Optimization model analysis of the conference preparation problem

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Abstract: This paper addresses the preparation for an international conference in the context of the problem D in the 2009 National University Student Mathematical Modeling Contest. The problem is mainly divided into four modules: predicting the number of participants, booking hotels, renting meeting rooms and renting buses. By comparing primary, secondary, tertiary, and quaternary function fits, we finally obtain that a univariate linear fitting function provided a more accurate estimate for the number of conference participants, which is determined to be 639. Based on the estimate, we aimed to minimize the number of required hotels and the distance between them. By adopting the 0-1 programming and solving it with LINGO software, we get the final hotels: ①②⑤⑦. The specific hotel room arrangements and the number of people accommodated in each hotel can be found in Tables 5 and 6 after collation. In addition, from the perspectives of economy, fairness, convenience and satisfaction of participants, we have analyzed an optimal plan for renting meeting rooms and buses, i.e., 6 meeting rooms ranging in size from 110-160 and 4 buses with 45 seats. As a result, the total cost for one day amounts to 17,600 yuan. The specific allocation of meeting rooms can be found in Table 7, while the bus pick-up and drop-off plan is illustrated in Figure 3.

Keywords: conference preparation, same probability event, 0-1 programming, curve fitting

1 Introduction

A conference is an activity in which people gather together for discussion and communication to address common issues or various objectives. It is often accompanied by a significant personnel flow of attendees and associated expenses. With the rapid development of Chinese economy, the conference and exhibition industry are becoming more and more important in the development of the country. As an important part of the convention and exhibition industry, large-scale conferences have a special role in enhancing the city image, promoting municipal infrastructure, and generating economic benefits.

Effective conference preparation is both a guarantee of conference quality and a prerequisite for conference success. This paper is based on the 2009 National University Student Mathematical Modeling Competition Question D, titled "Conference Preparation" [1]. we

ICBBEM 2024, March 29-31, Wuhan, People's Republic of China

DOI 10.4108/eai.29-3-2024.2347344

utilize mathematical modeling to create a practical and realistic plan for conference organizers, including predicting the number of attendees, booking hotels, renting meeting rooms, and planning transportation.

Researchers have studied this topic using nonlinear fitting, interpolation and multi-objective planning [2-8]. Literature [9] provides a brief description of the conference preparation problem in terms of modeling process and solution ideas. Inspired by the literature [9], in this paper, we use linear fitting and 0-1 programming methods to study the conference preparation problem by analyzing and organizing the data.

2 Problem description

A conference service company in a city is responsible for hosting a national conference in a professional field. The conference preparation team is responsible for booking rooms for participants, renting conference rooms, and renting buses to transport participants. Due to the large scale of the conference and the limited availability of suitable hotel rooms and conference spaces in multiple hotels, participants must be accommodated in several different hotels. In order to facilitate management, meet the needs of participants in terms of price and other aspects, our goal is to minimize the number of selected hotels and the distances involved. After on-the-spot investigation, the preparatory group selected 10 hotels as alternatives [10].

Question 1: Although participants cover their own hotel expenses, the organizing team is responsible for covering a day's hotel expense if the number of reserved rooms exceeds the actual demand. If the number of reserved rooms is insufficient, it will cause the dissatisfaction of the participants.

From the previous conferences, some participants sent a return receipt but didn't show up, while others attended without prior confirmation. Based on the above information, the first mathematical problem that the conference organizing team needs to solve is to predict the actual number of participants for the conference.

Question 2: Due to the large size of the conference and the limited availability of suitable hotel rooms and meeting space, participants will have to be accommodated in a number of hotels.

This requires that the needs of participants be met as much as possible in terms of price, with as few hotels and as short a distance as possible. The second mathematical problem that the conference organizing team needs to solve is determining the number of hotels and reserving rooms. In addition, there will be six sessions per day in the morning and six sessions per day in the afternoon during the conference. The conference organizing team needs to solve the meeting room booking plan that will provide the hotels where the participants will stay. Finally, based on the three types of buses available for renting, the organizing team also needed to solve the bus rental plan for transporting attendees to and from the conference in case there was uncertainty about the number of attendees.

In summary, the mathematical problem we need to solve is to give the organizing team a reasonable plan for predicting the number of attendees, booking hotel rooms, renting meeting rooms, and renting buses through mathematical modeling in terms of total cost, fairness, convenience, and attendee satisfaction.

3 Modeling method and experimental results

In this section, we focus on two issues: determining the number of participants, booking hotels.

3.1 Predicting the number of participants

3.1.1 Modeling method of determining the number of participants

For this problem, we mainly use the curve fitting method [11-13]. Curve fitting is a data-processing method that involves selecting the appropriate type of curve to fit the observed data and using the fitted curve equation to analyze the relationship between two variables. In a variety of physical and statistical problems, a number of data sets are obtained from multiple observations or experiments of the quantities concerned, which are fragmented and not only not easy to handle, but also usually do not accurately and adequately reflect their inherent patterns. In order to get the inherent law between the data or use the current data to predict the expected data, we should use the continuous curve to approximate or compare the plane of the discrete point group expressed by the coordinates of the functional relationship between. Let x and y be the observed quantities, and y be expressed as a function of x. Assume that this functional relationship has been determined by the actual data. Assuming that this functional relationship has been theoretically specified by the actual problem, it is called a theoretical function, but it contains n unknown parameters. Several sets of data can be obtained experimentally: (x_1, y_1), (x_2, y_2), $\cdots$, (x_m, y_m). The best estimate of the parameter b can be sought through these data, i.e., the best theoretical function is sought. In numerical analysis, curve fitting is the approximation of discrete data by analytical expressions, i.e., the formula of discrete data.

By organizing Schedule 3 of the original problem (see Table 1 for details), we get that the actual number of participants attending the conference and the number of people who sent return receipts approximate a stable proportional relationship, as shown in the table below.

Table 1: Proportional relationship of the actual number of participants attending the conference and the number of people who sent return receipts

	First	Second	Third	Fourth
The number of participants who sent return receipts	315	356	408	711
The number of participants who sent replies but did not attend the conference	89	115	121	213
The number of participants who attended the conference without sending return receipts	57	69	75	104
The actual number of participants	283	310	362	602

Based on the data in Table 1, we further use MATLAB to draw a scatter diagram of the number of callbacks versus the actual number of attendees, details of which are shown in Figure 1.

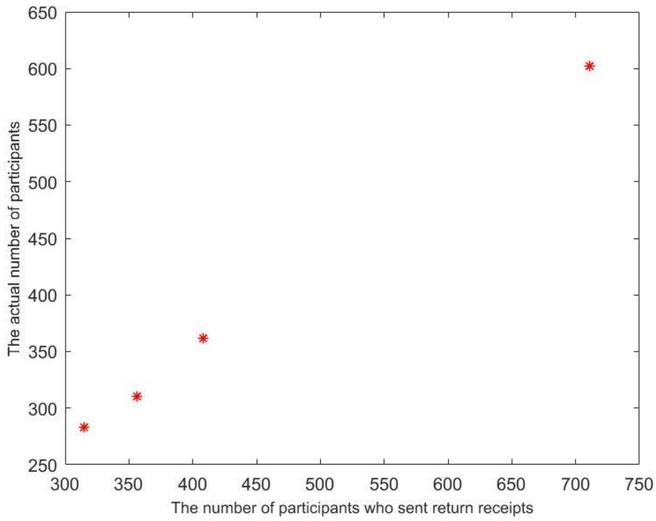
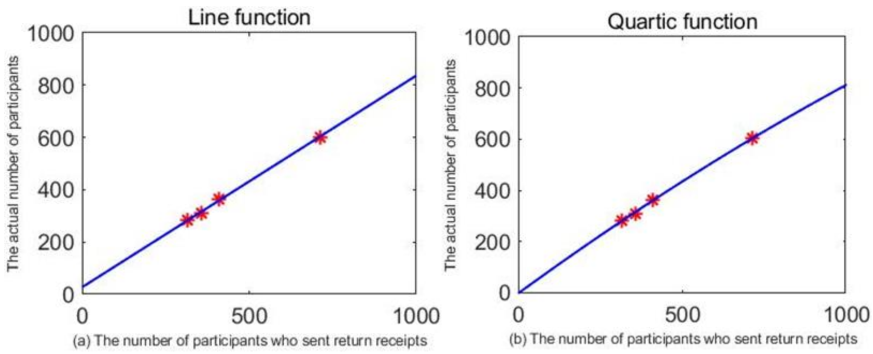


Figure 1: Scatter diagram

From Figure 1, the number of participants sent return receipts in the first four conferences and the actual number of participants attending the conference approximately meet the linear relationship. Therefore, we adopted the curve-fitting method to determine the number of participants in this meeting.

3.1.2 Experimental results of determining the number of participants

The primary, secondary, tertiary and quaternary functions are chosen to fit the original data, and the expressions of these four functions can be expressed uniformly as follows$y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3 + \beta_4 x^4$. The coefficients of each of the four fitted curves and the plot of the fitting effect were obtained by MATLAB. Some details see Figure 2.



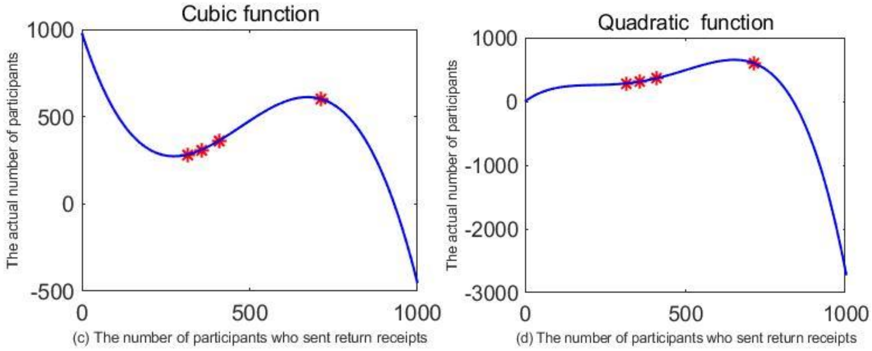


Figure 2: Results of curve fitting

From Figure 2, the number of delegates who sent in their acknowledgements and the number of delegates who actually attended the first four sessions are on the curve (straight line), which indicates that the fitting effect is very good. However, it is not difficult to find that in Figs. (c) and (d), as the number of delegates sending in acknowledgements increases, the actual number of delegates attending the meeting shows a decreasing trend, which is not reasonable. Further, according to the data in Table 2, we find that the fit of the four functions R^2. The values are all close to 1, indicating that the fitting effect is very good, among which the linear fit is the closest to 1 and the fitting effect is the most ideal. Excluding the cubic and quartic functions just discussed, we get that both the primary and quadratic functions are reasonable as fitting functions. Due to the coefficient of the quadratic term of the quadratic function, the β_2= -0.0001, close to 0, so the final choice of the linear fit function, which is the primary function $y = 0.8096x + 26.9620$ as the best fitting function, where x, y representing the number of representatives who sent return receipts and actual number of participants attending the conference, respectively.

Table 2: Coefficient of each fitting function and corresponding fitting degree

Fitting coefficients	β_0	β_1	β_2	β_3	β_4	R^2
Linear	26.9620	0.8096				0.9999
Secondary	-2.2607	0.9345	-0.0001			0.9989
Three times	979.1853	-5.9540	0.0153	-0.0000		0.9889
Four times	0	3.6822	-0.0194	0.0000	-0.0000	0.9889

We further calculate the Root Mean Square Error (RMSE), which is defined as $\sqrt{\sum \frac{1}{4}(y - y_i)^2}$, where y is the real value and y_i is the predicted value. Through the specific calculation, we get its RMSE value is 3.5529. The result can be considered that the fitted value differs from the true value by 3.5529, indicating a reasonable fit with a favorable fitting effect. By substituting $x = 755$, we can get $y = 638.21$. Consequently, the estimated number of participants is 639.

3.2 Booking hotels

In this subsection, the main problem we address is the selection of hotels.

Once we have determined the number of participants, we can proceed to construct the matrices representing the number of housing claims sent back C, the weight of housing requirements Dwhich in turn enables us to calculate the actual number of participants with different requirements E. Here, we list the matrices C, D and E.

$$C = \begin{bmatrix} 154 & 104 & 32 & 107 & 68 & 41 \\ 78 & 48 & 17 & 59 & 28 & 19 \end{bmatrix},$$

$$D = \frac{C}{755} = \begin{bmatrix} 0.20 & 0.14 & 0.04 & 0.14 & 0.09 & 0.05 \\ 0.10 & 0.06 & 0.02 & 0.09 & 0.04 & 0.03 \end{bmatrix},$$

$$E = D * 639 = \begin{bmatrix} 130 & 88 & 28 & 91 & 57 & 35 \\ 66 & 40 & 14 & 50 & 24 & 16 \end{bmatrix}.$$

The number of participants with different requirements is shown in Table 3.

Table 3: The number of participants with different requirements

	Living together 1	Living together 2	Living together 3	Living alone 1	Living alone 2	Living alone 3
Male	130	88	28	91	57	35
Female	66	40	14	50	24	16

Combining the number of rooms offered by the hotels in the original problem, we categorize them according to the needs of the attendees as follows.

Table 4: The number of rooms with different requirements

Price	120-160	161-200	201-300	120-160	161-200	201-300
Number of rooms	98	64	21	141	81	51

3.2.1 Modeling method of booking hotels

In accordance with the requirements in Tables 3-4, our objective is to minimize both the number of selected hotels and the distances between them, so the idea is to get the minimum value of the two objective functions established under the constraints of some equations or inequalities, and the idea is consistent with 0-1 integer planning [14-17]. 0-1 planning is a special form of integers planning, of such planning decision variablesIt only takes the value 0 or 1, i.e., if the hotel is selected, it takes the value 1, otherwise it takes 0, so it is called a 0-1 variable or, in other words, a 0-1 variable Binary Variables. The 0-1 variable can quantitatively describe the logical relations, sequential relations and mutually exclusive constraints among discrete variables reflected by the phenomena such as on and off, take and discard, with and without, etc. Therefore, 0-1 planning is very suitable for describing and solving a variety of problems that people are concerned about, such as circuit design, factory location, production planning, travel shopping, backpack problems, personnel arrangements, code selection, reliability and so on. Because of its profound background and wide range of applications, 0-1 planning has been emphasized for decades. 0-1 planning is mainly used to solve mutually exclusive planning problems, constraint-exclusive problems, fixed-cost problems and assignment problems.

We therefore establish the following objective function that

$$\min x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 + x_9 + x_{10} \quad (1)$$

and

$$\begin{aligned} min\ 150x1x2 &+ 850x1x3 + 650x1x4 + 600x1x5 + 600x1x6 + 300x1x7 + 500x1x8 \\ &+ 650x1x9 + 1300x1x10 + 750x2x3 + 500x2x4 + 750x2x5 \\ &+ 750x2x6 + 450x2x7 + 650x2x8 + 800x2x9 + 1450x2x10 \\ &+ 250x3x4 + 1500x3x5 + 1500x3x6 + 1200x3x7 + 1000x3x8 \\ &+ 1150x3x9 + 2200x3x10 + 1250x4x5 + 1250x4x6 + 950x4x7 \\ &+ 1150x4x8 + 1300x4x9 + 1950x4x10 + 600x5x6 + 300x5x7 \\ &+ 500x5x8 + 650x5x9 + 1300x5x10 + 300x6x7 + 500x6x8 \\ &+ 150x6x9 + 700x6x10 + 200x7x8 + 350x7x9 + 1000x7x10 \\ &+ 150x8x9 + 1200x8x10 + 1050x9x10 \end{aligned} \quad (2)$$

The constraints are

$$\begin{cases} 85x_2 + 50x_3 + 50x_4 + 70x_5 + 50x_7 + 40x_8 \geq 98 \\ 50x_1 + 65x_2 + 24x_3 + 45x_4 + 40x_5 + 40x_6 + 40x_8 \geq 64 \\ 30x_1 + 30x_6 + 60x_9 + 100x_{10} \geq 21 \\ 85x_2 + 77x_3 + 50x_4 + 70x_5 + 40x_6 + 90x_7 + 40x_8 \geq 239' \\ 80x_1 + 65x_2 + 24x_3 + 45x_4 + 40x_5 + 70x_6 + 85x_8 \geq 145 \\ 50x_1 + 30x_6 + 30x_7 + 120x_9 + 100x_{10} \geq 72 \end{cases}$$

Where x_i is the ith hotel and $x_i = \begin{cases} 0, \text{the ith hotel was not selected.} \\ 1, \text{the ith hotel was selected} \end{cases}, i = 1,2,\cdots,10.$

3.2.2 Experimental results of booking hotels

Considering that the above model is a bi-objective function, we adopt the approach of first solving the initial objective function (1), which yields the requirement for 4 hotels. Upon this result, we subsequently address the second objective function (2). We used LINGO software for programming and obtained the following results. The final result is shown in Table 5.

Table 5: The result of booking hotels

Global optimal solution found at iteration:		554
Objective value:		2550.000000
Variable	Value	Reduced Cost
X1	1.000000	1.000000
X2	1.000000	1.000000
X3	0.000000	1.000000
X4	0.000000	1.000000
X5	1.000000	1.000000
X6	0.000000	1.000000
X7	1.000000	1.000000
X8	0.000000	1.000000
X9	0.000000	1.000000
X10	0.000000	1.000000

Row	Slack or Surplus	Dual Price
1.000000	1	4.000000
0.000000	2	107.0000
0.000000	3	91.00000
0.000000	4	9.000000
0.000000	5	6.000000
0.000000	6	40.00000
0.000000	7	8.000000

That is, the selected hotels are: ①②⑤⑦.

4 Analysis of renting conference rooms and buses

Based on the four hotels①②⑤⑦in the previous section, the specific hotel room arrangements and the number of people accommodated in each hotel are obtained by collation as follows. Some details are shown in Tables 6-7.

Table 6: The hotel room arrangement

	specification	Hotel	Number of rooms	Price / Yuan
Living together 1	Ordinary double standard room	⑤A	35	140
	Ordinary double standard room	⑤B	35	160
	Ordinary double standard room	⑦	28	150
Living together 2	Deluxe double standard room	⑤	40	200
	Deluxe double standard room	②A	24	180
Living together 3	Business double standard room	①	21	220
Living alone 1	Business Single room	⑦	40	160
	Ordinary double standard room	②	50	140
	Business double standard room	②	29	160
	Ordinary double standard room	⑦	22	150
Living alone 2	Ordinary single room	①	30	180
	Deluxe double standard room	②A	6	180
	Deluxe double standard room	②B	35	200
	Ordinary double standard room	①	10	180
Living alone 3	Business Suite	⑦	30	300
	Business Single room	①	20	220
	Business double standard room	①	1	220

The number of people stay in the selected hotels is shown in Table 7.

Table 7: The number of people stay in the selected hotels

Hotel	Number of persons
⑦	148
②	168
①	103
⑤	220
Actual total number of participants / persons	639

From Table 6, a brief validation can be obtained to satisfy the different requirements of Table 4 with 98 rooms for living together 1, 64 rooms for living together 2, 21 rooms for living together 3, 141 rooms for living alone 1, 81 rooms for living alone 2, and 51 rooms for living alone 3. In addition, we further obtain the number of occupants in each hotel, which shows a relatively balanced distribution. The results are reasonable, indicating that the model has some extension value.

Based on the previous analysis, we know that the total number of people participating in this conference is 639. We use the average probability to calculate the number of each session since we lack specific information about the number of individuals in each session. Thus, an estimated number of participants for each session is approximately 107. From an economic point of perspective, we exclude meeting rooms with a size exceeding 160, considering them as too large for our needs. Additionally, in the rental of meeting rooms and buses, we prioritize minimizing costs by selecting hotels with a greater number of participants and more favorable meeting room prices. This approach aims to reduce participant movement and potentially necessitate fewer buses for transportation.

So, we finally select ⑤, ②, ⑦ three hotels, and each hotel arrange two meeting rooms based on these two principles. The specific meeting room sizes and prices for the three hotels are as follows.

Table 8: The meeting room arrangement

Hotel	The number of persons that can be accommodated	Prices of selected meeting rooms
⑤	150	1000
⑤	150	1000
②	130	1000
②	130	1000
⑦	140	800
⑦	140	800

When renting buses, we still use the average probability as the exact number of participants in each session remains unknown. For example, in Hotel 2, where 168 participants are accommodated (Hotel 2 rents 2 meeting rooms). The actual number of individuals needing transportation on a 45-seat bus is approximately 112, calculated as $168 \times 2/3 \approx 112$. Considering the shortest distances between hotels and the minimal travel time, the bus can run back and forth once and allow people to take halfway. In addition, considering the satisfaction of the participants and the absence of meeting rooms in the Hotel 1, we finally select the Hotel 2 as the starting point of the starting point for bus transportation. Consequently, we require 4 buses for this situation. The total cost of renting meeting rooms for half a day is: $2 \times 1000 + 2 \times 1000 + 2 \times 800 = 5600$ yuan. The bus transfer route for participants can see Figure 3.

We totally rented 4 buses, each of which is 45 seats. The total cost of half a day is $4 \times 800 = 3200$ yuan. The vehicle driving path diagram is shown in Figure 6, and the specific process is as follows.

Given the distance of 150 meters between Hotel 2 and Hotel 1, it is possible to have buses waiting at both hotels simultaneously. In Hotel 2, there are two meeting rooms, $1 / 3$ of the people in Hotel 2 are likely to participate in sessions within the hotel. Therefore, four cars depart from the Hotel 2 to pick up people, carrying $2 / 3$ of the people residing in Hotel 2, which totals 112 people. These individuals are then transported to Hotel 1.

There is no meeting room in Hotel 1. $1 / 3$ people in Hotel 1 will go to the meeting rooms in Hotel 2, $2 / 3$ people wait for buses in Hotel 1, i.e., 68 people. This brings the total on the buses to 180 people, and they are going to Hotel 7.

In Hotel 7, there are two meeting rooms. Approximately $1 / 3$ of the people at Hotel 7 are expected to attend sessions within the hotel. The combination of people from Hotel 2 and Hotel 1 results in 90 people disembarking from the buses, while 49 people boarding. At this point, there are 139 individuals on these four buses, and route to Hotel 5.

There are also two meeting rooms in Hotel 5. $1 / 3$ people attend meetings within the hotel, and all the 139 people on buses get off the bus, while $2 / 3$ people need to travel to other hotels for their sessions, thus resulting in 146 people boarding the buses.

The four buses carry 146 passengers return to Hotel 7, where 73 people disembark and 49 board. This brings the total on these buses to 122 people, heading for Hotel 1. Additionally, 35 more people board the buses at Hotel 1. Consequently, 157 people are transported to Hotel 2, and the four buses return to Hotel 2. Upon arrival, all passengers disembark, concluding the schedule.

Because the distance between the various hotels is not large, participants do not have to wait for extended periods. This ensures that the satisfaction of the attendees is minimally impacted,

and the representatives can be allocated into time periods to reduce waiting times, preserving their satisfaction. So, the total cost of a day is

$$2 \times 5600 + 2 \times 3200 = 17600 \text{ yuan.}$$

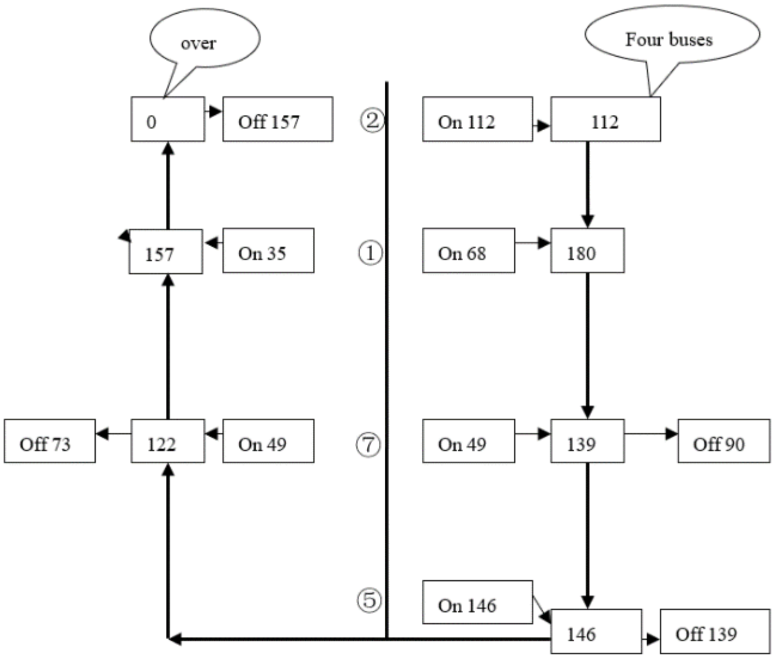


Figure 3: The bus transfer route for participants

5 Conclusions

We first obtained a linear relationship between the number of participants and the number of receipts sent back through data fitting by comparing primary, secondary, tertiary, and quaternary function fitting, and reasonably predicted the actual number of participants. In order to minimize the number of selected hotels and the distance between hotels, we calculated that at least 4 hotels were needed by using 0-1 programming, combined with LINGO. This method has popularization significance and it is also suitable for general conference preparation. By combining tables and figures to illustrate, it makes the paper more vivid and clearer.

The analysis and result of the model provide a more accurate solution to this practical problem. However, it's important to acknowledge that the model's assumptions simplify the problem, and various uncertainties exist throughout the arrangement process. For example, for the uncertainty of the representatives participating in sessions, the route of the vehicle in the process of driving and whether it conforms to the traffic rules. When addressing such a problem, assumptions are a necessary part of the discussion, and they also represent the limitations of the model. Furthermore, all our arrangements are primarily cost-centric, which may potentially reduce the satisfaction of the participants. Finally, the manual arrangement of meeting rooms and transportation limits the wider applicability of the proposed approach.

Acknowledgments. This work was supported by National Natural Science Foundation of China (12001281) and Qing Lan Project of the Jiangsu Province.

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