

# Simulation and Optimization of the Operation of the Catering Industry in the Ancient Town Scenic Area Adjacent to Wetland Parks based on the Agent-Based Modeling Method

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**Abstract:** In China, there are many ancient town scenic areas which are closely adjacent to wetland parks. Wetland parks can elevate the aesthetic appeal of adjacent ancient town scenic areas yet they remain vulnerable to pollution from these areas. Therefore, optimizing the operation of the catering industry within ancient town scenic areas serves as a significant contribution to the preservation of adjacent wetland parks. This study analyzed the operational characteristics of the catering business within an ancient town tourist area adjacent to wetland parks, employing the Agent-Based Modeling (ABM) approach to model the interaction process between tourists and restaurants, taking the catering business in an ancient town tourist area adjacent to wetland located in the southeast of Chongqing, China, as an example. Simulation results have demonstrated the capacity of this model to emulate reality, thereby facilitating its application in explaining, illustrating, and forecasting actual interaction between tourists and restaurants. Considering the environmental impact, the operation of the catering industry has been optimized through simulation. It is suggested that during peak seasons with high tourist flow, increasing seating capacity, as well as reducing customer waiting time for meals, can enhance the customer flow of catering businesses. In addition to economic benefits, this measure is also reduce the pollution of rivers and wetland parks caused by waste from customers dining in various locations, particularly by riverside, by fostering customer to gather and dine in the restaurant.

**Keywords-** ABM method, Catering Industry, Operation Optimization, Wetland Park Preservation, Customer Flow Forecast.

## 1. Introduction

There are numerous tourist areas featuring ancient towns and cities in China, including the Old Town of Lijiang, the Ancient City of Pingyao, and Wuzhen. These scenic areas preserve a vast amount of ancient architecture, reflecting the living conditions of people hundreds of years ago. In the development of tourist areas, the construction of service-oriented supporting facilities is crucial [1], as it can drive the development of tertiary industries such as catering and hotel services in the surrounding areas [2], playing a significant role in promoting economic growth [3]. However, for ancient town scenic areas, the construction of supporting facilities is restricted to maintain the historical appearance of the towns, and the development of the catering industry necessitates meticulous management and optimization with limitations on operating area and scale [4].

In addition to considerations related to operational area, the environmental impact is also a critical aspect in the management of the catering industry within ancient town scenic areas. Many ancient towns in southern China are situated amidst mountains and rivers, often adjacent to wetland parks [4]. The surge in tourist volume resultant from tourism activities constitutes a potential peril to the preservation of these wetland parks [5, 6]. Therefore, in the process of developing the catering industry within ancient town scenic areas, it is necessary to pursue optimization that minimizes environmental impact while achieving economic benefits [7].

Existing research primarily focuses on optimizing the development of the catering industry within ancient town tourist areas [8, 9] or mitigating the environmental impact of tourism [5, 6, 10]. However, few studies comprehensively consider both aspects. Additionally, most of the current research employs empirical analysis methods and rarely delves into the dynamic processes of catering operations. Therefore, in this study the ABM method is used to model the interaction between restaurants and customers, simulating the operating process of the catering industry within ancient town scenic areas, exploring the functioning patterns of catering industry and optimizing for both economic and environmental benefits.

## 2. Objectives

The objective of this study was to develop an agent-based model to represent the interaction of tourists and restaurants in an ancient town scenic area adjacent to a wetland park hence the operational pattern could be demonstrated from the perspective of individual micro-behaviors generating macro-phenomena. The catering business within an ancient town tourist area located in the southeast of Chongqing Municipality in southwestern China was selected as the research object. The field investigation result was used to verify the correctness of the model through comparison. Optimizations was then conducted to improve the performance of while considering the preservation of wetland park.

## 3. Methods

This study is based on the Agent-Based Modelling (ABM) method. ABM is a simulation approach that employs multi-agent modeling. This method involves setting up a certain number of individuals (Agents) with a degree of autonomous consciousness, simulating complex social phenomena through their actions and interactions, and achieving the effect of generating macro-phenomena from individual micro-behaviors. The ABM method has been widely applied in various fields such as organic farming [11], public policy toward terrorism [12], macroeconomics [13], monetary policy [14], inventory-production-transportation and distribution [15], service supply chains [16], spread of COVID-19 [17], etc.

### 3.1 Factors Influencing the Catering Industry

The development of the catering business is influenced by numerous factors, including total employment in the catering sector, permanent resident population [18], per capita income, consumer price index [19], and tourist numbers [20]. Specifically for individual restaurants, their customer count is affected by a series of factors such as brand, location, dish quality, dining environment, price [21], and the consumption level of potential customers [22].

The catering business located within ancient town scenic areas exhibits the following characteristics: Firstly, indigenous people reside within the scenic areas, and their local community also serves as the tourist zone. Secondly, to fully preserve the historical features of the ancient town, there are significant restrictions on building construction and renovation. Consequently, the number and size of restaurants are constrained. Thirdly, many tourists are willing to taste local specialty cuisines apart from experiencing the historical ambiance of the ancient town tourist area. Some tourists choose well-known restaurants based on their reputations, while others wander along the streets of the ancient town to find satisfactory dining options.

Therefore, this study mainly considers tourist volume in the scenic area and restaurant reputation as the primary influencing factors, while restaurant size and service are considered as secondary influencing factors.

### 3.2 Modelling of Tourists and Restaurants in the Ancient town Scenic Area Adjacent to the Wetland Park

This study utilizes Anylogic software as an ABM simulation tool to establish action rules for agents. Each agent performs actions such as movement and interaction according to the rules over time, leading to the formation of macroscopic phenomena.

The simulation space for this study is an ancient town scenic area in the southeast of Chongqing, as shown in Figure 1. The wetland park situates on the other side of the river. The numbers in the figure represent various restaurants.

The ABM simulation environment and rule settings in this study include:

Agent Restaurant: each Agent Restaurant represent a restaurant and locates at fixed positions along the roads within the operating space, each restaurant agent has several parameters. Crucial ones include:

- The location of the Agent Restaurant in the simulation space.
- The popularity and reputation in the community and on social medias
- The price level.
- Seating capacity and occupancy.
- the kind of cuisine the restaurant serves
- Dining ambiance

Agent Tourist: To improve simulation efficiency, each Agent Tourist represents a group of tourists. Tourists can choose a restaurant to dine at and become its customers. Each tourist agent has several parameters. crucial ones include:

- The number of tourists in the group
- Anticipated cost for this dinner
- Preference of cuisine category
- Preference of dining ambiance
- Preference of occupancy



**Figure 1.** Plan of simulation space

The interaction rules between Agents Restaurant and Tourist are as follows:

Some Agents Tourist do not predetermine which restaurant they will dine at before visiting the ancient town. They spawn at random locations within the scenic area and proceed along the streets. Upon encountering a Restaurant, they evaluate its parameters including the price, the cuisine it serves, the dining ambiance, and the occupancy to determine if the Restaurant meets their requirements. If it does, they will stay and dine there; if not, they will continue to visit the next restaurant. If they do not find a satisfactory restaurant after visiting several in succession, they will leave the ancient town scenic area without dining.

Some Agents Tourist predetermine which restaurant they will dine at before visiting. These Agents Tourist spawn at specific Restaurants, with the spawning probability related to the restaurant's popularity and reputation. These Tourists evaluate whether to dine at the planned restaurant based on parameters such as the Anticipated cost for this dinner, Preference of dining ambiance, and occupancy. If they are dissatisfied, they will search for a better one along the streets, following the same process as the other group of Tourists wandering in the street.

If an Agent Tourist decide to dine at an Agent Restaurant, the occupancy of Restaurant increase during the dining time, then return to the previous value. The dining time at a restaurant consists of several parts: ordering, waiting, eating, and post-meal rest.

#### 4. Results

The ancient town scenic area which serves as the simulation space is about 400 meters east-west and about 900 meters north-south, with a total of 14 restaurants of various types. The locations of the restaurants are marked on Figure 1. Each restaurant is modeled as a corresponding Agent, numbered 1 to 14. A questionnaire survey was conducted on various restaurants to determine the parameters of each Agent Restaurant. During the May Day holiday from April 28 to May 4, 2023, a questionnaire survey was conducted among customers, and the parameters for Tourist were set based on the results. According to the statistics of the tourism management department, the average daily tourist flow of the ancient town scenic areas during the peak season of May Day holiday in 2023 is about 20,000 people.

Due to the limitations of study conditions, it is impossible to obtain all the data of restaurant operating income and cost. Therefore, the focus of this study is on the customer flow of each restaurant, especially the relative customer flow of each restaurant. Through ABM modeling, simulate the customer flow of each restaurant over a period, and then compare it with the actual on-site collected customer flow to validate the model.

In this study, simulation time unit for the ABM simulation is set to 1 minute. Field investigations revealed that the primary dining times for tourists are between 11:00 and 15:00, and between 17:00 and 21:00 each day. Therefore, the duration of each ABM simulation is set to 240 minutes to simulate a single dining period.

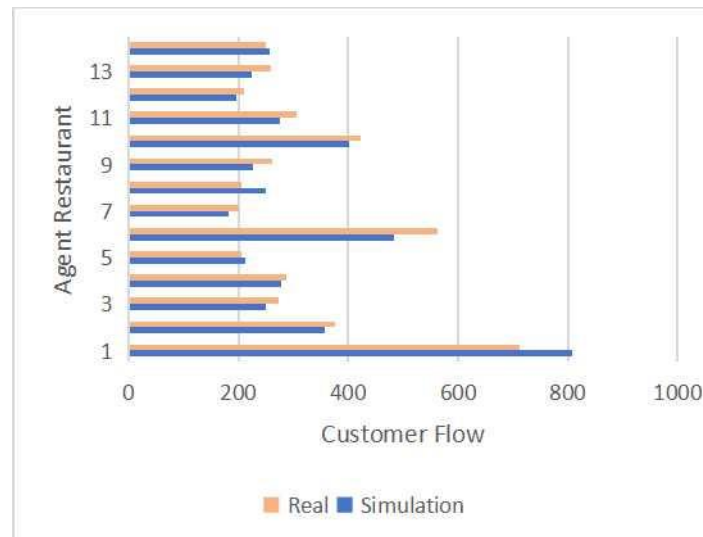
Assuming that 60% of the daily tourist flow in the scenic area intends to dine in the catering area, they are considered potential customers. With 90% of the daily tourist flow concentrated in the midday and evening periods, the total number of potential customers per period is 5,400.

Due to the presence of numerous random factors in the generation and interaction of Tourist agents, this study adopts an approach of increasing the number of simulations to eliminate the influence of these random factors. Simulations are conducted 100 times for the average results. Simulation results and field investigation result of total customer flow for each restaurant are shown in Figure 2.

By comparing the simulation results with the field investigation findings, it can be observed that all Restaurants achieved simulation results that closely approximate the investigation in terms of visitor flow distribution. This model can be used to simulate the operating conditions of restaurants within the ancient town scenic area.

Upon tallying the customer flow for each restaurant, it was found that the total customer flow for all 14 restaurants was 4405 in simulations and 4532 in the field investigation, which is less than the number of potential customers 5400. By studying the simulation process, it was discovered that due to limitations within the ancient town scenic

area, 10 restaurants had a seating capacity of less than 60, 3 restaurants had a seating capacity between 80 and 100, and 1 restaurant had a seating capacity of 120. The total seating capacity for all 14 restaurants was 720. Approximately 20 minutes after the simulation began, the occupancy rate of each restaurant reached over 90%. Only after guests had finished their meals and left could new guests enter. Subsequent tourists were unable to find restaurants within the ancient town to dine and had to leave.



**Figure 2.** Customer flow of Agents Restaurant

## 5. Discussion

The ancient town shares the same river with the wetland park, and the massive tourists may inadvertently cause environmental damage during their tourism activities, such as discarding waste into the river while picnicking by the riverside or other locations around the ancient town. Conversely, restaurants within the ancient town scenic area are capable of efficiently collecting and managing waste produced during dining. Hence, augmenting the flow of customers dining within restaurants while diminishing the number of people dining by the riverside and in other locations can mitigate environmental damage.

To increase the customer flow of restaurants within the ancient town scenic area, this model was utilized to explore optimization solutions. Based on the characteristics observed during the simulations, this study established two scenarios: increasing the seating capacity of the restaurants, and reducing the waiting time for customers during the dining time. The impacts of these two strategies on the restaurant's operating conditions were verified.

### 5.1 Increasing Restaurant Seating Capacity

Based on the analysis of the current operating status of the restaurants, it was found that the existing seating capacity of each restaurant was insufficient, leading many potential customers to abandon dining in the restaurants within the ancient town scenic area due to lack of availability. Therefore, in this scenario, the seating capacity of each restaurant is increased by 20% and the impact is observed. The simulation result is shown in Table 1.

In Table 1, Case 1 and 2 represent the original simulation case and the case with the rise of seating capacity, respectively. Table 1 demonstrates that by increasing the seating capacity by 20%, the customer flow of various restaurants has risen by 12% to 18%. This indicates that enhancing the seating capacity of restaurants can effectively boost their customer flow. However, due to maintain the historical appearance of the ancient town scenic area, large-scale renovations of existing historic buildings are not feasible, and the size of each restaurant is difficult to expand. Therefore, restaurants should consider increasing their seating capacity without expanding

their operating area, such as by optimizing the layout of tables, chairs, and facilities within the restaurant, or by setting up temporary outdoor dining areas outside the restaurant during the peak hour.

**Table 1.** Comparison of Simulation results with or without the rise of the seating capacity

Restaurant	Case1	Case2	Rise
1	808	907	12.2%
2	358	413	15.4%
3	249	286	15.0%
4	279	323	15.8%
5	213	250	17.2%
6	483	546	12.9%
7	183	205	12.1%
8	250	294	17.9%
9	227	259	14.0%
10	402	460	14.2%
11	275	321	16.9%
12	195	227	16.3%
13	225	266	17.9%
14	256	302	17.8%

## 5.2 Reducing Customer Waiting Time in Restaurants

Considering the situation during peak seasons where restaurants are nearly saturation, reducing the waiting time between ordering and dining for customers can accelerate the turnover rate of customers within the restaurant, thereby increasing the overall customer flow of the restaurant. In this scenario, the customers' waiting time is halved and the impact is observed. The simulation result is shown in Table 2.

**Table 2.** Comparison of Simulation results with or without the reduction of the waiting time of customers

Restaurant	Case1	Case2	Rise
1	808	855	5.7%
2	358	419	16.9%
3	249	264	6.1%
4	279	326	17.0%
5	213	248	16.4%
6	483	509	5.3%
7	183	211	15.1%
8	250	285	14.1%
9	227	260	14.3%
10	402	462	14.8%
11	275	314	14.2%
12	195	226	15.5%
13	225	236	4.7%
14	256	295	15.2%

In Table 2, Case 1 represent the original simulation case and Case 2 for the case with the reduction of waiting time of customers. Table 2 indicates that reducing customer waiting time can increase the customer traffic of various restaurants. The increase is minimal (3% to 7%) for restaurants serving Western or Chinese fast food (No. 1, 3, 6, 13), while it is more significant (12% to 17%) for those serving other types of food. This is because the waiting time for customers at fast food restaurants is relatively short (1 to 5 minutes), and halving the waiting time does not significantly reduce the overall dining time. In contrast, for restaurants serving other types of food, the waiting time is longer, and reducing it can notably shorten the dining time, thereby increasing customer turnover rate.

## 6. Conclusion

In this study, a model representing the interaction process between tourists and restaurants within an ancient town scenic area employing the Agent-Based Modeling (ABM) approach was proposed and verified. It was revealed that during peak seasons with high tourist flow, increasing seating capacity through measures such as optimizing the restaurant layout or adding temporary outdoor dining areas, as well as reducing customer waiting time for meals, could enhance the customer flow of catering businesses within the ancient town scenic area adjacent to the wetland park. Besides the economic benefit, the environment impact of the tourists was also mitigated since the waste produced from dinner was better collected and managed.

Certain deficiencies exist in this study: The modeling phase inadequately accounted for the waste produced by the restaurants themselves. The optimization process primarily aimed at augmenting customer traffic, without directly targeting the minimization of environmental impact as the primary optimization objective.

In future studies, relevant factors related to waste generated by restaurants will be included in the modeling, and the overall pollution generated by both restaurants and customers will be optimized as the simulation target. The mechanisms through which the beautiful scenery of wetland parks enhances the attractiveness of the ancient town scenic area will be incorporated into the model, enabling the harmonious development between the ancient town scenic area and the wetland park, and achieving a balance between economy and environment.

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