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Mathematical Modeling for Distribution Optimization of Senior High School Telephone Booths

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Abstract: Due to the policy of the Ministry of Education, many senior high schools in China have constructed some telephone booths. However, the survey found that the distribution of telephone booths in senior high school is irrational. Previous studies focused on the humanized design of telephone booths and the 0-1 planning optimization of charging pile location, but there were few studies on optimizing the distribution of phone booths in campus. It is necessary to optimize the distribution of telephone booths in senior high schools to facilitate students' life and save students' time. In this paper, Qingdao No. 2 Middle School in Shandong Province is taken as an example. Firstly, according to the previous research on 0-1 programming model, the number of people and demand in the distribution area of telephone booths in the campus are scored, and the scoring matrix is formed. Then 0-1 programming modeling was carried out and solved with Matlab. Finally, the optimal construction point to be built is obtained.

Keywords: Telephone booth, Site selection, 0-1 programming model, Mathematical modeling.

1. Introduction

On February 1, 2021, in order to protect students' eyesight, prevent the students being fully preoccupied with the Ministry of Education issued mobile phone ban for primary and secondary school students. Students will not be allowed to bring mobile phones to school. In order to ensure the normal contact and communication between students and their parents, many boarding high schools in China have constructed telephone booths on campus. Can the distribution of telephone booths actually facilitate students' study and life?

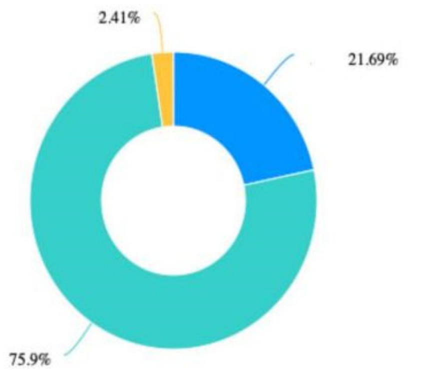

Figure 1. Students' thoughts of the distribution of telephone booths in campus

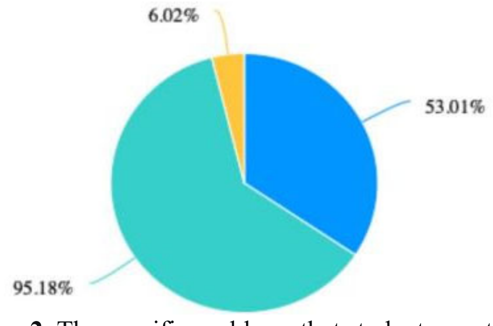

Figure 2. The specific problems that students meet

In figure 1, the blue part accounts for 21.69%, and it presents the proportion of students who contends that the distribution of telephone booths in campus is reasonable. The green part accounts for 75.9%, and it presents the proportion of students who contends that the distribution of telephone booths in campus is unreasonable. The yellow part accounts for 2.41%, and it presents the proportion of students whose school does not have telephone booth. In figure 2, the blue part accounts for 53.01%, and it presents the proportion of students who meet difficulties that some places do not have telephone booths so that they have to walk for a long distance to give their parents a call. The green part accounts for 95.18%, and it presents the proportion of students who meet difficulties that they have to wait for a long time to give their parents' a call because of the great number of students at some time. The yellow part accounts for 6.02%, and it presents the proportion of students who does not meet any difficulties in making a call on campus.

Figure 1 is a questionnaire published on the Internet about the rationality of the distribution of phone booths in high school campuses. Among the 83 high school students who are surveyed, only a small part of them live in high schools without telephone booths. 75.9% of them think the distribution of telephone booths on campus is not reasonable, while only 21.69% of them think the distribution of telephone booths on campus is reasonable. Thus it can be seen that the unreasonable existence of telephone booths in high school campus is relatively common. Figure 2 shows the survey on the main aspects of irrationality in the questionnaire. Due to the question is a multiple choice question, the sum of the proportions of each situation is not 100%. Except for 6.02% of the students, they do not think that the distribution of telephone booths was unreasonable, and most of the students meet some difficulties that some places do not have telephone booths so that they have to walk for a long distance to give their parents a call, and some students have to wait for a long time to give their parents' a call because of the great number of students at some time. It can be seen that optimizing the distribution of telephone booths on campus will greatly facilitate students' study and life and save students' time.

Based on the unreasonable distribution of telephone booths in senior high school, this paper uses the 0-1 programming modeling method to study the Qingdao No. 2 Middle School in Shandong Province, aiming at optimizing the location of telephone booths on the campus considering the number of people and the degree of demand.

2. Literature Review

In 2013, Cui Xiaofei designed and analyzed the function expansion of public telephone booths [1]. In 2018, Gao Peipei and others proposed an innovative design of public telephone booths based on functional requirements from the perspective of resource reuse and improvement of urban public space utilization [2]. In 2018, Gao Xuefeng and others proposed the innovation of urban public telephone booths based on the concept of environmental protection, investigated and analyzed the defects of existing telephone booths in the process of use, and redesigned them based on people's needs [3].

In terms of 0-1 programming model, in 2019, Zhou Xinrong took Xinjiekou Street, Xuanwu District, Nanjing City as an example, optimized the site selection of charging piles in this area by using 0-1 programming model, optimized the number and type of charging piles in charging stations by using integer programming, conducted comprehensive modeling from multiple perspectives, and put forward practical suggestions for urban planning [4]. In 2021, Li Yuan and others took the problem of personnel arrangement in real life as an example to establish a 0-1 programming model, which was firstly solved by bintprog function in Matlab and then solved by intlinprog function, and compared the results [5]. In 2022, Wan Liangqi and others proposed a Kriging combination modeling method based on 0-1 programming model screening strategy, aiming at the problem of low modeling accuracy and robustness of Kriging combination model under uncertain correlation function selection [6]. Previous studies on 0-1 programming model in various issues and aspects are also relatively significant, and the mathematical modeling methods they used are worthy of reference in this paper.

Therefore, it is not difficult to find that previous studies focused on the design, appearance of telephone booths and the method which can make the public telephone booths more humanized, while studies on the rationality of the distribution of telephone booths in senior high school were relatively lacking. However, the unreasonable distribution of telephone booths on campus does bring a lot of trouble to students, which should be solved urgently.

3. Method

3.1. Model Assumptions

It is convenient for students to stay within 50 meters from the telephone booths.

3.2. Symbol Description

A_i represents the ith point to be built; Bi represents the ith demand point; d_{ij} represents the distance between the ith point to be built and the jth demand point. If the distance between the ith point to be built and the jth demand point is less than 50 meters, d_{ij} is equal to 1. If the distance between the ith point to be built and the jth demand point is more than 50 meters, d_{ij} is equal to 0. f_i represents the demand level of the ith point to be built. c_i represents the traffic level of the ith point to be built.$x_i=0$ indicates that the telephone booth is not built at the ith point to be built. $x_i=1$ indicates that the telephone booth is built at the ith point to be built.

3.3. Screening model of telephone booth sites to be built

3.3.1. Definition and basic forms of 0-1 Planning

Linear programming problem is a mathematical theory and method to study the extreme value problem of linear objective function under linear constraints. Among them, some problems only take 0 or 1 as the decision variables. This kind of problem is called 0-1 programming problem. The 0-1 programming problem is a special integer programming.

Its basic form is:

$\min f^T x$

$Ax \le b$

$Aeq\ x = beq$

$x_i = 0 or 1$

3.3.2. 0-1 programming model for selection of telephone booth location

$A_i(i=1,...,n)$ represents n different telephone booths to be built. $B_i(i=1,...,m)$ represents m different demand points of telephone booths. $d_{ij}(d=d_{ij}, i=1,...,n, j=1,...,m)$ represents the distance between the ith telephone booth to be built and the jth demand point. If the distance between the ith telephone booth to be built and the ith demand point is less than or equal to 50 meters, d_{ij} is equal to 1. If the distance between the ith telephone booth to be built and the ith demand point is more than 50 meters, d_{ij} is equal to 0. Let $f=(f_1,f_2,... ,f_n)$ represents the demand level of n telephone booths to be built. $f \in \{1,2,3,4,5,6,7,8,9,10\}$, when the value is smaller, the demand level is smaller. Let $c=(c_1,c_2,...,c_n)$ represents the pedestrian volume level of n telephone booths to be built, where $c_i \in \{1,2,3,4,5,6,7,8,9,10\}$. When the value is smaller, the pedestrian volume level of the telephone booth to be built is smaller. On the premise of ensuring that there is at least one telephone booth near each demand point, this paper establishes a 0-1 programming model based on the comprehensive score of the pedestrian volume level and the demand level of the telephone booth to be built:

$\min(f+c)x$

$dx \ge e$

$x_i = 0 or 1$

e is equal to (1,1,...,1) in order to ensure that there is at least one telephone booth near each demand point. $x_i=0$ means that no telephone booth will be built at the point i to be built. Conversely, $x_i=1$ means that one telephone booth will be built at the point i to be built.

4. Result

This paper takes Qingdao No. 2 Middle School in Shandong Province as an example, and it selects ten sites to be built and ten demand points on campus. They are mainly distributed in teaching buildings, dormitories, auditoriums, canteens and other places on campus. In the figure 3, the red points represents the demand points, and the blue points represents the points to be built.

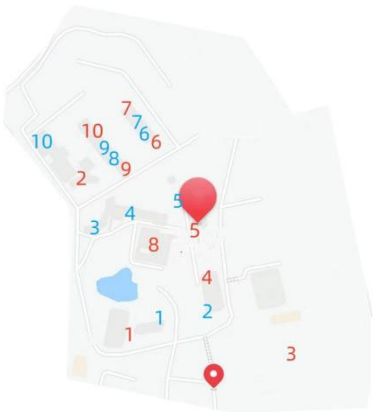

Figure 3. The demand points and the points to be built in Qingdao No.2 Middle School

The specific steps are as follows: The first step is to score the pedestrian volume level and the demand level of all the telephone booths to be built, and form a score matrix. For all the points to be built, the starting score of the pedestrian volume level is two points. If the maximum pedestrian volume at a certain time is more than or equal to five hundred and less than or equal to one thousand, the point plus 1 point. If the maximum pedestrian volume at a certain time is more than one thousand, the point plus 2 points. If the maximum pedestrian volume at a certain time is less than one hundred, the point minus 1 point. For all the points to be built, the starting point is also two points. If the quantity demand is more than 50, the point plus 1 point, where the quantity demand is according to the questionnaire. If the quantity demand is less than 10, the point minus 1point.

The second step is to determine the distance between the telephone booth to be built and the demand point. If the distance is less than 50 meters, d_{ij} is equal to 1. If the distance is more than 50 meters, d_{ij} is equal to 0.

The third step is to establish 0-1 programming model and solve it with Matlab. According to the results, telephone booths should be built at the points 2,4,5,7 and 8. The result also means that the telephone booths should be built in the teaching buildings and the dormitories because of the huge flow of people. This research is only a symptom, which may means that senior high students are more willing to call others in the teaching buildings and the dormitories.

5. Conclusion

According to the results of Matlab, the establishment of telephone booths at the points 2, 4, 5, 7 and 8 to be built can ensure that there is at least one telephone booth within 50m of each demand point and it is the most convenient for students. The research results mainly reflect the optimal solution of telephone booth location under this condition.

Compared with the existing research results, the research angle selected in this paper is relatively new and close to teenagers. Of course, there are some shortcomings in this study. In this paper, the number of people who are sample surveyed is small when investigating the demand degree of the site to be built.

Based on the previous research on 0-1 programming model and the unreasonable distribution of telephone booths in some senior high schools, this paper takes Qingdao No. 2 Middle School in Shandong Province as an example and uses Matlab software to optimize the distribution of telephone booths on the campus. Phone booths in boarding high schools have become a trend after the Ministry of Education issued the notice on strengthening the management of primary and secondary school students' mobile phones. Considering that students are under great pressure in nowadays social environment, it is important to optimize the distribution of telephone booths on campus in order to facilitate communication between students and their parents, save students' time and improve students' efficiency. Based on this, this paper puts forward some suggestions to this problem.

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