switch queues midway, and there are no instances of queue-cutting, resulting in n independent single-queue single-server queuing models.
Although multi-queue multi-server models may differ in service types, their service rates are roughly the same. Therefore, studying the total number of customers in the system only requires examining the situation of a single queue. The large deviation result for the length of a single queue is given by

$$P(Q>lq)\approx e^{-I(q)} \tag{3}$$

At time t, the probability that the queue length exceeds a certain value can be obtained from the above formula, thus the total number of customers in the multi-queue multi-server system at time t satisfies

$$P(\frac{Q^m}{m}>q)()\approx e^{-I(q)} \quad Q^m\approx Q \tag{4}$$

This implies that the average number of people in the multi-queue multi-server system at time t does not significantly differ from the number of people in a single queue at time t.
This paper uses this model to simulate and optimize the Beijing Zoo, designing suitable strategies.
Simulation and Optimization:
Taking the south gate of the Beijing Zoo as an example, there are currently 12 channels and 8 turnstiles, with 4 channels designated for wheelchairs and strollers. This study excludes special designated channels. Through surveys and statistics, the following table shows the flow of people at the Beijing Zoo for each period (Table 2):

Table 2 Flow of People at the Beijing Zoo for Each Period

Period	Off-Peak	Peak

7：00-8：00	688	1856
8：00-9：00	2530	3573
9：00-10：00	1562	2571
10：00-11：00	1842	3289
11：00-12：00	1560	3064
12：00-13：00	1660	2550
13:00-14：00	1275	1930
14：00-15：00	1130	1780
15：00-16：00	921	2064
16：00-17：00	529	1362
17:00-18:00	112	792

The data for the two periods represents the customer arrival rate in units of people per hour (Figure 14).

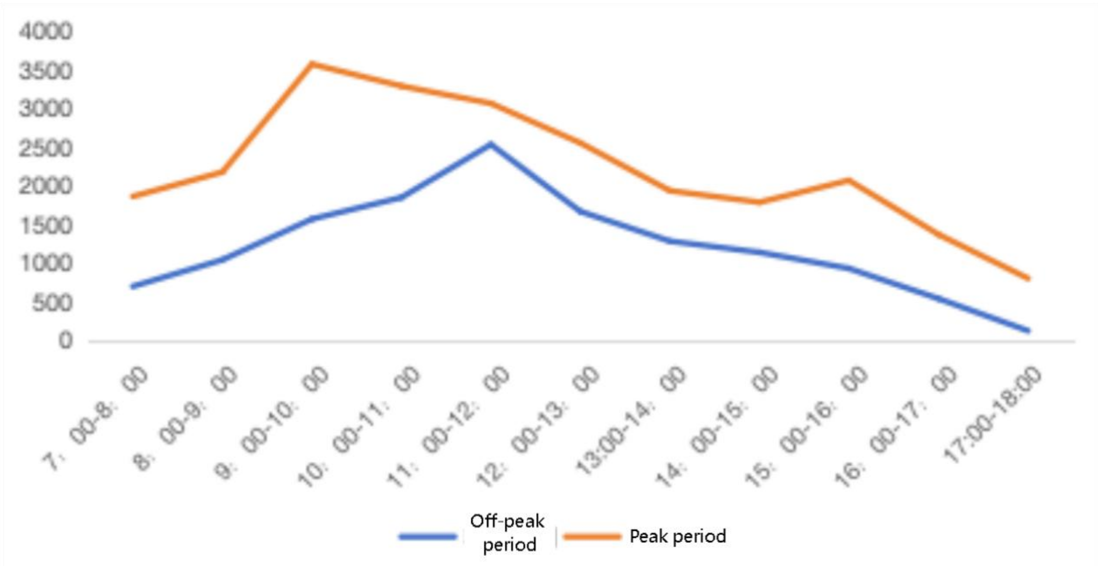


Figure 14 A line chart of the Beijing Zoo's Flow of People for Each Period.

The statistical characteristics of this data set are as follows (Table 3):

Table 3 Statistical Characteristics of the Flow of People at the Zoo for Each Period

Statistical Feature	Value
Mean	723
Standard Deviation	494.6787
Skewness	-0.1802249
Kurtosis	1.160637

Three common distributions were fitted to the data, and the best distribution was chosen based on different standard errors. The fitting results are shown in the table below (Table 4).

Table 4 Fitting Results Data Table

Fitting Distribution	Parameters	Standard Error

Fitting Distribution	Parameters	Standard Error
Poisson Distribution	723	5.48861
Normal Distribution	723	98.84697
	494.6787	69.89779
Negative Binomial Distribution	1.434907	0.3771129
	723	123.375

Although the standard error of the size parameter in the negative binomial distribution is the smallest at 0.377, the standard error of another parameter is as large as 123.375. Therefore, considering the overall fit, the Poisson distribution with a smaller standard error of 5.4886 indicates that the arrival process of visitors during off-peak hours approximates a Poisson distribution. Similarly, for peak hours, a Poisson distribution with different parameters is simulated.

Since the number of visitors varies greatly at different times, it is necessary to study different periods when considering the opening of windows. This paper selects the periods with the highest number of visitors during off-peak and peak hours for study, i.e., 8:00-9:00 for both off-peak and peak hours. The arrival rate during off-peak hours at 14:00-15:00 is 22.3 (people/min), approximately 3 visitors per 2 minutes per turnstile; during peak hours at 8:00-9:00, the arrival rate is 42.88 people/min, approximately 3 visitors per minute per turnstile.

Next, the service rate of the turnstiles or workers is studied. By observing the service time for 400 visitors entering the turnstiles, the following table is obtained (Table 5):

Table 5 Service Time Statistics for Visitors Entering Turnstiles

Turnstile Service Time (seconds)	Number of People
0～8	69
8～16	73
16～24	56
24～32	40
32～40	35
40～48	20
48～56	18
56～64	19
64～72	16
72～80	15
80～88	13

Turnstile Service Time (seconds)	Number of People
88 or more	26

Through literature review, it is found that the service time follows a negative exponential distribution with a parameter of u = 0.0307(people/second) = 1.842 (people/minute). Since the arrival rate of visitors during off-peak hours is 1.39 (people/minute), the service rate is higher than the arrival rate, and visitors will not form long queues; there may be idle turnstiles. During peak hours, the arrival rate per turnstile is 1.842 (people/minute), i.e., the service rate is less than the arrival rate, and queues will form over time. Using the theory shown in 3.3.1 (5), the number of channels to be opened at the zoo during peak hours is determined. With the rate function I(q)=qln $\frac{1.842k}{2.68}$ and setting the maximum queue length to 30, P(Q>30)= $e^{-3ln\frac{1.842k}{2.68}} < e^{-3}$ is obtained, and it is found that k > 1.6, i.e.,K > 11.6, thus at least 12 turnstile channels are needed.

3.4.2 Continuous improvement and feedback:

Based on the data and feedback after implementation, continuous improvement is carried out to ensure that the improvements are sustained and can adapt to changing circumstances. If there are still issues in some areas, adjustments and optimizations are made in a timely manner.

3.4.3 Communication and change management

During the implementation process communication is carried out with employees and visitors to explain the purpose and expected effects of the improvements. Ensure they understand the new processes and changes. The following table analyzes the key points of communication that need to be conveyed to employees and visitors (Table 6).

Table 6 Key Points of Communication with Employees and Visitors

Communica tion Object	Main Content
Employees	Organize meetings or training - Explain the purpose, significance, and expected effects of the improvements - Clearly explain the new processes and changes - Encourage employees to provide feedback and opinions
Visitors	Post improvement plans and changes on official websites, social media, etc. - Send emails or text messages to notify visitors in advance - Post promotional posters to explain the purpose and effects of the improvements - Provide information brochures or guides - Set up signs or signs to guide visitors to use new services or facilities

3.4.4 Expected results

(1) FlexSim Simulation

FlexSim simulation models can visually observe the operation mode of queuing at the south gate of the Beijing Zoo. Based on the content of 3.4.1 (5) in this paper, FlexSim simulation is used to simulate the multi-queue multi-server model system. The specific 3D simulation interface is as follows (Figure 15):

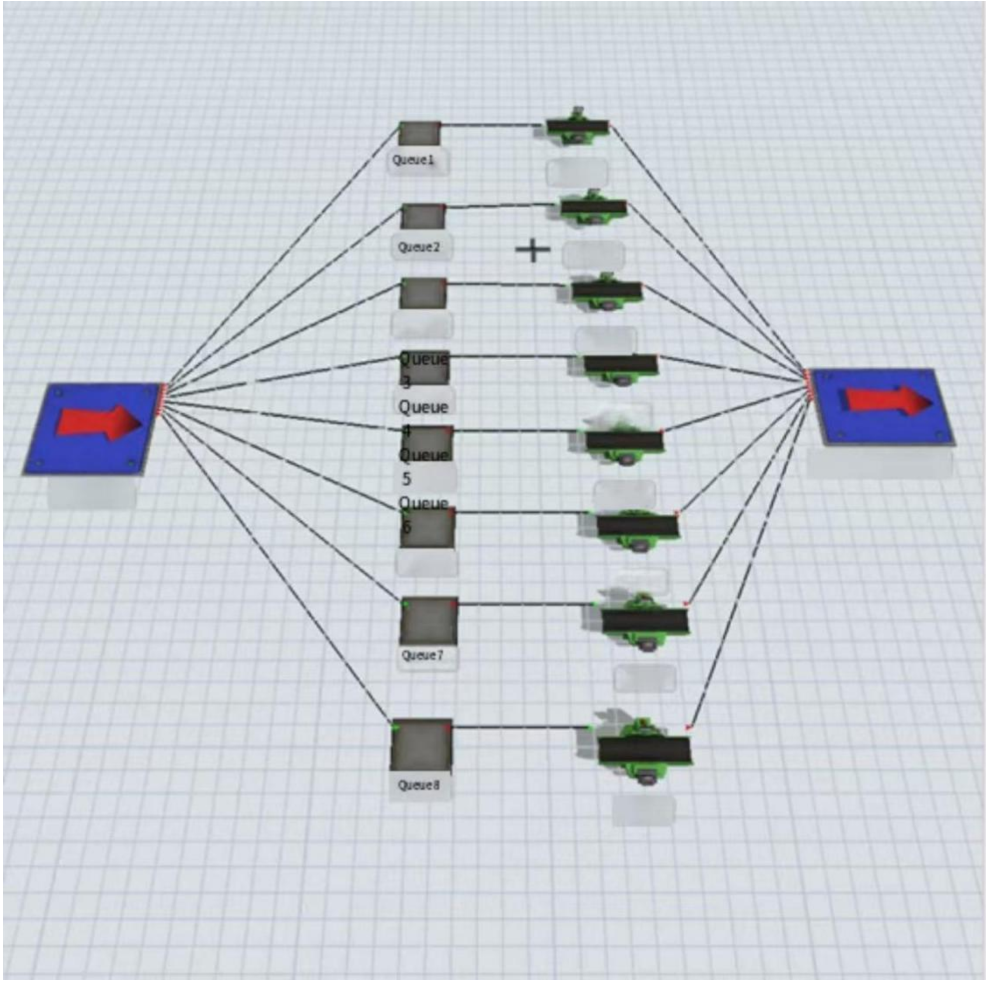


Figure 15 3D Simulation Interface of Multi-Queue Multi-Server Model

The interarrival time of visitors follows an exponential distribution with a parameter of 2.8 seconds, and the service time of the ticket gates follows an exponential distribution with a parameter of 32.57 seconds. After arriving at Beijing Zoo, visitors line up to enter, dispersing into the shortest queue without switching queues midway. Due to the large number of ticket gates, the difference between single queue-single server models in parallel queue models is small, so it is reasonable to convert to 8 ticket gates.

To determine if the number of ticket gates is reasonable, we need to see if the customer waiting time in line is appropriate. There is a slight difference in the number of people queuing at different ticket gates. We are now looking at the change in the number of customers waiting in Queue 1 and Queue 8 over time (Figure 16).

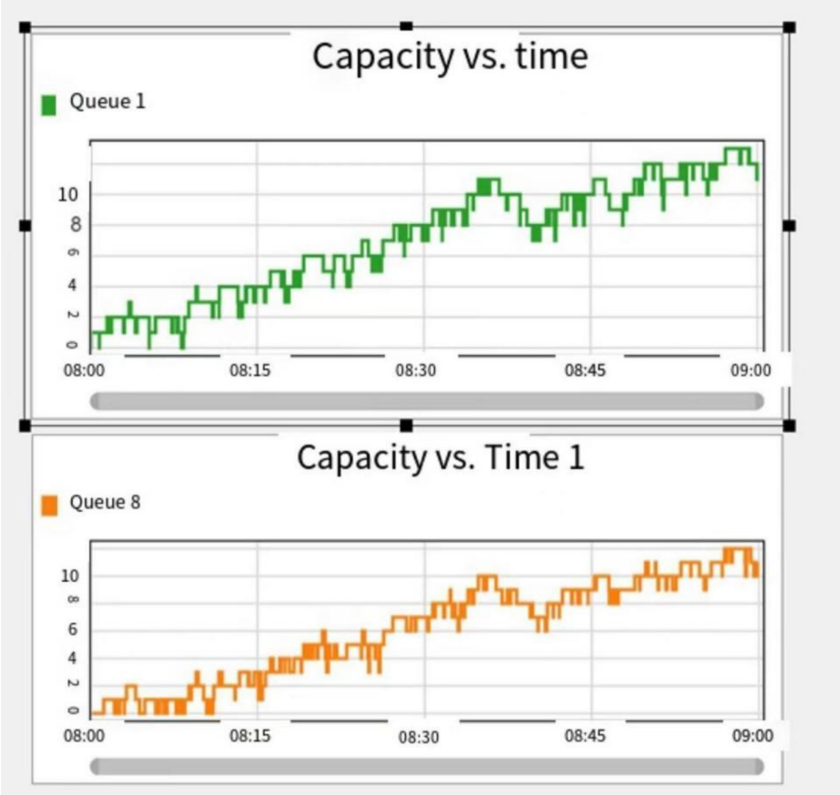


Figure 16 Change in the Number of Waiting Customers in Queue 1 and Queue 8

Observing the above figure, the trend of the number of people in Queue 1 and Queue 8 over time is roughly the same, with the maximum number of people in line around 30, and both starting to gradually increase from 8:00, then gradually rising and slowly stabilizing.

The service system is just a process of averaging. If it is during a busy period, the interarrival time of visitors will shorten, and the waiting time will increase. To reduce the waiting time for visitors and alleviate the workload of service staff, the number of ticket gates needs to be increased.

After mathematical analysis, it is necessary to add 4 more ticket gates, as shown in the figure below (Figure 17):

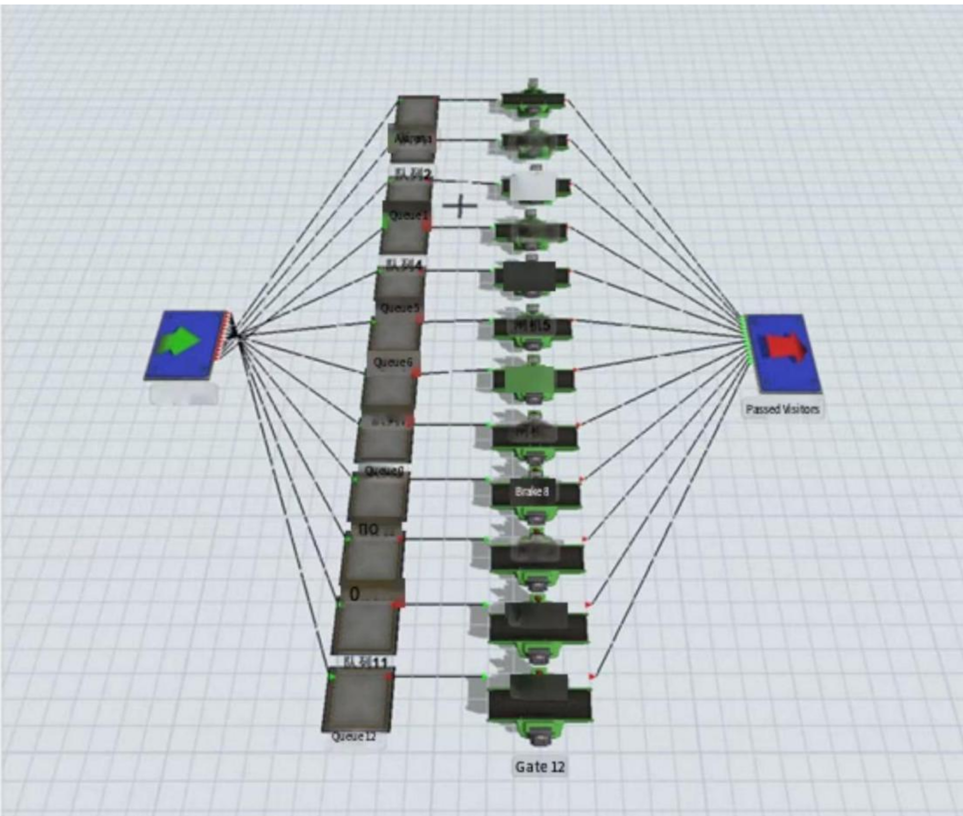


Figure 17 Simulation Diagram After Adding 4 Ticket Gates

The above figure shows the specific 3D simulation interface of the 12 queues in the zoo queue, that is, the entire system includes 12 queues and 12 ticket gates, with the customer arrival interval and average service time remaining unchanged. Next, we look at the change in the number of people queuing in Queue 1 and Queue 8 after adding 4 ticket gates, see the figure below (Figure 18):

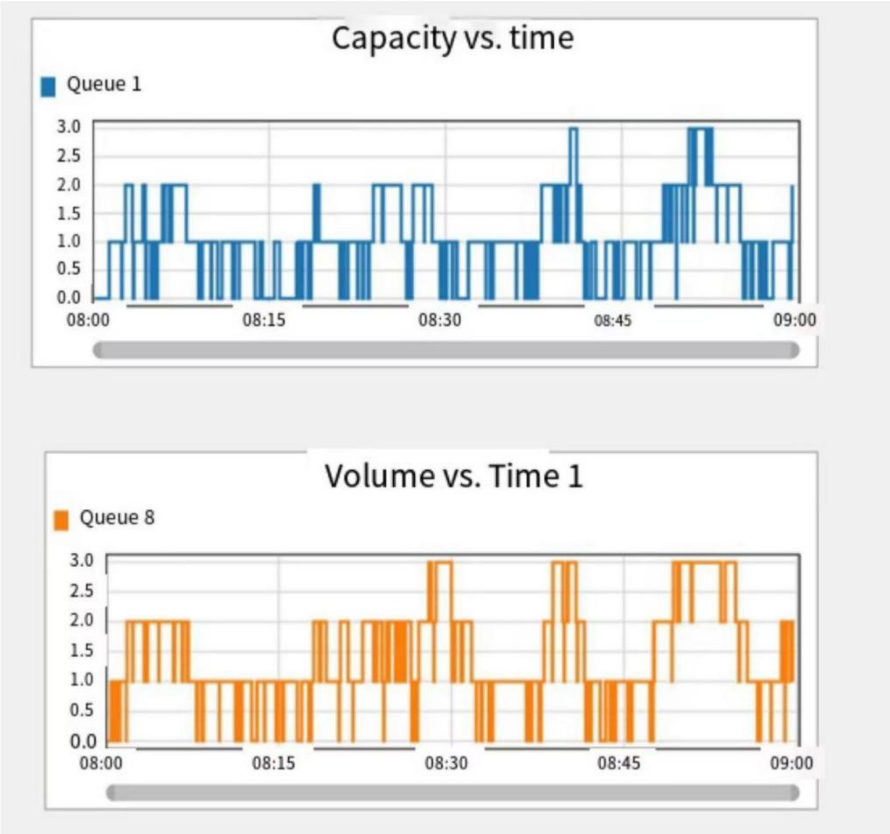


Figure 18 Change in the Number of People Queuing in Queue 1 and Queue 8 After Adding 4 Ticket Gates

There is a slight difference in the change in queue length between Queue 1 and Queue 8. The maximum number of people in Queue 1 is 3, and the maximum number of people in Queue 8 is also 3, but the trend is basically the same, with the peak appearing around 8:48. From this, it can be seen that after adding 4 ticket gates, the queue length has become significantly shorter.

In addition to simulating the increase in the number of ticket gates, we also optimized each ticket gate based on the improvement concept in 3.4.1 (1). Due to the large number of ticket gates, the difference between single queue-single server models in parallel queue models is small, so it is reasonable to convert to 1 ticket gate. The comparison before and after the improvement is shown in the figure below (Figure 19):

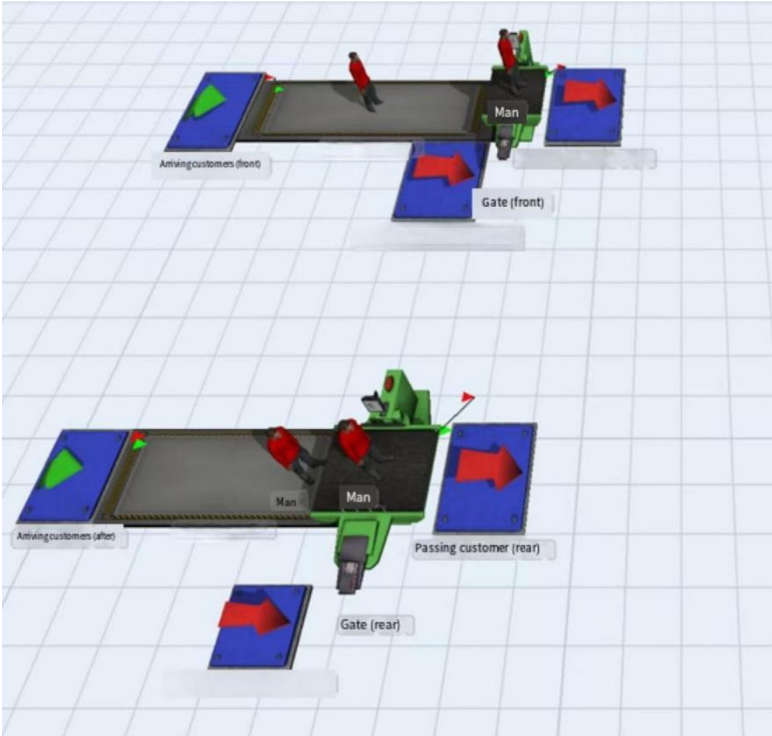


Figure 19 Comparison Diagram Before and After Improvement

As shown in the above figure, after the conversion, the interarrival time of visitors before the improvement follows an exponential distribution with a parameter of 22.4 seconds, and the service time of the ticket gates still follows an exponential distribution with a parameter of 32.57 seconds. When some visitors need to pass through the ticket gate, and the ticket gate cannot recognize their admission vouchers, it will cause a stall, thereby extending the queue time. According to observations, the solution time for visitors due to the ticket gate's inability to recognize admission voucher information generally exceeds 150 seconds. Therefore, in the simulation, visitors who have been queuing for more than 150 seconds will enter the group of customers who cannot pass through the ticket gate, and those who have been queuing for no more than 150 seconds will enter the group of visitors who pass through smoothly. After the improvement, due to the supplementation of the ticket gate's admission information, the situation where the ticket gate cannot recognize the visitor's admission voucher information has been greatly reduced, thereby improving the queue progress. After mathematical analysis, the interarrival time of visitors in the simulation after the improvement still follows an exponential distribution with a parameter of 22.4 seconds, and the service time of the ticket gates still follows an exponential distribution with a parameter of 25 seconds.
After running the FlexSim simulation, we obtained the following chart data (Figure 20):

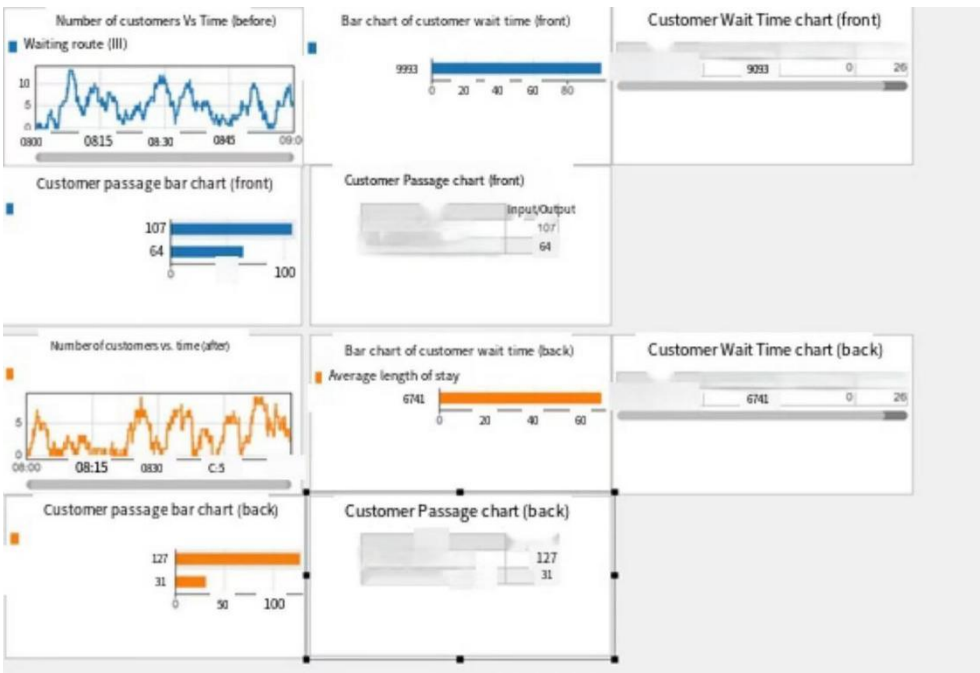


Figure 20 Chart Data Obtained After Running FlexSim Simulation

As shown in the above figure, the first five charts (from left to right) are the relevant data of visitors passing through the ticket gates before the improvement, and the last five charts (from left to right) are the relevant data after the improvement. After comparison, it is observed that the number of people on the waiting route has relatively decreased, the customer waiting time has also decreased, and the number of customers who cannot pass through the ticket gates has also decreased. Therefore, it is concluded that after the improvement, the situation where the ticket gate cannot recognize the visitor's admission voucher information will be reduced.

(2) Distribution of Survey Questionnaires

We distributed survey questionnaires to collect visitors' satisfaction with different improvement measures and the expected queuing time, and processed the data to obtain the following results (Table 7):

Table 7 Expected Results of Visitor Queuing Time and Satisfaction

measure	Queue time (minutes)	Satisfaction rating (out of 10)
Improve the gate system	4	8
Improve the queue path	3	9
Small program Improvements	4	7
Allocate parking properly	5	7

Through the above steps, the improvement plan can be effectively implemented to solve the problem of long queuing times, and continuous monitoring and feedback are maintained during the implementation process. After completing the fourth step Improve, we will enter the last stage of DMAIC, that is, Control.

3.5 Control

When using the fifth step Control to study the improvement of the current queuing situation at the scenic spot, it can ensure that the solution to the problem is maintained for a long time, and a control plan is formulated to monitor and manage the process.

3.5.1 Control plan development

We will develop a detailed control plan to ensure the continuous maintenance of the solution to the queuing time problem. After team discussion, the plan will include the following content (Table 8):

Table 8 Control Plan and Content Explanation

Control Plan	Content Explanation
Measurement Indicators	Determine the key indicators that need to be monitored, such as average queuing time, visitor satisfaction, etc.
Data Collection Frequency	Determine the frequency of data collection, such as daily, weekly, or monthly.
Responsible Person	Appoint a person in charge of data collection and monitoring work.
Control Limits and	Set control limits and target values to take timely measures when the data exceeds the

Control Plan	Content Explanation
Targets	threshold.
Feedback Mechanism	Determine how to communicate the changes and results of the data to relevant stakeholders.
Corrective Actions	Define the corrective actions to be taken when the data exceeds the control limits.

3.5.2 Data collection and monitoring

After the plan is determined, we will implement the identified improvement measures and establish a monitoring mechanism to monitor their impact, and verify the effectiveness of the improvement after a period of time. Continue to collect feedback and data, compare the queuing time and visitor satisfaction before and after the improvement, and other indicators to ensure the accuracy and consistency of the data and that the improvement measures meet the original goals.

3.5.3 Implementation of statistical process control

In the statistical process, set key performance indicators such as average queuing time and visitor satisfaction, and conduct continuous monitoring. Use statistical process control (SPC) tools, such as control charts, to analyze and monitor the data. Control charts can help detect any abnormalities or trends in a timely manner, so that necessary measures can be taken in a timely manner.

3.5.4 Performance review and reporting

Regularly review the data and compare it with the control limits and targets. Report the project results to the scenic spot management and other stakeholders based on the data, and create reports to show the results of the improvement and the status of the problem.

3.5.5 Continuous improvement and adaptation

Based on the monitoring results, we regularly evaluate the queuing time and make necessary adjustments and improvements according to the obtained queuing time. If the data shows that the problem reoccurs or exceeds the control limits, take immediate corrective actions for continuous improvement and adaptation to achieve a long-term solution and continuous improvement of the queuing problem at the scenic spot entrance.

3.5.6 Training and communication

Train staff to understand and be able to implement the new queuing process, ensuring that all employees understand the control plan, know how to collect data, and understand its importance. At the same time, team members should maintain communication with employees and relevant departments to ensure that the scenic spot management team provides key support and resources. Ensure the smooth progress of the project.

After completing the fifth step Control, we can ensure that the solution to the queuing time problem is sustained, thereby achieving long-term improvement effects and laying the foundation for continuous improvement and management.

Through the implementation of the above plan, we anticipate that we can effectively reduce the waiting time for visitors in queues, enhance the visitor experience, reduce the rate of visitor loss, and increase the retention rate of visitors. At the same time, optimized queue management will alleviate the work pressure on management staff, improve the efficiency of resource utilization at the scenic spot, and increase the economic benefits and reputation of the scenic spot. The successful implementation of the project will provide an innovative example for solving queuing problems at scenic spots and also provide valuable experience for the application of industrial engineering and lean management in the tourism industry.

4 Summary and Outlook

With the recovery of the tourism economy and the expectation of continued steady growth in domestic tourism in the coming years, we have identified the issue of queuing at tourist attractions as a significant factor affecting visitors' experience. We have managed this queuing problem using queuing theory, stratification, and other industrial engineering and lean management methods, which holds positive significance and plays an essential role. The implementation of these industrial engineering and lean management methods can improve the management efficiency of tourist attractions, reduce costs, enhance competitiveness and innovation capabilities, and promote the sustainable development of the tourism industry. At the same time, it can also promote the improvement of service quality and human resource management in tourist attractions, making a positive contribution to the development of the cultural and tourism industry.

COMPETING INTERESTS

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